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Research Article

Modeling of a Complex Digital Air Data System for Measuring Attitude and Flight Direction of Aircraft

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Abstract

The process of measuring attitude, yaw and drift signals of aircraft using aerometric methods becomes especially important during intercontinental flights, when GNSS is inoperative, GNSS denial during intercontinental flights limits attitude and drift measurement. To determine the values of the aircraft's pitch, roll, yaw angles, by the aerometric system the new method and modified smart probe should be used and a new method using a smart probe within a digital air data system (CDADS) is proposed. Theoretical foundations for the operation of a comprehensive complex digital air data systems are presented and a computer model for determining flight and navigation parameters is compiled, a comparison of the results of modeling the complex digital air data systems computer model and literature data was obtained, a mathematical model and computer simulations are developed obtaining information on flight and navigation signals, including additional parameters such as roll, pitch, yaw, lateral speed, wind velocity, drift angle are compiled, and a computer model simulation is performed.

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1. Introduction

The importance of avionics systems in aviation cannot be overstated. They are critical to the efficiency and safety of flight (Oxford Aviation, 2001).

The Air Data Inertial Reference Unit (ADIRU) is one of the most important systems in modern aircraft. Critical flight parameters such as the aircraft's attitude (roll, pitch, and yaw), airspeed, altitude, and even its orientation in space are measured by this system (Lerro & Battipede, 2021). The ADIRU helps maintain flight stability by collecting and analysing data from multiple sensors, including gyroscopes and accelerometers, especially in challenging situations such as poor visibility or turbulence. Without such reliable systems, flight safety risks would increase significantly (Airbus S.A.S., 2003).

The ADIRU installed in the Airbus A-340 aircraft is part of a complex system composed of air data blocks (Air Data Reference) and inertial parameter blocks (IR) (Fig. 1).

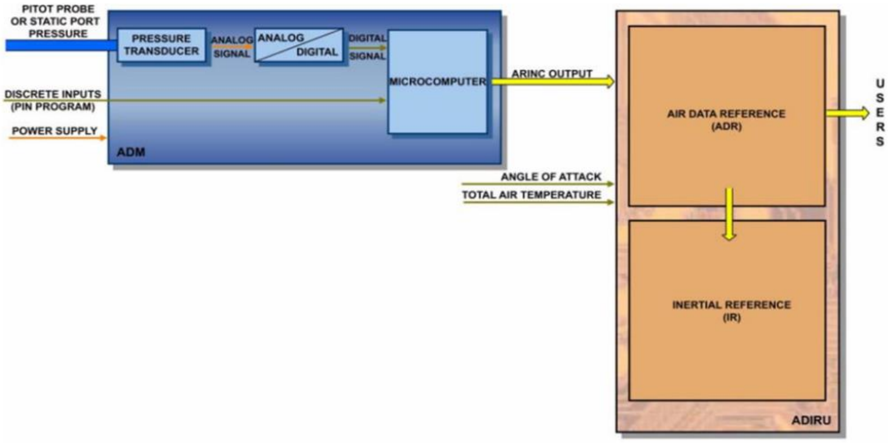

Fig. 1. Airbus A-340 ADIRU

This allows for automatic adjustment of the combined parameters of the Air Data System (ADS) and inertial systems (IS). The integrated system contains three computers (ADR1, ADR2, ADR3), each connected to an Air Data Module (ADM), which measures total and static pressure. These ADM converters, which are connected to pressure transducers, essentially convert non-electrical quantities into digital signals. Computers ADR1 and ADR2 calculate the average pressure values from sensors located on the left and right sides of the Airbus A-340 fuselage (Airbus S.A.S., 2003).

Using signals from backup pressure sensors, computer ADR3 computes the altitude-speed parameters of the aircraft. The ADR1, ADR2, and ADR3 computers also receive signals from angle-of-attack sensors (AOA1, AOA2, and AOA3 sensors) and from external air temperature sensors (Capt. TAT sensor and F/O TAT sensor). Additionally, backup total and static pressure sensors (STBY pitot probe and STBY static port) are connected to the inputs of the Integrated Standby Instrument System (ISIS) (Fig. 2).

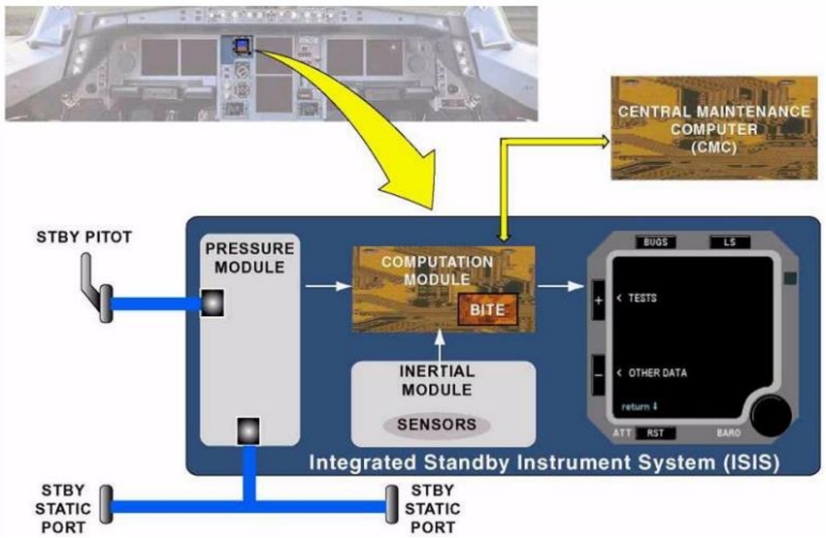

Fig. 2. A-340 Intergrated Standby Instrument system (A340 manual)

In the ISIS, the total and static pressures are converted into encoded digital electrical signals, which are then compared with digital signals from the inertial module.

