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Drag modification systems for aircraft and related methods

Abstract

Drag modification systems for aircraft and related methods. An example system for modifying drag on an aircraft includes a boundary layer intake plenum and an eductor. The eductor defines a primary inlet to receive a primary fluid, a secondary inlet in fluid communication with the intake plenum to receive a secondary fluid entrained from the intake plenum, and an outlet to exhaust a mixed flow including the primary fluid and the secondary fluid. The primary fluid is a motive fluid having flow parameters to generate a suction at the secondary inlet.

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Background/Summary

RELATED APPLICATIONS (1) This patent claims the benefit of U.S. Provisional Patent Application Ser. No. 63/187,182 entitled “DRAG MODIFICATION SYSTEMS FOR AIRCRAFT AND RELATED METHODS”, which was filed on May 11, 2021. Priority to U.S. Provisional Patent Application No. 63/187,182 is hereby claimed.

FIELD OF THE DISCLOSURE
(1) This disclosure relates generally to aerodynamics of an aircraft and, more particularly, to drag modification systems for aircraft and related methods.
BACKGROUND
(2) Air traveling over the fuselage of an aircraft creates a boundary layer along the fuselage (e.g., along an aft and/or rear portion of the fuselage) where the velocity of the air reduces below the free stream velocity. The velocity deficit of the boundary layer relative to the free stream generates a drag force on the fuselage and/or, more generally, on the aircraft. At present, drag resulting from the aforementioned fuselage boundary layer is accepted as part of the overall drag associated with operating the aircraft. However, as drag increases, the amount of fuel consumed also increases. Thus, there is a persistent interest in the aircraft industry with regard to developing and implementing technologies designed to reduce drag, including reducing drag attributed to the existence of the fuselage boundary layer.
SUMMARY
(3) An example system for modifying drag on an aircraft includes a boundary layer intake plenum

and an eductor. The eductor defines a primary inlet to receive a primary fluid, a secondary inlet in fluid communication with the intake plenum to receive a secondary fluid entrained from the intake plenum, and an outlet to exhaust a mixed flow including the primary fluid and the secondary fluid. The primary fluid is a motive fluid having flow parameters to generate a suction (e.g., a negative pressure) at the secondary inlet.
(4) Another example system to modify drag of an aircraft includes a manifold defining a passageway to extend from an exterior of a fuselage of the aircraft to an exhaust of the aircraft. The passageway includes a first inlet in fluid communication with a motive fluid, a second inlet in fluid communication with the exterior of the fuselage, and an outlet in fluid communication with the exhaust. The motive fluid is to generate a suction to cause airflow to draw through the second inlet and channel the airflow to the exhaust to reduce drag.
(5) An example method to reduce drag of an aircraft includes providing a high energy airflow into an eductor; entraining air from an intake plenum into the high energy airflow via the eductor; receiving a boundary layer airflow into the intake plenum as a result of a negative pressure gradient effectuated by entrainment of air from the intake plenum into the eductor; and discharging the high energy airflow and the boundary layer airflow from the eductor.
(6) An example method to increase drag of an aircraft includes providing a high energy airflow into an eductor; blocking an exit of the eductor such that the high energy airflow flows into an intake plenum; and discharging the high energy airflow into a boundary layer from the intake plenum as a result of a positive pressure gradient from the intake plenum into the ambient air.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a perspective view of an example aircraft having an example drag modification system constructed in accordance with teachings of this disclosure.
(2) FIG. **2**A is a partial, side view of the example aircraft of FIG. **1**.
(3) FIG. **2**B is a side cross-sectional view of a partial portion of the example aircraft taken along line **2**B-**2**B of FIG. **2**A.
(4) FIGS. **2**C-**2**E are partial views of an example empennage of an aircraft illustrating different configurations of example outlets of example drag modification systems disclosed herein.
(5) FIG. **3** is a perspective view of the example drag modification system of FIGS. **1**, **2**A and **2**B.
(6) FIG. **4** is a schematic illustration of the example drag modification system of FIGS. **1**, **2**A, **2**B and **3**.
(7) FIG. **5**A is a side view of the example aircraft of FIG. **1** illustrating an example boundary layer profile of the aircraft of FIG. **1** when modified by the example drag modification system of FIGS. **1**, **2**A, **2**B, **3**, and **4**.
(8) FIG. **5**B is a side view of another example aircraft illustrating an example boundary layer profile of the aircraft when not modified by the example drag modification system of FIGS. **1**, **2**A, **2**B, **3**, and **4**.
(9) FIG. **6** is a schematic illustration of another example drag modification system disclosed herein that can implemented the example aircraft of FIG. **1**.
(10) FIGS. **7**A and **7**B are schematic illustrations of another example drag modification system disclosed herein that can implemented the example aircraft of FIG. **1**.
(11) FIG. **8**A is a flowchart of an example method to reduce drag using example drag modification systems disclosed herein.
(12) FIG. **8**B is a flowchart of an example method to increase drag using example drag modification systems disclosed herein.
(13) FIG. **9** is a block diagram representative of an example implementation of an example

controller that may be used to implement the example drag modification systems disclosed herein.
(14) FIGS. **10-12** are flowcharts representative of example machine readable instructions that may be executed to implement the example controller of FIG. **9**.
(15) FIG. **13** is a block diagram of an example processor platform capable of executing the instructions of FIGS. **10-12** to implement an example controller of FIG. **9**.
(16) The figures are not to scale. Instead, the thickness of the layers or regions may be enlarged in the drawings. In general, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts. As used in this patent, stating that any part (e.g., a layer, film, area, region, or plate) is in any way on (e.g., positioned on, located on, disposed on, or formed on, etc.) another part, indicates that the referenced part is either in contact with the other part, or that the referenced part is above the other part with one or more intermediate part(s) located therebetween. Connection references (e.g., attached, coupled, connected, and joined) are to be construed broadly and may include intermediate members between a collection of elements and relative movement between elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and in fixed relation to each other. Stating that any part is in "contact" with another part means that there is no intermediate part between the two parts. Although the figures show layers and regions with clean lines and boundaries, some or all of these lines and/or boundaries may be idealized. In reality, the boundaries and/or lines may be unobservable, blended, and/or irregular.
(17) Descriptors "first," "second," "third," etc. are used herein when identifying multiple elements or components which may be referred to separately. Unless otherwise specified or understood based on their context of use, such descriptors are not intended to impute any meaning of priority, physical order or arrangement in a list, or ordering in time but are merely used as labels for referring to multiple elements or components separately for ease of understanding the disclosed examples. In some examples, the descriptor "first" may be used to refer to an element in the detailed description, while the same element may be referred to in a claim with a different descriptor such as "second" or "third." In such instances, it should be understood that such descriptors are used merely for ease of referencing multiple elements or components.

DETAILED DESCRIPTION

(18) Boundary layer airflow can build up and spill into a wake of an aircraft during flight, thereby increasing drag and reducing aircraft efficiency. Drag resulting from the existence of a fuselage boundary layer is generally accepted as part of the overall drag associated with operating an aircraft. However, as drag increases, the amount of fuel consumed also increases.
(19) To accelerate an aircraft fuselage boundary layer, some known aircraft employ boundary layer ingestion techniques. Boundary layer ingestion (BLI) is an area of aerodynamic research that focuses on reducing drag by ingesting (e.g., via a propeller) the fuselage boundary layer, and to accelerate the associated airflow of the ingested fuselage boundary layer to a velocity that equals or exceeds the free stream velocity. A common characteristic among known BLI solutions is the requirement that one or more large, heavy, thrust-producing engine(s) be installed at the rear of the fuselage (e.g., proximate a tail of the aircraft), with the propeller of each such engine being configured to ingest the fuselage boundary layer and accelerate the associated airflow of the ingested fuselage boundary layer to a velocity that equals or exceeds the free stream velocity. Such known BLI solutions are typically not retrofittable to existing aircraft designs absent significant structural modifications to the aircraft. Furthermore, while such known BLI solutions conceptually generate the aforementioned drag-reduction benefit associated with the fuselage boundary layer, the bulk (e.g., the size and/or weight) of the large, heavy, thrust-producing engine(s) required by such known BLI solutions introduces system penalties on the aircraft that undermine the drag-reduction benefit associated with the fuselage boundary layer.
(20) In some examples, boundary layer systems employ a suction system to draw air from a porous fuselage skin using one or more fluid energizing sources, such as turbomachines, compressors, etc.

For example, a suction system includes a plenum having a system of ducts that suck air from an exterior of the fuselage via one or more compressors or pumps. However, the suction systems employing compressors or other turbomachinery are complex, add significant weight, and/or require additional energy to operate the pumps, thereby reducing aircraft efficiency.

(21) Example apparatus, systems and methods disclosed herein modify drag of an aircraft. For example, the apparatus, systems and/or methods disclosed herein can decrease drag during one or more phases of flight when such reduction of drag is beneficial to improve efficiency characteristics during flight in some examples, example systems and apparatus disclosed herein can increase drag during one or more other phases of flight when such increase of drag is beneficial to flight performance. The methods and apparatus disclosed herein can modify drag without the use of external and/or additional fans, compressors, turbomachines and/or the like.

(22) For example, unlike the known BLI solutions described above, which require the installation of one or more large, heavy, thrust-producing engine(s) at the rear of the fuselage of the aircraft, the methods and apparatus disclosed herein modify drag due to fuselage boundary layer via a suction (e.g., a vacuum) generated at an exterior of the fuselage without the use of additional fans, compressors, turbomachines, etc. In some examples, the methods and apparatus disclosed herein ingest and accelerate an aircraft fuselage boundary layer to improve the boundary layer profile, which results in a reduction of drag. The disclosed methods and apparatus advantageously implement a manifold and a fluid mixer (e.g., an eductor or ejector) having a size and/or a weight that is substantially less than the bulk of the large, heavy, thrust-producing engine(s) required by known BLI solutions.

(23) To create suction and ingest the boundary layer, the example manifold apparatus disclosed herein employs a high energy fluid (e.g., a motive fluid). A mass flow rate of the high energy fluid is increased via a fluid mixer, eductor, ejector and/or other fluid mixer. In other words, the motive fluid provides a suction or vacuum via the manifold and the fluid mixer to entrain air from the boundary layer of the fuselage into the high energy airflow via the eductor. Specifically, the fluid mixer receives a boundary layer airflow as a result of a negative pressure gradient effectuated by entrainment of air from the plenum into the eductor.

(24) For example, to provide the motive fluid, example methods and apparatus disclosed herein advantageously leverage pressurized airflow from existing air supply systems of an aircraft. For example, the methods and apparatus disclosed herein advantageously leverage the pressure and/or velocity of cabin air supply and/or cabin trim air to provide a high energy or motive fluid for siphoning off the boundary layer (e.g., boundary layer bleed suction) and reducing aircraft drag. Although example methods and apparatus disclosed herein employ pressurized air from a cabin air supply source and/or a cabin trim air supply source, the example methods and apparatus disclosed herein can be configured or structured to receive or bleed air from an aircraft engine, air supply from shaft driven compressors, fan air, and/or any other pressurized air from any other pressurized fluid supply source of an aircraft. For example, during cruise, cabin air can be employed as a high energy or motive fluid to flow through a fluid mixer (e.g., an eductor, an ejector, etc.) to create suction necessary for a boundary layer removal system to reduce aircraft drag on an aircraft fuselage. Additionally, example methods and apparatus disclosed herein can advantageously discharge or exhaust the mixed airflow overboard in a low momentum flow region (e.g., wake of an aircraft), which reduces drag and/or improves (e.g., increases) thrust recovery.

