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Aircraft with an unducted fan propulsor

Abstract

The present disclosure is generally related to aircraft having one or more unducted fan propulsors at locations within specific regions relative to an airfoil, such as a wing or horizontal stabilizer. More specifically, the specific regions are located where there is a relatively higher pressure air flow beneath the wings or above a horizontal stabilizer. That higher pressure air flow can be utilized to provide increased thrust from the unducted fan propulsor.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application is a continuation-in-part of U.S. patent application Ser. No. 18/230,609, filed on Aug. 4, 2023, the disclosure of which is hereby incorporated by reference in its entirety.

FIELD
(1) The present disclosure relates generally to an aircraft with a fan propulsor.
BACKGROUND
(2) Winged aircraft have undermounted propulsors in the form of a turboprop engine. The addition of a propulsor to a wing can lead to installation penalties, including increased drag. As the size of the undermounted propulsor increases, installation penalties can also increase, such as increased weight.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) A full and enabling disclosure of the aspects of the present description, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which refers to the appended figures, in which:
(2) FIG. **1** comprises a top plan view of an aircraft as configured in accordance with various embodiments of these teachings, with undermounted, unducted fan propulsors mounted on forward

wings of the aircraft;
(3) FIG. **2** comprises a top plan view of an aircraft as configured in accordance with various embodiments of these teachings, with unducted fan propulsors mounted on top of horizontal stabilizers of the aircraft;
(4) FIG. **3** comprises an elevational cross-sectional view of an exemplary unducted fan propulsor having a plurality of blades arranged in a single array;
(5) FIG. **4** comprises an elevational cross-sectional view of an exemplary unducted fan propulsor having a plurality of blades arranged in a forward array and a rearward array;
(6) FIG. **5** comprises a schematic side elevation view showing the location of one of the unducted fan propulsors of FIG. **3** relative to one of the forward wings of the aircraft of FIG. **1**;
(7) FIG. **6** comprises a schematic side elevation view similar to that of FIG. **5**, showing the location of one of the unducted fan propulsors of FIG. **4** relative to one of the forward wings of the aircraft;
(8) FIG. **6**A comprises a top plan view of the propulsor of FIG. **6** and inboard and outboard locations of the wing relative to an unducted fan propulsor centerline, with the inboard and outboard locations in FIG. **6**A used to determine a chord length of an airfoil section associated with the unducted fan propulsor;
(9) FIG. **6**B comprises a schematic side elevation view of a first section and a second section of the wing of FIG. **6**, which sections are used in determining the depicted airfoil section;
(10) FIG. **7** comprises a schematic side elevation view similar to that of FIG. **6**, but showing a first ellipse, a second ellipse, a third ellipse, and a fourth ellipse to illustrate various embodiments of mounting locations of one of the unducted fan propulsors relative to one of the wings;
(11) FIG. **8** comprises a schematic side elevation view similar to that of FIG. **7**, but showing a first ellipse, a second ellipse, a third ellipse, and a fourth ellipse to illustrate various embodiments of mounting locations of one of the unducted fan propulsors relative to one of the horizontal stabilizers;
(12) FIG. **9** comprises a schematic side elevation view similar to that of FIG. **7**, showing the first ellipse, the second ellipse, the third ellipse, and the fourth ellipse to illustrate various embodiments of mounting locations of one of the unducted fan propulsors relative to one of the wings;
(13) FIG. **10** comprises a schematic side elevation view similar to that of FIG. **8**, showing the first ellipse, the second ellipse, the third ellipse, and the fourth ellipse to illustrate various embodiments of mounting locations of one of the unducted fan propulsors relative to one of the horizontal stabilizers; and
(14) FIG. **11** is a schematic representation showing exemplary locations of a point P of one of the unducted fan propulsors, as defined herein, within the first ellipse, the second ellipse, the third ellipse, and the fourth ellipse.
(15) Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions and/or relative positioning of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of various embodiments of the present teachings. Also, common but well-understood elements that are useful or necessary in a commercially feasible embodiment are often not depicted in order to facilitate a less obstructed view of these various embodiments of the present teachings. Certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required.

DETAILED DESCRIPTION

(16) Aspects and advantages of the present disclosure will be set forth in part in the following description or may be learned through practice of the present disclosure.
(17) The word “or” when used herein shall be interpreted as having a disjunctive construction rather than a conjunctive construction unless otherwise specifically indicated.
(18) The terms “coupled,” “fixed,” “attached to,” and the like refer to both direct coupling, fixing,

or attaching, as well as indirect coupling, fixing, or attaching through one or more intermediate components or features, unless otherwise specified herein.

(19) The singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise.

(20) The term “at least one of” in the context of, e.g., “at least one of A, B, and C” refers to only A, only B, only C, or any combination of A, B, and C.

(21) The terms “forward” and “aft” refer to relative positions within a gas turbine engine or vehicle, and refer to the normal operational attitude of the gas turbine engine or vehicle. For example, with regard to a gas turbine engine, forward refers to a position closer to an engine inlet and aft refers to a position closer to an engine nozzle or exhaust.

(22) The terms “upstream” and “downstream” refer to the relative direction with respect to fluid flow in a fluid pathway. For example, “upstream” refers to the direction from which the fluid flows, and “downstream” refers to the direction to which the fluid flows.

(23) The term “leading edge” refers to components and/or surfaces which are oriented predominately upstream relative to the fluid flow of the system, and the term “trailing edge” refers to components and/or surfaces which are oriented predominately downstream relative to the fluid flow of the system.

(24) “Airfoil section” is defined as the average of a first offset plane section and a second offset plane section of an airfoil (e.g., an airfoil associated with a horizontal stabilizer or wing of an aircraft), where the first offset plane section is the section of the airfoil taken at a first plane and the second offset plane section is the section of the airfoil taken at a second plane, the first and second planes each being offset perpendicular to, and equidistant from a central plane by a distance of ½ of a fan diameter (D) of rotating blades of a propulsor mounted to the portion of the aircraft body associated with the airfoil section (wing or horizontal stabilizer). The first plane is inboard of the central plane (towards the fuselage) and the second plane is outboard of the central plane. When the aircraft is on the ground, both the gravity vector and axis of rotation of the rotating blades lie in the central plane. The intersection of the first offset plane with the airfoil defines a first section having a first section leading edge (LE**1**) and a first section trailing edge (TE**1**), with the LE**1** at the forward-most point of the first section and the TE**1** at the aft-most point of the first section. The intersection of the second offset plane with the airfoil defines a second section having a second section leading edge (LE**2**) and a second section trailing edge (TE**2**), with the LE**2** at the forward-most point of the section and the TE**2** at the aft-most point of the second section. Averaging the coordinates of LE**1** and LE**2** yields a representative LE location for the airfoil section. Averaging the coordinates of TE**1** and TE**2** yields a representative TE location for the airfoil section. The LE and TE points obtained this way are indicated in FIGS. **5**, **6** and **6**B. An “Airfoil Section” defined herein has its leading and trailing edges TE, LE determined in this manner.

(25) “Quarter-chord position” (“QC”) is defined as ¼ of the distance from the leading edge LE of an Airfoil Section as defined above, measured along the chord of this airfoil section.

(26) It is understood that the plurality blades, whether forward or rearward, may have a variation of root forward-most points and root rearward-most points. This can be due to both installed position as well as orientation in the case of variable pitch blades. For purposes of defining the distances TRL, RTL, and VTL it is understood that a rotating blade or rotating array of blades are orientated such that the respective leading edges of the blades are in their most forward position, e.g., a feathered position. The respective trailing edge position is also obtained when the leading edge is in the most forward position. For purposes of defining the distances TRL, RTL, and VTL it is understood that the forward or leading edge or rearward or trailing edge of a stationary blade (or vane) or array of stationary blades (or vanes) is the most forward or leading edge position across the array of vanes or the most rearward or trailing edge position across the array of vanes.

(27) “Blade” can refer to a stationary or rotating blade. “Stationary blade(s)” has the same meaning as “vane(s)”.

(28) Approximating language, as used herein throughout the specification and claims, is applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms such as "about", "approximately", and "substantially", are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or machines for constructing or manufacturing the components and/or systems. For example, the approximating language may refer to being within a 10 percent margin.
(29) Here and throughout the specification and claims, range limitations are combined and interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.
(30) As used herein, the term "proximate" refers to being closer to one side or end than an opposite side or end.
(31) Installing an unducted fan propulsion system presents the challenge of addressing penalties that can result due to the interaction with the rest of the aircraft. The manner in which these penalties are addressed is unique for this type of engine, and unlike how related penalties have previously been addressed for turboprops or ducted propulsion systems. For example, the interaction of the propulsor flow stream with the wing can produce scrubbing and interference drag. Thus, it would be desirable to improve the positioning of the unducted fan propulsion system on the aircraft to reduce the penalties as well as increase the thrust of the propulsor to offset remaining penalties.
(32) As explained below, after recognizing the flow characteristics of an aircraft and an unducted fan propulsor, the inventors were able to establish criteria for positioning the propulsor relative to an aircraft airfoil section for enhanced thrust without a conventional iterative process. In particular, certain relationships between the quarter-chord position of an airfoil section and a propulsor centerline (midway between the propulsor blade roots) can be utilized to identify a region for positioning unducted fan propulsors to improve aircraft performance and efficiency. Thus, mounting unducted fan propulsors relative to the quarter-chord position of the airfoil section as described in embodiments provided herein improves aircraft performance over other mounting locations, including conventional mounting locations that are more forward of, and more in line with, a wing chord line.
(33) Various aspects of the present disclosure describe aspects of an aircraft characterized in part by a specific relation between a quarter-chord position of an airfoil section associated with a wing (or horizontal stabilizer) and the unducted fan propulsor, which is believed to result in improved aircraft performance and/or fuel efficiency. According to the disclosure, an aircraft includes a fuselage and an unducted fan propulsor installed relative to a section of the wing or the horizontal stabilizer.
(34) Reference will now be made in detail to present embodiments of the disclosure, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the disclosure.
(35) As shown in FIGS. **1** and **2**, the aircraft **10** includes a fuselage **12** that extends longitudinally from a forward or nose section **14** and an aft or tail section **16** of the aircraft **10**. The aircraft **10** further includes airfoils including a first wing **18** that extends laterally outwardly from a port side **20** and a second wing **18** that extends laterally outwardly from a starboard side **22** of the fuselage **12**. The tail section **16** of the aircraft **10** includes a vertical stabilizer **24**, a first airfoil of the horizontal stabilizer **26** that extends laterally outwardly from the port side **20**, and a second airfoil of the horizontal stabilizer **26** that extends laterally outward from the starboard side **22** of the fuselage **12**. An unducted fan propulsor **30** or **38** is undermounted relative to each of the wings **18**,

as shown in the embodiment of FIG. **1**. Alternatively, the unducted fan propulsor **30** or **38** is mounted relative to the top of each of the horizontal stabilizers **26**, as shown in FIG. **2**. In some embodiments, more than one of the unducted fan propulsors **30** or **38** may be mounted to each of the wings **18** or each of the horizontal stabilizers **26**.