A similar integrated system of air parameters and inertial navigation parameters is used in the Boeing 747-8 (The Boeing Company, 2015). The ADIRU system installed on these aircraft is made by the company Honeywell. However, the ADS instruments on the Boeing 747-8 differ from those of the Airbus A-340 in that the Boeing 747-8 additionally installs two static pressure ports with tubes in the tail section of the fuselage. These are intended to connect to the altitude control computer.

The non-integrated ADS of the Boeing 787 (Air Data Reference System - ADRS) differs in that total and static pressure information is sent through the CENTER PITOT PROBE, LEFT PITOT PROBE, and RIGHT PITOT PROBE to the Air Data Module (ADM), where it is converted into digital signals through analogue-to-digital converters (The Boeing Company, 2010). These signals, together with analogue signals from the angle-of-attack sensors installed on the left and right sides of the fuselage, are sent to the flight control module (FCM3). Digital signals from static pressure sensors connected to the STATIC PORT are also sent to the inputs of the ADM modules (Fig. 3).

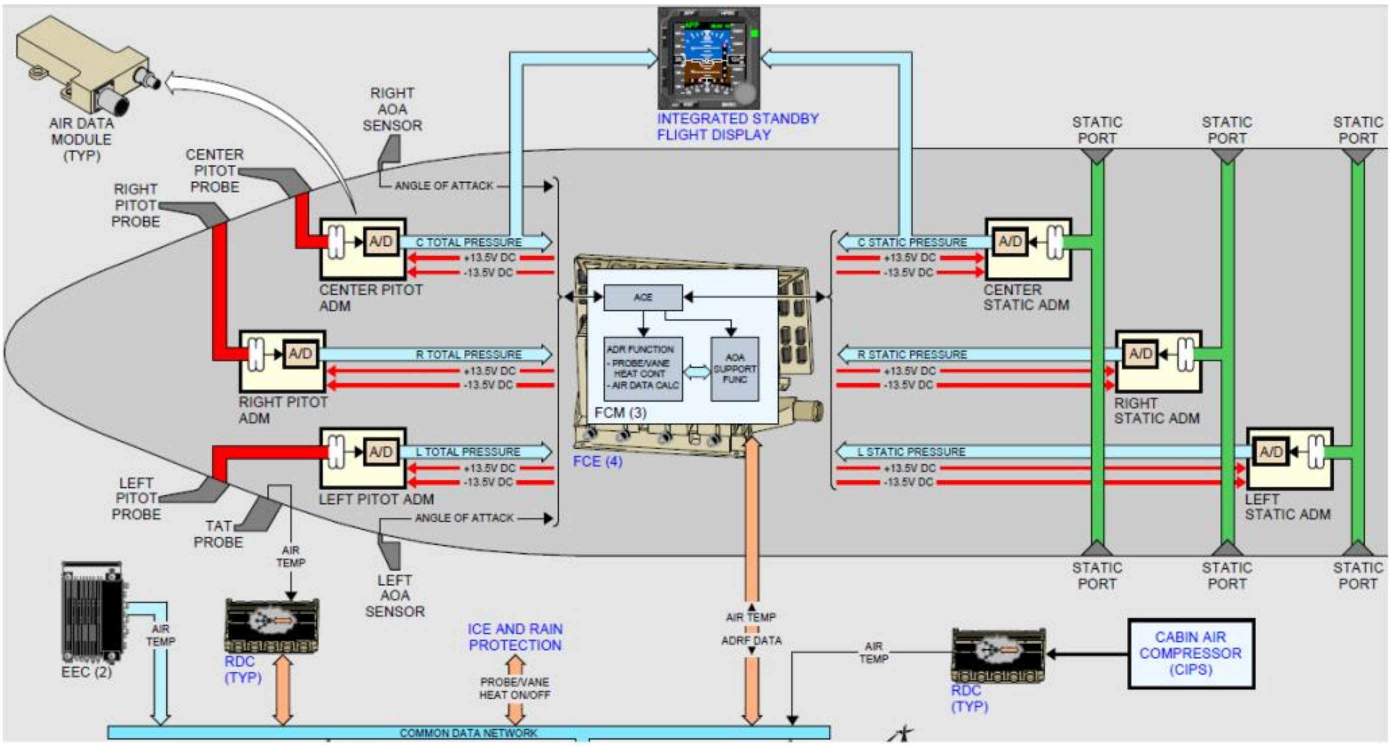

Fig. 3. Boeing 787 Air data Reference System (ADRS)

The Air Data Smart Systems (ADSS) installed on the Embraer ERJ-170/190 aircraft consists of four Air Data Smart Probe (ADS1-ADS4) and two external air temperature sensors (TAT1, TAT2), as well as a control panel (Embraer, 2011; SmartProbe, 2017). The ADS probes are multifunctional, handling channels for total, static, and differential pressures. For vaneless angle-of-attack measurement, the differential pressure channel is used. The signals from the pressure frequency converters and ADC are connected to the Air Data Computers (ADC), forming a unified ADS system and providing additional information to the aircraft's flight control and anti-stall systems.

The ADC computer system includes a Modular Avionics Unit (MAU). Digital signals from the total, static, and differential pressures, as well as the external air temperature sensors, are sent directly to the Air Data Application (ADA) processor, which is part of this module. The system automatically adjusts current flight altitude and speed values. ADS1 serves as the primary source of information for the first pilot's flight-navigation instruments and flight control system, ADS2 for the second pilot's instruments, and ADS3 for backup instruments and the flight control system. Additionally, a fourth information source, ADS FC (Air Data Systems of Flight Control), supplies the flight control system with current air data signals. All information received from the probe, as well as data processed by the system, is displayed on the primary flight displays (PFD) and the Integrated Electronic Standby Instrument System (IES) (Miftakhov et al., 2023).