(25) In some examples, apparatus, systems and methods disclosed herein can increase drag during a flight phase when increasing drag is beneficial. For example, during decent, increased drag can reduce the distance needed to descend the aircraft, which can increase and/or improve aircraft efficiency. In some examples, apparatus, systems and methods disclosed herein provide the dual function of reducing drag and increasing drag during different phases of flight For example, to increase drag, a high energy airflow is provided into the fluid mixer (e.g., an eductor). An outlet of the fluid mixer is blocked such that the high energy airflow flows into a fuselage intake plenum and

discharges into a boundary layer from the fuselage plenum into the ambient air.
(26) In some examples, the disclosed methods and apparatus for ingesting and accelerating an aircraft fuselage boundary layer utilize structural components that are retrofittable with, and/or easily incorporated into, one or more existing aircraft design(s). In such examples, the disclosed methods and apparatus can advantageously be implemented on an existing aircraft and/or incorporated into an existing aircraft design without making significant structural modifications to the aircraft.
(27) Although example methods and apparatus disclosed herein employ pressurized air from a cabin air supply source and/or a cabin trim air supply source, and/or any other pressurized fluid sources of an aircraft, the example methods and apparatus disclosed herein can be configured or structured to operate independently from an environmental control system of an aircraft that regulates cabin airflow, a control system for regulating cabin trim air, and/or any other system from which example methods and apparatus disclosed herein receive pressurized fluid.
(28) FIG. **1** is a perspective view of an example aircraft **100** having an example drag modification system **102** constructed in accordance with teachings of this disclosure. The example aircraft **100** of FIG. **1** is a commercial airliner (e.g., a jumbo jet). However, in other examples, the drag modification system **102** disclosed herein can be implemented with other aircraft. The aircraft **100** of FIG. **1** includes a fuselage **104**, wings **106** to support respective engines **108**, and an empennage **110** (e.g., a tail or rear section) having example horizontal stabilizers **112** and an example vertical stabilizer **114** respectively coupled to and projecting outward from the fuselage **104**. The aircraft **100** of FIG. **1** includes an auxiliary power unit (APU) exhaust **116** that exhausts into a wake region **118** of the aircraft **100** during flight.
(29) As shown in FIG. **1**, the drag modification system **102** is located adjacent and/or supported by the fuselage **104** at a position that is rearward (e.g., aft) of the wings **106**. In other examples, the position at which the drag modification system **102** is located can be along any other portion of the fuselage **104** (e.g., fore of the wings **106**, at a midsection of the fuselage **104**, etc.). As described in greater detail below, the drag modification system **102** of the illustrated example reduces a boundary layer airflow without use of external and/or additional compressors, fans, pumps, and/or other turbomachinery. Instead, the drag modification system **102** employs a motive fluid to suction off a boundary layer airflow from the fuselage **104** (e.g., an external surface) of the aircraft **100** during flight. Specifically, the drag modification system **102** of the illustrated example leverages pressurized air from existing pressurized air sources of the aircraft **100**. In some examples, the drag modification system **102** can employ pressurized fluid from a pressurized fluid source **120** including, but not limited to for example, an cabin air system **122** (e.g., pressurized bleed flow conditioned by an environmental control system **123**), a cabin trim air system **124**, an anti-icing system **126** (e.g., an engine anti-icing system (EAI) and/or wing anti-icing system (WAI)), a fan **128** (e.g., an electric fan, fan air, etc.) and/or any other pressurized fluid source of the aircraft **100**.
(30) For example, to provide airflow and/or pressurization for a cabin **130** of the fuselage **104** during flight (e.g., taxiing, take-off, climb, cruise, descent, landing), the aircraft **100** of the illustrated example employs the cabin air system **122**. The cabin air system **122** can receive pressurized air from, for example, an electric air compressor, bleed air from a turbo-compressor, bleed air provided from one or more compressor stages of the turbine engines **108**, a cabin trim air from the cabin trim air system **124**, an air conditioning pack of the environmental control system **123**, and/or any other air source for supporting the environmental control system **123** of the aircraft **100**. For example, bleed air from the turbine engines **108** can be provided at a pressure sufficient to pressurize air to the cabin **130**. In addition, bleed air pressure is sufficient to operate one or more air conditioning packs of the cabin air system **122** and/or the environmental control system **123** to control a temperature of the cabin air. To exhaust or vent the cabin air from the cabin **130**, the aircraft **100** of FIG. **1** can include a plurality of outflow values, such as a primary outflow valve **132** and/or a secondary outflow valve **134**. Thus, the environmental control system **123** controls or

modulates the primary outflow valve **132** and/or the secondary outflow valve **134** automatically to regulate airflow and/or pressure in the cabin **130** to maintain a desired cabin pressure.
(31) For example, during flight, atmospheric pressure decreases as altitude increases. The environmental control system **123** controls and/or maintains air pressure inside the cabin **130** based on a flight altitude of the aircraft **100**. For example, the environmental control system **123** determines, obtains or otherwise uses a cabin pressure altitude schedule to set or maintain cabin air pressure at a required or desired pressure (e.g., between about 14.6 psia and 11 pounds per square inch absolute (psia) during cruise, such as 14.6 psia, 12.2 psia, or 11 psia) corresponding to a specific flight altitude of the aircraft **100**. In some examples, the environmental control system **123** may operate or control (e.g., modulate) the primary outflow valve **132** and/or the secondary outflow valve **134** in accordance with a predetermined schedule or as a function of one or more operational criteria. For example, the environmental control system **123** may include a controller (e.g., a processor) that receives data and/or signals from sensors representative of current flight conditions including, for example, aircraft airspeed, altitude, a number of passengers in the cabin **130**, air temperature, atmospheric pressure, cabin pressure, angle of attack, and/or other parameter(s). Based on this pressure differential, the environmental control system **123** controls the operation of the primary outflow valve **132** and/or the secondary outflow valve **134** to control or modulate the rate (i.e., mass flow rate) at which pressurized air is transferred between the cabin **130** and the atmosphere to control the air pressure within the cabin **130** of the aircraft **100** based on a predetermined pressure differential schedule or criterion.
(32) To heat cabin air, the example aircraft **100** of FIG. **1** employs the cabin trim air system **124**. The cabin trim air system **124** provides pressurized, heated air that bypasses air conditioning units of the cabin air system **122** and/or the environmental control system **123** to heat cabin air to a desired temperature (e.g., between 60 and 70 degrees Fahrenheit) at various or different zones of the cabin **130**. Trim air is hot bleed air that bypasses air conditioning packs of the environmental control system. Small amounts of trim air are mixed with air supplied to the cabin from a mixing manifold to provide independent fine temperature control in different zones of the cabin. The anti-icing system **126** employs pressurized and/or heated fluid (e.g., bleed air, air from a shaft driven compressor, etc.) that can be used to de-ice (e.g., heat) portions of the turbine engines **108** (e.g., inlet cowls of the turbine engines **108**) and/or the wings **106** of the aircraft **100**.
(33) The drag modification system **102** disclosed herein employs pressurized fluid as a high energy or motive fluid to suction off and/or ingest boundary layer airflow during flight (e.g., from the cabin air system **122**, cabin trim air from the cabin trim air system **124**, pressurized air from the anti-icing system **126**, the fan **128**, and/or any other pressurized source). Although the drag modification system **102** of FIG. **1** receives pressurized fluid from the pressure fluid source **120**, the drag modification system **102** operates independently of the other systems of the aircraft **100** from which it receives the pressurized fluid. For example, although the drag modification system **102** of the illustrated example consumes pressurized fluid from an existing pressurized fluid source **120** of the aircraft **100**, the drag modification system **102** does not affect (e.g., decrease) an efficiency and/or operation of the systems from which the drag modification system **102** receives the pressurized fluid. Thus, the drag modification system **102** does not affect operation of the cabin air system **122**, the environmental control system **123**, the cabin trim air system **124**, the anti-icing system **126**, and/or any other pressurized fluid source **120** from which the drag modification system **102** leverages the pressurized fluid. In some examples, the drag modification system **102** can receive cabin air that would otherwise be dumped overboard via the primary outflow valve **132** and/or the secondary outflow valve **134**. Thus, the drag modification system **102** can be used to dump the cabin air from the cabin **130**.
(34) FIG. **2**A is a partial side view of the aircraft **100** of FIG. **1**. FIG. **2**B is a cross-sectional view of the aircraft **100** taken along line **2**B-**2**B of FIG. **2**A Referring to FIGS. **2**A and **2**B, the drag modification system **102** of the illustrated example includes a manifold **200** defining a passageway

202 extending between an external and/or exterior surface **204** (e.g., a fuselage skin **204***a*) of the fuselage **104** of the aircraft **100** and an exhaust **206** of the aircraft **100** when the manifold **200** is coupled to the aircraft **100**. Specifically, the passageway **202** of the illustrated example includes a first inlet **208** (e.g., a primary inlet), a second inlet **210** (e.g., a secondary inlet), and an outlet **212**. The passageway **202** of the illustrated example channels fluid flow from the first inlet **208** and the second inlet **210** to the outlet **212**. The passageway **202** of the illustrated example can be formed using tubes, hoses, ducts, pipes, and/or other fluid flow channels or passageways and extends between the first inlet **208**, the second inlet **210** and the outlet **212**.

(35) The first inlet **208** of the illustrated example receives pressurized fluid from the aircraft **100**. For example, the first inlet **208** receives pressurized fluid or a motive fluid from the pressurized fluid source **120** of FIG. **1**. In the illustrated example, the first inlet **208** receives pressurized fluid from the cabin air system **122** (FIG. **1**). To receive the pressurized fluid flow, the first inlet **208** is fluidly coupled to the pressurized fluid source **120** via a flow path **214**. For example, the flow path **214** can be tubing, piping, a hose, a duct and/or any other passageway for fluidly coupling the first inlet **208** and the pressurized fluid source **120**. The pressurized fluid received by the first inlet **208** has a pressure or energy that is greater than the ambient pressure of air external to the fuselage **104**. For example, the pressurized fluid at the first inlet **208** can have a pressure range of between approximately 14.6 psia and 11 psia, such as about 14.6 psia, about 12.2 psia, or about 11 psia.

(36) The second inlet **210** receives and/or suctions off boundary layer airflow during flight. To receive the boundary layer airflow, the second inlet **210** of the drag modification system **102** of FIG. **2** is in fluid communication with the external and/or exterior surface **204** (e.g., a fuselage skin **204***a*) of the fuselage **104**. The second inlet **210** is positioned downstream from the wings **106** (FIG. **1**) of the aircraft **100** and upstream from the empennage **110** (e.g., the horizontal stabilizers **112**) of the aircraft **100**. In the illustrated example, the second inlet **210** includes an inlet plenum **216** (e.g., an inlet manifold). The intake plenum **216** of FIG. **2** has an intake frame **218** that is mounted to the exterior surface **204** of the fuselage **104**. Specifically, referring to FIG. **2**B, the second inlet **210** (e.g., the intake frame **218**) is flush mounted relative to the fuselage skin **204***a*. For example, the inlet frame **218** has a shape and/or contour that maintains a flush orientation relative to the fuselage skin **204***a* along a perimeter (e.g., an entire perimeter) of the intake frame **218**. For example, the intake frame **218** of the illustrated example has a rectangular shape and has a curvature (e.g., a radius of curvature) complementary to a curvature (e.g., a radius of curvature) of the fuselage skin **204***a* to enable the intake frame **218** to flush mount relative to the fuselage skin **204***a*. To allow intake of boundary layer airflow via the second inlet **210**, the intake plenum **216** (e.g., the intake frame **218**) includes a plurality of openings **220**. The openings **220** of the intake plenum **216** have a relatively small diameter to prevent debris and/or other foreign objects from entering in the second inlet **210** and/or the passageway **202**. In some examples, the intake frame **218** having the openings **220** is a perforated plate and/or skin. In some embodiments the openings **220** and/or perforations in the plate can be micro-perforations. In some examples, a size of each one of the openings **220** can be between approximately 0.02 millimeters and 1.5 millimeters. The intake frame **218** can be composed of titanium, aluminum and/or any other suitable material. In some examples, second inlet **210** and/or the intake frame **218** can include slits, holes, perforations (shaped holes), louvers, a screen, and/or any other frame having openings to allow intake of boundary layer airflow during flight. To seal between an internal surface **223** (e.g., the cabin **130**) of the fuselage **104** and the intake plenum **216** (e.g., an exterior surface **224** (FIG. **2**B), the drag modification system **102** includes a seal **226**. The seal **226** can be provided around a perimeter of the intake frame **218** to prevent airflow from flowing within the cabin **130** of the aircraft **100** between the intake frame **218** and the fuselage skin **204***a*. The seal **226** can be a rubber gasket, foam, and/or any other seal. Thus, airflow is permitted only through the openings **220** of the drag modification system **102**.