(36) FIG. **3** shows an elevational cross-sectional view of an embodiment of one of the unducted fan propulsors **30**. As is seen from FIG. **3**, the unducted fan propulsor **30** takes the form of an open fan propulsion system and has a rotating element in the form of rotatable propeller assembly **32** on which is mounted a first array of blades **34** around an axial centerline CL of the unducted fan propulsor **30**. The first array of blades **34** defines a diameter D representing the tip-to-tip diameter of the blades and a maximum radial extent from the axial centerline CL. This diameter D is measured along a radial direction perpendicular to the axial centerline CL. Each of the blades **34** has a root **35** where the blade **34** is attached to the rotatable propeller assembly **32**, and each blade **34** defines a root length (RTL). The root length (RTL) is defined as the axial extent (in a direction parallel to the axial centerline CL) from the radially innermost leading edge (LE) of the blade **34** airfoil, e.g., closest to the axial centerline CL, to the axial location of the radially innermost trailing edge (TE) of the blade **34** airfoil.

(37) FIG. **4** shows an elevational cross-sectional view of an embodiment of an alternative one of the unducted fan propulsors **38**. Like the embodiment of FIG. **3**, the unducted fan propulsor **38** of FIG. **4** takes the form of an open fan propulsion system and has a rotating element in the form of rotatable propeller assembly **32** on which is mounted a first array of blades **34** around an axial centerline CL of the unducted fan propulsor **30**. The unducted fan propulsor **38** of FIG. **4** differs from that of FIG. **3** in that the former includes a second array of blades or vanes, which can either be rotating—such as counter-rotating—or stationary. In some embodiments, a non-rotating stationary element in the form of vane assembly **40** includes an array of vanes **42** disposed around the axial centerline CL. The first array of blades **34** defines a diameter D representing the tip-to-tip diameter of the blades and a maximum radial extent from the axial centerline CL. This diameter D is measured along a radial direction perpendicular to the axial centerline CL. Each of the blades **34** has a root where the blade **34** is attached to the rotatable propeller assembly **32** with a blade root length RTL. Each of the vanes **42** also has a root **43** with a vane root distance VTL where the vane **42** is attached to the non-rotating vane assembly **40**. The total root length (TRL) is the distance between the leading edge (LE) of the blade **34** airfoil (radially nearest to CL) of the blades **34** and the trailing edge (LE) of the root **43** of the vanes **42**, as shown in FIGS. **4** and **6**. TRL is a measured axial distance from the radial innermost LE of the foremost row of blades/vanes and the trailing edge (TE) of the vanes **42**. In some embodiments, the second array may instead be a second rotating elements and the TRL is the measured axial distance from the radially innermost LE of the blades **34** of the first rotating element and the TE of the root of the blades of the second rotating elements. In some embodiments, the vanes **42** may be forward of the rotating blades, and the TRL is the distance between the LE edge of the root of the vanes and the TE of the root of the rotating blades. In some embodiments, an unducted fan propulsor having rotating elements (e.g., rotating blades) and stationary elements (e.g. vanes) may be mounted according to the relationship described in the present disclosure. In unducted fan propulsors having multiple rows of blade and/or vanes, the TRL of an unducted fan propulsor is defined as the distance between the LE of the root of the foremost row of blades/vanes and the rearward edge of the root of the aftmost row of blades/vanes of the unducted fan propulsor.

(38) Referring to FIG. **5**, for purposes explained more later, each of the foregoing unducted fan propulsors **30** and **38** has a point P. The point P is defined differently depending upon whether the unducted fan propulsor **30** has a single rotating element with a plurality of blades **34** or whether the unducted fan propulsor **38** has multiple rows of rotating blades and/or stationary vanes. For an unducted fan propulsor **30** with a single array of blades **34**, the point P is located at the intersection of the axial centerline CL and a line (HP) perpendicular to the axial centerline CL and that passes

through an axial midpoint of the root length RTL of any one of the blades **34**.

(39) Referring to FIG. **6**, for an unducted fan propulsor **38** with a first array of blades or vanes **34** and a second array of blades or vanes **42**, the point P is located at the intersection of the axial centerline CL and a line HP perpendicular to the axial centerline CL and that passes through an axial midpoint of the total root length TRL between a forward end at the root of one of the blades **34** of the forward array and a rearward end at the root of one of the blades **42** of the rearward array when aligned with the one of the blades **34** of the forward array, as shown in FIG. **6** (note: either the forward or rearward array can be vanes or blades). In other words, the line HP is located equidistant from a forward end of the root of one of the forward blades **34** and a rearward end of the root of one of the rearward blades or vanes **42**. In unducted fan propulsors with multiple rows of blades and/or vanes, the TRL of an unducted fan propulsor is defined as the distance between the LE of the root of the forward row of blades/vanes and the rearward edge of the root of the aftmost blade/vane on the unducted fan propulsor.

(40) Referring again to FIGS. **3** and **4**, the exemplary unducted fan propulsors **30** and **38** each include a drive mechanism **44** that provides torque and power to the propeller assembly **32** through a transmission **46**. In various embodiments, the drive mechanism **44** may be a gas turbine engine, an electric motor, an internal combustion engine, or any other suitable source of torque and power and may be located in proximity to the propeller assembly **32** or remotely located with a suitably configured transmission **46**. Transmission **46** transfers power and torque from the drive mechanism **44** to the propeller assembly **32**. The transmission system can be configured as a direct drive engine, transferring power from a low pressure turbine (LPT) or electric motor to the propeller assembly, or an indirect drive system where torque from the LPT is transferred to the propeller assembly **32** through a gearbox. The transmission system can generate power producing shaft torque to the propeller assembly via a gas turbine engine, including in serial order a compressor, combustor, high pressure turbine and LPT.

(41) The unducted fan propulsors **30** or **38** are attached relative to the wings **18**, horizontal stabilizer **26**, or fuselage either directly or indirectly through one or more intermediate components or features, e.g., a pylon **39**, as shown in FIGS. **5** and **6**.

(42) Each of the wings **18** shown in FIG. **1**, and horizontal stabilizers **26** shown in FIG. **2**, has an airfoil section **41** associated with it, where the airfoil section **41** is defined above.

(43) The chord C in FIGS. **5** and **6** is shown as a straight line extending from LE to TE of the airfoil section (no camber). The airfoil section can have different shapes than shown for illustration purposes, and may, for example, have a positive camber or a negative camber. A quarter-chord position (QC) of the airfoil section is located on the chord C line at a distance of C/4 from the LE of the airfoil section **41**.

(44) The position of the open fan propulsor is defined relative to the quarter-chord position of the relevant wing section. The airfoil section, as defined above, is the average of a first offset plane section and a second offset plane section of the airfoil, where the first offset plane section is the section of the airfoil taken at a first plane and the second offset plane section is the section of the airfoil taken at a second plane, the first and second planes being offset perpendicular to, and equidistant from a central plane by a distance of ½ the maximum fan diameter (D) for the rotating blades, as shown in FIG. **6**A. Both the gravity vector and axis of rotation of the rotating blades of the propulsor lie in this central plane when the aircraft is on the ground.

(45) There are specific locations that the inventors have found to be advantageous to position the unducted fan propulsors **30** or **38** to generate increased thrust using higher pressure air flow. The higher pressure air flow can be beneath the wings **18**. In the case of a horizontal stabilizer **26**, the higher pressure air flow is above the horizontal stabilizer **26**. Accordingly, the high-pressure side of an airfoil may refer to the underside of a wing **18** or the top side of a horizontal stabilizer **26**.

(46) The aircraft described herein has a fuselage, wings and/or stabilizers, and an unducted fan propulsor system (or propulsor). The unducted fan propulsor system, which is mounted on the

pressure side of a wing or horizontal stabilizer, provides thrust to the aircraft. To improve upon what the propulsor system can deliver, there often is a need to make compromises to other parts of aircraft design (trade-offs). Stated another way, the benefits of an unducted fan propulsor cannot be viewed without consideration of the effect of placement of the propulsor on the aircraft. For example, placement can affect loads on and size of the pylon, wing loads, landing gear length and associated forces, weight, and cost.

(47) The teachings described below enable improved balancing of the tradeoffs required in the aircraft design.

