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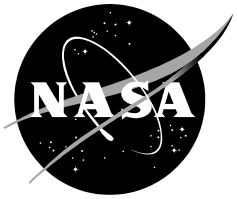

Transonic Truss-Braced Wing Airplane Characteristics for Airport Operations

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March 2025

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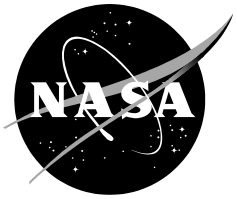

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TABLE OF CONTENTS

LIST OF FIGURES ……...4

LIST OF TABLES ……5

ABSTRACT ……...6

I. INTRODUCTION ...……...…….... 6

II. TTBW AIRCRAFT DESIGN ...…… 7

III. AIRCRAFT REFERENCE CODES AND AIRPORT DESIGN STANDARDS ……..10

IV. WING FOLDING ……..…....……...……15

V. ANALYSIS OF MAJOR US AIRPORTS ……...…….. 16
A. Analysis Based on Traffic Data ……... 16
B. Analysis Based on Geometric Data ……...…… 18

VI. CONCLUSIONS ……..…....……...……...20

APPENDIX ……22

ACKNOWLEDGEMENTS ..…….27

REFERENCES ……27

LIST OF FIGURES

Figure 1. Airport areas affected by aircraft dimensions ..……....7

Figure 2. Truss-braced wing structure ……....8

Figure 3a. Top view of TTBW ……..……9

Figure 3b. Side and front view of TTBW ……9

Figure 4. Taxiway Design Group …….....11

Figure 5. Wing folding geometry …….....16

Figure 6. Wingspan (WS), folded wingtip height (FH), and tail height (TH) as a function of fold angle ..…….....16

LIST OF TABLES

Table 1. TTBW conceptual model characteristics ……9

Table 2. TTBW conceptual model dimensions ……....10

Table 3. Aircraft Approach Category ……..10

Table 4. Airplane Design Group ……..11

Table 5. Design standards based on Taxiway Design Group ……..……11

Table 6. Taxiway/taxilane design standards based on Airplane Design Group ...……...12

Table 7. Runway design standards matrix, C/D/E-IV ……..……...12

Table 8a. Approach Reference Code ……..…….....13

Table 8b. Approach Reference Code (contd.) ……..…….....13

Table 9. Departure Reference Code ……..……..…….....14

Table 10. ICAO Aerodrome Reference Code ……..…….....14

Table 11. Airport groups by AAC-ADG-TDG (TTBW aircraft codes: C-IV-3 and C-III-3 …… 18

Table 12. Longest runway statistics of 77 ASPM airports ……..18

Table 13. Airports grouped by the length of the longest runway …….. 19

Table 14. Airports grouped by the width of the longest runway ...……19

Table 15. Airport groups by longest runway to taxiway/runway separation ...……20

TRUSS-BRACED WING AIRPLANE CHARACTERISTICS FOR AIRPORT OPERATIONS

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ABSTRACT

This study seeks to identify the major US airports where the Transonic Truss-Braced Wing aircraft could operate without folding its wings. Aircraft reference codes, which are based on the aircraft characteristics and dimensions, and the taxiway/taxilane design and runway to parallel taxiway separation specifications based on the reference codes are used to determine the operational compatibility of the aircraft design with airport design; these are described. The characteristics and dimensions of a conceptual Transonic Truss-Braced Wing aircraft are listed, and the reference codes based on them are given. Expressions for determining the wingspan and the wingtip height of the folded wing as a function of fold angle are provided. Two different approaches: (1) using historical air traffic data to associate the airport with the aircraft reference codes and (2) using the airport geometry for identifying airports suitable for Transonic Truss-Braced Wing aircraft operations are described. Results of analysis of 77 major US airports show the Transonic Truss-Braced Wing aircraft could operate at most of these airports without wing folding after landing.

I. INTRODUCTION

National Aeronautics and Space Administration's (NASA) Sustainable Flight Demonstrator (SFD) initiative seeks to collaborate with industry, academia, and other government organizations to identify, select, and mature key airframe technologies with substantial potential of being adopted by the future generations of single-aisle seat class airliner. NASA is currently developing a Transonic Truss Braced Wing (TTBW) aircraft with the Boeing company to demonstrate the benefits of TTBW design. In addition, this X-Plane (X-66A) demonstrator aircraft will include additional technologies that are expected to help reduce fuel consumption and emissions by about 30%.

For operating the aircraft at an airport, the aircraft dimensions and its performance characteristics need to be compatible with the airport design. Every manufacturer of a commercial aircraft provides a document detailing the airplane characteristics for airport planning. For example, Ref. 1 provides the characteristics of different variants of the Boeing 737 aircraft, including Boeing 737-100 through 737-900, variants with winglets, and long-range variants, for airport planning. The compatibility of the aircraft with respect to the airport is determined by the reference codes established by the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO). The primary reference codes are Aircraft Approach Category (AAC), Airplane Design Group (ADG) and Taxiway Design Group (TDG). AAC is based on the approach speed. ADG is a function of the wingspan and the tail height. TDG is a function of the Main Gear Width (MGW) and the Cockpit to Main Gear Distance (CMG). The airports are designed for these reference codes of a reference aircraft. The dimensions of the runways and taxiways/taxilanes are specified for the corresponding reference codes in Ref. 2. The geometry

of runways, taxiways, taxilanes and ramp areas enable the reference aircraft and other aircraft with lower reference codes to operate at the airport. That means, they can park at the gate, taxi in and out of runways, and takeoff and land. For example, an airport designed for Boeing 747 operations can also be used for Airbus A320 operations. Figure 1, which is from Ref. 3, shows some of the areas on the airport that are affected by the dimensions of the aircraft such as wingspan, MGW and CMG.

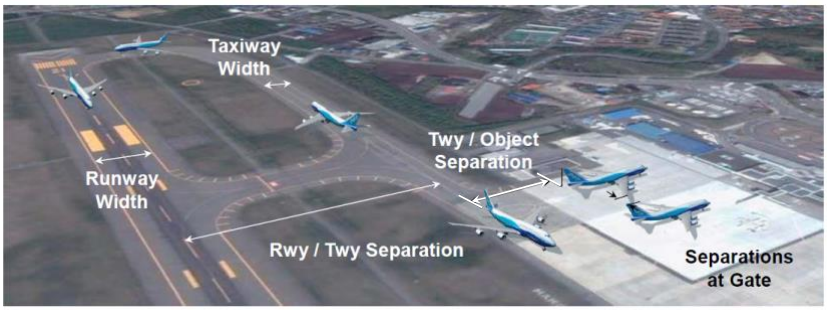

Figure 1. Airport areas affected by aircraft dimensions.

The motivation for this report is to use the AAC, ADG and TDG of the TTBW aircraft derived from the conceptual design — characteristics and dimensions — to identify the major US airports where it could operate without folding its wings. To enable this analysis, archived historical air traffic data are analyzed and characteristics and dimensions of 387 aircraft from the FAA's aircraft characteristics database are employed to determine the highest AAC, ADG and TDG aircraft that arrived or departed from the major US airports. Because there were not any flights to and from the Luis Muñoz Marín International Airport, which is Puerto Rico's main international airport, in the archived historical data, it was excluded from the analysis. Results are therefore obtained for the remaining 76 major US airports, which are called Aviation System Performance Metrics 77 (ASPM 77) airports. Thirty-five of these 77 airports are known as Operational Evolution Partnership 35 (OEP 35) airports. These commercial airports serve major metropolitan areas and are hubs for airline operations. More than 70% of passengers travel through these airports.

The other motivation is providing airport design data from FAA's comprehensive advisory circular on standards and recommendations for airport design (see Ref. 2) needed for preliminary analysis of the compatibility of the novel aircraft with the design of a chosen airport.