(37) The passageway **202** of the example drag modification system **102** is structured to generate

suction at the second inlet **210** when the passageway **202** receives pressurized fluid via the first inlet **208**. To generate suction at the second inlet **210**, the drag modification system **102** of the illustrated example includes a fluid mixer **228**. In some examples, the fluid mixer **228** can be, but is not limited to, a mixing manifold, an eductor, an ejector, a nozzle, a flow mixer, a venturi device or manifold, and/or any other structure for mixing flow to generate suction at the second inlet **210** by utilizing pressurized fluid from the pressurized fluid source **120** (FIG. **1**) as a motive fluid. In other words, the passageway **202** and/or the fluid mixer **228** generates a negative pressure gradient proximate to (e.g., across) the second inlet **210** when the pressurized fluid **208** is provided at the first inlet **208** and discharges to the outlet **212**. The outlet **212** exhausts mixed airflow (e.g., the mixed motive fluid and the suctioned fluid) from the aircraft **100**.
(38) To control, manage, regulate, and/or adjust one or more aspects(s) of an operation of the drag modification system **102**, the drag modification system **102** of the illustrated example employs a system controller **222**. For example, the system controller **222** can be integrated and/or otherwise incorporated into the aircraft **100**. For example, the system controller **222** can be communicatively coupled with a main controller (e.g., Flight Management System (FMS), Full Authority Digital Engine Control (FADEC), or Environmental Control Systems Controller (ECSC)) of the aircraft **100**.
(39) The outlet **212** of the illustrated example is in fluid communication with the APU exhaust **116** and airflow from the drag modification system **102** expels in the exhaust **206** of the aircraft **100**. Specifically, the mixed airflow exhausts in the wake region **118** of the aircraft **100** during flight, which decreases drag and increases thrust recovery efficiency. In the illustrated example, the outlet **212** is positioned below the APU exhaust **116**.
(40) Additionally, the outlet **212** of the illustrated example is positioned upstream from the APU exhaust **116**. The outlet **212** is not limited to the configuration shown in FIG. **2**A For example, the outlet **212** can be positioned at any desirable location. Various configurations are shown in FIGS. **2**C-**2**E.
(41) FIGS. **2**C-**2**E are partial views of the empennage **110** of the aircraft **100** illustrating different configurations of the outlet **212** of the drag modification system **102** disclosed herein. Referring to FIG. **2**C, the outlet **212** of the passageway **202** at positioned proximate to the APU exhaust **116**. Referring to FIG. **2**D, the outlet **212** of the passageway **202** is concentric and/or symmetrical with the APU exhaust **116**. Referring to FIG. **2**E, the outlet **212** of the passageway **202** is coupled with an exhaust passageway **215** of an auxiliary power unit **217** of the aircraft **100**. For example, the passageway **202** receives the exhaust passageway **215** of the auxiliary power unit **217** upstream from the outlet **212** and/or the APU exhaust **116**. In some examples, the outlet **212** can be coupled to the exhaust passageway **215**, and the exhaust passageway **215** can fluidly couple the outlet **212** of the passageway **202** and the APU exhaust **116**. Thus, the outlet **212** of the drag modification systems disclosed herein can be structured and/or fluidly coupled to various components and/or outlets of the aircraft **100**.
(42) FIG. **3** is a perspective view of the example drag modification system **102** of FIGS. **1**, **2**A and **2**B. The manifold **200** of the illustrated example includes a head **302**. The head **302** of the illustrated example is an enclosed structure that defines a cavity of the intake plenum **216**. For example, the head **302** includes frame members **304** to define a shape of the head **302** and panels **306** that couple to the frame members **304** to enclose the head **302**. The frame members **304** form an opening to receive the intake frame **218**, which provides an opening for the head **302**. The head **302** attaches to the internal surface **223** (FIG. **2**B) of the fuselage **104**. For example, the head **302** attaches to a frame of the fuselage **104**, a stringer, a longeron, a bulkhead, and/or any other structure of the fuselage **104**. The head **302** can be formed of sheet metal, stainless steel, aluminum, rubber, and/or any other material(s). The head **302** includes an end **308** that is structured or forms a tube to configure the head **302** for attachment to a pipe defining the outlet **212**.
(43) FIG. **4** is a schematic illustration of the example drag modification system **102** of FIGS. **1**, **2**A,

2B, and **3**. In operation, the first inlet **208** receives a high energy or motive fluid **402** (e.g., a primary motive fluid, compressed air, or pressurized fluid from the pressurized fluid source **120**) to be received by the fluid mixer **228**. The motive fluid **402** has fluid flow parameters to generate a suction at the second inlet **210** to entrain a secondary fluid **404** (e.g., air) from the intake plenum **216** into the high energy or motive fluid **402** flowing through the fluid mixer **228** and discharges via the outlet **212**.

(44) To generate suction at the second inlet **210**, the passageway **202** and/or the fluid mixer **228** of the illustrated example includes a nozzle **408** and a diffuser **410**. The nozzle **408** defines a nozzle passageway **412** having a nozzle throat **414** between a nozzle inlet **416** (e.g., a primary inlet) and a nozzle outlet **418**. The nozzle inlet **416** is fluidly coupled to or in fluid communication with the first inlet **208**. Additionally, the passageway **202** and/or the fluid mixer **228** defines a suction inlet **420** (e.g., a secondary inlet). The suction inlet **420** is fluidly coupled to or in fluid communication with the second inlet **210**. In the illustrated example, the suction inlet **420** is in fluid communication with a suction chamber **422** defined by the passageway **202** and/or the fluid mixer **228**. The passageway **202** and/or the fluid mixer **228** of the illustrated example includes a mixing zone **424** (e.g., a throat area of the passageway **202**) located between the nozzle **408** and the diffuser **410**. Specifically, the mixing zone **424** is located downstream from the suction chamber **422** and upstream from the diffuser **410**. Additionally, the nozzle outlet **418** of the nozzle **408** is in fluid communication with the mixing zone **424** and downstream from the suction inlet **420**. In other words, the nozzle outlet **418** is located downstream from the suction chamber **422** and/or the suction inlet **420** such that the motive fluid **402** exits into the mixing zone **424** via the nozzle outlet **418**. The diffuser **410** of the illustrated example defines a diffuser passageway **426** having a diffuser inlet **428** and a diffuser outlet **430**. The diffuser inlet **428** is fluidly coupled to and/or in fluid communication from with the mixing zone **424** and the diffuser outlet **430** is fluidly coupled to and/or in fluid communication with the outlet **212**. The diffuser outlet **430** of the illustrated example defines a converging-diverging outlet.

(45) In operation, the drag modification system **102** activates during certain flight phases. For example, the drag modification system **102** activates during a cruise phase of flight to modify (e.g., reduce) drag during cruise. To activate the drag modification system **102**, the drag modification controller **230** operates a first control valve **432** (e.g., a primary motive fluid valve). The drag modification controller **230** causes a first control valve **432** to move between an open position to allow the motive fluid **402** to flow from the pressurized fluid source **120** to the first inlet **208** and/or the first nozzle inlet **416** and a closed position to prevent the motive fluid **402** from flowing from the pressurized fluid source **120** to the first inlet **208** and/or the first nozzle inlet **416**. The first control valve **432** can be a pneumatically actuated fluid valve, an electrically actuated fluid valve, a shut off valve (SOV), a high pressure shut off valve (HPSOV), a normally closed fluid valve and/or any other flow control device. To detect a flow parameter of the motive fluid **402**, the drag modification system **102** includes a first sensor **434**. The first sensor **434** (e.g., outputs from the first sensor **434**) can be used by the system controller **222** to detect a pressure, a velocity, a mass flow rate and/or fluid flow parameter of the motive fluid **402** to be received from the pressurized fluid source **120**. In some examples, the system controller **222** modulates the first control valve **432** based on output signal(s) from the first sensor **434**. In some examples, the drag modification system **102** does not include the first sensor **434**. In some examples, the system controller **222** receives flow characteristic information of the motive fluid **402** from the main controller (e.g., FMS, FADEC, or ECSC). In some examples, the drag modification system **102** of the illustrated example can include a pressure regulator (e.g., positioned downstream from the first control valve) to regulate a pressure of the motive fluid **402** prior to flowing to the first inlet **208** and/or the nozzle inlet **416**.

(46) The first inlet **208** receives the motive fluid **402** (e.g., a pressurized fluid) from the pressurized fluid source **120** of FIG. **1** and provides the motive fluid **402** to the nozzle inlet **416**. For example,

the first inlet **208** receives pressurized fluid from the cabin air system **122** of FIG. **1**. A pressure of the motive fluid **402** at the first inlet **208** is greater than a pressure of the secondary fluid **404** at the second inlet **210** and/or the suction inlet **420**. In other words, a pressure or energy of the pressurized fluid at the first inlet **208** is greater than a pressure of the boundary layer airflow to be received at the second inlet **210**.

(47) As the motive fluid **402** flows through the nozzle **408**, a pressure of the motive fluid **402** decreases and a velocity of the motive fluid **402** increases. For example, the motive fluid has a velocity at the nozzle outlet **418** that is greater than a velocity of the motive fluid **402** at the nozzle inlet **416** and the motive fluid **402** has a pressure at the nozzle outlet **418** that is less than a pressure of the motive fluid **402** at the nozzle inlet **416**. The nozzle outlet **418** discharges the motive fluid **402** into the mixing zone **424**. When the motive fluid **402** discharges from the nozzle outlet **418** into the mixing zone **424**, a low-pressure region (e.g., a pressure drop) forms in the passageway **202** and/or the fluid mixer **228** that causes or otherwise generates a suction in the suction chamber **422** and/or at the suction inlet **420**. As a result, the motive fluid **402** generates a suction at the suction inlet **420** and/or within the suction chamber **422**. The suction generated at the suction inlet **420** causes the passageway **202** to receive the secondary fluid **404** entrained from the intake plenum **216** (e.g., the boundary layer airflow **406**). In other words, the suction inlet **420** generates a suction at the second inlet **210** to intake (e.g., ingest or siphon off) boundary layer airflow **406** from the fuselage **104** and cause the secondary fluid **404** to flow to the mixing zone **424**. In other words, the second inlet **210** and/or the intake plenum **216** receive a boundary layer airflow as a result of a negative pressure gradient effectuated by entrainment of air from the intake plenum **216** into the fluid mixer **228**.

(48) The secondary fluid **404** mixes with the motive fluid **402** in the mixing zone **424** to provide the mixed fluid **436**. The diffuser **410** reduces a velocity of the mixed fluid **436** (e.g., to pipeline velocities), which allows recovery (e.g., an increase) of a pressure of the mixed fluid **436** as the mixed fluid **436** exits the diffuser outlet **430**. The diffuser outlet **430** is fluidly coupled and/or in fluid communication with the outlet **212** to enable the mixed fluid **436** to discharge via the outlet **212**. In the illustrated example, the mixed fluid **436** discharges into the wake region **118** (FIG. **1**) of the aircraft **100** during flight to reduce drag. To deactivate the drag modification system **102**, the system controller **222** operates and/or otherwise causes the first control valve **432** to move to a closed position to prevent the motive fluid **402** from flowing to the first inlet **208** and/or the nozzle inlet **416**.