(48) Referring to FIGS. **5** and **6**, the location of an unducted fan propulsor relative to an airfoil section **41**, such as a section of the wing **18** or the horizontal stabilizer **26**, is defined herein using a polar coordinate system having an angular (θ) coordinate and a radial (R) component, with origin located at the quarter chord point (C/4) of the airfoil section (as defined above) having a chord length (C) as shown. The radial component is referred to herein as a "positioning line (R)". The location of the point P of the unducted fan propulsors **30** and **38** relative to the origin (QC) of the polar coordinate system (QC being coincident with the quarter chord point (C/4) of the airfoil section **41**) is expressed in terms of a vector having radial component R with magnitude RL and angular component θ. The vector magnitude RL is called a "positioning line length (RL)". The angle θ is measured relative to the coordinate axis extending from the QC to the TE of the airfoil section to the positioning line R. When viewed looking from an outboard position towards an inboard position (e.g., the fuselage), θ is positive in a counter-clockwise direction when the propulsor is below the airfoil section **41** (wing, FIG. **9**), and θ is positive in a clockwise direction when the propulsor is above the airfoil section (horizontal stabilizer, FIG. **10**) as indicated in the drawings, respectively, by the direction of the arrow from the origin.

(49) The location of the unducted fan propulsor relative to the origin depends on the number of arrays of airfoils. When there is a single array of blades (FIG. **5**), the unducted fan propulsor location relative to the origin (i.e., point "P") is located at an intersection of the CL and a line perpendicular to the CL that passes through an axial midpoint between edges at the root of one of the plurality of blades. When there are a forward and rearward array of blades (FIG. **6**) the unducted fan propulsor location relative to the origin (i.e., point "P") is located at an intersection of the CL and an axial midpoint between a rearward trailing edge (TE) of the aft array and leading edge (LE) of the forward array when a blade of the forward and rearward arrays are aligned with each other.

(50) The inventors found that for an unducted fan propulsor system the ratio of RL over D (i.e., RL/D) is desirably less than or equal to 2, less than or equal to 2 and greater than or equal to 0.15, or less than or equal to 2 and greater than or equal to 0.35. Additionally, for the undermounted unducted fan propulsor systems (pressure side of the airfoil section) of FIGS. **5** and **6** the angular component θ associated with these ranges for RL/D and locating the unducted fan propulsor system (i.e., the location of P relative to the airfoil section) are desirably between 187° and 342°, between 198° and 310°, or between 205° and 285°. These regions of RL and θ locating the unducted fan propulsor system relative to the airfoil section were found to have advantageous aero performance requirements for an aircraft with an unducted fan propulsor system mounted relative to a wing.

(51) Alternatively, the point P for the unducted fan propulsor can be located within a defined ellipse. FIGS. **7-10** each illustrate such ellipses according to several embodiments. Each of the ellipses has an origin OR, a major axis length (MajAL), and a minor axis length (MinAL), as shown in FIGS. **9** and **10** with respect to one of several ellipses and as will be explained further below. The location of OR is expressed relative to QC using the polar coordinate system frame of reference defined earlier. The propulsor system is mounted such that the point P of the unducted fan propulsors **38** is located within an ellipse as defined herein.

(52) Referring to FIG. **9**, the radial ellipse origin positioning line (EOR) extends from the ellipse origin OR, e.g., ellipse E**1**, to QC (quarter chord of the airfoil section). The ellipse origin position

line EOR has a length EORL. The origin of each of the ellipses is defined in the adopted polar coordinates with a radial coordinate defined as the ratio of EORL to the array of blades diameter (D), i.e., the quantity EORL/D. An angle θ for the ellipse origin positioning line EOR is measured from a vector from the QC to the TE of the airfoil section to the line EOR, where, when viewed with the LE to the left of TE, a positive θ (1) increases in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and (2) increases in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section.

(53) In a first embodiment, the point P of the unducted fan propulsor **30** or **38** is located in a first ellipse E**1** with a first ellipse origin defined by EORL/D of 0.938 and θ of 253.6°. The first ellipse E**1** also has a first major axis length (1MajAL) and a first minor axis length (1MinAL), where 1MajAL/D is 2.8 and 1MinAL/D is 1.7.

(54) In a second embodiment, the point P of the unducted fan propulsor **30** or **38** is located in a second ellipse E**2** having a second ellipse origin defined by EORL/D of 1.051 and θ of 248.8°. The second ellipse E**2** has a second major axis length (2MajAL) and a second minor axis length (2MinAL), where 2MajAL/D is 1.86 and 2MinAL/D is 1.56.

(55) In a third embodiment, the point P of the unducted fan propulsor **30** or **38** is located in a third ellipse E**3** having a third ellipse origin defined by EORL/D of 0.870 and θ of 239.6°. The third ellipse E**3** has a third major axis length (3MajAL) and a third minor axis length (3MinAL), where 3MajAL/D is 1.4 and 3MinAL/D is 0.9.

(56) In a fourth embodiment, the point P of the unducted fan propulsor **30** or **38** is located in a fourth ellipse E**4** having a fourth ellipse origin defined by EORL/D of 0.763 and θ of 235.7°. The fourth ellipse E**4** has a fourth major axis length (4MajAL) and a fourth minor axis length (4MinAL), where 4MajAL/D is 0.94 and 4MinAL/D is 0.44.

(57) The location of the unducted fan propulsor system (i.e. point P) relative to the airfoil section may also be expressed in terms of the following expressions:

(58) $\frac{RL}{D} + \frac{(\sqrt{a * [b * \sin^2(\theta) - c * \cos^2(\theta) + d * \sin(\theta) * \cos(\theta)]} + e * \sin(\theta) + f * \cos(\theta))}{g * \sin^2(\theta) + h * \cos^2(\theta)} > 0$and

$\frac{RL}{D} + \frac{(-\sqrt{a * [b * \sin^2(\theta) - c * \cos^2(\theta) + d * \sin(\theta) * \cos(\theta)]} + e * \sin(\theta) + f * \cos(\theta))}{g * \sin^2(\theta) + h * \cos^2(\theta)} < 0$ where 0.07<RL/D<1.98 and θ is between 187° and 340°, and where a, b, c, d, e, f, g and h have the values set forth in the following table under the heading "Fifth Emb.":

(59) TABLE-US-00001 Fifth Sixth Seventh Eighth Variable Emb. Emb. Emb. Emb. a 1.4161 0.52621 0.09923 0.01069156 b 1.88978 0.7205 0.2964 0.036 c 0.0875 0.352 0.36 0.3485 d 0.477 0.7448 0.66 0.5418 e 1.764 0.8476 0.3675 0.139167 f 0.19146 0.23119 0.0891 0.020812 g 1.96 0.8649 0.49 0.2209 h 0.7225 0.6084 0.2025 0.0484

(60) In a sixth embodiment, the point P of the unducted fan propulsors **30** and **38** can be defined by the above expression, but where 0.254<RL/D<1.86 and θ is between 199° and 306°, and where a, b, c, d, e, f, g and h have the values set forth in the above table under the heading "Sixth Emb."

(61) In a seventh embodiment, the point P of the unducted fan propulsors **30** and **38** can be defined by the above expression, but where 0.369<RL/D<1.43 and θ is between 204° and 291°, and where a, b, c, d, e, f, g and h have the values set forth in the above table under the heading "Seventh Emb.".

(62) In an eighth embodiment, the point P of the unducted fan propulsors **30** and **38** can be defined by the above expression, but where 0.477<RL/D<0.9455 and θ is between 211° and 274°, And where a, b, c, d, e, f, g and h have the values set forth in the above table under the heading "Eighth Emb."

(63) The unducted fan propulsor locations illustrated in FIG. **7** are made relative to an airfoil section of an aircraft wing and refer to an undermounted unducted fan propulsor system.

(64) TABLES 1 and 3-6 set forth examples of embodiments of invention. TABLE 1 shows each maximum outer diameter (D) and the location of point P of the unducted fan propulsor relative to

the quarter chord of the airfoil, QC, contemplated, where the point P is defined by RL and θ. The term “Ref.” refers to the row in Table 1 for reference. The exemplary types of aircraft indicated with reference letters A through I in TABLE 1 are identified in TABLE 2. The point P of the unducted fan propulsor locations from Table 1 are shown in FIG. **11** for an under-wing mounted propulsor (for a propulsor mounted above a horizontal stabilizer the maximum outer diameter (D) and the point P of the unducted fan propulsor locations would be mirrored about the chord line of the airfoil section, which, for purposes of explanation, may be thought of as an axis passing through θ=0 deg and θ=180 deg in FIG. **11**) relative to the first ellipse (E**1**), second ellipse (E**2**), third ellipse (E**3**), and the fourth ellipse (E**4**). The size of the points in FIG. **11** represent the relative size of D for the range provided in TABLE 1 (not to scale). The rotating blades diameter (D) may be, for example, between 2-50, 8-16, 10-15, 12-14, or 14-16 feet.