The report is organized as follows. Section II describes the TTBW aircraft conceptual model characteristics and dimensions. Tables listing FAA and ICAO aircraft and airport reference codes are provided in Section III and the airport design standards based on them are discussed. The reference codes of the TTBW aircraft determined using the characteristics and the dimensions are also discussed in this section. The effect of wing folding on the wingspan and the wingtip height as a function of the fold angle, and the resulting ADG is discussed in Section IV. The procedure of using the traffic data and the aircraft characteristics database for determining the reference aircraft with highest AAC, ADG and TDG that operated at an airport is described in Section V. The classification of the 76 major US airports into nine groups based on the AAC, ADG and TDG resulting from this process are tabulated in Section V. Detailed results of the classification are provided in the Appendix. Results of analysis of the runways at the 77 major US airports including summary statistics are also provided in Section V. Finally, the report is concluded in Section VI.

II. TTBW AIRCRAFT DESIGN

Modern commercial aircraft employ a cantilever-wing design. While the cantilever wing has become more efficient with technological advancements over the years, further significant aerodynamic improvements are expected to be challenging. This has motivated research in alternative designs such as blended wing body [4], joined wing [5], and truss-braced wing (TBW) [3]. Figure 2 from Ref. 3 illustrates the structure of the TBW; it consists of a wing, primary wing struts, jury struts, and a truss support structure — the fuselage. Primary wing struts affect the

transfer of wing bending loads to the fuselage for example by directing a portion of the load from the wing box to the lower fuselage. Jury struts add rigidity to the primary struts; they stabilize the primary wing struts and the wing by pushing the buckling modes to higher frequencies. A wing that is supported by a single primary strut is called a strut-braced wing (SBW) as opposed to a TBW.

The reduction of bending moment in the wing due to the truss, enables a wing design with lower thickness to chord ratio and skin thickness [6]. Flow over the wing with reduced thickness of the chord, spar and skin has lower chord Reynolds number. Such a wing also has lower wave drag; therefore, the wings do not have to be swept back as much, which reduces the spanwise crossflow disturbances [6]. These result in increasing the extent of laminar flow and lowering fuel consumption. The TBW of the TTBW aircraft is designed to be aerodynamically efficient at an aspect ratio of about 19.55, which is significantly greater than the wing aspect ratio of 11 of Boeing 777 — a large commercial aircraft [7]. The increased aspect ratio of the TTBW wing substantially reduces induced drag. A multidisciplinary design optimization (MDO) process is employed that strikes a balance between aerodynamic efficiency and structural efficiency to design a truss-braced structure.

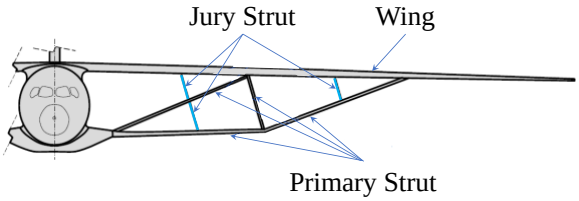

Figure 2. Truss-braced wing structure.

Reference 8 employed MDO to study several TBW designs and a SBW design. They found the one-jury with a single primary strut TBW outperformed the SBW in terms of fuel burn for all span limits. Addition of one more jury strut only offered marginal improvements for spans longer than 170 ft, therefore, they concluded there was no need to investigate more complex truss systems such as three-jury or four-jury TBWs. They found longer span led to higher cruise efficiency for all three TBW architectures studied. The benefit of increasing wingspan was found to quickly diminish beyond a wingspan of 170 ft because the wing weight penalty significantly offset reduction in induced drag.

Characteristics and dimensions of the conceptual model of the TTBW aircraft discussed in this paper were provided by the Vehicles Design Group at the NASA Ames Research Center. They used the newer version of NASA's General Aviation Synthesis Program (GASP) for synthesis of the conceptual model of the TTBW aircraft powered by two direct-drive turbofan engines with fan pressure ratio of 1.5 and designed to cruise at Mach 0.8. GASP can be used to assess the impact of aircraft requirements, design factors, and novel technologies both individually and integrated together into the configuration design. The outputs of GASP enable assessment of tradeoffs in terms of overall aircraft weights, dimensions, and mission performance.

GASP consists of six sub-modules: geometry, aerodynamics, propulsion, weight and balance, mission performance, and economics, which are integrated into a single system by a control module [9]. Integration ensures the interactions amongst the modules are properly captured in the synthesis. The geometry module ingests inputs such as the number of passengers, aspect ratio, taper ratio, sweep angles, and the thickness to chord ratio of wing and tail surfaces to compute the dimensions of the aircraft components. The aerodynamics module uses information about configuration geometry, flight conditions, and high-lift devices to compute lift and drag coefficients. The propulsion module sizes the engine for cruise, takeoff, and climb requirements based on input reference engine performance information. This module simulates turbojet, turbofan, turboprop, and reciprocating engines and provides performance, weight, and noise estimates. The weight and balance module computes the component weights based on historically established weight relationships. This module also accounts for advanced technologies affecting aircraft structural weight. The fuel needed for the mission — flight from

origin to destination — consisting of taxi, takeoff, climb, cruise, descent and landing, reserve fuel requirement, and flight to an alternate airport are computed by the mission performance module. Manufacturing cost and operational cost — fuel and crew — are used in the economics module for analysis of economic feasibility of building and operating the aircraft.

Table 1 lists some of the characteristics of the conceptual TTBW aircraft with body tanks model described in Ref. 10 (see Table 9 in Ref. 10). This configuration reduces the crossover range to below 300 nautical miles with respect to the tube and wing design aircraft. Figures 3a and 3b show the top view, side view and front view of this aircraft. The aircraft images for these two figures were copied from Ref. 3, altered, and labeled. Note the wingspan is the wingtip-to-wingtip distance. Similarly, the truss length is the straight distance between the two locations where the primary strut attaches to the wing at the location closest to the wingtips. The wing fold hinges are assumed to be at these two locations. The length of the aircraft is defined as the largest horizontal distance between the front and rear extremities of the aircraft — nose to farthest tip on vertical or horizontal stabilizer. The tail and truss height are with respect to the ground. The main gear width is the distance between the outer wheels of the main gear. The aircraft dimensions listed in Table 2 are marked in Figs. 3a and 3b. The characteristics and the dimensions in Tables 1 and 2 are used to determine the AAC, ADG and TDG of the TTBW aircraft. Although a commercial aircraft might be substantially different compared to those based on the assumptions in Ref. 10 or the design and performance of X-66A demonstrator aircraft, the process for determining the operational compatibility with respect to the airport design described in this paper would be applicable to it.

Table 1. TTBW conceptual model characteristics

Characteristics	Value	Characteristics	Value
Approach speed	137.49 kn	Max. landing weight	113,808 lb
Design range	3,400 nm	Max. takeoff weight	132,843 lb
Max. number of Passengers	150	Max. zero fuel weight	105,874 lb
Max. fuel weight	26,969 lb	Operating empty weight	73,409 lb

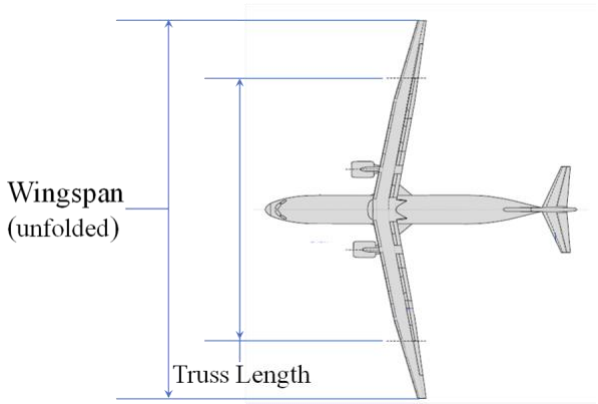

Figure 3a. Top view of TTBW.