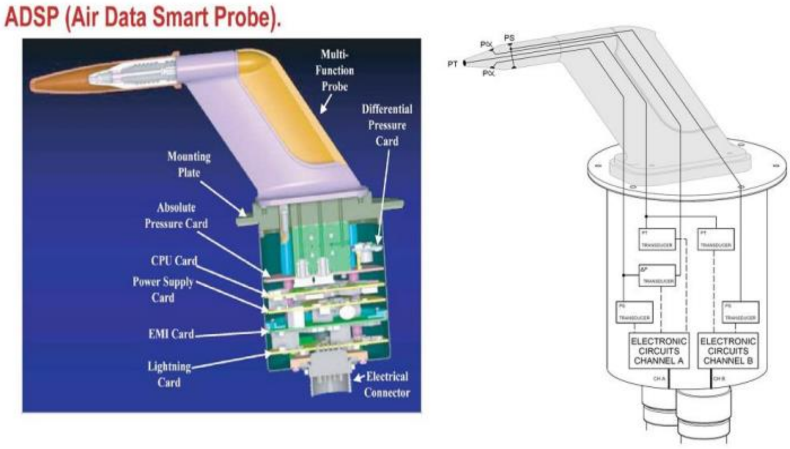

Fig. 4. Air Data Smart Probe of the Embraer ERJ-170/190 aircraft

Fig. 4 shows the general and structural diagrams of the Aid Data Smart Probe (ADSP) used in Embraer ERJ-170/190 (Embraer, 2011; SmartProbe, 2017).

Total pressure (Pt) is measured by a probe in the shape of a truncated cone, with a hole at its front end along the axis of symmetry. Static pressure (Ps) is measured by a probe in the shape of a straight tube with symmetrically placed holes at the top and bottom. Angle-of-attack data is derived from the differential pressure ($P\alpha$) measured through two holes symmetrically placed on the upper and lower surfaces of the truncated cone. The calculations performed by the ADSS computer generate an informational picture, including corrected values for static and total pressures, dynamic pressures, total and static air temperatures, barometric corrections, barometric altitude, corrected barometric altitude, current altitude changes, indicated and calibrated airspeeds, true airspeed, maximum operating speed, current Mach number, and angle of attack. The ADSS computer inputs are connected to pressure frequency converters, which are electrically connected to the corresponding pressure probe (Eski et al., 2023).

The analysis of the structural, functional, and operational characteristics of a range of ADS from different types of aircraft allows us to conclude that, despite their indisputable effectiveness, the systems also have certain drawbacks. These include the inability to generate information about roll, pitch, and yaw angles, as well as the measurement of the aircraft's lateral speed using the aerometric method.

The process of measuring attitude, yaw and drift signals of aircraft using aerometric methods becomes especially important during intercontinental flights, when GNSS is inoperative. To improve the reliability and accuracy of the obtained flight parameter information, as well as to enhance the efficiency of determining measurement method errors, it is advisable to use several redundant sources (both primary and backup) whose sensors operate on different physical measurement methods. For example, if the aircraft is flying in conditions where there is no connection with navigation satellites, ground-based radio navigation, and air traffic control systems (such situations arise during flights over oceans, the Earth's poles, or high, extensive mountain ranges), then, in these cases, the aircraft is entirely controlled by its autonomous inertial system. This places additional demands on the system's operational reliability and information precision (Derevyankin et al., 2022).

Based on this, it can be concluded that, despite the relatively high technological level of modern aircraft ADS, there remains the issue of more reliable and precise determination of flight navigation parameters such as roll, pitch, yaw, and lateral speed using aerometric measurement methods. On the other hand, the development of such a multifunctional CADS could provide the aircraft's onboard control system with an additional channel of information about current flight values and environmental conditions, which would undoubtedly improve the reliability and accuracy of flight control information, especially when there is no reliable connection with ground and space-based navigation systems.

2. Method

To achieve a stable level of providing flight navigation information, especially in areas with uncertain satellite navigation signal reception or even in cases where such signals are completely absent, it is necessary to use alternative techniques and tools for flight navigation measurements that allow for autonomous resolution of relevant tasks. Among them are the so-called aerometric methods, which provide highly reliable and precise information about flight parameters, such as, attitude, angles of attack and side slip, which determine the corresponding flight navigation characteristics of the aircraft.

In other words, aerometric methods of measuring air signals form an effective scientific and technical base for developing high-tech tools for measuring fundamental flight navigation signals, such as devices for measuring roll, pitch, yaw angles and drift of the aircraft, as well as systems for controlling and monitoring vertical and horizontal flight speeds.

One such device, operating since aerometric measurement methods, consists of a movable vane, a heater, and a housing, inside which the measuring circuit is placed. The device generates an electrical signal corresponding to the value of the angle of attack, which is formed by converting the mechanical rotation of the vane, depending on the aircraft's angle of attack, into the corresponding electrical quantity.

The vane is a streamlined symmetrical body of wing-like shape that rotates around its axis in accordance with the direction of the airflow, resulting in an aerodynamically balanced state. However, besides its ability to determine only the values of the angle of attack and slip, this device has drawbacks such as reduced sensitivity and increased instrument errors caused by friction during its rotation.