(65) TABLE-US-00002 TABLE 1 P-location relative to airfoil section quarter chord point Type of Ref. aircraft RL D θ (deg) RL/D 1 C I 2.60 2.0 220.00 1.30 2 F I 1.07 2.0 189.00 0.54 3 I 3.13 2.0 199.73 1.57 4 C F I 2.18 3.0 319.20 0.73 5 F I 2.82 3.0 242.40 0.94 6 C I 1.47 4.0 293.60 0.37 7 C I 2.43 4.0 217.87 0.61 8 I 6.64 4.0 259.47 1.66 9 C F I 4.23 5.0 265.87 0.85 10 C H I 6.57 5.0 194.40 1.31 11 F I 2.03 5.0 250.93 0.41 12 C F H I 8.03 5.0 275.47 1.61 13 C 2.52 6.0 337.33 0.42 14 H 4.44 6.0 228.53 0.74 15 C I 1.88 6.0 208.27 0.31 16 C F 7.14 7.0 244.53 1.02 17 B F H 4.15 7.0 332.00 0.59 18 B C I 6.49 7.0 292.53 0.93 19 C G 8.05 8.0 216.80 1.01 20 B F I 11.89 8.0 256.27 1.49 21 C G H 10.08 8.0 277.60 1.26 22 B C G I 7.31 8.0 330.93 0.91 23 C H 9.97 8.0 294.67 1.25 24 G I 11.57 8.0 312.80 1.45 25 B F I 11.58 9.0 260.53 1.29 26 C H 6.06 9.0 224.27 0.67 27 F G H 3.06 9.0 233.87 0.34 28 C I 12.78 9.0 204.00 1.42 29 B H 10.47 10.0 210.40 1.05 30 B I 5.53 10.0 221.07 0.55 31 A B C F G H 7.00 10.0 253.07 0.70 32 I 2.47 10.0 306.40 0.25 33 A C 15.27 10.0 222.13 1.53 34 G 11.67 10.0 241.33 1.17 35 A C F H 17.13 10.0 243.47 1.71 36 A B G I 18.70 11.0 210.00 1.70 37 G 10.93 11.0 249.87 0.99 38 A H 4.33 11.0 285.07 0.39 39 F I 6.82 11.0 206.13 0.62 40 A F H 11.60 12.0 272.27 0.97 41 A B F I 10.64 12.0 227.47 0.89 42 A H 21.84 12.0 232.80 1.82 43 A G 8.56 12.0 236.00 0.71 44 B F H 0.78 12.0 263.50 0.07 45 A F 10.00 12.5 200.00 0.80 46 A B G H I 15.25 12.5 268.00 1.22 47 B 19.92 12.5 279.73 1.59 48 A B F 15.92 12.5 316.00 1.27 49 A B 6.25 12.5 270.13 0.50 50 A F H 18.42 12.5 211.47 1.47 51 F G 24.25 12.5 215.73 1.94 52 A B H 19.50 13.0 287.20 1.50 53 H 10.66 13.0 234.93 0.82 54 B 14.99 13.0 326.67 1.15 55 I 18.11 13.0 239.20 1.39 56 A B F H 23.49 13.0 225.33 1.81 57 A F G H 10.49 13.0 302.13 0.81 58 B I 3.38 13.0 231.73 0.26 59 A B G 13.95 13.0 212.53 1.07 60 A B H 10.14 13.0 255.20 0.78 61 F 10.80 13.5 215.00 0.80 62 A H I 19.35 13.5 198.67 1.43 63 B F 15.39 13.5 220.00 1.14 64 A G H I 7.83 13.5 207.20 0.58 65 B H 10.30 13.5 235.70 0.76 66 A B 23.49 13.5 237.07 1.74 67 A H 22.05 13.5 238.13 1.63 68 F G 13.08 13.5 192.00 0.97 69 A B F 6.03 13.5 195.47 0.45 70 A F 13.23 13.5 200.80 0.98 71 B H 16.89 14.0 201.87 1.21 72 B I 22.68 14.0 254.13 1.62 73 A B F H 24.17 14.0 269.07 1.73 74 B E G 19.69 14.0 301.07 1.41 75 A 12.60 14.0 223.20 0.90 76 H I 23.30 15.0 214.67 1.55 77 A B E G H 10.30 15.0 248.80 0.69 78 A B E H 17.90 15.0 288.27 1.19 79 F G 21.23 16.0 246.67 1.33 80 A E 8.64 16.0 290.40 0.54 81 E G 17.60 16.0 207.00 1.10 82 A E 25.20 18.0 230.00 1.40 83 F 19.80 18.0 225.00 1.10 84 A G 6.84 18.0 263.73 0.38 85 A E 35.64 18.0 221.00 1.98 86 A E 6.17 20.0 297.03 0.31 87 F 30.55 21.0 259.78 1.45 88 A D 10.99 22.0 252.33 0.50 89 A E 21.50 22.0 237.43 0.98 90 D 14.29 24.0 222.53 0.60 91 D E 25.75 24.0 319.38 1.07 92 D E 3.41 29.0 267.23 0.12 93 D 39.42 29.0 304.48 1.36 94 E 38.55 33.0 282.13 1.17 95 D 51.16 33.0 229.98 1.55 96 D E 44.23 35.0 215.08 1.26 97 E 24.18 35.0 311.93 0.69 98 D 8.53 40.0 207.63 0.21 99 D 31.45 40.0 274.68 0.79 100 D 18.19 45.0 334.28 0.40 101 D 42.32 48.0 192.73 0.88 102 D 90.00 50.0 244.88 1.80

(66) TABLE-US-00003 TABLE 2 Designator for TABLE 1 Aircraft Type A Narrow Body, twin engine B Narrow Body, 4 engines C Narrow Body, distributed propulsors (>4 engines) D Wide Body, twin engine E Wide Body, 4 engines F Wide Body, distributed propulsors (>4 engines) G Regional Jet H Business Jet I UAV

(67) TABLES 3-6 provide exemplary embodiments for EORL and D for each of the first ellipse E**1**,

second ellipse E**2**, third ellipse E**3** and fourth ellipse E**4**, respectively, relative to the quarter chord point C/4 (origin OC).

(68) TABLE-US-00004 TABLE 3 First Ellipse E1 Embodiments EORL 1MajAL 1MinAL D (ft) θ (deg) (ft) (ft) (ft) EORL/D 1MajAL/D 1MinAL/D 2 253.6 1.876 5.6 3.4 0.938 2.8 1.7 3 253.6 2.814 8.4 5.1 0.938 2.8 1.7 4 253.6 3.752 11.2 6.8 0.938 2.8 1.7 5 253.6 4.69 14 8.5 0.938 2.8 1.7 6 253.6 5.628 16.8 10.2 0.938 2.8 1.7 7 253.6 6.566 19.6 11.9 0.938 2.8 1.7 8 253.6 7.504 22.4 13.6 0.938 2.8 1.7 9 253.6 8.442 25.2 15.3 0.938 2.8 1.7 10 253.6 9.38 28 17 0.938 2.8 1.7 11 253.6 10.318 30.8 18.7 0.938 2.8 1.7 12 253.6 11.256 33.6 20.4 0.938 2.8 1.7 12.5 253.6 11.725 35 21.25 0.938 2.8 1.7 13 253.6 12.194 36.4 22.1 0.938 2.8 1.7 13.5 253.6 12.663 37.8 22.95 0.938 2.8 1.7 14 253.6 13.132 39.2 23.8 0.938 2.8 1.7 15 253.6 14.07 42 25.5 0.938 2.8 1.7 16 253.6 15.008 44.8 27.2 0.938 2.8 1.7 18 253.6 16.884 50.4 30.6 0.938 2.8 1.7 20 253.6 18.76 56 34 0.938 2.8 1.7 21 253.6 19.698 58.8 35.7 0.938 2.8 1.7 22 253.6 20.636 61.6 37.4 0.938 2.8 1.7 24 253.6 22.512 67.2 40.8 0.938 2.8 1.7 29 253.6 27.202 81.2 49.3 0.938 2.8 1.7 33 253.6 30.954 92.4 56.1 0.938 2.8 1.7 35 253.6 32.83 98 59.5 0.938 2.8 1.7 40 253.6 37.52 112 68 0.938 2.8 1.7 45 253.6 42.21 126 76.5 0.938 2.8 1.7 48 253.6 45.024 134.4 81.6 0.938 2.8 1.7 50 253.6 46.9 140 85 0.938 2.8 1.7

(69) TABLE-US-00005 TABLE 4 Second Ellipse E2 Embodiments EORL 2MajAL 2MinA D (ft) θ (deg) (ft) (ft) L (ft) EORL/D 2MajAL/D 2MinAL/D 2 248.8 2.102 3.72 3.12 1.051 1.86 1.56 3 248.8 3.153 5.58 4.68 1.051 1.86 1.56 4 248.8 4.204 7.44 6.24 1.051 1.86 1.56 5 248.8 5.255 9.3 7.8 1.051 1.86 1.56 6 248.8 6.306 11.16 9.36 1.051 1.86 1.56 7 248.8 7.357 13.02 10.92 1.051 1.86 1.56 8 248.8 8.408 14.88 12.48 1.051 1.86 1.56 9 248.8 9.459 16.74 14.04 1.051 1.86 1.56 10 248.8 10.51 18.6 15.6 1.051 1.86 1.56 11 248.8 11.561 20.46 17.16 1.051 1.86 1.56 12 248.8 12.612 22.32 18.72 1.051 1.86 1.56 12.5 248.8 13.1375 23.25 19.5 1.051 1.86 1.56 13 248.8 13.663 24.18 20.28 1.051 1.86 1.56 13.5 248.8 14.1885 25.11 21.06 1.051 1.86 1.56 14 248.8 14.714 26.04 21.84 1.051 1.86 1.56 15 248.8 15.765 27.9 23.4 1.051 1.86 1.56 16 248.8 16.816 29.76 24.96 1.051 1.86 1.56 18 248.8 18.918 33.48 28.08 1.051 1.86 1.56 20 248.8 21.02 37.2 31.2 1.051 1.86 1.56 21 248.8 22.071 39.06 32.76 1.051 1.86 1.56 22 248.8 23.122 40.92 34.32 1.051 1.86 1.56 24 248.8 25.224 44.64 37.44 1.051 1.86 1.56 29 248.8 30.479 53.94 45.24 1.051 1.86 1.56 33 248.8 34.683 61.38 51.48 1.051 1.86 1.56 35 248.8 36.785 65.1 54.6 1.051 1.86 1.56 40 248.8 42.04 74.4 62.4 1.051 1.86 1.56 45 248.8 47.295 83.7 70.2 1.051 1.86 1.56 48 248.8 50.448 89.28 74.88 1.051 1.86 1.56 50 248.8 52.55 93 78 1.051 1.86 1.56