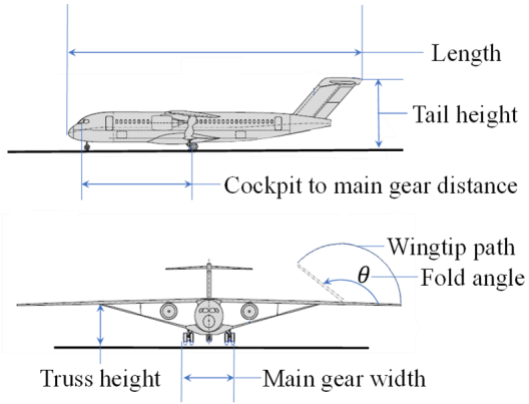

Figure 3b. Side and front view of TTBW.

Table 2. TTBW conceptual model dimensions

Dimensions	Value	Dimensions	Value
Cockpit to main gear distance	51 ft	Truss height	13.1 ft
Length	114.16 ft	Truss length	118 ft
Main gear width	23.97 ft	Wing area	1,231.2 ft^2
Parking area	19,686 ft^2	Wingspan (unfolded)	155.2 ft
Tail height	27.7 ft	Wingspan (min. folded)	118 ft
Tire diameter	3.75 ft		

III. AIRCRAFT REFERENCE CODES AND AIRPORT DESIGN STANDARDS

Aircraft Approach Category (AAC) is a classification of aircraft based on a reference landing speed (V_{REF}), if specified, else, it is 1.3 times the stall speed (V_{SO}) at the maximum certificated landing weight [2]. Aircraft certification includes specification of V_{REF}, V_{SO}, and the maximum certificated landing weight ─ reference weight. Stall speed, V, at a different weight, W, compared to the specified reference weight, W_{REF}, can be determined as:

$$V = V_{SO}\sqrt{\frac{W}{W_{REF}}} \tag{1}$$

Similarly, reference speed, V, at a different weight can be found by replacing V_{SO} in Eq. (1) with V_{REF}. The relationship in Eq. (1) is obtained by assuming the same angle-of-attack but different amounts of dynamic pressure needed for generating the lift for supporting the weight of the aircraft in the two instances. Table 3 from Ref. 2 lists the five approach categories from A through E. The AAC of the TTBW aircraft is C according to Table 3 based on its approach speed of 137.49 knots (see Table 1). An aircraft that can land on a runway with maximum certificated landing weight can also land on the same runway at a lower weight because as Eq. (1) shows, the reference speed decreases with reduced landing weight.

Table 3. Aircraft Approach Category

AAC	V_{REF}/Approach Speed
A	< 91 kn
B	91 kn to < 121 kn
C	121 kn to < 141 kn
D	141 kn to < 166 kn
E	166 kn or more

Airplane Design Group (ADG) is a classification of aircraft based on the wingspan and tail height [2]. Table 4 lists the FAA and ICAO codes/group numbers. The FAA denotes the six groups by roman numerals, I through VI, while the ICAO denotes them by alphabets, A through F. For aircraft categorization by wingspan and by tail height, the group with the higher value applies. For example, the tail height of 27.7 feet (see Table 2) places TTBW aircraft in the FAA Group II, but the wingspan of 155.2 feet places it in Group IV. Thus, the ADG of the TTBW aircraft with these dimensions is FAA Group IV and ICAO Group D. according to Table 4. Lowering the wingspan to

less than 118 feet by folding the wings would lower the ADG to FAA Group III and ICAO Group C.

Table 4. Airplane Design Group

FAA Code	ICAO Code	Tail Height	Wingspan
I	A	< 20 ft	< 49 ft
II	B	20 ft to < 30 ft	49 ft to < 79 ft
III	C	30 ft to < 45 ft	79 ft to < 118 ft
IV	D	45 ft to < 60 ft	118 ft to < 171 ft
V	E	60 ft to < 66 ft	171 ft to < 214 ft
VI	F	66 ft to < 80 ft	214 ft to < 262 ft

Taxiway Design Group (TDG) is a classification of airplanes based on undercarriage dimensions: outer to outer Main Gear Width (MGW) and the Cockpit to Main Gear (CMG) distance [2]. CMG distance represents the distance from the pilot's eye to the main gear turn center. Different areas of an airport designed for operations of different sizes of aircraft may have different TDG classifications. Figure 4 shows the layout of the eight quadrilaterals marking the MGW and CMG distance ranges of the respective groups. The TDG of TTBW aircraft is 3 as indicated by the location marked with 'x' in Fig. 4. The abscissa and the ordinate of the marked location are the TTBW aircraft MGW of 23.97 feet and CMG distance of 51 feet (see Table 2), respectively.

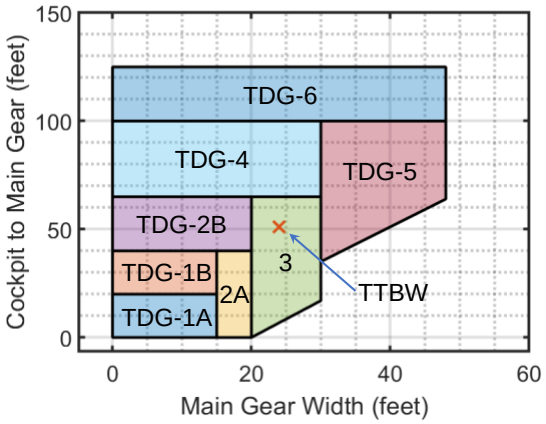

Figure 4. Taxiway Design Group.

TDG is used as the primary design factor for taxiway/taxilane width and fillet standards. Taxiways provide paths for aircraft to taxi from one part of an airport to another such as from the spot outside the parking area to the queuing location for entry to the runway. Taxi speeds on taxiways are typically less than 30 knots. Taxilanes provide a path from taxiway to aircraft parking and other terminal areas. Taxi speeds on taxilanes generally do not exceed 13 knots [2]. A taxiway fillet is an additional area added to a taxiway when turns are tight, such as in a 90-degree turn from taxiway to taxiway or taxiway to runway. Fillets help prevent the main gear from leaving the taxiway during a turn. Table 5 lists the taxiway/taxilane design standards based on TDG [2]. Table 6 lists some of the taxiway/taxilane design standards based on ADG from Ref. 2.

Table 5. Design standards based on Taxiway Design Group

Structure	TDG							
	1A	1B	2A	2B	3	4	5	6
Taxiway/Taxilane Width	25 ft	25 ft	35 ft	35 ft	50 ft	50 ft	75 ft	75 ft
Taxiway Edge Safety Margin	5 ft	5 ft	7.5 ft	7.5 ft	10 ft	10 ft	14 ft	14 ft
Taxiway Shoulder Width*	10 ft	10 ft	15 ft	15 ft	20 ft	20 ft	30 ft	30 ft

*The standard taxiway shoulder width for operating four engine TDC 6 aircraft is 40 feet.

Table 6. Taxiway/taxilane design standards based on Airplane Design Group

Structure	ADG					
	I	II	III	IV	V	VI
Taxiway/Taxilane Safety Area (Max. Wingspan)	49 ft	79 ft	118 ft	171 ft	214 ft	262 ft
Taxiway centerline to parallel taxiway centerline	70 ft	101.5 ft	144.5 ft	207 ft	249.5 ft	298.5 ft
Taxilane centerline to parallel taxilane centerline	64 ft	94.5 ft	138 ft	197.5 ft	242 ft	292 ft
Taxiway wingtip clearance	20 ft	22.5 ft	26.5 ft	36 ft	35.5 ft	36.5 ft
Taxilane wingtip clearance	15 ft	15.5 ft	20 ft	26.5 ft	28 ft	30 ft

Table 7 lists some of the runway design standards based on AAC C, D and E, ADG IV and visibility minimums which are applicable for operating the TTBW aircraft. Observe, the listed design standards are the same for different visibility minimums. Runway design standards matrices for different AAC-ADG combinations and visibility minimums containing additional items are provided in Ref. 2.