(49) FIG. **5**A is a side view of the aircraft **100** of FIG. **1** illustrating a representation of a boundary layer **502** provided by the drag modification system **102** disclosed herein. FIG. **5**B is a side view an aircraft **501** similar to the aircraft **100** of FIG. **1** illustrating a representation of a boundary layer **503** when the aircraft **501** is not implemented with the drag modification system **102** disclosed herein.

(50) Referring to FIG. **5**A, as a result of the drag modification system **102** ingesting or siphoning off boundary layer airflow **406**, the drag modification system **102** of the illustrated example reduces drag. In some examples, the drag modification system **102** of the illustrated example can reduce drag by a factor of four when implemented with some aircraft (e.g., the aircraft **100**). To reduce drag, the drag modification system **102** of the illustrated example modifies the boundary layer **502**. For example, the drag modification system **102** of the illustrated example reduces and/or at least partially eliminates the boundary layer **502**. To modify a profile of the boundary layer **502**, the drag modification system **102** causes a velocity and/or acceleration of the boundary layer airflow **406** to increase during flight. Such increase in velocity and/or acceleration of the boundary layer airflow **406** ensures or induces a laminar profile of the boundary layer **502** by causing the boundary layer **502** to remain closer to the fuselage **104** (e.g., the fuselage skin **204***a* of the fuselage **104**). By reducing and/or eliminating the boundary layer **502**, the boundary layer **502** does not build up and/or spill into the wake region **118** of the aircraft **100**, which reduces drag.

Additionally, the mixed fluid **436** exhausts into the wake region **118**, which reduces drag and/or increases thrust recovery efficiencies.
(51) In contrast, referring to FIG. **5**B, a profile of the boundary layer **503** of the aircraft **501** separates from a fuselage **505** of the aircraft **501**. Such separation, in some instances, can induce a turbulent profile. For example, the boundary layer **503** separates from the fuselage **505** a distance **507** that is greater than a distance **508** at which the boundary layer **502** separates from the fuselage **104** when the aircraft **100** and **501** are at the same altitude and moving at the same speeds in the same environmental conditions. As the boundary layer **503** of FIG. **5**B builds up and/or separates from the fuselage **505**, the boundary layer **503** spills into the wake region **118** of the aircraft, which increases drag.
(52) In addition, referring to FIG. **5**A, the aircraft **100** experiences further thrust recovery from cabin air **510** discharged from the cabin **130** via the primary and/or secondary outflow valves **132**, **134**. Thus, the mixed fluid **436** provides thrust recovery in addition to thrust recovery from discharged cabin air **510**. In some examples, the first inlet **208** and/or the nozzle inlet **416** (FIG. **4**) can receive cabin air as the motive fluid **402**. For example, instead of removing the cabin air **510** via the via the primary and/or secondary outflow valves **132**, **134**, the cabin air **510** can be channeled to the first inlet **208** and/or the nozzle inlet **416** to provide the motive fluid **402**. In some such examples, the primary and/or secondary outflow valves **132**, **134** can be commanded by the system controller **222** to remain closed and a separate valve (not shown), can be operated to discharge the cabin air **510** to the first inlet **208** when the drag modification system **102** is activated. In some examples, the cabin air system **122** can replace the cabin air **510** using a combination of the primary and/or secondary outflow valves **132**, **134** and the drag modification systems **102**.
(53) FIG. **6** illustrates another example drag modification system **600** disclosed herein that can be implemented on an aircraft such as, for example, the aircraft **100** of FIG. **1**. Many of the components of the example drag modification system **600** of FIG. **6** are substantially similar or identical to the components of the drag modification system **102** described above in connection with FIGS. **1**, **2**A, **2**B, **3**, **4** and **5**A. As such, those components will not be described in detail again below. Instead, the interested reader is referred to the above corresponding descriptions for a complete written description of the structure and operation of such components. To facilitate this process, identical reference numbers will be used for structures in FIG. **6** that correspond to structures in FIGS. **1**, **2**A, **2**B, **3**, **4** and **5**A. For example, the drag modification system **600** of the illustrated example includes a passageway **202** and/or a fluid mixer **228** including a nozzle **408**, a diffuser **410**, and a mixing zone **424** positioned between the nozzle **408** and the diffuser **410**, and a system controller **222**.
(54) Referring to FIG. **6**, the drag modification system **600** of the illustrated example is substantially similar to the drag modification system **102** except that drag modification system **600** enables high energy airflow or motive fluid (e.g., pressurized fluid) from multiple pressurized fluid sources **120** (e.g., two or more of the pressurized fluid sources **120** of FIG. **1**). For example, the drag modification system **600** of the illustrated example includes a supplemental motive fluid system **601**.
(55) In the illustrated example, the drag modification system **600** of the illustrated example includes a first inlet **208** (e.g., a primary inlet), a second inlet **210** (e.g., a secondary inlet), and a third inlet **602** (e.g., a tertiary inlet). For example, a nozzle inlet **416** of the nozzle **408** of the fluid mixer **228** can receive a first motive fluid **604** (e.g., the motive fluid **402** of FIG. **4**) from a first pressurized fluid source **606** and/or a second motive fluid source **608** (e.g., a supplemental motive fluid) from a second pressurized fluid source **610** different from the first pressurized fluid **606**. For example, the first motive fluid **604** can be pressurized cabin air from the cabin air system **122** and the second motive fluid **608** can be pressurized fluid from the cabin trim air systems **124**, the anti-icing system **126**, pressurized fluid from the fan **128** (e.g., fan air), and/or any other pressurized

fluid source **120** of the aircraft **100**. In some examples, a fluid parameter of the first motive fluid **604** is different than a fluid parameter of the second motive fluid **608**. For example, a pressure, velocity and/or temperature of the first motive fluid **604** can be less than a pressure, velocity and/or temperature of the second motive fluid **608**. For example, the second motive fluid **608** has a higher energy than the first motive fluid **402** and/or **604**. In some examples, the fluid parameters of the first motive fluid **604** and the second motive fluid **608** are similar (e.g., identical).

(56) During operation, the drag modification system **600** of FIG. **6** can receive the first motive fluid **604**, the second motive fluid **608**, or a combined motive fluid **612** provided by the first motive fluid **604** and the second motive fluid **608** to generate or provide a suction at the second inlet **210** and/or the suction inlet **420** and entrain air from the intake plenum **216** into the high energy airflow via the fluid mixer **228**. For example, the drag modification system **600** can receive the first motive fluid **604**, without receiving or using the second motive fluid **608**, if the first pressurized fluid source **606** can provide the first motive fluid **604** with a desired fluid parameter (e.g., a pressure, volume and/or mass flow rate) that is sufficient to provide or generate a suction at the second inlet **210** and/or a suction inlet **420** when the first motive fluid **604** discharges from the nozzle outlet **418**. Alternatively, the drag modification system **600** can receive the second motive fluid **608**, without receiving or using the first motive fluid **604**, if the second pressurized fluid source **610** can provide the second motive fluid **608** with a desired fluid parameter (e.g., a pressure, volume and/or mass flow rate) that is sufficient to provide or generate a suction at the second inlet **210** and/or a suction inlet **420** when the second motive fluid **608** discharges from the nozzle outlet **418**. In some examples, the drag modification system **600** can receive the first motive fluid **604** and the second motive fluid **608** to provide the combined motive fluid **612** with a desired fluid parameter (e.g., has a pressure, volume and/or mass flow rate) that is sufficient to provide a suction at the second inlet **210** and/or a suction inlet **420**. In some examples, the drag modification system **600** of the illustrated example can select between the first motive fluid **604**, the second motive fluid **608** and/or the combined motive fluid **612** based on an availability of the first pressurized fluid source **606** and/or the second pressurized fluid source **610** during a flight schedule. In some examples, the drag modification system **600** can select between the first motive fluid **604**, the second motive fluid **608** and/or the combined motive fluid **612** based on an efficiency (e.g., optimized or maximum efficiency) of the aircraft system(s) and/or any other operational scheme. In some instances, the second motive fluid **608** provides a back-up or fail-safe system if the first motive fluid **604** is not available and/or the first pressurized fluid source **606** cannot produce the first motive fluid **604** with fluid parameter(s) and/or characteristic(s) sufficient to generate a suction at the second inlet **210** and/or the suction inlet **420**. In such example, the second motive fluid **608** can supplement the first motive fluid **604** to provide a motive fluid (e.g., the combined motive fluid **612**) having fluid parameter(s) and/or characteristic(s) to generate suction at the second inlet **210** and/or the suction inlet **420**.

(57) To control fluid flow of the first motive fluid **604** to the nozzle inlet **416**, the drag modification system **600** includes a first control valve **432**. Likewise, to control fluid flow of the second motive fluid **608** to the nozzle inlet **416**, the drag modification system **600** includes a second control valve **614** (e.g., a supplemental motive fluid valve). The system controller **222** operates the first control valve **432** and the second control valve **614**. Thus, the system controller **222** operates the first control valve **432** (e.g., between an open position and a closed position) and the second control valve **614** (e.g., between an open position and a closed position) to provide the first motive fluid **604**, the second motive fluid **608**, and/or the combined motive fluid **612** to the nozzle inlet **416**. To detect a flow parameter of the first motive fluid **604** and the second motive fluid **608**, respectively, the drag modification system **600** includes a first sensor **434** and a second sensor **616**. The first sensor **434** (e.g., outputs from the first sensor **434**) can be used by the system controller **222** to detect a pressure, a velocity, a mass flow rate and/or fluid flow parameter of the first motive fluid **604** to be received from the first pressurized fluid source **606**. The second sensor **616** (e.g., outputs