(70) TABLE-US-00006 TABLE 5 Third Ellipse E3 Embodiments 3MajAL 3MinAL D (ft) θ (deg) EORL (ft) (ft) (ft) EORL/D 3MajAL/D 3MinAL/D 2 239.6 1.74 2.8 1.8 0.87 1.4 0.9 3 239.6 2.61 4.2 2.7 0.87 1.4 0.9 4 239.6 3.48 5.6 3.6 0.87 1.4 0.9 5 239.6 4.35 7 4.5 0.87 1.4 0.9 6 239.6 5.22 8.4 5.4 0.87 1.4 0.9 7 239.6 6.09 9.8 6.3 0.87 1.4 0.9 8 239.6 6.96 11.2 7.2 0.87 1.4 0.9 9 239.6 7.83 12.6 8.1 0.87 1.4 0.9 10 239.6 8.7 14 9 0.87 1.4 0.9 11 239.6 9.57 15.4 9.9 0.87 1.4 0.9 12 239.6 10.44 16.8 10.8 0.87 1.4 0.9 12.5 239.6 10.875 17.5 11.25 0.87 1.4 0.9 13 239.6 11.31 18.2 11.7 0.87 1.4 0.9 13.5 239.6 11.745 18.9 12.15 0.87 1.4 0.9 14 239.6 12.18 19.6 12.6 0.87 1.4 0.9 15 239.6 13.05 21 13.5 0.87 1.4 0.9 16 239.6 13.92 22.4 14.4 0.87 1.4 0.9 18 239.6 15.66 25.2 16.2 0.87 1.4 0.9 20 239.6 17.4 28 18 0.87 1.4 0.9 21 239.6 18.27 29.4 18.9 0.87 1.4 0.9 22 239.6 19.14 30.8 19.8 0.87 1.4 0.9 24 239.6 20.88 33.6 21.6 0.87 1.4 0.9 29 239.6 25.23 40.6 26.1 0.87 1.4 0.9 33 239.6 28.71 46.2 29.7 0.87 1.4 0.9 35 239.6 30.45 49 31.5 0.87 1.4 0.9 40 239.6 34.8 56 36 0.87 1.4 0.9 45 239.6 39.15 63 40.5 0.87 1.4 0.9 48 239.6 41.76 67.2 43.2 0.87 1.4 0.9 50 239.6 43.5 70 45 0.87 1.4 0.9

(71) TABLE-US-00007 TABLE 6 Fourth Ellipse E4 Embodiments EORL 4MajAL 4MinAL D (ft) θ (deg) (ft) (ft) (ft) EORL/D 4MajAL/D 4MinAL/D 2 235.7 1.526 1.88 0.88 0.763 0.94 0.44 3 235.7 2.289 2.82 1.32 0.763 0.94 0.44 4 235.7 3.052 3.76 1.76 0.763 0.94 0.44 5 235.7 3.815 4.7 2.2 0.763 0.94 0.44 6 235.7 4.578 5.64 2.64 0.763 0.94 0.44 7 235.7 5.341 6.58 3.08 0.763 0.94 0.44 8 235.7 6.104 7.52 3.52 0.763 0.94 0.44 9 235.7 6.867 8.46 3.96 0.763 0.94 0.44 10 235.7 7.63 9.4 4.4 0.763 0.94 0.44 11 235.7 8.393 10.34 4.84 0.763 0.94 0.44 12 235.7 9.156 11.28 5.28 0.763 0.94 0.44 12.5 235.7 9.5375 11.75 5.5 0.763 0.94 0.44 13 235.7 9.919 12.22 5.72 0.763 0.94

0.44 13.5 235.7 10.3005 12.69 5.94 0.763 0.94 0.44 14 235.7 10.682 13.16 6.16 0.763 0.94 0.44 15 235.7 11.445 14.1 6.6 0.763 0.94 0.44 16 235.7 12.208 15.04 7.04 0.763 0.94 0.44 18 235.7 13.734 16.92 7.92 0.763 0.94 0.44 20 235.7 15.26 18.8 8.8 0.763 0.94 0.44 21 235.7 16.023 19.74 9.24 0.763 0.94 0.44 22 235.7 16.786 20.68 9.68 0.763 0.94 0.44 24 235.7 18.312 22.56 10.56 0.763 0.94 0.44 29 235.7 22.127 27.26 12.76 0.763 0.94 0.44 33 235.7 25.179 31.02 14.52 0.763 0.94 0.44 35 235.7 26.705 32.9 15.4 0.763 0.94 0.44 40 235.7 30.52 37.6 17.6 0.763 0.94 0.44 45 235.7 34.335 42.3 19.8 0.763 0.94 0.44 48 235.7 36.624 45.12 21.12 0.763 0.94 0.44 50 235.7 38.15 47 22 0.763 0.94 0.44

(72) Referring to FIG. **8**, the locations for P relative to the airfoil section and advantages therefrom described above can also be realized for an unducted fan propulsor system mounted above a horizontal stabilizer. For an unducted fan propulsor mounted to horizontal stabilizers, the foregoing examples and embodiments would be mirrored about the chord line of the airfoil section (again, for purposes of explanation, this chord line may be thought of as an axis passing through θ=0 deg and θ=180 deg in FIG. **11**) for the case where the airfoil section **41** produces a lift in the downward direction, such as a horizontal stabilizer, as compared to a wing which produces a lift in the upward direction. The above descriptions for an undermount propulsor can apply, with the location being shifted as shown in FIG. **8** as compared to FIG. **7**.

(73) In any of the foregoing examples or embodiments, the unducted fan propulsor **30**, incorporating the vane assembly described herein, can have a cruise flight Mach M.sub.0 of between 0.5 and 0.9, between 0.7 and 0.9, or between 0.75 and 0.9. The unducted fan propulsor **30** can be part of a winged aircraft, such as an airplane.

(74) A propulsor that operates at a high cruise flight Mach number (e.g., greater than 0.7) encounters velocities near the surfaces of the rotor, vanes, and nacelle that approach or exceed the speed of sound, or Mach 1.0. In general, friction drag increases roughly in proportion to the square of the air velocity. However, as the Mach number increases, a significant contributor to the increase in drag can come from wave drag. Wave drag is a drag resulting from shock waves that form as the flow of air near a surface becomes supersonic (e.g., Mach>1.0).

(75) In addition to the cruise flight Mach number, another factor contributing to increased drag on propulsor surfaces is high non-dimensional cruise fan net thrust based on fan annular area and flight speed. The same acceleration of the air stream by the fan that produces thrust also tends to increase the drag force on the rotor, vanes, and nacelle.

(76) Expressing thrust non-dimensionally in a way that accounts for flight speed, ambient conditions, and fan annular area yields a thrust parameter as follows:

(77) $\frac{F_{net}}{\rho_0 A_{an} V_0^2}$

(78) In the above thrust parameter, F.sub.net is cruise fan net thrust, ρ.sub.0 is ambient air density, V.sub.o is cruise flight velocity, and A.sub.an is fan stream tube cross-sectional area at the fan inlet. Fan annular area, A.sub.an, is computed using a maximum radius as the tip radius of the forward-most rotor blades and a minimum radius as the minimum radius of the fan stream tube entering the fan.

(79) A propulsor that operates at a high cruise fan net thrust parameter (e.g., greater than 0.06) tends to have higher propulsor velocities with risk of higher drag on propulsor surfaces.

(80) According to any of the foregoing examples or embodiments, there may be a particularly beneficial range of a dimensionless cruise fan net thrust parameter normalized by ambient density, cruise flight speed squared, and fan stream tube annular area at fan inlet defined by the following expression:

(81) $0.15 > \frac{F_{net}}{\rho_0 A_{an} V_0^2} > 0.06$

(82) Both a high cruise flight Mach and high dimensionless cruise fan net thrust parameter contribute to higher drag levels on the propulsor surfaces. Advantageously, the specific unducted fan propulsor positions relative to the wing airfoil section, as described herein, can increase

unducted fan propulsor net thrust for a given power input when there is a high cruise flight Mach and a high dimensionless cruise fan net thrust parameter.

(83) Using the conditions described herein, the specific regions for placing the unducted fan propulsor system can be located where there is a relatively higher pressure on the high pressure side of the airfoil, beneath the wings or above the horizontal stabilizers. The higher pressure provides increased thrust from the unducted fan propulsor to thereby offset drag penalties resulting from the installation of unducted fan propulsors.

(84) The foregoing conditions for the placement of the propulsors relative to the wing airfoils can be present for any mounting configuration of the propulsors wing. While the mounting configuration can be fixed, it is contemplated that the mounting configuration could be variable. For example, the mounting configuration of an unducted fan propulsor relative to a wing could be different for takeoff as compared to cruise operating conditions. In such a scenario, the foregoing conditions for placement of the propulsors relative to the wing airfoils can be present in either or both operating conditions, or any other operating condition.

(85) Further aspects of the disclosure are provided by the subject matter of the following clauses:

(86) Clause 1: An aircraft is provided that includes a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section with a leading edge (LE) and a trailing edge (TE), a chord extending between the LE and TE, and a quarter-chord location (QC) along the chord measured from the LE; an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL) and a plurality of blades arranged in one or more arrays, each of the blades having a root and the plurality of blades defining a maximum outer diameter (D), the unducted fan propulsor having a point (P) defined as one of: (a) wherein the plurality of blades is arranged in a single array, the point P is located at an intersection of the CL and a line perpendicular to the CL that passes through a midpoint between edges at the root of one of the plurality of blades, and (b) wherein the plurality of blades is arranged in a forward array and a rearward array, the point P is located at an intersection of the CL and midpoint between a rearward trailing edge (TE) of the rearward array and leading edge (LE) of the forward array when a blade of the forward and rearward arrays are aligned with each other; and an ellipse origin positioning line (EOR) having a length (EORL) extending from the QC to an ellipse origin (OR) and at an angle θ as measured from a vector from the QC to the TE of the airfoil section to the line EOR, where, when viewed with the LE to the left of TE, a positive θ (1) increases in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and (2) increases in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, and wherein the P of the unducted fan propulsor is located within a first ellipse having a first major axis length (1MajAL) and a first minor axis length (1MinAL) with a first ellipse origin defined by EORL/D of 0.938 and θ of 253.6°, and where 1MajAL/D is 2.8 and 1 MinAL/D is 1.7.