Table 7. Runway design standards matrix, C/D/E-IV

Structure	Visibility Minimums			
	Visual	Not < 1 mile	Not < ¾ mile	< ¾ mile
Runway Width	150 ft	150 ft	150 ft	150 ft
Crosswind Component	20 kn	20 kn	20 kn	20 kn
Runway Safety Area Width	500 ft	500 ft	500 ft	500 ft
Runway Object Free Area Width	800 ft	800 ft	800 ft	800 ft
Runway centerline to parallel taxiway/taxilane centerline	400 ft	400 ft	400 ft	400 ft

Tables 8a and 8b list the Approach Reference Codes (APRC) consisting of a three-component code: AAC/ADG/Runway Visual Range (RVR) considering the visibility minimums and existing runway to parallel taxiway separation for landing operations. Aircraft up to the listed AAC and ADG and down to the visual minimum specified for the runway to taxiway separation can operate concurrently on the runway and taxiway without operational mitigation [2]. Note, (S) in Table 8a denotes a small aircraft. Units for RVR is feet. Visibility minimums are specified in statute miles. Entries for AAC D in Table 8b also apply to AAC E. However, the current civil fleet does not have an aircraft with AAC E. ADG V separation standards also apply for ADG VI aircraft with tail heights of less than 66 feet.

The APRC B/II/4000 for the runway to parallel taxiway separation ≥ 250 feet in Table 8a means that aircraft with AAC/ADG A/I(S), A/I, A/II, B/I(S), B/I and B/II can concurrently land on this runway and taxi on the parallel taxiway provided the RVR is at least 4,000 ft. Aircraft are not permitted to be on final approach and within two miles of the runway threshold when the parallel

taxiway is occupied by an ADG III or larger aircraft in this example. Interpretation of the APRC can be explained further by considering the following example with APRC B/III/4000 and D/II/4000 for the runway to parallel taxiway separation ≥ 350 feet in Table 8b. Aircraft with AAC A and B and ADG I(s), I, II and III can operate with RVR of 4,000 feet or more. Aircraft with AAC C and D and ADG I and II can also conduct concurrent landing and taxi operations in this example.

Table 8a. Approach Reference Code

Visibility Minimums	**Runway to Taxiway Separation (ft)**				
	≥ 150	≥ 200	≥ 225	≥ 240	≥ 250
Not < 3/4 mile [4,000 RVR]	B/I(S)/4000	B/I(S)/4000	B/I/4000	B/II/4000	B/II/4000
< 3/4 mile but not < 1/2 mile [2,400 RVR]	N/A	B/I(S)/2400	B/I(S)/2400	B/I(S)/2400	B/I/2400
< 1/2 mile but not < 1/4 mile [1,600 RVR]	N/A	N/A	N/A	N/A	N/A
< 1/4 mile [1,200 RVR]	N/A	N/A	N/A	N/A	N/A

Table 8b. Approach Reference Code (contd.)

Visibility Minimums	**Runway to Taxiway Separation (ft)**					
	≥ 300	≥ 350	≥ 400	≥ 450	≥ 500	≥ 550
Not < 3/4 mile [4,000 RVR]	B/III/4000 D/II/4000	B/III/4000 D/II/4000	D/IV/4000 D/V/4000*	D/IV/4000 D/V/4000†	D/V/4000‡ D/VI/4000	D/VI/4000
< 3/4 mile but not < 1/2 mile [2,400 RVR]	B/II/2400	B/III/2400	D/IV/2400 D/V/2400*	D/IV/2400 D/V/2400†	D/V/2400‡ D/VI/2400	D/VI/2400
< 1/2 mile but not < 1/4 mile [1,600 RVR]	N/A	N/A	D/IV/1600	D/IV/1600	D/V/1600	D/VI/1600
< 1/4 mile [1,200 RVR]	N/A	N/A	D/IV/1200	D/IV/1200	D/V/1200	D/VI/1200

* Airport elevation at or below 1,345 ft.
† Airport elevation between 1,345 ft and 6,560 ft.
‡ Airport elevation above 6,560 ft.

Table 9 lists the two-component AAC/ADG Departure Reference Codes (DPRC). For the specified runway to taxiway separation, DPRC describes the type of aircraft that can depart a runway while an aircraft is on the parallel taxiway. Airplanes with AAC/ADG up to DPRC may conduct unrestricted departure operations [2]. The DPRC in Table 9 can be interpreted as follows. Consider the example of DPRC D/IV and D/V with separation of 400 ft. These reference codes mean that aircraft with (1) AAC of A and B and ADG of I(s), I, II, III and IV, and (2) AAC of C, D and E and ADG of I, II, III, IV and V can operate with a separation of 400 feet. Recollect, entries for AAC D also apply to AAC E.

It should be noted that APRC and DPRC are not design standards. They are separation specifications for aircraft types to operate on runways and parallel taxiways without requiring Air Traffic Control (ATC) mitigation. These reference codes help ATC determine whether adequate

separation exists for two aircraft to concurrently conduct runway and taxiway/taxilane operations in the present or forecast visibility conditions.

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Table 9. Departure Reference Code

Runway to Taxiway Separation (ft)					
≥ 150	≥ 225	≥ 240	≥ 300	≥ 400	≥ 500
B/I(S)	B/I	B/II	B/III D/II	D/IV D/V	D/VI*

* ADG VI airplanes may depart with runway to taxiway separation of 400 feet if a ADG VI aircraft is not on the parallel taxiway beyond 1,500 feet of the point of the start of takeoff roll. ADG VI airplanes may also depart with separation of 400 feet when there is snow, ice, or slush contamination of the runway provided there is no aircraft on the parallel taxiway beyond 1,500 feet of the point of the start of the takeoff roll [2].

Table 10 lists the ICAO Aerodrome Reference Code (ARC), which is a classification of runways solely based on their length. It does not state whether the runway length is adequate for the aircraft type to successfully takeoff or land.

Table 10. ICAO Aerodrome Reference Code

Code	Reference Field Length
1	< 2,625 ft
2	≥ 2,625 ft to < 3,937 ft
3	≥ 3,937 ft to < 5,906 ft
4	≥ 5,906 ft

Reference 11 provides FAA's guidance for airport designers and planners to determine recommended runway lengths for new runways or extensions to existing runways. The design criteria for length of the runway needed are based on the following eight factors: (1) critical airplanes that require the longest runway length, (2) landing flap settings that result in the shortest runway, (3) aircraft operating weights for takeoff and landing, (4) airport elevation above mean sea level, (5) mean daily maximum temperature of the hottest month at the airport, (6) zero wind velocity for both takeoff and landing operations for all airplane weight categories, (7) dry and wet/slippery runway conditions, and (8) maximum difference of runway centerline elevation for addressing uphill longitudinal runway profiles for takeoff operations of large airplanes [11]. The takeoff and landing runway length requirements provided by airplane manufacturers' Airport Planning Manuals (APM), for example Ref. 1, should be reviewed for each individual airplane for determining the suitability of the runway intended for operations. The takeoff field length requirements graphs provided in Ref. 1 for different variants of the Boeing 737 aircraft and engine combinations show the runway length is a function of the operational takeoff weight, airport elevation, and ambient temperature with optimum flap setting. The operational takeoff weight should not cause the tire speed limit — 210 miles/hour or 225 miles/hour — and maximum brake energy limit for aborting takeoff to be exceeded. If it does, the operational takeoff weight should be reduced. Lowering the takeoff weight reduces the runway length required for takeoff. The landing runway length requirement graphs for different variants of the Boeing 737 aircraft for different flap settings show the runway length to be a function of the operational landing weight, airport elevation, and wet or dry runway condition. Shorter runways are needed for landing as operational landing weight is reduced. A larger runway is required when the runway is wet compared to when it is dry for the same operational landing weight. Landing and takeoff runway length requirements will need to be determined for the conceptual model of the TTBW aircraft

using the Python version of GASP, which provides the takeoff distance required for clearing a 50 feet obstacle.