from the second sensor **616**) can be used by the system controller **222** to detect a pressure, a velocity, a mass flow rate and/or fluid flow parameter of the second motive fluid **608** to be received from the second pressurized fluid source **610**. In some examples, the system controller **222** modulates the first control valve **432** based on output signal(s) from the first sensor **434** to provide the first motive fluid **604**, modulates the second control valve **614** based on output signal(s) from the second sensor **616** to provide the second motive fluid **608**, and/or modulates the first control valve **432** and the second control valve **614** based on input signals from the first sensor **434** and the second sensor **616** to provide the combined motive fluid **612** having desired or target fluid parameters (e.g., pressure, velocity, mass flow rate, etc.). In some examples, the drag modification system **600** does not include the first sensor **434** and/or the second sensor **616**. In some examples, the system controller **222** receives flow characteristic information of the first motive fluid **604** and/or the second motive fluid **608** from the main controller (e.g., FMS, FADEC, or ECSC). In some examples, the drag modification system **600** of the illustrated example can include a first pressure regulator (e.g., positioned downstream from the first control valve **432**) to regulate a pressure of the first motive fluid **604** prior to flowing to the first inlet **208** and/or the nozzle inlet **416** and a second pressure regulator (e.g., positioned downstream from the second control valve **614**) to regulate a pressure of the second motive fluid **618** prior to flowing to the third inlet **602** and/or the nozzle inlet **416**. The drag modification system **600** (e.g., the fluid mixer **228**) functions substantially similar to the drag modification system **102** of FIGS. **1**, **2**A, **2**B, **3**, **4**, and **5**A. Thus, for brevity, the operation of the drag modification system **600** will not be described.
(58) FIGS. **7**A and **7**B are schematic illustrations of another example drag modification system **700** disclosed herein that can implement an aircraft such as, for example, the aircraft **100** of FIG. **1**. Many of the components of the example drag modification system **700** of FIGS. **7**A and **7**B are substantially similar or identical to the components of the drag modification system **102** and/or the drag modification system **600** described above in connection with FIGS. **1**, **2**A, **2**B, **3**, **4**, **5**A and **6**. As such, those components will not be described in detail again below. Instead, the interested reader is referred to the above corresponding descriptions for a complete written description of the structure and operation of such components. To facilitate this process, identical reference numbers will be used for structures in FIGS. **7**A and **7**B that correspond to structures in FIGS. **1**, **2**A, **2**B, **3**, **5**A and **6**. For example, the drag modification system **700** of the illustrated example includes a passageway **202** and/or a fluid mixer **228** including a nozzle **408**, a diffuser **410**, and a mixing zone **424** positioned between the nozzle **408** and the diffuser **410**, and a system controller **222**. In some examples, the drag modification system **700** can include the third inlet **602** of FIG. **6**.
(59) The drag modification system **700** of the illustrated example operates between a first mode of operation **702** to reduce drag and a second mode of operation **704** to increase drag. For example, the drag modification system **700** of the illustrated example can operate in the first mode of operation **702** to decrease drag during a first flight phase (e.g., cruise, take-off, etc.) and operate in the second mode of operation **704** to increase drag during a second flight phase (e.g., descent, landing, etc.). For example, in the first mode of operation **702**, the drag modification system **700** induces or promotes a laminar boundary layer profile during flight to reduce drag and, in the second mode of operation **704**, the drag modification system **700** induces or promotes a turbulent boundary layer profile during flight to increase drag.
(60) The drag modification system **700** of the illustrated example includes a third control valve **706** at the outlet **212** of the passageway **202**. Specifically, the third control valve **706** is positioned between the diffuser outlet **430** of the diffuser **410** and the outlet **212** of the passageway **202**. In operation, the system controller **222** operates the third control valve **706** between an open position and a closed position.
(61) In the first mode of operation **702** to reduce drag shown in FIG. **7**A, the system controller **222** moves the third control valve **706** to an open position to allow fluid flow through the outlet **212**. When the third control valve **706** is moved to the open position, the drag modification system **700**

operates substantially similar (e.g., identical) to the drag modification system **102** of FIGS. **1**, **2**A, **2**B, **3**, **4**, and **5**A. For example, the system controller **222** can activate the drag modification system **102** by controlling, commanding and/or otherwise causing the first control valve **432** and the third control valve **706** to move to respective open positions. In this manner, the motive fluid **402** from a first pressurized fluid source **606** flows to the nozzle inlet **416** and discharges from the nozzle outlet **418** to cause or create a suction at the suction inlet **420** and/or the second inlet **210** that draws the boundary layer airflow **406** into the intake plenum **216**. The secondary fluid **404** entrained from the intake plenum **216** mixes with the motive fluid **402** in the mixing zone **424** and discharges from the diffuser outlet **430**. The third control valve **706** allows the mixed fluid **436** (e.g., a high energy fluid flow) to flow or discharge from the outlet **212** (e.g., into the wake region **118**).

(62) In some examples, the drag modification system **700** can include a third inlet **602** that provides a second motive fluid **608** (e.g., a supplemental motive fluid). The drag modification system **700** when implemented with the third inlet **602** operates substantially similar to the drag modification system **600** of FIG. **6**.

(63) In the second mode of operation **704** to increase drag shown in FIG. **7**B, the system controller **222** moves the third control valve **706** to a closed position to prevent or restrict fluid flow through the outlet **212** and/or the diffuser outlet **430**. Additionally, the system controller **222** operates and/or causes the first control valve **432** to move to an open position to allow the motive fluid to flow into the nozzle **408** and/or the diffuser **410**. Because the third control valve is in the closed position, the motive fluid is prevented from flowing to the outlet **212**. Because the motive fluid **402** is prevented from flowing or discharging from the outlet **212**, the motive fluid **402** does not create a suction at the suction inlet **420** and/or the second inlet **210**. Additionally, a pressure of the motive fluid is greater than a pressure (e.g., atmospheric pressure) of airflow external to the aircraft **100**. As a result, the pressurized fluid provided by the motive fluid **402** that exits the nozzle outlet **418** flows through second inlet **210** and exits or discharges from the intake plenum **216** adjacent the external surface of the fuselage **104** of the aircraft **100**. The pressurized airflow provided by the motive fluid **402** adjacent (e.g., along) the external surface of the fuselage **104** affects and/or interrupts the boundary layer airflow. As a result, the pressurized fluid provided by the motive fluid **402** exiting or discharging from the second inlet **210** causes the boundary layer to separate from the fuselage **104** to induce a turbulent boundary layer profile. Pressurized fluid provided by the motive fluid **402** exiting the second inlet **210** causes a boundary layer to build and spill into the wake region **118** during flight and thereby increase drag. For example, increasing drag during descent can reduce a speed of the aircraft. In some examples, increasing drag during descent reduces a distance needed to compete the decent phase, allowing greater travel distance of a cruise phase of a flight and thereby improving aircraft efficiency.

(64) When the drag modification system **700** is implemented with the third inlet **602**, the second motive fluid **608** can be employed in addition to, or instead of, the motive fluid **402**. For example, the system controller **222** can operate the first control valve **232** and/or a second control valve **614** to provide the motive fluid **402**, the second motive fluid **608** and/or a combination of the motive fluid **402** and the second motive fluid **608** (e.g., similar to the drag modification system **600** of FIG. **6**) to increase drag when the drag modification system **700** is in the second mode of operation **704**.

(65) FIG. **8**A is a flow chart of an example method for reducing drag of an aircraft. The method **800** of FIG. **8**A includes providing a high energy airflow into a fluid mixer (block **802**). For example, the high energy fluid is a motive fluid (e.g., the motive fluid **402**, **604**, **608**) provided to an inlet (e.g., the nozzle inlet **416**) of the fluid mixer **228** (e.g., eductor). The high energy airflow is provided to entrain air from the intake plenum **216** into the high energy airflow via the fluid mixer **228** (block **804**). As a result, a boundary layer airflow is received into the intake plenum **216** as a result of a negative pressure gradient effectuated by entrainment of air from the intake plenum into the fluid mixer **228** (block **806**). The high energy airflow and the boundary layer airflow (e.g., the mixed fluid **436**, the combined motive fluid **612**) from the fluid mixer **228** (block **808**). For

example, the high energy airflow and the boundary layer airflow can discharge from the eductor into a wake of the aircraft **100** to reduce drag during flight.

(66) FIG. **8**B is a flow chart of an example method for increasing drag of an aircraft. The method of **801** of FIG. **8**B includes providing a high energy airflow into a fluid mixer (block **803**). For example, the high energy fluid is a motive fluid (e.g., the motive fluid **402**, **604**, **608**) provided to an inlet (e.g., the nozzle inlet **416**) of the fluid mixer **228** (e.g., eductor). An exit of the fluid mixer **228** is blocked or closed such that the high energy airflow flows from the fluid mixer **228** to the intake plenum **216**. For example, to block the exit (e.g., the outlet **212**), the third control valve **706** moves to the closed position to prevent fluid flow through the outlet **212**. The high energy airflow flow discharges into a boundary layer (e.g., the boundary layer **502**) from the intake plenum **216** (e.g., the second inlet **210**) as a result of a positive pressure gradient from the intake plenum **216** into ambient air (e.g., a boundary layer **502** of FIG. **5**A) external to the aircraft **100** (block **807**).

(67) FIG. **9** is a block diagram of an example implementation of the system controller **222** of the example drag modification system **102** of FIGS. **1**, **2**A, **2**B, **3**, **4**, and **5**A, the drag modification system **600** of FIG. **6**, and the drag modification system **700** of FIGS. **7**A and **7**B. The system controller **222** of FIG. **9** includes an example flight phase determiner **902**, an example boundary layer system activator **904**, an example motive fluid determiner **906**, and an example valve operator **908**. The example flight phase determiner **902**, the example boundary layer system activator **904**, the example motive fluid determiner **906**, and the example valve operator **908** are communicatively coupled via an example bus **910**. In some examples, the system controller **222** of the illustrated example is communicatively coupled to a main controller **912** (e.g., FMS, FADEC, or ECSC) of an aircraft (e.g., the aircraft **100**) via a bus **914**, wireless protocol and/or any other suitable communication protocol. The system controller **222** is communicatively coupled (e.g., via an input/output interface) to one or more devices such as, for example, one or more of the first control valve **432**, the second control valve **614**, the third control valve **706**, the first sensor **434**, the second sensor **616** and/or any other system of the aircraft **100**. As used herein, the phrase “in communication,” including variations thereof, encompasses direct communication and/or indirect communication through one or more intermediary components, and does not require direct physical (e.g., wired) communication.

(68) The flight phase determiner **902** of the illustrated example determines a fight phase of the aircraft **100**. To determine a flight phase, the flight phase determiner **902** of FIG. **9** receives a phase of flight status from the main controller **912** via the bus **914**. For example, the phase of flight is determined by the main controller **912** from one or more parameter(s) of an aircraft during flight. For example, the main controller **912** determines phase of flight based on one or more of a speed of an aircraft, revolution per minute (RPMs) of the turbine engines **108** of FIG. **1**, altitude of the aircraft, and/or any other parameter(s). In some examples, the flight phase determiner **902** is configured to receive the one or more parameter(s) of the aircraft during flight to determine a phase of flight without input from the main controller **912**. The phase of flight data can include, for example, taxiing, take-off, climb, cruise, descent, and landing.

(69) The flight phase determiner **902** communicates the phase of flight status to the boundary layer system activator **904**. In some examples, the flight phase determiner **902** communicates the flight phase data to memory and the boundary layer system activator **904** retrieves the flight phase data from the memory. In some examples, the flight phase determiner **902** provides and/or generates different signals (e.g., binary signals, analog, etc.) for use by the boundary layer system activator **904** that associated with each phase of flight. For example, the flight phase determiner **902** can output a first signal representative of a phase of flight associated with take-off, a second signal representative of a phase of flight associated with cruise, a third signal representative of a phase of flight associated with descent, a fourth signal representative of a phase of flight associated with landing, and a fifth signal representative of a phase of flight associated with taxiing.

(70) The boundary layer system activator **904** activates the drag modification system **102**, **600**

and/or **700** disclosed herein. For example, the boundary layer system activator **904** receives, retrieves or otherwise obtains a phase of flight status from the flight phase determiner **902** and/or memory. Based on the flight phase detected by the flight phase determiner **902**, the boundary layer system activator **904** activates and/or deactivates the drag modification systems **102**, **600** and/or **700**.

(71) The motive fluid determiner **906** determines if a primary motive fluid and/or a supplemental motive fluid is available for use by the drag modification system **102**, **600**, **700**. For example, the motive fluid determiner **906** receives one or more outputs from the first sensor **434** to determine, measure and/or otherwise detect one or more fluid parameter(s) or characteristic(s) of the primary motive fluid. For example, the motive fluid determiner **906** determines if the primary motive fluid (e.g., the motive fluid **402**, the first motive fluid **604**) has sufficient fluid flow characteristic(s) (e.g., pressure, velocity, mass flow rate, etc.) to generate suction at the second inlet **210**.

(72) The motive fluid determiner **906** determines if a supplemental or second motive fluid (e.g., the second motive fluid **608**) is available at the third inlet **602**. For example, the motive fluid determiner **906** can retrieve and/or receive from memory, via user input instructions, and/or preinstalled instructions or information relating to the availability of the supplemental motive fluid system. For example, the system controller **222** can be pre-configured with information indicative an availability of a supplemental motive fluid system.