It is known that on aircraft models such as Airbus A318/319/320/321, A340-500/600, Boeing 747-8, Boeing 767, Boeing 787, which are equipped with aerometric measurement systems, four (three on the Boeing 787) total pressure tubes and six static pressure ports are installed, along with two air temperature sensors and angle-of-attack sensors with two vanes and heaters. In the corresponding blocks and computers, operations such as calculation, heating of pressure sensors, temperature and angle of attack measurement, as well as monitoring malfunctions in the air signals determination system, are performed.

The air data determination systems generate information that contains data on static, dynamic, total and effective pressures, as well as static and total air temperatures, barometric altitude and its rate of change, indicated speed, calibrated and true airspeed, maximum operating speed, Mach number, and angle of attack.

However, such systems are unable to measure pitch, roll, yaw angles, drift which is a significant disadvantage of the aerometric method, since there are strict limits for these angles on aircraft. It should be noted that in the most modern and advanced air signals measurement systems based on the application of the aerometric method, it is possible to obtain information on the following signals: barometric and relative altitude, vertical speed (by measuring static pressure, which changes depending on flight altitude); indicated speed and Mach number (by measuring dynamic pressure, which changes depending on the change in flight speed); air temperature; true airspeed (by measuring static and total air pressures); and the aircraft's angle of attack (by measuring differential pressure).

In the newest civil and military fifth-generation aircraft models, such as the Airbus A380, A350, A400M, Embraer 170/190, Bombardier Learjet 85, Boeing C-130 AMP, Boeing X-45C, Lockheed Martin F-22, F-35, Northrop Grumman X-47B, Sikorsky X2, the products of GOODRICH, UTC Aerospace Systems are successfully used—systems for measuring air data signals based on the aerometric method – Air Data Smart Probe, where several smart probe (from two to four) are used as primary sources of information to measure air signals, as well as two sensors to measure the total air temperature (SmartProbe, 2017).

In the aerometric system under analysis, there is no capability to measure static pressure at the tips of the aircraft wings or at the tail section of the fuselage, which is determined by the structural layout of its components. This leads to the inability to obtain information about pitch, roll, yaw angles, and lateral speed, which is undoubtedly a significant disadvantage of the considered air data signals measurement system.

In this regard, conducting relevant scientific research aimed at further improving the functional and operational characteristics of the pressure receivers and air signal measurement systems currently used on aircraft seems to be a very relevant and therefore in-demand task. At the same time, of particular interest is the development of such an air signal system in which it would be possible to generate operational information on such important flight and navigation parameters as bank, pitch, yaw and attack angles, as well as lateral speed using pressure sensors appropriately placed along the aircraft profile.

For this purpose, along with their traditional arrangement in the front part of the aircraft fuselage, pressure ports should also be placed on other elements of its design that are promising from the point of view of solving the task at hand. Thus, with the help of pressure probe placed on the tail section of the aircraft fuselage on both sides, it is possible to obtain with sufficient accuracy the necessary information related to determining the values of the pitch, yaw and lateral speed angles, and with the help of pressure receivers that are supposed to be installed on the wingtips - about the bank angle.

The development of such a multifunctional Complex Digital Air Data Systems (CDADS) could provide the aircraft on-board control system with an additional information channel on current flight values and air conditions, which would improve the reliability and authenticity of the relevant information to manage aircraft in an environment where there is no reliable connection to ground and space navigation systems.

Fig. 5 shows a schematic diagram showing the placement of air pressure probes, which allows performing aerometric measurements of such parameters, as pitch, roll, yaw and lateral speed. Located in the front section of the fuselage four smart probes (1) (total, static, differential and lateral static pressure probes), two air temperature sensors (2) (total air temperature), four smart probes (3) (static and lateral static pressure probes), and four air data computers (not shown in the diagram) constitute the basis of the aerometric system.

The roll angle is generated based on the difference in signals received from the static pressure probes (3) installed at the wingtips of the aircraft; the pitch angle is generated based on the difference in signals received from the static pressure probes installed in the nose (1) and tail (3) sections of the fuselage; the yaw angle is generated based on the difference in signals received from the lateral static pressure probes installed in the nose (1) and tail (3) sections of the fuselage; and the lateral speed of the aircraft is generated based on the variation of the difference in signals received from the lateral static pressure probes installed in the nose (1) and tail (3) sections of the fuselage.

To determine the value of the aircraft yaw angle, the output signals of the static pressure probe 1, 3 located in the modified smart sensors of the front and rear fuselage should be used. If, during a flight affected by a crosswind, a yaw effect occurs, this leads to the fact that the lateral pressure acting on the pressure receiver located on the leeward side of the aircraft fuselage will increase, and this increment should be the same for both the receivers of the front and rear parts of the aircraft. As for the corresponding devices installed on the opposite side of the fuselage, the pressure here will decrease accordingly to the same extent.

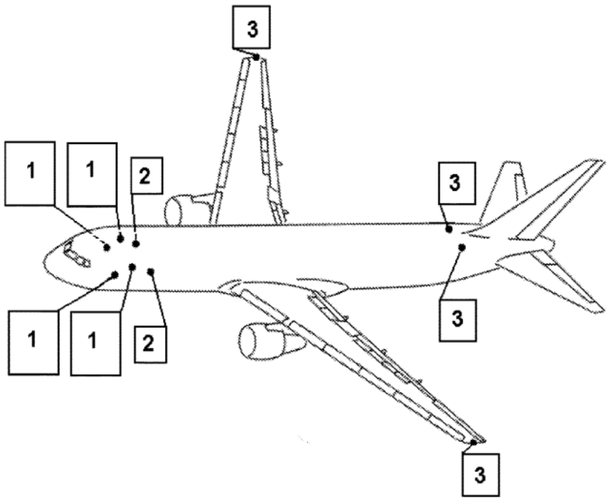

Fig. 5. Layout of pressure receivers of the integrated central pressure system on aircraft