The FAA Order 7110.65, Ref. 12, documents operational procedures for parallel runways, including dependencies related to aircraft avionics and ATC automation equipment. Simultaneous operations on parallel runways are authorized if there is adequate centerline-to-centerline separation. When the separation is inadequate, dependent operations can be authorized by ATC. The throughput for dependent operations is less than independent operations. The minimum separation between centerlines is 700 feet at a non-towered airport or when the tower is not operating for simultaneous independent landings and takeoffs using Visual Flight Rules (VFR). The separation requirement is reduced to 300 feet for dependent landings and takeoffs using VFR with an operating control tower. For dual simultaneous straight-in instrument approaches, the separation requirement between the centerlines of the adjacent runways for airports below 2,000 feet elevation is 3,200 feet and above 2,000 feet elevation is 4,300 feet. Simultaneous operations can also be conducted with reduced separation with high-update surveillance and Simultaneous Offset Instrument Approaches (SOIA). Reference 12 also provides separation, surveillance, and other requirements for simultaneous Instrument Flight Rules (IFR) departures and mixed arrival-departure operations.

IV. WING FOLDING

The objective of wing folding is to reduce the wingspan to enable the aircraft to operate at an airport designed for lower ADG aircraft. For example, the TTBW aircraft wingspan of 155.2 feet makes it an ADG IV aircraft (See Table 4). Reducing the wingspan to less than 118 feet by wing folding would make it an ADG III aircraft. The extent of reduction of the wingspan is limited by the truss length — distance between the wing fold hinges. The minimum wingspan is truss length. To prevent the shift to a higher ADG based on the tail height criteria, the height of the wingtip of the folded wing should be at or below the height of the tail. Given that the wing of the TTBW aircraft is on the top of the fuselage (see Fig. 3b), the wing folding upwards is unobstructed. The wing could be folded downwards, in theory, but it would be obstructed by the ground. To maintain clearance from the ground, the height of the wingtip of the folded wing needs to be at least the height of the top of the tire.

The folded wing geometry and the parameters needed for determining the wingtip height and the resulting wingspan are shown in Fig. 5. The frame of reference with the axes marked x and h is located where the truss ends. The dashed lines with filled circles at the end represent the folded portion of the wing. The folded section is shown in three separate locations in the figure. Let the length of the folded section be S_F and the fold angle be θ_F. Let h_W be the height of the wing and $h_{F_{min}}$ be the minimum permissible height of the wingtip above ground. The minimum fold angle, $\theta_{F_{min}}$, is $-\pi/2$ if,

$$s_F + h_{F_{min}} \leq h_W \tag{2}$$

otherwise, it is,

$$\theta_{F_{min}} = -\sin^{-1}\left(\frac{h_W - h_{F_{min}}}{s_F}\right) \tag{3}$$

Observe from Fig. 5 that the height of the wingtip changes with θ_F, with maximum at $\theta_F = \pi/2$, but the wingspan does not shorten beyond $\theta_F \geq \pi/2$. With this observation, the following expressions can be written for wingtip height, h_F, and wingspan, b_F:

$$h_F = h_W + s_F \sin\{\min[\pi, \max(\theta_F, \theta_{F_{min}})]\} \tag{4}$$

and

$$b_F = b - 2s_F\left(1 - \cos\left\{\min\left[\frac{\pi}{2}, \max\left(\theta_F, \theta_{F_{min}}\right)\right]\right\}\right) \quad (5)$$

where b is the wingspan of the unfolded wing ($b_F = b$ at $\theta_F = 0$). Both Eqs. (4) and (5) constrain the solution to $\theta_{F_{min}} \leq \theta_F \leq \pi$.

Figure 6 shows the wingspan and wingtip height (fold height) as a function of the fold angle. The horizontal line in black corresponding to the tail height of 27.7 feet is provided as a reference for the wingtip height graph in magenta color. The lowest wingtip height was set to the tire diameter of 3.75 feet. The fold angle is -30.2 degrees for the wingtip to be at this height. With the wing fold length of 18.6 feet, the wingspan (graph in blue) at -30.2 degrees is about 150.2 feet. As the fold angle is increased to zero degrees, the wingtip height increases to the wing height of 13.1 feet and the wingspan increases to its unfolded wingspan of 155.2 feet at zero degrees. The wingtip height keeps increasing till it reaches the maximum at the fold angle of 90 degrees. The wingspan continues to decrease with an increasing fold angle till it reaches the minimum of 118 feet at 90 degrees. The wingspan does not decrease beyond 90 degrees fold angle. The wingtip height continues to decrease with an increasing fold angle till it reaches the wing height at 180 degrees. The crossover point shown in Fig. 6 is the location where the wingtip height is the same as the tail height of 27.7 feet. This occurs between 128 and 129 degrees. At 128 degrees, the wingtip height is 27.76 feet.

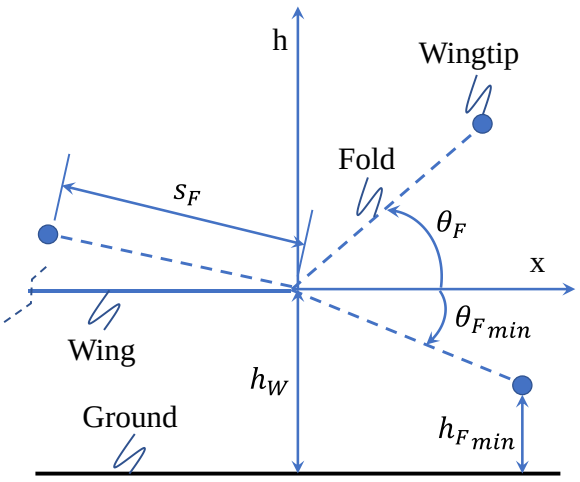

Figure 5. Wing folding geometry.

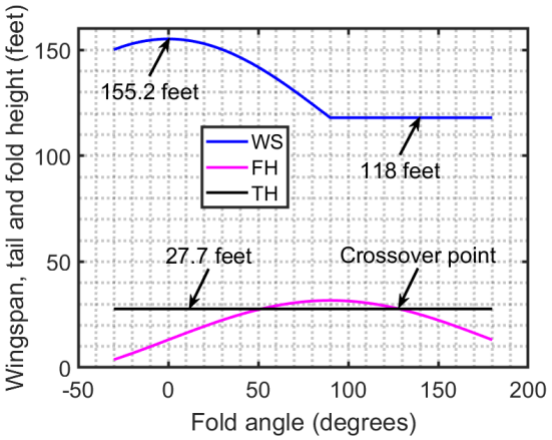

Figure 6. Wingspan (WS), folded wingtip height (FH), and tail height (TH) as a function of fold angle.

V. ANALYSIS OF MAJOR US AIRPORTS

With the objective of developing a procedure for identifying airports where TTBW aircraft and other aircraft with designs that are being investigated by the industry, academia, and NASA, could operate, 77 major US airports, whose performance is tracked in the FAA's ASPM database, were analyzed. Two different approaches were used for the analysis: (1) using archived historical air traffic data and (2) using airport geometric data. These approaches are discussed in the subsections below.

A. Analysis Based on Traffic Data

Three days — 04/26/2018, 07/20/2023 and 02/29/2024 — of 24-hour air traffic data containing flight ID, aircraft type, and origin airport and destination airport information of 151,394 flights were obtained from NASA's Sherlock database. The System-Wide Information Management (SWIM)

data provided by the FAA is the original source of these data. The data from SWIM are conditioned, processed, and reorganized into datasets in Sherlock for analysis. The three days of traffic data contained flights arriving to and departing from US airports. The origin and destinations of these flights were 3,710 US and foreign airports.

In addition to the traffic data, the data provided in the FAA's aircraft characteristics database were needed. The subset of data for the 387 different types of aircraft available in the database consisting of: AAC, ADG, TDG, approach speed at maximum landing weight, wingspan, length, tail height, CMG, MGW, maximum allowable landing weight, and maximum takeoff weight (MTOW) were used in this study. AAC, ADG and TDG values of each aircraft in the dataset were verified by computing them using their wingspan, tail height, approach speed at maximum landing weight, MGW and CMG distance data. The dataset was augmented with the corresponding TTBW aircraft data.