(87) In the preceding clause, the P of the unducted fan propulsor is located in a second ellipse having a second major axis length (2MajAL) and a second minor axis length (2MinAL) with a second ellipse origin defined by EORL/D of 1.051 and θ of 248.8°, and where 2MajAL/D is 1.86 and 2MinAL/D is 1.56.

(88) In any of the preceding clauses, the P of the unducted fan propulsor is located in a third ellipse having a third major axis length (3MajAL) and a third minor axis length (3MinAL) with a third ellipse origin defined by EORL/D of 0.870 and θ of 239.6°, where 3MajAL/D is 1.4 and 3MinAL/D is 0.9.

(89) In any of the preceding clauses, the P of the unducted fan propulsor is located in a fourth ellipse having a fourth major axis length (4MajAL) and a fourth minor axis length (4MinAL) with a fourth ellipse origin defined by EORL/D of 0.763 and θ of 235.7°, and where 4MajAL/D is 0.94 and 4MinAL/D is 0.44.

(90) In any of the preceding clauses, the unducted fan propulsor is undermounted to the airfoil,

such as a wing, with one or more intermediate structures.
(91) In any of the preceding clauses, wherein the unducted propulsor has two arrays of blades and only one of the array of blades is rotating.
(92) In any of the preceding clauses, the P of the unducted fan propulsor is variable to accommodate different operating conditions.
(93) Clause 2: An aircraft is provided including a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section with a leading edge (LE) and a trailing edge (TE), a chord extending between the LE and TE, and a quarter-chord location (QC) along the chord measured from the LE; an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL) and a plurality of blades arranged in one or more arrays, each of the blades having a root and the plurality of blades defining a maximum outer diameter (D), the unducted fan propulsor having a point (P) defined as one of: (a) wherein the plurality of blades is arranged in a single array, the point P is located at an intersection of the CL and a line perpendicular to the CL that passes through a midpoint between edges at the root of one of the plurality of blades, and (b) wherein the plurality of blades is arranged in a forward array and a rearward array, the point P is located at an intersection of the CL and midpoint between a rearward trailing edge (TE) of the rearward array and leading edge (LE) of the forward array when a blade of the forward and rearward arrays are aligned with each other; and a positioning line (R) having a length (RL) and extending from the QC to the point P of the unducted fan propulsor and at an angle θ as measured from a vector from the QC to the TE of the airfoil section to the line R, where, when viewed with the LE to the left of TE, a positive θ (1) increases in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and (2) increases in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, and wherein 0.065<RL/D<1.98 and 0 is between 187° and 340°, and wherein RL/D and θ of the P of the unducted fan propulsor adhere to the following expressions:
(94) $\frac{RL}{D} + \frac{(\sqrt{1.4161 * [1.88978 * \sin^2(\theta) - 0.0875 * \cos^2(\theta) + 0.477 * \sin(\theta) * \cos(\theta)]} + 1.764 * \sin(\theta) + 0.19146 * \cos(\theta))}{1.96 * \sin^2(\theta) + 0.7225 * \cos^2(\theta)} > 0$and

$$\frac{RL}{D} + \frac{(-\sqrt{1.4161 * [1.88978 * \sin^2(\theta) - 0.0875 * \cos^2(\theta) + 0.477 * \sin(\theta) * \cos(\theta)]} + 1.764 * \sin(\theta) + 0.19146 * \cos(\theta))}{1.96 * \sin^2(\theta) + 0.7225 * \cos^2(\theta)} < 0.$$

(95) In the preceding clause, 0.254<RL/D<1.86 and 0 is between 199° and 306°, and the P of the unducted fan propulsor is defined by the following expressions:
(96) $\frac{RL}{D} + \frac{(\sqrt{0.52621 * [0.7205 * \sin^2(\theta) - 0.352 * \cos^2(\theta) + 0.7448 * \sin(\theta) * \cos(\theta)]} + 0.8476 * \sin(\theta) + 0.23119 * \cos(\theta))}{0.8649 * \sin^2(\theta) + 0.6084 * \cos^2(\theta)} > 0$and

$$\frac{RL}{D} + \frac{(-\sqrt{0.52621 * [0.7205 * \sin^2(\theta) - 0.352 * \cos^2(\theta) + 0.7448 * \sin(\theta) * \cos(\theta)]} + 0.8476 * \sin(\theta) + 0.23119 * \cos(\theta))}{0.8649 * \sin^2(\theta) + 0.6084 * \cos^2(\theta)} < 0$$

(97) In any of the two preceding clauses, 0.369<RL/D<1.43 and 0 is between 204° and 291°, and the P of the unducted fan propulsor is defined by the following expressions:
(98) $\frac{RL}{D} + \frac{(\sqrt{0.52621 * [0.7205 * \sin^2(\theta) - 0.352 * \cos^2(\theta) + 0.7448 * \sin(\theta) * \cos(\theta)]} + 0.8476 * \sin(\theta) + 0.23119 * \cos(\theta))}{0.8649 * \sin^2(\theta) + 0.6084 * \cos^2(\theta)} > 0$and

$$\frac{RL}{D} + \frac{(-\sqrt{0.52621 * [0.7205 * \sin^2(\theta) - 0.352 * \cos^2(\theta) + 0.7448 * \sin(\theta) * \cos(\theta)]} + 0.8476 * \sin(\theta) + 0.23119 * \cos(\theta))}{8.649 * \sin^2(\theta) + 0.6084 * \cos^2(\theta)} < 0$$

(99) In any of the three preceding clauses: 0.477<RL/D<0.9455 and θ is between 211° and 274°, and the P of the unducted fan propulsor is defined by the following expressions:
(100)

$$\frac{RL}{D} + \frac{(\sqrt{0.01069156 * [0.036 * \sin^2(\theta) - 0.3485 * \cos^2(\theta) + 0.5418 * \sin(\theta) * \cos(\theta)]} + 0.139167 * \sin(\theta) + 0.020812 * \cos(\theta))}{0.2209 * \sin^2(\theta) + 0.0484 * \cos^2(\theta)} > 0\text{and}$$

$$\frac{RL}{D} + \frac{(-\sqrt{0.01069156 * [0.036 * \sin^2(\theta) - 0.3485 * \cos^2(\theta) + 0.5418 * \sin(\theta) * \cos(\theta)]} + 0.139167 * \sin(\theta) + 0.020812 * \cos(\theta))}{0.2209 * \sin^2(\theta) + 0.0484 * \cos^2(\theta)} < 0$$

(101) In any of the four preceding clauses, the unducted fan propulsor is undermounted to the airfoil, such as a wing, with one or more intermediate structures.
(102) In any of the five preceding clauses, the P of the unducted fan propulsor is variable to accommodate different operating conditions.
(103) In any of the preceding clauses, wherein the unducted propulsor has two arrays of blades and

only one of the array of blades is rotating.
(104) Clause 3: An aircraft is provided that includes a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section with a leading edge (LE) and a trailing edge (TE), a chord extending between the LE and TE, and a quarter-chord location (QC) along the chord measured from the LE; an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL) and a plurality of blades arranged in one or more arrays, each of the blades having a root and the plurality of blades defining a maximum outer diameter (D), the unducted fan propulsor having a point (P) defined as one of: (a) wherein the plurality of blades is arranged in a single array, the point P is located at an intersection of the CL and a line perpendicular to the CL that passes through a midpoint between edges at the root of one of the plurality of blades, and (b) wherein the plurality of blades is arranged in a forward array and a rearward array, the point P is located at an intersection of the CL and midpoint between a rearward trailing edge (TE) of the rearward array and leading edge (LE) of the forward array when a blade of the forward and rearward arrays are aligned with each other; and a positioning line (R) having a length (RL) and extending from the QC to the point P of the unducted fan propulsor and at an angle θ as measured from a vector from the QC to the TE of the airfoil section to the line R, where, when viewed with the LE to the left of TE, a positive θ (1) increases in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and (2) increases in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, and wherein RL/D≤2 and 0 is between 187° and 342°.
(105) In any of the foregoing clauses, 0.15≤RL/D.
(106) In any of the foregoing clauses, 0.35≤RL/D, and preferably RL/D is about 0.72.
(107) In any of the foregoing clauses, wherein 0 is between 198° and 310°, and preferably between 205° and 285°.
(108) In any of the foregoing clauses, the unducted fan propulsor operates at a cruise flight Mach M.sub.0 of between 0.5 and 0.9, preferably between 0.7 and 0.9, and more preferably between 0.75 and 0.9.
(109) In any of the foregoing clauses, the unducted fan propulsor has a dimensionless cruise fan net thrust parameter expressed as follows:
(110) $0.15 > \frac{F_{net}}{\rho_0 A_{an} V_0^2} > 0.06,$ wherein F.sub.net is cruise fan net thrust, ρ.sub.0 is ambient air density, V.sub.o is cruise flight velocity, and A.sub.an is annular cross-sectional area perpendicular to an axis of rotation of a rotor axis of rotation.
(111) In any of the foregoing clauses, the unducted fan propulsor is undermounted to the airfoil with one or more intermediate structures.
(112) In any of the foregoing clauses, the P of the unducted fan propulsor is variable to accommodate different operating conditions.
(113) In any of the foregoing clauses, the aircraft includes a plurality of the unducted fan propulsors.
(114) In the foregoing clause, the plurality of the unducted fan propulsors may be each mounted to the same airfoil, such as a wing or horizontal stabilizer; or the plurality of the unducted fan propulsors may be each mounted to different airfoils, such as a wing or horizontal stabilizer; or combinations thereof.
(115) In any of the preceding clauses, wherein the unducted propulsor has two arrays of blades and only one of the array of blades is rotating.
(116) Clause 4: An aircraft is provided that includes a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section defining a quarter-chord location (QC); an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL), a plurality of counterclockwise rotating blades arranged in a forward array and a plurality clockwise rotating blades arranged in a rearward array, wherein one

of the forward and rearward array of blades define a maximum outer diameter (D); a point (P) located at the intersection of the CL and a midpoint (TRL) between a rearward trailing edge nearest a root of a blade of the rearward array and a leading edge nearest a root of a blade of the forward array when the forward leading edge and rearward trailing edge of the respective blades are aligned with each other; and an ellipse origin positioning line (EOR) having a length (EORL) extending from the QC to an ellipse origin (OR) at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section; wherein the P of the unducted fan propulsor is located within a first ellipse having a first major axis length (1MajAL) and a first minor axis length (1MinAL) with a first ellipse origin defined by EORL/D of 0.938 and θ of 253.6°, and where 1 MajAL/D is 2.8 and 1MinAL/D is 1.7.