(73) When the supplemental motive fluid system is not available, the motive fluid determiner **906** can command the main controller **912** to provide a primary motive fluid from one or more pressurized fluid sources **120** of the aircraft **100**. For example, the first inlet **208** can receive primary motive fluid from the cabin air system **122**. If the motive fluid determiner **906** determines that the primary motive fluid from the cabin air system **122** is not sufficient, the motive fluid determiner **906** commands a primary motive fluid from a different one of the pressurized fluid sources **120** (e.g., the cabin trim air) that is fluidly coupled to the first inlet **208**.

(74) When a supplemental motive fluid is available, the motive fluid determiner **906** receives one or more outputs from the second sensor **616** to determine, measure and/or otherwise detect one or more fluid parameter(s) or characteristic(s) of the supplemental motive fluid. The motive fluid determiner determines whether to employ the primary motive fluid, a supplemental motive fluid, or a combination of the primary and supplemental motive fluids.

(75) The valve operator **908** of the illustrated example instructs, commands and/or otherwise causes operation of the first control valve **432**, the second control valve **614**, and/or the third control valve **706**. For example, the valve operator **908** receives one or more instructions from the boundary layer system activator **904** and/or the motive fluid determiner **906** to operate the one or more of the first control valve **432**, the second control valve **614**, and/or the third control valve **706**. For example, the valve operator **908** sends a first signal (e.g., a binary value or logic “O” value) to the one or more of the first control valve **432**, the second control valve **614**, and/or the third control valve **706** to move the one or more of the first control valve **432**, the second control valve **614**, and/or the third control valve **706** to move the one or more of the first control valve **432**, the second control valve **614**, and/or the third control valve **706** to respective closed positions, and sends a second signal (e.g., a binary value or logic “1” value) different than the first signal to the one or more of the first control valve **432**, the second control valve **614**, and/or the third control valve **706** to move the one or more of the first control valve **432**, the second control valve **614**, and/or the third control valve **706** to respective open positions.

(76) While an example manner of implementing the drag modification system controller of FIGS. **1**, **2**A, **2**B, **3**, **4**, **5**A, **6**, **7**A and **7**B is illustrated in FIG. **9**, one or more of the elements, processes and/or devices illustrated in FIG. **9** may be combined, divided, re-arranged, omitted, eliminated and/or implemented in any other way. Further, the example flight phase determiner **902**, the example boundary layer system activator **904**, the example motive fluid determiner **906**, and the example valve operator **908** and/or, more generally, the example system controller **222** of FIGS. **1**,

2A, **2**B, **3**, **4**, **5**A, **6**, **7**A and **7**B may be implemented by hardware, software, firmware and/or any combination of hardware, software and/or firmware. Thus, for example, any of the example the example flight phase determiner **902**, the example boundary layer system activator **904**, the example motive fluid determiner **906**, and the example valve operator **908** and/or, more generally, the example system controller **222** could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), programmable controller(s), graphics processing unit(s) (GPU(s)), digital signal processor(s) (DSP(s)), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)) and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example flight phase determiner **902**, the example boundary layer system activator **904**, the example motive fluid determiner **906**, and the example valve operator **908** and/or, more generally, the example system controller **222** is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc. including the software and/or firmware. Further still, the example system controller **222** of FIGS. **1**, **2**A, **2**B, **3**, **4**, **5**A, **6**, **7**A and **7**B may include one or more elements, processes and/or devices in addition to, or instead of, those illustrated in FIG. **9**, and/or may include more than one of any or all of the illustrated elements, processes and devices. As used herein, the phrase "in communication," including variations thereof, encompasses direct communication and/or indirect communication through one or more intermediary components, and does not require direct physical (e.g., wired) communication and/or constant communication, but rather additionally includes selective communication at periodic intervals, scheduled intervals, aperiodic intervals, and/or one-time events.

(77) Flowcharts representative of example hardware logic, machine readable instructions, hardware implemented state machines, and/or any combination thereof for implementing the system controller **222** of FIGS. **1**, **2**A, **2**B, **3**, **4**, **5**A, **6**, **7**A and **7**B are shown in FIGS. **10-12**. The machine readable instructions may be one or more executable programs or portion(s) of an executable program for execution by a computer processor such as the processor **1312** shown in the example processor platform **1300** discussed below in connection with FIG. **13**. The program may be embodied in software stored on a non-transitory computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a DVD, a Blu-ray disk, or a memory associated with the processor **1312**, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor **1312** and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowcharts illustrated in FIGS. **10-12**, many other methods of implementing the example system controller **222** may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined. Additionally or alternatively, any or all of the blocks may be implemented by one or more hardware circuits (e.g., discrete and/or integrated analog and/or digital circuitry, an FPGA, an ASIC, a comparator, an operational-amplifier (op-amp), a logic circuit, etc.) structured to perform the corresponding operation without executing software or firmware.

(78) The machine readable instructions described herein may be stored in one or more of a compressed format, an encrypted format, a fragmented format, a compiled format, an executable format, a packaged format, etc. Machine readable instructions as described herein may be stored as data (e.g., portions of instructions, code, representations of code, etc.) that may be utilized to create, manufacture, and/or produce machine executable instructions. For example, the machine readable instructions may be fragmented and stored on one or more storage devices and/or computing devices (e.g., servers). The machine readable instructions may require one or more of installation, modification, adaptation, updating, combining, supplementing, configuring, decryption, decompression, unpacking, distribution, reassignment, compilation, etc. in order to

make them directly readable, interpretable, and/or executable by a computing device and/or other machine. For example, the machine readable instructions may be stored in multiple parts, which are individually compressed, encrypted, and stored on separate computing devices, wherein the parts when decrypted, decompressed, and combined form a set of executable instructions that implement a program such as that described herein.

(79) In another example, the machine readable instructions may be stored in a state in which they may be read by a computer, but require addition of a library (e.g., a dynamic link library (DLL)), a software development kit (SDK), an application programming interface (API), etc. in order to execute the instructions on a particular computing device or other device. In another example, the machine readable instructions may need to be configured (e.g., settings stored, data input, network addresses recorded, etc.) before the machine readable instructions and/or the corresponding program(s) can be executed in whole or in part. Thus, the disclosed machine readable instructions and/or corresponding program(s) are intended to encompass such machine readable instructions and/or program(s) regardless of the particular format or state of the machine readable instructions and/or program(s) when stored or otherwise at rest or in transit.

(80) The machine readable instructions described herein can be represented by any past, present, or future instruction language, scripting language, programming language, etc. For example, the machine readable instructions may be represented using any of the following languages: C, C++, Java, C#, Perl, Python, JavaScript, HyperText Markup Language (HTML), Structured Query Language (SQL), Swift, etc.

(81) As mentioned above, the example processes of FIGS. **10-12** may be implemented using executable instructions (e.g., computer and/or machine readable instructions) stored on a non-transitory computer and/or machine readable medium such as a hard disk drive, a flash memory, a read-only memory, a compact disk, a digital versatile disk, a cache, a random-access memory and/or any other storage device or storage disk in which information is stored for any duration (e.g., for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media.

(82) “Including” and “comprising” (and all forms and tenses thereof) are used herein to be open ended terms. Thus, whenever a claim employs any form of “include” or “comprise” (e.g., comprises, includes, comprising, including, having, etc.) as a preamble or within a claim recitation of any kind, it is to be understood that additional elements, terms, etc. may be present without falling outside the scope of the corresponding claim or recitation. As used herein, when the phrase “at least” is used as the transition term in, for example, a preamble of a claim, it is open-ended in the same manner as the term “comprising” and “including” are open ended. The term “and/or” when used, for example, in a form such as A, B, and/or C refers to any combination or subset of A, B, C such as (1) A alone, (2) B alone, (3) C alone, (4) A with B, (5) A with C, (6) B with C, and (7) A with B and with C. As used herein in the context of describing structures, components, items, objects and/or things, the phrase “at least one of A and B” is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing structures, components, items, objects and/or things, the phrase “at least one of A or B” is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. As used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase “at least one of A and B” is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase “at least one of A or B” is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at

least one B.
(83) As used herein, singular references (e.g., “a”, “an”, “first”, “second”, etc.) do not exclude a plurality. The term “a” or “an” entity, as used herein, refers to one or more of that entity. The terms “a” (or “an”), “one or more”, and “at least one” can be used interchangeably herein. Furthermore, although individually listed, a plurality of means, elements or method actions may be implemented by, e.g., a single unit or processor. Additionally, although individual features may be included in different examples or claims, these may possibly be combined, and the inclusion in different examples or claims does not imply that a combination of features is not feasible and/or advantageous.
(84) The method **1000** of FIG. **10** is an example method for implementing the drag modification system **102** of FIGS. **1**, **2**A, **2**B, **3**, **4**, and **5**A. The method **1000** begins with the system controller **222** receiving flight phase data (block **1002**). For example, the flight phase determiner **902** receives flight phase data from the main controller **912**. Based on the flight phase data received, the system controller **222** determines whether to activate the drag modification system **102** (block **1004**). For example, the system controller **222** activates the drag modification system **102** during certain phases of flight. For instance, the boundary layer system activator **904** activates the drag modification system **102** when the flight phase determiner **902** determines that the aircraft is in a cruise phase of flight and deactivates the drag modification system **102** when the flight phase determiner **902** determines that the aircraft is in a taxiing, a descent, a landing, a take-off, or a climb phase of flight.
(85) If the system controller **222** at block **1004** determines that the drag modification system **102** should not be activated, the system controller **222** causes a motive fluid valve (e.g., the first control valve **432**) to move to a closed position (block **1006**). For example, to deactivate the drag modification system **102**, the boundary layer system activator **904** instructs, commands and/or otherwise causes the valve operator **908** to move the first control valve **432** to a closed position.
(86) If the system controller **222** at block **1004** determines that the drag modification system **102** should be activated to reduce drag, the system controller **222** causes the motive fluid valve (e.g., the first control valve **432**) to move to an open position (block **1008**). For example, to activate the drag modification system **102**, the boundary layer system activator **904** instructs, commands and/or otherwise causes the valve operator **908** to move the first control valve **432** to an open position.
(87) The system controller **222** determines if the drag modification system **102** should persist (block **1010**). For example, the system controller **222** can continue to persist the drag modification system **102** until the system controller **222** determines that the aircraft **100** is taxiing, parked or idle via the flight phase determiner **902**. If the system controller **222** determines at block **1010** that drag modification of the boundary layer is to continue (e.g., the drag modification system **102** should persist), control returns to block **1002**. If the system controller **222** determines at block **1010** that the drag modification of the boundary layer should not continue, the method **1000** ends.
(88) The method **1100** of FIG. **11** is an example method for implementing the drag modification system **600** of FIG. **6**. The method **1100** begins with the system controller **222** receiving flight phase data (block **1102**). For example, the flight phase determiner **902** receives flight phase data from the main controller **912**. Based on the flight phase data received, the system controller **222** determines whether to activate the drag modification system **600** (block **1104**). For example, the system controller **222** activates the drag modification system **600** during certain phases of flight. For instance, the boundary layer system activator **904** activates the drag modification system **102** during a cruise phase of flight and deactivates the drag modification system **600** during taxiing, descent, landing, take-off, and climb phases of flight.
(89) If the system controller **222** at block **1104** determines that the drag modification system **600** should be activated, the system controller **222** causes a motive fluid valve (e.g., the first control valve **432**) to move to an open position (block **1106**). For example, to activate the drag modification system **600**, the boundary layer system activator **904** instructs, commands and/or

otherwise causes the valve operator **908** to move the first control valve **432** to a first or open position to allow the first motive fluid **604** to flow to the nozzle inlet **416**.

(90) The system controller **222** then receives first motive fluid parameter(s) (block **1108**). For example, the system controller **222** and/or the motive fluid determiner **906** receives outputs or signals representative of one or more fluid parameter(s) of the first motive fluid from the first sensor **434**.