The data in the aircraft characteristics dataset for the aircraft in the traffic dataset are used to determine the largest AAC, ADG and TDG aircraft at the airports in the traffic dataset. Out of the 3,710 airports, the aircraft types operating out of 154 airports were not found in the aircraft characteristics dataset. These airports, which are small airports, were excluded from further analysis. The largest AAC, ADG, TDG and parking area along with the associated aircraft at the 76 ASPM airports are listed in Table A1 in the Appendix. There were no flights to/from Luis Munoz Marin airport (PSJU) in Puerto Rico, which is one of the ASPM 77 airports, in the traffic dataset; therefore, AAC, ADG, TDG and parking area data could not be provided for it. The parking area (minimum parking position size in Ref. 13), P, is determined using the wingspan, b, and the length, l, of the aircraft as

$$P = (b + 10)(l + 5) \tag{6}$$

where ten feet is added to the wingspan and five feet to the length (see Table E-1 in [13]). The aircraft associated with the largest AAC, ADG, TDG and parking area at each airport is the first one in the group of aircraft with the same attribute found during processing. For example, if there were several Boeing 747-8 (B748) and Airbus A380-800 (A388) — both ADG VI aircraft — flights to and from the airport, the aircraft appearing in the first such flight would be the aircraft associated with the largest ADG at that airport.

The largest AAC, ADG and TDG associated with the airports were used for assigning a three-component code: AAC-ADG-TDG. For example, an airport associated with the largest AAC D, ADG IV and TDG 5 is labeled: D-IV-5. Table 11 shows the 76 ASPM airports categorized into nine groups based on their three-component code. With AAC C, ADG IV and TDG 3, the conceptual TTBW aircraft can operate from any of the airports in Group 4 through 9 without wing folding. With reduced ADG III with wing folding, the TTBW aircraft would be able to operate from all the airports except from Oxnard airport (KOXR) in Southern California based on evidence of historical traffic. Geometric analysis of the runways, taxiways and parking areas is needed to determine whether TTBW aircraft could operate at KOXR with wing folding.

Table 11. Airport groups by AAC-ADG-TDG (TTBW aircraft codes: C-IV-3 and C-III-3)

Group	AAC-ADG-TDG	Airports
1	D-III-2B	KOXR
2	D-III-3	KISP, KLGA, KVNY
3	D-III-4	KPSP, KTEB
4	D-IV-4	KDCA, KHOU, KHPN
5	D-IV-5	KABQ, KBHM, KBUF, KBUR, KDAL, KDAY, KGYY, KJAX, KMDW, KMHT, KOMA, KPBI, KPVD, KRSW, KSNA, KSTL, KTUS
6	D-IV-6	KBDL, KMCI, KMKE
7	D-V-5	KBNA, KFLL, KLGB, KMSY, PHOG, KSJC, KSWF
8	D-V-6	KAUS, KBWI, KCLE, KCLT, KDEN, KDTW, KIND, KLAS, KMCO, KMEM, KOAK, KPHX, KPIT, KRDU, KRFD, KSAN, KSAT, KSLC, KSMF, KTPA
9	D-VI-6	PANC, KATL, KBOS, KCVG, KDFW, KEWR, PHNL, KIAD, KIAH, KJFK, KLAX, KMIA, KMSP, KONT, KORD, KPDX, KPHL, KSDF, KSEA, KSFO

B. Analysis Based on Geometric Data

Length and width data of 243 runways at the ASPM 77 airports were obtained from https://airnav.com/. These data were processed to identify the longest runways at each airport. The longest runway statistics are summarized in Table 12. Table 13 provides the classification of the airports by longest runway length. Other than John Wayne Airport-Orange County (KSNA) with the longest runway of 5,700 feet, the longest runway at other 76 airports are ICAO Airport Reference Code 4 (see Table 10) runways. The other airport in Group 1 in Table 13 is Oxnard Airport (KOXR) with the longest runway of 5,953 feet. Table 14 shows the classification of airports based on the widths of the longest runways. Other than the 100 feet wide longest runway at KOXR, the runways are at least 150 feet wide. At the thirteen airports, Group 4 in Table 14, the width of the longest runway is 200 feet.

Table 12. Longest runway statistics of 77 ASPM airports

Statistics	Value	Statistics	Value
Minimum	5,700 ft	Mode	10,000 ft
Mean	10,463 ft	Standard Deviation	2,115 ft
Median	10,901 ft	Maximum	16,000 ft

To determine the longest runway to the nearest parallel taxiway or runway distance, the airport diagrams were displayed in Google Maps and the distance measurement function was used to visually measure the distance. The distance and the parallel runway and taxiway names were recorded in an Excel Workbook for further processing in Matlab. Table 15 shows the runway to the nearest parallel taxiway or runway separation. The distances shown in this table are for

parallel taxiways except for Van Nuys (KVNY) and Ted Stevens Anchorage Intl. (PANC). At these two airports, the separation is 375 feet and 700 feet with respect to adjacent runways,

Table 13. Airports grouped by the length of the longest runway

Group	Length	Airports
1	5,000-6,000 ft	KOXR, KSNA
2	6,000-7,000 ft	KBUR, KHPN, KMDW, PHOG
3	7,000-8,000 ft	KDCA, KHOU, KISP, KLGA, KTEB
4	8,000-9,000 ft	KBUF, KDAL, KGYY, KPVD, KSAT, KSMF, KVNY
5	9,000-10,000 ft	KBDL, KCLE, KFLL, KMHT, KMKE, KOMA, KSAN
6	10,000-11,000 ft	KBOS, KBWI, KCLT, KDAY, KJAX, KLGB, KMCI, KMSY, KOAK, KPBI, KPSP, KRDU, KRFD, PSJU, KTUS
7	11,000-12,000 ft	KBNA, KEWR, KIAD, KIND, KMEM, KMSP, KPDX, KPHX, KPIT, KSDF, KSEA, KSFO, KSJC, KSTL, KSWF, KTPA
8	12,000-13,000 ft	PANC, KATL, KAUS, KBHM, KCVG, KDTW, PHNL, KIAH, KLAX, KMCO, KONT, KPHL, KRSW, KSLC
9	13,000-14,000 ft	KABQ, KDFW, KMIA, KORD
10	14,000-15,000 ft	KJFK, KLAS
11	15,000-16,000 ft	KDEN

Table 14. Airports grouped by the width of the longest runway

Group	Width	Airports
1	100	KOXR
2	150	KABQ, KATL, KAUS, KBHM, KBNA, KBOS, KBUF, KBUR, KBWI, KCLE, KCLT, KCVG, KDAL, KDAY, KDCA, KEWR, KFLL, KGYY, PHNL, KHOU, KHPN, KIAD, KIAH, KIND, KISP, KJAX, KLAS, KLAX, KLGA, KMCI, KMDW, KMEM, KMHT, KMIA, KMSP, KMSY, KOAK, PHOG, KOMA, KONT, KORD, KPBI, KPDX, KPHX, KPSP, KPVD, KRDU, KRFD, KRSW, KSAT, KSDF, KSEA, KSJC, KSLC, KSMF, KSNA, KSTL, KSWF, KTEB, KTPA, KTUS, KVNY
3	193	PSJU
4	200	PANC, KBDL, KDEN, KDFW, KDTW, KJFK, KLGB, KMCO, KMKE, KPHL, KPIT, KSAN, KSFO

respectively.