(117) Clause 5: An aircraft is provided that includes a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section and the airfoil section having a quarter-chord location (QC), and a plurality of rotating blades defining a maximum outer diameter (D); a point (P) located at an intersection of the CL and a line perpendicular to the CL that passes through a midpoint between leading and trailing edges nearest the root of one of the plurality of blades, and an ellipse origin positioning line (EOR) having a length (EORL) extending from the QC to an ellipse origin (OR) and at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, and wherein the P of the unducted fan propulsor is located within a first ellipse having a first major axis length (1MajAL) and a first minor axis length (1MinAL) with a first ellipse origin defined by EORL/D of 0.938 and θ of 253.6°, and where 1MajAL/D is 2.8 and 1MinAL/D is 1.7.

(118) Clause 6: An aircraft is provided that includes a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section defining a quarter-chord location (QC); an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL), a plurality of blades arranged in a forward array and a plurality of blades arranged in a rearward array, wherein only one of the forward and rearward array of blades are rotating blades and the rotating blades define a maximum outer diameter (D); a point (P) located at the intersection of the CL and a midpoint (TRL) between a rearward trailing edge nearest a root of a blade of the rearward array and a leading edge nearest a root of a blade of the forward array when the forward leading edge and rearward trailing edge of the respective blades are aligned with each other; and a positioning line (R) having a length (RL) and extending from the QC to the point P of the unducted fan propulsor at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section; wherein 0.065<RL/D<1.98 and θ is between 187° and 340°; and wherein RL/D and θ of the P of the unducted fan propulsor adhere to the following expressions:

(119) $\frac{RL}{D} + \frac{(\sqrt{1.4161 * [1.88978 * \sin^2(\theta) - 0.0875 * \cos^2(\theta) + 0.477 * \sin(\theta) * \cos(\theta)]} + 1.764 * \sin(\theta) + 0.19146 * \cos(\theta))}{1.96 * \sin^2(\theta) + 0.7225 * \cos^2(\theta)} > 0$and

$\frac{RL}{D} + \frac{(-\sqrt{1.4161 * [1.88978 * \sin^2(\theta) - 0.0875 * \cos^2(\theta) + 0.477 * \sin(\theta) * \cos(\theta)]} + 1.764 * \sin(\theta) + 0.19146 * \cos(\theta))}{1.96 * \sin^2(\theta) + 0.7225 * \cos^2(\theta)} < 0.$

(120) The aircraft of Clause 6, wherein: 0.254<RL/D<1.86 and θ is between 199° and 306°, and the P of the unducted fan propulsor is defined by the following expressions:

(121) $0\frac{RL}{D} + \frac{(\sqrt{0.52621 * [0.7205 * \sin^2(\theta) - 0.352 * \cos^2(\theta) + 0.7448 * \sin(\theta) * \cos(\theta)]} + 0.8476 * \sin(\theta) + 0.23119 * \cos(\theta))}{0.8649 * \sin^2(\theta) + 0.6084 * \cos^2(\theta)} > 0$

and$\frac{RL}{D} + \frac{(-\sqrt{0.52621 * [0.7205 * \sin^2(\theta) - 0.352 * \cos^2(\theta) + 0.7448 * \sin(\theta) * \cos(\theta)]} + 0.8476 * \sin(\theta) + 0.23119 * \cos(\theta))}{8.649 * \sin^2(\theta) + 0.6084 * \cos^2(\theta)} < 0$

(122) The aircraft of Clause 6, wherein: 0.369<RL/D<1.43 and θ is between 204° and 291°, and the P of the unducted fan propulsor is defined by the following expressions:

(123) $\frac{RL}{D} + \frac{(\sqrt{0.09923 * [0.2964 * \sin^2(\theta) - 0.36 * \cos^2(\theta) + 0.66 * \sin(\theta) * \cos(\theta)]} + 0.3675 * \sin(\theta) + 0.0891 * \cos(\theta))}{0.49 * \sin^2(\theta) + 0.2025 * \cos^2(\theta)} > 0$and

$\frac{RL}{D} + \frac{(-\sqrt{0.09923 * [0.2964 * \sin^2(\theta) - 0.36 * \cos^2(\theta) + 0.66 * \sin(\theta) * \cos(\theta)]} + 0.3675 * \sin(\theta) + 0.0891 * \cos(\theta))}{0.49 * \sin^2(\theta) + 0.2025 * \cos^2(\theta)} < 0$

(124) The aircraft of Clause 6, wherein: 0.477<RL/D<0.9455 and θ is between 211° and 274°, and the P of the unducted fan propulsor is defined by the following expressions:

(125)

$\frac{RL}{D} + \frac{(\sqrt{0.01069156 * [0.036 * \sin^2(\theta) - 0.3485 * \cos^2(\theta) + 0.5418 * \sin(\theta) * \cos(\theta)]} + 0.139167 * \sin(\theta) + 0.020812 * \cos(\theta))}{0.2209 * \sin^2(\theta) + 0.0484 * \cos^2(\theta)} > 0$and

$\frac{RL}{D} + \frac{(-\sqrt{0.01069156 * [0.036 * \sin^2(\theta) - 0.3485 * \cos^2(\theta) + 0.5418 * \sin(\theta) * \cos(\theta)]} + 0.139167 * \sin(\theta) + 0.020812 * \cos(\theta))}{0.2209 * \sin^2(\theta) + 0.0484 * \cos^2(\theta)} < 0$

(126) The aircraft of Clause 6, wherein the unducted fan propulsor is undermounted to the airfoil with one or more intermediate structures.

(127) The aircraft of Clause 6, wherein the P of the unducted fan propulsor is variable to accommodate different operating conditions.

(128) Clause 7: An aircraft is provided that includes a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section defining a quarter-chord location (QC); an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL), a plurality of blades arranged in a forward array and a plurality of blades arranged in a rearward array, wherein only one of the forward and rearward array of blades are rotating blades and the rotating blades define a maximum outer diameter (D); a point (P) located at the intersection of the CL and a midpoint (TRL) between a rearward trailing edge nearest a root of a blade of the rearward array and a leading edge nearest a root of a blade of the forward array when the forward leading edge and rearward trailing edge of the respective blades are aligned with each other; and a positioning line (R) having a length (RL) and extending from the QC to the point P of the unducted fan propulsor at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section; wherein RL/D≤2 and θ is between 187° and 342°.

(129) The aircraft of Clause 7, wherein 0.15≤RL/D.

(130) The aircraft of Clause 7, wherein 0.35≤RL/D, and preferably RL/D is about 0.72.

(131) The aircraft of Clause 7, wherein 0 is between 198° and 310°, and preferably between 205° and 285°.

(132) The aircraft of Clause 7, wherein the unducted fan propulsor operates at a cruise flight Mach M.sub.0 of between 0.5 and 0.9, preferably between 0.7 and 0.9, and more preferably between 0.75 and 0.9.

(133) The aircraft of Clause 7, wherein the unducted fan propulsor has a dimensionless cruise fan net thrust parameter expressed as follows:

(134) $0.15 > \frac{F_{net}}{\rho_0 A_{an} V_0^2} > 0.06$, wherein F.sub.net is cruise fan net thrust, ρ.sub.0 is ambient air density, V.sub.o is cruise flight velocity, and A.sub.an is annular cross-sectional area perpendicular to an axis of rotation of a rotor axis of rotation.

(135) The aircraft of Clause 7, wherein the unducted fan propulsor is undermounted to the airfoil with one or more intermediate structures.

(136) The aircraft of Clause 7, wherein the P of the unducted fan propulsor is variable to accommodate different operating conditions.

(137) Clause 8: A method of assembly, comprising: using an aircraft body comprising a fuselage and an airfoil extending from the fuselage, wherein the airfoil has an airfoil section defining a quarter-chord location (QC); and attaching an unducted fan propulsor to the aircraft body relative to the airfoil section on a high pressure side thereof; the unducted fan propulsor having a centerline (CL), a plurality of blades arranged in a forward array and a plurality of blades arranged in a rearward array, wherein only one of the forward and rearward array of blades are rotating blades