3. Results

Fig. 6(a) show a schematic diagram of acquiring air data by the information sources, which reflects the generation by the air data computer of the algorithm for calculating the proposed additional parameters, such as roll, pitch and yaw angles as well as lateral speed in the following form (Pashayev et al., 2019):

1. Roll angle: determined as $\gamma \sim P_{stat4} - P_{stat3}$, where $\gamma < 0$ corresponds to a left roll (left wing down), and $\gamma > 0$ corresponds to a right roll (right wing down). When $P_{stat4} - P_{stat3} = 0, \gamma = 0$;

2. Pitch angle: determined as $\vartheta \sim P_{stat5} - P_{stat1}$ or $\vartheta \sim P_{stat6} - P_{stat2}$, where $\vartheta < 0$ corresponds to a dive (nose down), and $\vartheta > 0$ corresponds to a pullup (nose up). When $P_{stat5} - P_{stat1} = 0$ or $P_{stat6} - P_{stat2} = 0$, $\vartheta = 0$;

3. Yaw angle: determined as $\psi \sim (P_{lateral\ stat5} - P_{lateral\ stat1}) = (P_{lateral\ stat2} - P_{lateral\ stat6})$, where $\psi < 0$corresponds to a left yaw, and $\psi > 0$ corresponds to a right yaw. When $(P_{lateral\ stat5} - P_{lateral\ stat1}) = (P_{lateral\ stat2} - P_{lateral\ stat6}) = 0$, $\psi = 0$;

4. Lateral speed:

$$\begin{cases} v_{lateral} \sim (P_{lateral\ stat1} - P_{lateral\ stat2}) = (P_{lateral\ stat5} - P_{lateral\ stat6}) \\ P_{lateral\ stat1} = P_{lateral\ stat3} = P_{lateral\ stat5} \\ P_{lateral\ stat2} = P_{lateral\ stat4} = P_{lateral\ stat6} \end{cases}$$

where $v_{lateral} < 0$ corresponds to a leftward movement, and $v_{lateral} > 0$ corresponds to a rightward movement.

5. In case of concurrent yawing and lateral speed of the aircraft:

$$\begin{cases} \varphi \sim (P_{lateral\ stat5} - P_{lateral\ stat1}) = (P_{lateral\ stat2} - P_{lateral\ stat6}) \\ v_{lateral} \sim (P_{lateral\ stat1} - P_{lateral\ stat2}) = (P_{lateral\ stat5} - P_{lateral\ stat6}) \end{cases}$$

Fig. 6(b)-(d) presents the developed schemes of CDADS. Located at the front of the fuselage are four smart probes (total, static, differential and lateral static air pressures), two air temperature sensors 2 (total air temperature), four smart probes 3 (static and lateral static air pressure probes), as well as four air data computers form the basis of the comprehensive (fig. 6(a)).