The TTBW aircraft will not be able to operate from KOXR based on runway width data listed in Table 14 and the design standard of runway width of 150 feet in Table 7. Based on the runway

to taxiway distance classification in Table 15 and the separation requirement of 400 feet in Table 7, the TTBW aircraft will be able to conduct concurrent operations at all other airports except the ones in Group 1 without wing folding. Wing folding and/or ATC mitigation will likely be required to

Table 15. Airport groups by longest runway to taxiway/runway separation

Group	Distance	Airports
1	300-375 ft	KBUR, KLGA, KBHM, KLAX, KLGB, KSJC, KSAN, KVNY
2	400-500 ft	KATL, KBOS, KBUF, KBWI, KCLE, KCVG, KDAL, KDCA, KDTW, KEWR, KGYY, KHOU, KHPN, KIAH, KISP, KJFK, KMDW, KMEM, KMHT, KMIA, KMKE, KMSP, KOMA, KONT, KPBI, KPDX, KPHL, KPHX, KPSP, KPVD, KRDU, KRFD, KRSW, KSAT, KSEA, PSJU, KSNA, KTEB, KTPA, KLAS, KSTL, KMSY, PHOG, KBDL, KDAY, KFLL, KSDF, KMCI, PHNL, KORD, KSFO
3	520-600 ft	KBNA, KABQ, KSLC, KTUS, KCLT, KDEN, KDFW, KIND, KJAX, KPIT, KSMF
4	630-700 ft	KSWF, KOXR, PANC, KIAD, KMCO, KOAK
5	1780 ft	KAUS

operate from Group 1 airports listed in Table 15.

Note that the classifications provided in Tables 11, 13, 14 and 15 might appear to be somewhat inconsistent in some instances. For example, according to Table 11, one might conclude that the TTBW aircraft would not be able to operate from KISP, KPSP, and KTEB airports without wing folding, but the classification of these airports in Table 15 suggests that the TTBW can operate out of these airports without wing folding. The classification in Table 11 is based on traffic data, while that in Table 15 is based on the actual dimensions of the airport. The fact that an aircraft with similar characteristics as the TTBW aircraft is not found to be operating out of an airport does not mean that the airport design is incompatible with TTBW aircraft characteristics. The only way to determine compatibility, without operational evidence of aircraft of similar characteristics, is by detailed analysis of the airport geometry.

In summary, the results in the tables show that TTBW aircraft can operate without wing folding with ATC mitigation at KBUR, KBHM, KLAX, KLGB, KSJC and KSAN. Wing folding will be required to operate at KLGA and KVNY. TTBW aircraft will probably not be able to operate from KOXR. TTBW aircraft will be able to operate without wing folding and ATC mitigation at the remaining 68 of the 77 ASPM 77 airports.

VI. CONCLUSIONS

For identifying airports that the conceptual model of the Transonic Truss-Braced Wing aircraft could operate — park, taxi, takeoff, and land — given its characteristics and dimensions, tables listing Federal Aviation Administration and International Civil Aviation Organization aircraft and airport reference codes were provided and the airport design standards based on them were discussed. The reference codes: Aircraft Approach Category, Airplane Design Code and Taxiway Design Group of the Transonic Truss-Braced Wing aircraft were determined to be C, IV and 3 using its characteristics and dimensions. The effect of wing folding on the wingspan and the wingtip height as a function of the fold angle was discussed. It was shown that a fold angle of 128 degrees was required to reduce the Airplane Design Group of the Transonic Truss-Braced Wing

aircraft from IV to III, which would enable it to operate on taxiways/taxilanes with smaller safety area, and less separation from parallel taxiways. The procedure of using the historical traffic data and the aircraft characteristics database for determining the reference aircraft with highest Aircraft Approach Category, Airplane Design Code and Taxiway Design Group that can operate at an airport was described. The classification of the major US airports into nine groups resulting from this process was tabulated. Summary statistics of the length of the longest runways were provided. Airports were categorized into 11 groups based on the length of the longest runway and into four groups based on the width of the longest runway. Airports were classified into five groups based on the centerline separation distance between the longest runway and the nearest taxiway or runway. It was determined that the Transonic Truss-Braced Wing aircraft would be permitted to operate from 68 of the 77 major US airports without wing folding and air traffic control mitigation. It might not be able to operate out of Oxnard Airport because its single runway is 100 feet wide while the requirement calls for 150 feet. The Transonic Truss-Braced Wing aircraft could probably operate from the remaining eight airports with wing folding and/or mitigation from air traffic control.

APPENDIX

Table A1 lists the largest Aircraft Approach Category (AAC), Airplane Design Code (ADG), Taxiway Design Group (TDG), Parking Area or minimum parking position size (PA), Number of Departures (ND) and Number of Arrivals (NA) for the 76 major US airports. The only airport missing from this list of the major airports tracked in the FAA's Aviation System Performance Metrics database is the Luis Munoz Marin airport (PSJU) in Puerto Rico. The aircraft with the largest AAC, ADG, TDG and PA found during processing of the three days of historical air traffic data are listed in columns AC*, AC†, AC‡ and AC§, respectively.

Table A1. ASPM 77 airport classification

APT	AAC	AC*	ADG	AC†	TDG	AC‡	PA	AC§	ND	NA
KABQ	D	B738	IV	B752	5	B763	32,711	DC10	425	397
PANC	D	B748	VI	B748	6	B748	59,819	B748	342	236
KATL	D	B753	VI	B748	6	B748	59,819	B748	3,501	3,586
KAUS	D	B738	V	B744	6	MD11	54,955	A35K	1,045	1,042
KBDL	D	B738	IV	B752	6	MD11	37,400	MD11	401	365
KBHM	D	B738	IV	A306	5	A306	30,778	B763	403	400
KBNA	D	B738	V	B788	5	A306	49,862	A359	1,065	1,037
KBOS	D	CRJ9	VI	B748	6	B77W	66,186	A388	2,066	1,890
KBUF	D	CRJ2	IV	B752	5	A306	28,655	A306	320	308
KBUR	D	B738	IV	A306	5	A306	28,655	A306	440	441
KBWI	D	B738	V	B772	6	MD11	44,940	B772	1,067	1,079
KCLE	D	MD90	V	B744	6	MD11	48,730	B744	501	490
KCLT	D	A321	V	A332	6	MD11	55,030	A346	2,404	2,381
KCVG	D	B748	VI	B748	6	B748	59,819	B748	751	760
KDAL	D	B738	IV	B752	5	B762	27,274	B762	1,068	1,032
KDAY	D	CRJ2	IV	B752	5	C17	32,184	C17	176	185
KDCA	D	CRJ2	IV	B752	4	B752	24,749	B753	1,364	1,321
KDEN	D	B739	V	B772	6	MD11	55,049	B77W	2,630	2,686
KDFW	D	A321	VI	B748	6	MD11	66,186	A388	3,085	3,089
KDTW	D	B739	V	A333	6	MD11	49,862	A359	1,449	1,458
KEWR	D	B739	VI	B748	6	MD11	59,819	B748	2,030	2,008
KFLL	D	B739	V	A332	5	DC10	47,552	B77L	1,380	1,353
KGYY	D	GLF4	IV	A306	5	A306	28,655	A306	42	53
PHNL	D	A321	VI	B748	6	MD11	59,819	B748	304	348
KHOU	D	B738	IV	B752	4	B752	21,608	B752	848	813
KHPN	D	GLF5	IV	B752	4	B752	21,608	B752	552	557

Table A1. ASPM 77 airport classification (contd.)