and the rotating blades define a maximum outer diameter (D); a point (P) located at the intersection of the CL and a line HP perpendicular to the axial centerline CL that passes through the axial midpoint between a rearward trailing edge at a root of a blade of the rearward array and a forward leading edge at a root of a blade of the forward array when the forward leading edge and rearward trailing edge of the respective blades are aligned with each other; and a positioning line (R) having a length (RL) and extending from the QC to the point P of the unducted fan propulsor at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, when viewed looking from an outboard position towards an inboard position; wherein 0.07≤RL/D≤2.0 and θ is between 187° and 342°.
(138) The aircraft of Clause 8, wherein 0.15≤RL/D.
(139) The method of Clause 8, wherein 0.35≤RL/D, and preferably RL/D is about 0.72.
(140) The method of Clause 8, wherein 0 is between 198° and 310°, and preferably between 205° and 285°.
(141) The method of Clause 8, wherein the unducted fan propulsor operates at a cruise flight Mach M.sub.0 of between 0.5 and 0.9, preferably between 0.7 and 0.9, and more preferably between 0.75 and 0.9.
(142) The method of Clause 8, wherein the unducted fan propulsor has a dimensionless cruise fan net thrust parameter expressed as follows:
(143) $0.15 > \frac{F_{net}}{\rho_0 A_{an} V_0^2} > 0.06$,
(144) wherein F.sub.net is cruise fan net thrust, ρ.sub.0 is ambient air density, V.sub.o is cruise flight velocity, and A.sub.an is annular cross-sectional area perpendicular to an axis of rotation of a rotor axis of rotation.
(145) The method of Clause 8, wherein the unducted fan propulsor is undermounted to the airfoil with one or more intermediate structures.
(146) The method of Clause 8, wherein the P of the unducted fan propulsor is variable to accommodate different operating conditions.
(147) Clause 9: A method of assembly, comprising: using an aircraft body comprising a fuselage and an airfoil extending from the fuselage, the airfoil having an airfoil section with a leading edge (LE) and a trailing edge (TE), a chord extending between the LE and TE, and a quarter-chord location (QC) along the chord measured from the LE, wherein the airfoil has an airfoil section defining a quarter-chord location (QC); and attaching an unducted fan propulsor to the aircraft body relative to the airfoil section on a high pressure side thereof; the unducted fan propulsor having a centerline (CL) and a plurality of blades arranged in one or more arrays, each of the blades having a root and the plurality of blades defining a maximum outer diameter (D), the unducted fan propulsor having a point (P) defined as one of: (a) wherein the plurality of blades is arranged in a single array, the point P is located at an intersection of the CL and a line perpendicular to the CL that passes through a midpoint between edges at the root of one of the plurality of blades, and (b) wherein the plurality of blades is arranged in a forward array and a rearward array, the point P is located at an intersection of the CL and midpoint between a rearward trailing edge (TE) of the rearward array and leading edge (LE) of the forward array when a blade of the forward and rearward arrays are aligned with each other; and an ellipse origin positioning line (EOR) having a length (EORL) extending from the QC to an ellipse origin (OR) and at an angle θ as measured from a vector from the QC to the TE of the airfoil section to the line EOR, where, when viewed with the LE to the left of TE, a positive θ (1) increases in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and (2) increases in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, and wherein the P of the unducted fan propulsor is located within a first ellipse

having a first major axis length (1MajAL) and a first minor axis length (1MinAL) with a first ellipse origin defined by EORL/D of 0.938 and θ of 253.6°, and where 1MajAL/D is 2.8 and 1MinAL/D is 1.7.
(148) In the preceding clause, the P of the unducted fan propulsor is located in a second ellipse having a second major axis length (2MajAL) and a second minor axis length (2MinAL) with a second ellipse origin defined by EORL/D of 1.051 and θ of 248.8°, and where 2MajAL/D is 1.86 and 2MinAL/D is 1.56.
(149) In any of the preceding clauses, the P of the unducted fan propulsor is located in a third ellipse having a third major axis length (3MajAL) and a third minor axis length (3MinAL) with a third ellipse origin defined by EORL/D of 0.870 and θ of 239.6°, where 3MajAL/D is 1.4 and 3MinAL/D is 0.9.
(150) In any of the preceding clauses, the P of the unducted fan propulsor is located in a fourth ellipse having a fourth major axis length (4MajAL) and a fourth minor axis length (4MinAL) with a fourth ellipse origin defined by EORL/D of 0.763 and θ of 235.7°, and where 4MajAL/D is 0.94 and 4MinAL/D is 0.44.
(151) In any of the preceding clauses, the unducted fan propulsor is undermounted to the airfoil, such as a wing, with one or more intermediate structures.
(152) In any of the preceding clauses, the P of the unducted fan propulsor is variable to accommodate different operating conditions.

Claims

1. An aircraft comprising: a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section defining a quarter-chord location (QC); an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL), a plurality of blades arranged in a forward array and a plurality of blades arranged in a rearward array, wherein only one of the forward and rearward array of blades are rotating blades and the rotating blades define a maximum outer diameter (D); a point (P) located at the intersection of the CL and a line HP perpendicular to the axial centerline CL that passes through the axial midpoint between a rearward trailing edge at a root of a blade of the rearward array and a forward leading edge at a root of a blade of the forward array when the forward leading edge and rearward trailing edge of the respective blades are aligned with each other; and a positioning line (R) having a length (RL) and extending from the QC to the point P of the unducted fan propulsor at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, when viewed looking from an outboard position towards an inboard position; wherein 0.07≤RL/D≤2.0 and θ is between 187° and 342°.
2. The aircraft of claim 1, wherein 0.15≤RL/D.
3. The aircraft of claim 1, wherein 0.35≤RL/D, and preferably RL/D is about 0.72.
4. The aircraft of claim 1, wherein 0 is between 198° and 310°, and preferably between 205° and 285°.
5. The aircraft of claim 1, wherein the unducted fan propulsor operates at a cruise flight Mach M.sub.0 of between 0.5 and 0.9, preferably between 0.7 and 0.9, and more preferably between 0.75 and 0.9.
6. The aircraft of claim 1, wherein the unducted fan propulsor has a dimensionless cruise fan net thrust parameter expressed as follows: $0.15 > \frac{F_{net}}{\rho_0 A_{an} V_0^2} > 0.06$, wherein F.sub.net is cruise fan net thrust, ρ.sub.0 is ambient air density, V.sub.o is cruise flight velocity, and A.sub.an is annular cross-sectional area perpendicular to an axis of rotation of a rotor axis of rotation.

7. The aircraft of claim 1, wherein the unducted fan propulsor is undermounted to the airfoil with one or more intermediate structures.

8. The aircraft of claim 1, wherein the P of the unducted fan propulsor is variable to accommodate different operating conditions.

9. An aircraft, comprising: a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section defining a quarter-chord location (QC); an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL), a plurality of blades arranged in a forward array and a plurality of blades arranged in a rearward array, wherein only one of the forward and rearward array of blades are rotating blades and the rotating blades define a maximum outer diameter (D); a point (P) located at the intersection of the CL and a line HP perpendicular to the axial centerline CL that passes through the axial midpoint between a rearward trailing edge at a root of a blade of the rearward array and a forward leading edge at a root of a blade of the forward array when the forward leading edge and rearward trailing edge of the respective blades are aligned with each other; and an ellipse origin positioning line (EOR) having a length (EORL) extending from the QC to an ellipse origin (OR) at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, when viewed looking for an outboard position towards an inboard position; wherein the P of the unducted fan propulsor is located within a first ellipse having a first major axis length (1MajAL) and a first minor axis length (1MinAL) with a first ellipse origin defined by EORL/D of 0.938 and θ of 253.6°, and where 1MajAL/D is 2.8 and 1 MinAL/D is 1.7.

10. The aircraft of claim 9, wherein the P of the unducted fan propulsor is located in a second ellipse having a second major axis length (2MajAL) and a second minor axis length (2MinAL) with a second ellipse origin defined by EORL/D of 1.051 and θ of 248.8°, and where 2MajAL/D is 1.86 and 2MinAL/D is 1.56.

11. The aircraft of claim 9, wherein the P of the unducted fan propulsor is located in a third ellipse having a third major axis length (3MajAL) and a third minor axis length (3MinAL) with a third ellipse origin defined by EORL/D of 0.870 and θ of 239.6°, where 3MajAL/D is 1.4 and 3MinAL/D is 0.9.

12. The aircraft of claim 9, wherein the P of the unducted fan propulsor is located in a fourth ellipse having a fourth major axis length (4MajAL) and a fourth minor axis length (4MinAL) with a fourth ellipse origin defined by EORL/D of 0.763 and θ of 235.7°, and where 4MajAL/D is 0.94 and 4MinAL/D is 0.44.

13. An aircraft, comprising: a fuselage; an airfoil extending from the fuselage, the airfoil having an airfoil section defining a quarter-chord location (QC); an unducted fan propulsor mounted relative to the airfoil section on a high pressure side thereof, the unducted fan propulsor having a centerline (CL), a plurality of blades arranged in a forward array and a plurality of blades arranged in a rearward array, wherein one of the forward and rearward array of blades are rotating blades and the rotating blades define a maximum outer diameter (D); a point (P) located at the intersection of the CL and a line HP perpendicular to the axial centerline CL that passes through the axial midpoint between a rearward trailing edge at a root of a blade of the rearward array and a forward leading edge at a root of a blade of the forward array when the forward leading edge and rearward trailing edge of the respective blades are aligned with each other; and a positioning line (R) having a length (RL) and extending from the QC to the point P of the unducted fan propulsor at an angle θ measured positive in a counter-clockwise direction when the high pressure side of the airfoil section is below the airfoil section, and measured positive in a clockwise direction when the high pressure side of the airfoil section is above the airfoil section, when viewed looking from an outboard position towards an inboard position (e.g. the fuselage) OR when viewed with the LE to the left of the TE; wherein $0.065<RL/D<1.98$ and θ is between 187° and 340°; and wherein RL/D

and θ of the P of the unducted fan propulsor adhere to the following expressions:

$$\frac{RL}{D} + \frac{(\sqrt{1.4161 * [1.88978 * \sin^2(\theta) - 0.0875 * \cos^2(\theta) + 0.477 * \sin(\theta) * \cos(\theta)]} + 1.764 * \sin(\theta) + 0.19146 * \cos(\theta))}{1.96 * \sin^2(\theta) + 0.7225 * \cos^2(\theta)} > 0 \text{ and}$$

$$\frac{RL}{D} + \frac{(-\sqrt{1.4161 * [1.88978 * \sin^2(\theta) - 0.0875 * \cos^2(\theta) + 0.477 * \sin(\theta) * \cos(\theta)]} + 1.764 * \sin(\theta) + 0.19146 * \cos(\theta))}{1.96 * \sin^2(\theta) + 0.7225 * \cos^2(\theta)} < 0.$$