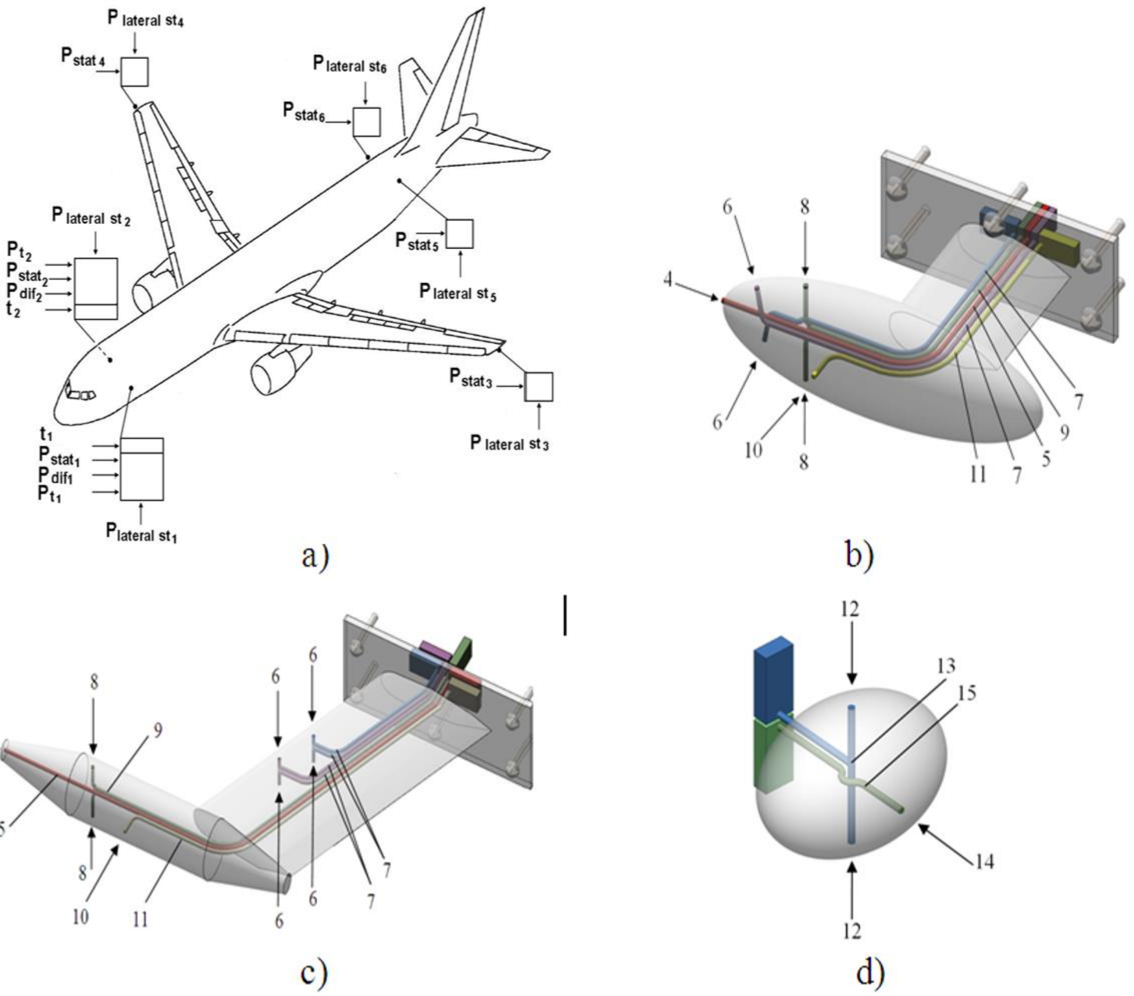

Fig. 6. Complex CDADS: (a) the scheme for the placement of CDADS and pressure probes; (b), (c) design schemes of total, static, differential, lateral static pressures; (d) the scheme of static and lateral static pressure probe.

Fig. 6(b) presents a scheme of pressure probes, which are designed for non-manoeuvrable aircraft (for civilian), in fig. 6(c) - for manoeuvrable aircraft (for aircrafts flying at large angles of attack). Pressure receivers consist of a total air pressure probes 4, its pipeline 5 and de-icing system.

Figure 6(d) presents a scheme of pressure probes installed on the wing tips and tail of the aircraft consist of static pressure probes 12, its pipeline 13 and de-icing system, the probe of the lateral static pressure 14, its pipeline 15 and de-icing system, The air data probe includes static pressure ports 6 for ambient pressure measurement, pressure transmission tubes 7 for conveying pressure to onboard sensors, a total pressure port 8 for stagnation pressure measurement, drain holes 9 to remove moisture, a temperature sensor 10 for air temperature measurement, and heating elements 11 to prevent ice formation. (Pashayev et al., 2019; Karimli, 2023).

Logical algorithms for obtaining information about flight and navigation parameters have been designed and a simulation of the computer model has been performed.

In the process of spatial evolutions of aircraft associated with its roll, you should use the output signals of static pressure probes installed at the wing tips - (Pst3, Pst4). In this case, the value of the angle of the bank will be determined by the difference of these signals. In determining the value of the pitch angle, you should use the difference in output signals of static pressure probes installed on the nose and tail parts of the fuselage surface - (Pst5, Pst1) and (Pst6, Pst2). In the process of yawing and determining the lateral speed of aircraft the difference in output signals of lateral static pressure probes (Plateralst3, Plateralst1) and (Plateralst2, Plateralst4) should be used.

On the basis of these algorithms, a generalized functional scheme of the comprehensive CDADS is drawn up, as well as a computer model of the subsystem for determining the direction of the angle.

The theoretical basis for the operation of the comprehensive CDADS has been presented and a computer model has been drawn up to determine qualitative parameters (Karimli, 2023).

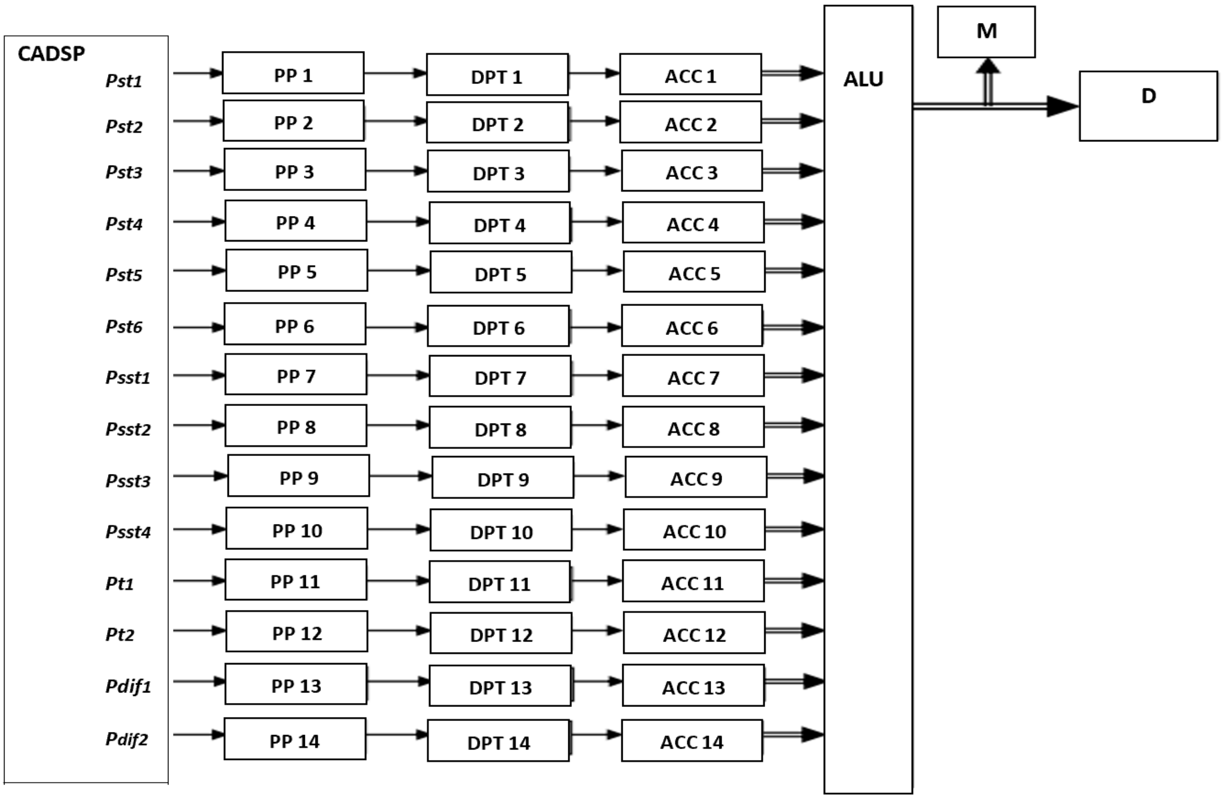

Fig. 7. Generalized functional diagram of the Complex Digital Air Data System

Fig. 7 illustrates the CADSP - comprehensive Complex Aid Data Smart Probe; PP - pressure probe; DPT – Digital Pressure Transducer; ACC - Analog-Code Converter; ALU- Arithmetic and Logical Operations Unit; D - Display or Monitor; M - Memory