APT	AAC	AC*	ADG	AC†	TDG	AC‡	PA	AC§	ND	NA
KIAD	D	B738	VI	A388	6	A388	66,186	A388	1,355	1,296
KIAH	D	B739	VI	B748	6	B77W	66,186	A388	1,906	1,890
KIND	D	DC10	V	B77L	6	MD11	47,552	B77L	812	819
KISP	D	A321	III	A320	3	A320	19,253	A21N	187	139
KJAX	D	DC10	IV	A306	5	A306	32,711	DC10	410	407
KJFK	D	A321	VI	A388	6	B77W	66,186	A388	2,197	2,141
KLAS	D	B738	V	A332	6	B77W	55,049	B77W	2,228	2,149
KLAX	D	A321	VI	B748	6	B77W	66,186	A388	2,753	2,678
KLGA	D	B38M	III	E170	3	E170	19,253	A21N	1,739	1,695
KLGB	D	CRJ9	V	B744	5	A306	48,730	B744	298	281
KMCI	D	CRJ9	IV	B752	6	MD11	37,400	MD11	516	515
KMCO	D	B738	V	B77W	6	MD11	55,049	B77W	1,732	1,730
KMDW	D	B38M	IV	B752	5	DH8D	21,608	B752	1,075	1,027
KMEM	D	MD11	V	B77L	6	MD11	47,552	B77L	1,120	1,124
KMHT	D	B738	IV	A306	5	A306	30,778	B763	172	177
KMIA	D	A321	VI	B748	6	MD11	66,186	A388	2,011	1,996
KMKE	D	B738	IV	A306	6	MD11	37,400	MD11	445	465
KMSP	D	DC10	VI	A124	6	MD11	57,916	A124	1,656	1,721
KMSY	D	B739	V	B788	5	B788	39,615	B788	548	552
KOAK	D	B738	V	B789	6	MD11	47,552	B77L	729	737
PHOG	D	B738	V	A332	5	A332	44,940	B772	110	122
KOMA	D	MD83	IV	A306	5	A306	30,778	B763	388	400
KONT	D	MD11	VI	B748	6	MD11	59,819	B748	465	454
KORD	D	B739	VI	B748	6	B748	66,186	A388	3,406	3,407
KOXR	D	GLF5	III	GLF5	2B	GLF5	10,495	GLF5	34	49
KPBI	D	B739	IV	B752	5	A306	30,778	B763	708	731
KPDX	D	B738	VI	B748	6	MD11	59,819	B748	915	885
KPHL	D	A321	VI	B748	6	MD11	59,819	B748	1,473	1,454
KPHX	D	B739	V	B744	6	MD11	54,955	A35K	2,063	1,898
KPIT	D	B738	V	B77L	6	MD11	47,552	B77L	593	583
KPSP	D	B739	III	A320	4	GA5C	18,407	A321	219	220
KPVD	D	CRJ9	IV	B763	5	B763	30,778	B763	278	262
KRDU	D	CRJ9	V	B772	6	MD11	44,940	B772	888	824
KRFD	D	MD83	V	B744	6	MD11	48,730	B744	149	153

Table A1. ASPM 77 airport classification (contd.)

APT	AAC	AC*	ADG	AC†	TDG	AC‡	PA	AC§	ND	NA
KRSW	D	B739	IV	A310	5	A310	28,655	A306	503	402
KSAN	D	A321	V	A332	6	B77W	55,049	B77W	953	960
KSAT	D	MD11	V	B788	6	MD11	39,615	B788	698	661
KSDF	D	B748	VI	B748	6	B748	59,819	B748	879	876
KSEA	D	B739	VI	B748	6	B77W	59,819	B748	1,857	1,884
KSFO	D	B738	VI	B748	6	B77W	66,186	A388	1,700	1,695
KSJC	D	B738	V	B789	5	B763	43,761	B789	736	722
KSLC	D	CRJ9	V	B789	6	MD11	49,862	A359	1,400	1,358
KSMF	D	A321	V	A332	6	MD11	41,269	A332	536	539
KSNA	D	B738	IV	B752	5	A306	28,655	A306	884	816
KSTL	D	B738	IV	B752	5	B763	30,778	B763	755	744
KSWF	D	B38M	V	B744	5	A306	48,730	B744	79	62
KTEB	D	GLF5	III	GLF5	4	GA5C	13,213	GL7T	820	767
KTPA	D	GLF4	V	A333	6	MD11	47,058	A339	979	947
KTUS	D	CRJ9	IV	B763	5	B763	30,778	B763	333	296
KVNY	D	GLF4	III	FA8X	3	B737	14,136	B737	458	441

Table A2 lists the names of the 76 ASPM airports in Table A1 along with their location.

Table A2. ASPM 77 airport names

APT	Name	State
KABQ	Albuquerque International Sunport Airport	New Mexico
PANC	Ted Stevens Anchorage International Airport	Alaska
KATL	Hartsfield/Jackson Atlanta International Airport	Georgia
KAUS	Austin-Bergstrom International Airport	Texas
KBDL	Bradley International Airport	Connecticut
KBHM	Birmingham-Shuttlesworth International Airport	Alabama
KBNA	Nashville International Airport	Tennessee
KBOS	General Edward Lawrence Logan International Airport	Massachusetts
KBUF	Buffalo Niagara International Airport	New York
KBUR	Bob Hope Airport	California
KBWI	Baltimore/Washington International Thurgood Marshall Airport	Maryland

Table A2. ASPM 77 airport names (contd.)

APT	Name	State
KCLE	Cleveland-Hopkins International Airport	Ohio
KCLT	Charlotte/Douglas International Airport	North Carolina
KCVG	Cincinnati/Northern Kentucky International Airport	Kentucky
KDAL	Dallas Love Field Airport	Texas
KDAY	James M Cox Dayton International Airport	Ohio
KDCA	Ronald Reagan Washington National Airport	District of Columbia
KDEN	Denver International Airport	Colorado
KDFW	Dallas-Fort Worth International Airport	Texas
KDTW	Detroit Metro Wayne County Airport	Michigan
KEWR	Newark Liberty International Airport	New Jersey
KFLL	Fort Lauderdale/Hollywood International Airport	Florida
KGYY	Gary/Chicago International Airport	Indiana
PHNL	Daniel K Inouye International Airport	Hawaii
KHOU	William P Hobby Airport	Texas
KHPN	Westchester County Airport	New York
KIAD	Washington Dulles International Airport	District of Columbia
KIAH	George Bush Intercontinental/Houston Airport	Texas
KIND	Indianapolis International Airport	Indiana
KISP	Long Island Mac Arthur Airport	New York
KJAX	Jacksonville International Airport	Florida
KJFK	John F Kennedy International Airport	New York
KLAS	Harry Reid International Airport	Nevada
KLAX	Los Angeles International Airport	California
KLGA	LaGuardia Airport	New York
KLGB	Long Beach Airport (Daugherty Field)	California
KMCI	Kansas City International Airport	Missouri
KMCO	Orlando International Airport	Florida
KMDW	Chicago Midway International Airport	Illinois
KMEM	Memphis International Airport	Tennessee
KMHT	Manchester Boston Regional Airport	New Hampshire
KMIA	Miami International Airport	Florida
KMKE	General Mitchell International Airport	Wisconsin
KMSP	Minneapolis-St Paul International/Wold-Chamberlain Airport	Minnesota
KMSY	Louis Armstrong New Orleans International Airport	Louisiana

Table A2. ASPM 77 airport names (contd.)

APT	Name	State
KOAK	San Francisco Bay Oakland International Airport	California
PHOG	Kahului Airport	Hawaii
KOMA	Eppley Airfield	Nebraska
KONT	Ontario International Airport	California
KORD	Chicago O'Hare International Airport	Illinois
KOXR	Oxnard Airport	California
KPBI	Palm Beach International Airport	Florida
KPDX	Portland International Airport	Oregon
KPHL	Philadelphia International Airport	Pennsylvania
KPHX	Phoenix Sky Harbor International Airport	Arizona
KPIT	Pittsburgh International Airport	Pennsylvania
KPSP	Palm Springs International Airport	California
KPVD	Rhode Island TF Green International Airport	Rhode Island
KRDU	Raleigh-Durham International Airport	North Carolina
KRFD	Chicago/Rockford International Airport	Illinois
KRSW	Southwest Florida International Airport	Florida
KSAN	San Diego International Airport	California
KSAT	San Antonio International Airport	Texas
KSDF	Louisville Muhammad Ali International Airport	Kentucky
KSEA	Seattle-Tacoma International Airport	Washington
KSFO	San Francisco International Airport	California
KSJC	Norman Y Mineta San Jose International Airport	California
KSLC	Salt Lake City International Airport	Utah
KSMF	Sacramento International Airport	California
KSNA	John Wayne/Orange County Airport	California
KSTL	St Louis Lambert International Airport	Missouri
KSWF	New York Stewart International Airport	New York
KTEB	Teterboro Airport	New Jersey
KTPA	Tampa International Airport	Florida
KTUS	Tucson International Airport	Arizona
KVNY	Van Nuys Airport	California

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