(91) The motive fluid determiner **906** determines if the fluid parameter(s) of the first motive fluid **604** exceed a threshold (block **1110**). For example, the system controller **222** and/or the motive fluid determiner **906** determines whether a pressure, a velocity, a mass flow rate, and/or any other parameter(s) are sufficient to enable the first motive fluid **604** to generate a suction at the suction inlet **420**. For example, the system controller **222** and/or motive fluid determiner **906** can compare the one or more fluid parameter(s) to one or more corresponding threshold values retrieved from a look-up table from a memory of the system controller **222** and/or the main controller **912**.

(92) If the system controller **222** at block **1110** determines that the first motive fluid parameter(s) exceeds the threshold, the system controller **222** causes a supplemental motive fluid valve (e.g., the second control valve **614**) to move to a closed position (block **1112**). For example, the valve operator **908** causes the second control valve **614** to move to a closed position. In the closed position, the second control valve **614** prevents the second motive fluid **608** from flowing to the nozzle inlet **416**.

(93) If the system controller **222** at block **1110** determines that the first motive fluid parameter(s) does not exceed the threshold, the system controller **222** causes the supplemental motive fluid valve (e.g., the second control valve **614**) to move to an open position (block **1114**). For example, the valve operator **908** causes the second control valve **614** to move to an open position. In the open position, the second control valve **614** allows the second motive fluid **608** to flow to the nozzle inlet **416**.

(94) The system controller **222** then receives second motive fluid parameter(s) (block **1116**). For example, the system controller **222** and/or the motive fluid determiner **906** receives outputs or signals representative of one or more fluid parameter(s) of the second motive fluid **608** from the second sensor **616**.

(95) The motive fluid determiner **906** determines if the fluid parameter(s) of the second motive fluid **608** exceeds a threshold (block **1118**). For example, the system controller **222** and/or the motive fluid determiner **906** determine whether a pressure, a velocity, a mass flow rate, and/or any other parameter(s) of the second motive fluid **608** is sufficient to enable the second motive fluid **608** (e.g., without use of the first motive fluid **604**) to generate a suction at the suction inlet **420**. For example, the system controller **222** and/or motive fluid determiner **906** can compare the one or more fluid parameter(s) to one or more corresponding threshold values retrieved from a look-up table from a memory of the system controller **222** and/or the main controller **912**.

(96) If the system controller **222** at block **1118** determines that the second motive fluid parameter(s) exceeds the threshold, the system controller **222** causes the first motive fluid valve (e.g., the first control valve **432**) to move to a closed position (block **1120**). For example, the valve operator **908** causes the first control valve **432** to move to an open position. In the closed position, the first control valve **432** prevents the first motive fluid **604** from flowing to the nozzle inlet **416**. In such an example, the second motive fluid **608** generates suction at the suction inlet **420** without using the first motive fluid **604**.

(97) If the system controller **222** at block **1118** determines that the second motive fluid parameter(s) does not exceed the threshold, the system controller **222** causes the first motive fluid valve (e.g., the first control valve **432**) to move to an open position (block **1122**). In the open position, the first control valve **432** allows the first motive fluid **604** to flow to the nozzle inlet **416**. In this example, the first motive fluid **604** and the second motive fluid **608** work together and/or mix together through the nozzle **408** to generate suction at the suction inlet **420**.

(98) If the system controller **222** at block **1104** determines that the drag modification system **102** should not be activated, the system controller **222** causes a first motive fluid valve (e.g., the first control valve **432**) to move to a closed position (block **1124**) and the second motive fluid valve (e.g., the second control valve **614**) to move to a closed position (block **1126**). For example, to deactivate the drag modification system **600**, the boundary layer system activator **904** instructs, commands and/or otherwise causes the valve operator **908** to move the first control valve **432** to a closed position and the second control valve **614** to a closed position to prevent flow of the first motive fluid **604** and the second motive fluid **608** to the nozzle inlet **416**.
(99) The system controller **222** determines if the drag modification system **102** should persist (block **1128**). For example, the system controller **222** can continue to persist the drag modification system **600** until the system controller **222** determines that the aircraft **100** is taxiing, parked or idle via the flight phase determiner **902**. If the system controller **222** determines at block **1128** that drag modification of the boundary layer is to continue (e.g., the drag modification system **600** should persist), control returns to block **1102**. If the system controller **222** determines that the drag modification of the boundary layer should not continue (block **1128**), the method **1100** ends.
(100) The method **1200** of FIG. **12** is an example method for implementing the drag modification system **700** of FIGS. **7**A and **7**B. The method **1200** begins with the system controller **222** receiving flight phase data (block **1202**). For example, the flight phase determiner **902** receives flight phase data from the main controller **912**. Based on the flight phase data received, the system controller **222** determines whether to activate the drag modification system **700** (block **1204**). For example, the system controller **222** activates the drag modification system **700** during certain phases of flight. For instance, the boundary layer system activator **904** activates the drag modification system **700** during cruise, descent and/or landing phases of flight and deactivates the drag modification system **700** during taxiing, take-off, and climb phases of flight. For example, as noted above, the drag modification system **700** provides dual functionality for reducing drag and increasing drag.
(101) If the system controller **222** determines at block **1204** to activate the drag modification system **700**, the system controller **222** determines if drag should be decreased (block **1206**). For example, the boundary layer system activator **904** determines to decrease drag when the flight phase determiner **902** determines that the aircraft **100** is in a cruise phase of flight. Thus, the system controller **222** activates the first mode of operation **702** (FIG. **7**A) of the drag modification system **700** to decrease and/or reduce drag.
(102) If the system controller **222** at block **1206** determines to decrease drag, the system controller **222** causes the first motive fluid valve (e.g., the first control valve **432**) to move to an open position (block **1208**) and the causes the exit valve (e.g., the third control valve **706**) to move to an open position (block **1210**). For example, to activate the first mode of operation **702** of the drag modification system **700** and decrease drag, the valve operator **908** instructs, commands and/or otherwise causes the first control valve **432** to move to an open position to allow the first motive fluid **604** to flow to the nozzle inlet **416** and the third control valve **706** to move to the open position to allow the mixed fluid **436** to exhaust via the outlet **212** and create a suction at the suction inlet **420**.
(103) Furthermore, the system controller **222** determines if the drag modification system **700** includes an active supplemental motive fluid system (e.g., the supplemental motive fluid system **601**) (block **1212**). For example, the motive fluid determiner **906** detects whether a supplemental motive fluid system **601** and/or a secondary motive fluid valve (e.g., the second control valve **614**) is active, available for control, and/or otherwise communicatively coupled to the system controller **222**. If the system controller **222** determines at block **1212** that the supplemental motive fluid system **601** is not active, the process moves to block **123**
(104) If the system controller **222** determines at block **1212** that the supplemental motive fluid system **601** is active, the system controller **222** receives the motive fluid parameters from the first sensor **434** (block **1214**). For example, the system controller **222** receives output signals from the

first sensor **434** to determine and/or detect a pressure, a velocity and/or other parameter of the first motive fluid **604**.

(105) The system controller **2222** then determines whether to add supplemental motive fluid (e.g., the second motive fluid **608**) based on the received first motive fluid parameters (block **1216**). If the system controller **222** determines at block **1216** that a supplemental motive fluid is not needed, the system controller **222** commands, instructs and/or otherwise causes the secondary motive fluid valve (e.g., the second control valve **614**) to move to a closed position to prevent the second motive fluid **608** from flowing to the nozzle inlet **416** (block **1218**), and the program returns to block **1236**. If the system controller **222** determines at block **1216** that a supplemental motive fluid is needed, the system controller **222** commands, instructs and/or otherwise causes the secondary motive fluid valve (e.g., the second control valve **614**) to move to an open position to enable the supplemental motive fluid (e.g., the second motive fluid **608**) to flow to the nozzle inlet **416** (block **1220**), and the program returns to block **1236**. Alternatively, if the drag modification system **700** does not include the supplemental motive fluid system **601**, then blocks **1212-1220** can be omitted from the method **1200** or ignored by the system controller **222**. The method **1200** would then return to block **1236** from block **1210** and/or **1212**.

(106) Referring back to block **1206**, if the system controller **222** determines at block **1206** that drag should not be decreased, the system controller **222** determines whether drag should be increased or induced (block **1222**). For example, the boundary layer system activator **904** determines to increase drag when the flight phase determiner **902** detects that the aircraft **100** is in a descent phase of flight and/or a landing phase of flight. Thus, the system controller **222** activates the second mode of operation **704** (FIG. 7B) of the drag modification system **700** to increase drag.

(107) If the system controller **222** at block **1206** determines to increase drag, the system controller **222** causes the first motive fluid valve (e.g., the first motive fluid **604**) to move to an open position (block **1224**) and the causes the exit valve (e.g., the third control valve **706**) to move to a closed position (block **1226**). For example, to activate the second mode of operation **704** of the drag modification system **700** and decrease drag as shown in FIG. 7B, the valve operator **908** instructs, commands and/or otherwise causes the first control valve **432** to move to an open position to allow the first motive fluid **604** to flow to the nozzle inlet **416** and the third control valve **706** to move to the closed position to prevent the mixed fluid **436** from discharging from the outlet **212** and instead causing the first motive fluid **604** to discharge from the second inlet **210**.

(108) Furthermore, the system controller **222** returns to block **1212** to determine if the drag modification system **700** includes an active supplemental motive fluid system (e.g., the supplemental motive fluid system **601**) (block **1212**). If the system controller **222** determines at block **1212** that the supplemental motive fluid system is active, the system controller **222** receives the motive fluid parameters from the first sensor **434** (block **1214**). For example, the system controller **222** receives output signals from the first sensor **434** to determine and/or detect a pressure, a velocity and/or other parameter of the first motive fluid **604**. The system controller **222** then determines whether to add supplemental motive fluid (e.g., the second motive fluid **608**) based on the received first motive fluid parameters (block **1216**). If the system controller **222** determines that a supplemental motive fluid is not needed, the system controller **222** commands, instructs and/or otherwise causes the secondary motive fluid valve (e.g., the second control valve **614**) to move to a closed position to prevent supplemental motive fluid from flowing to the nozzle inlet **416** (block **1218**), and the program returns to block **1236**. If the system controller **222** determines that a supplemental motive fluid is needed, the system controller **222** commands, instructs and/or otherwise causes the secondary motive fluid valve (e.g., the second control valve **614**) to move to an open position to enable the supplemental motive fluid (e.g., the second motive fluid **608**) to flow to the nozzle inlet **416** (block **1220**), and the program returns to block **1236**.