To model the system for measuring air temperature, static atmospheric pressure, air speed and determining the Mach number using the aerometric method, we will use formulas (Karimli, 2023).

Fig. 8 shows the developed complex model of CDADS:

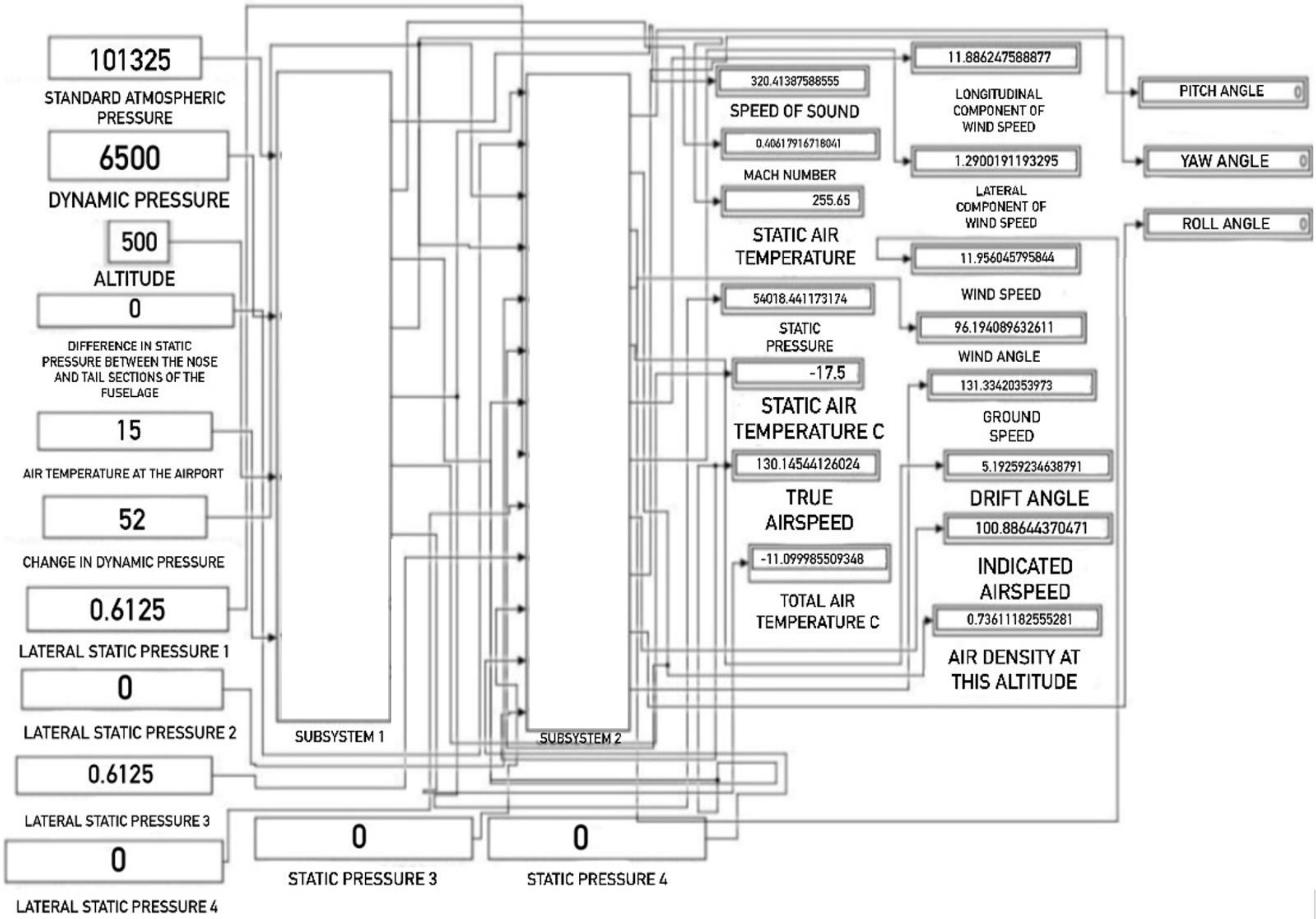

Fig. 8. Computer model of the CDADS (MATLAB Simulink)

"Subsystem 1" is based on the aerometric formulas. The "Subsystem 2" block contains algorithms for determining the angles of roll, pitch, yaw, lateral speed of the aircraft and well-known formulas of the sine and cosine laws for solving the navigation triangle, determining the ground speed, wind angles and drift (Karimli, 2023).

The “Subsystem 2” block also contains a formula for determining air density depending on the altitude, which is characterized by static pressure at a given altitude.

To determine the difference in altitude relative to the horizontal position, the difference in barometric air pressure between the nose and tail of the aircraft is used, that is, between the places where the pressure sensors Pst1 and Pst5 or Pst2 and Pst6 are located.

To determine the pitch, roll and yaw angles in degrees, known trigonometric formulas are used. According to the standardized data, the distance R between the aircraft neutral centring point and the pressure receiver installation point is taken to be 28.65 m. Since with the values of the pitch, roll and yaw deviation angles from the initial position at an angle of φ= 1° with a displacement of L = 0.5 m from the geometry formula $L = \frac{2\pi r}{360}\varphi$, we see that R=28.65m.

4. Discussion

Table 1 presents the simulation results for determining parameters such as static temperature and pressure, air density, and the speed of sound at flight altitudes of H=5000 m, 9000 m, 10000 m and 12000 m, with dynamic pressure Pd=6650 Pa and with a difference of static pressures taken from sensors Pst1 and Pst5 or Pst2 and Pst6 of 4.579 Pa.

Table 1. Comparison of simulation results of the CDADS computer model

Flight Altitude (m)		**Static Temperature (K, C°)**		**Static Pressure (Pa)**	**Air Density** (kg/m^3)	**Speed of Sound (m/s)**
5000	**Results of Simulations;**	255.65	-17.5	54018.4	0.737	320.4
	Literature data	255.68	-17.47	54048.3	0.736	320.5
9000	**Results of Simulations;**	229.65	-43.45	30740.8	0.467	303.68
	Literature data	255.73	-43.42	30800.7	0.467	320.8
10000	**Results of Simulations;**	223.15	-50	26434.7	0.413	299.35
	Literature data	223.25	-49.40	26499.9	0.413	299.6
12000	**Results of Simulations;**	216.65	-56.5	19330.2	0.310	294.9
	Literature data	216.68	-56.5	19399.4	0.312	295.1

As can be seen from the table, the reliability of the simulation results, with sufficiently high accuracy (for visual devices, and automatic control system, when GNSS is inoperative), is confirmed by the data given in the literature.

Table 2 presents the simulation to determine the crosswind, drift, pitch, yaw, roll, and some aerometric signals of the aircraft by CDADS at altitude H=10000 m (Karimli, 2023).

Table 2. Results of computer simulation of the improved CDADS

№	Input signals			Output signals		
	Signals	Symbol	Value of measurement	Signals	Symbol	Value of measurement
1	**2**	**3**	**4**	**5**	**6**	**7**
1	Standard Atmospheric Pressure	Pa	101325	Static pressure at a given altitude	Pa	26434
2	Dynamic Pressure	Pa	12500	Static air temperature at a given altitude	K (⁰C)	223.5 (-50)
3	Altitude	feet meter	30480 10000	Total air temperature at a given altitude	⁰C	-30.19
4	Difference of static pressure in the nose and tail sections of the fuselage	Pa	12.5	Speed of sound	m/sec	299.3
5	Standard air temperature	K (⁰C)	288.15 (15)	Mach number		0.76
6	Dynamic pressure difference	Pa	0	True airspeed	knot km/hour	445 824.2

7	Lateral static pressure 1	Pa	0,6125	Longitudinal component of wind velocity	m/sec	0
8	Lateral static pressure 2	Pa	0	Crosswind velocity	m/sec	6.22
9	Lateral static pressure 3	Pa	0,6125	Wind velocity	m/сек	15.95
10	Lateral static pressure 4	Pa	1,2	Wind angle relative to true airspeed vector	^{0} deg.	90
11	Static pressure 3	Pa	2,03	Ground speed	knot km/hour	445.2 824.5
12	Static pressure 4	Pa	-2,03	Drift angle	^{0} deg.	1.55

The aerometric systems existing on modern aircraft are not capable of measuring the parameters of roll, pitch, yaw angles, as well as crosswind and drift of the aircraft.

5. Conclusions

This work presents the development and analysis of a complex Computational-Digital Air Data System (CDADS) designed to determine flight and navigation parameters using data obtained from the Aid Data Smart Probe air pressure sensor, supported by computer-based modeling and simulation. The following key outcomes have been achieved:

- It is proposed to create a complex CDADS for determining flight and navigation parameters based on processing signals taken from Aid Data Smart Probe air pressure probe, and a computer model simulation is performed;
- Theoretical foundations for the operation of a complex CDADS are presented and a computer model for determining flight and navigation parameters is compiled;
- A mathematical model for obtaining information on flight and navigation signals, including additional parameters such as roll, pitch, yaw, lateral speed, is compiled, and a computer model simulation is performed;
- As the simulation of the resulting model shows, it is clear that it is possible to use the measured parameters of roll, pitch, yaw, lateral velocity of the aircraft, as well as wind direction and speed based on the aerometric method with sufficient accuracy for visual displays, as well as in automatic control systems, in the absence of GNSS satellite navigation

After digging into all the technical stuff in this study, the big takeaway is actually pretty simple: aircraft need better backup systems for when GPS or external signals aren't there to help. That's where this new system, CDADS, really shines.

What makes this setup clever is how it uses pressure sensors placed all around the aircraft—not just in the usual places at the front, but also at the wingtips and the tail. That way, it can pick up on small changes in pressure that actually tell you a lot about how the aircraft is moving and we can receive a lot of data, which is very beneficial. And with those sensors feeding data into some solid math and logic in a computer model, it turns out the results are pretty accurate. They tested the system under different flight conditions, and the numbers matched up well with real-world data. That's a good sign.

By using simulation model, it is clear that different types in size of aircraft can be studied for next research programs.

This method can also be applied to submarines.

Abbreviations

ACC : Analog Code Converter

ADIRU : Air Data Inertial Reference Unit

ADS : Air Data Smart Systems

ADSP : Air Data Smart Probe

ALU : Arithmetic and Logical Operations Unit

CDADS : Complex Digital Air Data Systems

GNSS : Global Navigation Satellite Systems

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