(109) Referring to block **1204**, if the system controller **222** at block **1204** determines that the drag modification system **700** should not be activated, the system controller **222** deactivates the drag

modification system **700**. To deactivate the drag modification system **700**, the system controller **222** instructs, commands and/or otherwise causes the first motive fluid valve to move to a closed position (block **1228**). In this example, the system controller **222** also causes the exit valve (e.g., the third control valve **706**) to move to an open position (block **1230**). In some examples, at block **1230**, the system controller **222** can alternatively command the exit valve to move to a closed position. Additionally, if the drag modification system **700** includes the supplemental motive fluid system, the system controller **222** causes the secondary motive fluid valve (e.g., the second control valve **614**) to move to a closed position (block **1234**). If the drag modification system **700** does not include the supplemental motive fluid system, then block **1232** or block **1234** can be omitted or ignored by the system controller **222** and the method proceeds to block **1236**.
(110) The system controller **222** determines if the drag modification system **700** should persist (block **1236**). For example, the system controller **222** can continue to persist the drag modification system **700** until the system controller **222** determines that the aircraft **100** is taxiing, parked or idle via the flight phase determiner **902**. If the system controller **222** determines at block **1236** that drag modification of the boundary layer is to continue (e.g., the drag modification system **700** should persist), control returns to block **1202**. If the system controller **222** determines that the drag modification of the boundary layer should not continue (block **1236**), the method **1200** ends.
(111) FIG. **13** is a block diagram of an example processor platform **1300** structured to execute the instructions of FIGS. **10-12** to implement the system controller **222** of FIG. **9**. The processor platform **1300** can be, for example, a server, a personal computer, a workstation, a self-learning machine (e.g., a neural network), or any other type of computing device.
(112) The processor platform **1300** of the illustrated example includes a processor **1312**. The processor **1312** of the illustrated example is hardware. For example, the processor **1312** can be implemented by one or more integrated circuits, logic circuits, microprocessors, GPUs, DSPs, or controllers from any desired family or manufacturer. The hardware processor may be a semiconductor based (e.g., silicon based) device. In this example, the processor implements the flight phase determiner **902**, the boundary layer system activator **904**, the motive fluid determiner **906**, and the valve operator **908**.
(113) The processor **1312** of the illustrated example includes a local memory **1313** (e.g., a cache). The processor **1312** of the illustrated example is in communication with a main memory including a volatile memory **1314** and a non-volatile memory **1316** via a bus **1318**. The volatile memory **1314** may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS® Dynamic Random Access Memory (RDRAM®) and/or any other type of random access memory device. The non-volatile memory **1316** may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory **1314**, **1316** is controlled by a memory controller.
(114) The processor platform **1300** of the illustrated example also includes an interface circuit **1320**. The interface circuit **1320** may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), a Bluetooth® interface, a near field communication (NFC) interface, and/or a PCI express interface.
(115) In the illustrated example, one or more input devices **1322** are connected to the interface circuit **1320**. The input device(s) **1322** permit(s) a user to enter data and/or commands into the processor **1312**. The input device(s) can be implemented by, for example, an audio sensor, a microphone, a keyboard, a button, a touchscreen, and/or a voice recognition system.
(116) One or more output devices **1324** are also connected to the interface circuit **1320** of the illustrated example. The output devices **1324** can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display (LCD), a cathode ray tube display (CRT), an in-place switching (IPS) display, a touchscreen, etc.), a tactile output device, and/or speaker. The interface circuit **1320** of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip and/or a graphics driver processor.

(117) The interface circuit **1320** of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem, a residential gateway, a wireless access point, and/or a network interface to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network **1326**. The communication can be via, for example, an Ethernet connection, a digital subscriber line (DSL) connection, a telephone line connection, a coaxial cable system, a satellite system, a line-of-site wireless system, a cellular telephone system, etc.
(118) The processor platform **1300** of the illustrated example also includes one or more mass storage devices **1328** for storing software and/or data Examples of such mass storage devices **1328** include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, redundant array of independent disks (RAID) systems, and digital versatile disk (DVD) drives.
(119) The machine executable instructions **1332** of FIGS. **10-12** may be stored in the mass storage device **1328**, in the volatile memory **1314**, in the non-volatile memory **1316**, and/or on a removable non-transitory computer readable storage medium such as a CD or DVD.
(120) Although certain example methods, apparatus and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.
(121) The following claims are hereby incorporated into this Detailed Description by this reference, with each claim standing on its own as a separate embodiment of the present disclosure.
(122) The following paragraphs provide various examples of the examples disclosed herein.
(123) Example 1 includes a system for modifying drag on an aircraft including a boundary layer intake plenum and an eductor. The eductor having a primary inlet to receive a primary fluid, a secondary inlet in fluid communication with the intake plenum to receive a secondary fluid entrained from the intake plenum, and an outlet to exhaust a mixed flow including the primary fluid and the secondary fluid. The primary fluid is a motive fluid having flow parameters to generate a suction at the secondary inlet.
(124) Example 2 includes the system of Example 1, wherein the boundary layer intake plenum is to be flush mounted relative to exterior surface of a fuselage of an aircraft.
(125) Example 3 includes the system of any of Examples 1-2, wherein the intake plenum is to be positioned downstream from a wing of the aircraft and upstream from an empennage of the aircraft.
(126) Example 4 includes the system of any of Examples 1-3, wherein the intake plenum includes a plurality of openings to allow intake of the boundary layer to the secondary inlet during flight.
(127) Example 5 includes the system of any of Examples 1-4, wherein the outlet is to fluidly couple with a wake of the aircraft.
(128) Example 6 includes the system of any of Examples 1-5, wherein the primary inlet is to receive pressurized air.
(129) Example 7 includes the system of any of Examples 1-6, wherein the primary inlet is to receive pressurized air from an aircraft cabin.
(130) Example 8 includes the system of any of Examples 1-7, further including a fluid control valve to control cabin air flow into the primary inlet.
(131) Example 9 includes the system of any of Examples 1-8, further including a third inlet to receive a tertiary fluid, where the primary fluid is entrained from the primary inlet via a second eductor, wherein the tertiary fluid is pressurized air from the trim air system.
(132) Example 10 includes the system of any of Examples 1-9, further including further comprising an outlet valve in fluid communication with the outlet, wherein when the exit value is moved to a closed, the primary fluid is exhausted through the secondary inlet to increase drag.
(133) Example 11 includes the system of any of Examples 1-10, wherein the primary fluid is to have a pressure that is greater than a pressure of the secondary fluid.
(134) Example 12 includes the system of any of Examples 1-11, wherein the tertiary fluid is to

have a pressure that is greater than a pressure of the primary fluid.
(135) Example 13 includes a system to modify drag of an aircraft including a manifold defining a passageway to extend between an exterior of a fuselage of the aircraft to an exhaust of the aircraft. The passageway includes a first inlet in fluid communication with a motive fluid, a second inlet in fluid communication with the exterior of the fuselage, and an outlet in fluid communication with the exhaust. The motive fluid to generate a suction to cause airflow to draw through the second inlet and channel the airflow to the exhaust to reduce drag.
(136) Example 14 includes the system of Example 13, wherein the manifold includes a plenum in fluid communication with the first inlet.
(137) Example 15 includes the system of any of Examples 13-14, wherein the plenum includes a screen having perforations to allow boundary layer airflow within the plenum.
(138) Example 16 includes the system of any of Examples 13-15, wherein the screen has a contour that is complementary to a contour of an exterior of the fuselage.
(139) Example 17 includes the system of any of Examples 13-16, wherein the screen is flush mounted relative to an exterior surface of the fuselage.
(140) Example 18 includes the system of any of Examples 13-17, further comprising a third inlet, where the third inlet is in fluid communication with a second motive fluid that is higher energy than the first motive fluid.
(141) Example 19 includes the system of any of Examples 13-18, further comprising an exit valve in fluid communication with the outlet, where when the exit value is closed, instead of the motive fluid generate a suction to cause airflow to draw through the second inlet and channel the airflow to the exhaust, the primary fluid is exhausted through the second inlet; whereby instead of the drag being reduced, the drag is increased.
(142) Example 20 includes a method to reduce drag of an aircraft including providing a high energy airflow into an eductor; entraining air from an intake plenum into the high energy airflow via the eductor; receiving a boundary layer airflow into the intake plenum as a result of a negative pressure gradient effectuated by entrainment of air from the intake plenum into the eductor; and discharging the high energy airflow and the boundary layer airflow from the eductor.
(143) Example 21 includes the method of Example 20, wherein the discharging of the high energy airflow and the boundary layer airflow includes discharging the high energy airflow and the boundary layer airflow from the eductor into a wake of the aircraft to reduce drag during flight.
(144) Example 22 includes the system of any of Examples 20-21, wherein the providing of the high energy airflow includes controlling an overboard valve to cause cabin air to flow into the eductor.
(145) Example 23 includes a method to increase drag of an aircraft including providing a high energy airflow into an eductor; blocking an exit of the eductor such that the high energy airflow flows into an intake plenum; and discharging the high energy airflow into a boundary layer from the intake plenum as a result of a positive pressure gradient from the intake plenum into ambient air external of the aircraft.
(146) Example 24 includes the method of Example 23, wherein the providing of the high energy airflow.
(147) Although certain example methods, apparatus and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.

Claims

1. A system to modify drag on an aircraft, the system comprising: a boundary layer intake plenum mounted to an exterior surface of a fuselage of the aircraft; an eductor defining: a primary inlet to receive a primary fluid pressurized air from a cabin of the aircraft; a secondary inlet in fluid

communication with the intake plenum configured to receive a secondary fluid entrained from the intake plenum and generate a suction at the secondary inlet to ingest boundary layer air and modify a boundary layer of the aircraft by reducing the boundary layer such that the portion of the boundary layer ingested does not build up or locally spill into the wake of the aircraft to reduce drag during flight, the pressurized air from the cabin of the aircraft to provide the eductor a propulsive force; and an outlet to exhaust a mixed flow including the primary fluid and the secondary fluid.
2. The system of claim 1, wherein the intake plenum is to be positioned downstream from a wing of the aircraft and upstream from an empennage of the aircraft.
3. The system of claim 1, wherein the intake plenum includes a plurality of openings to allow intake of the boundary layer to the secondary inlet during flight.
4. The system of claim 1, wherein the outlet is to fluidly couple with a wake of the aircraft.
5. The system of claim 1, further including a fluid control valve to control cabin air flow into the primary inlet.
6. The system of claim 1, further comprising a third inlet to receive a tertiary fluid, wherein the tertiary fluid is pressurized air from a cabin trim air system.
7. The system of claim 6, wherein the primary fluid is to have a pressure that is greater than a pressure of the secondary fluid.
8. The system of claim 7, wherein the tertiary fluid is to have a pressure that is greater than the pressure of the primary fluid.
9. The system of claim 1, further including an outlet valve in fluid communication with the outlet, wherein the primary fluid exhausts through the secondary inlet to increase drag when the outlet valve is in a closed position.
10. A system to modify drag of an aircraft, the system including: a manifold defining a passageway to extend between an exterior of a fuselage of the aircraft and an exhaust of the aircraft, the passageway including: a first inlet in fluid communication with a first motive fluid, the first motive fluid including pressurized air from a cabin of the aircraft; a second inlet in fluid communication with the exterior of the fuselage, the second inlet flush mounted relative to the exterior of the fuselage at least a portion of the second inlet has a curvature complementary to a curvature of the exterior of the fuselage, the manifold configured to receive the first motive fluid and generate a suction at the second inlet to ingest a boundary layer airflow to reduce the boundary layer such that the portion of the boundary layer ingested does not build up or locally spill into the wake of the aircraft to increase at least one of a velocity or acceleration of the boundary layer airflow during flight to reduce drag; and an outlet in fluid communication with the exhaust.
11. The system of claim 10, wherein the manifold includes a plenum in fluid communication with the second inlet.
12. The system of claim 11, wherein the plenum includes a plurality of openings to allow boundary layer airflow within the plenum.
13. The system of claim 12, wherein the plurality of openings has a contour that is complementary to a contour of the exterior of the fuselage.
14. The system of claim 10, further including a third inlet, where the third inlet is in fluid communication with a second motive fluid having a higher energy than the first motive fluid.
15. The system of claim 10, further including an outlet valve in fluid communication with the outlet, wherein when the outlet valve is closed, the first motive fluid is exhausted through the second inlet to increase drag instead of reducing drag.
16. The system of claim 1, wherein the intake plenum includes an intake frame, the intake frame having a rectangular shape and a curvature complementary to the exterior surface of the fuselage.
17. The system of claim 1, wherein the intake plenum defines an opening have a rectangular shape.
18. The system of claim 3, wherein the plurality of openings is a perforated plate.
19. The system of claim 1, wherein the boundary layer intake plenum is flush mounted relative to

the exterior surface of the fuselage.
20. The system of claim 1, wherein the eductor is structured to accelerate the boundary layer to a velocity that equals or exceeds a free stream velocity of the boundary layer during flight.
21. The system of claim 1, wherein the suction to be generated by the eductor modifies a velocity of the boundary layer that equals or exceeds a free stream velocity of the boundary layer.