UDC 329.735.05:621.38711.4
DOI: 10.18372/2306-1472.70.11425

Dmytro Prusov[1]
Mykhaylo Matiychyk[2]
Oleksiy Mykhatskyi[3]

COMPARATIVE ANALYSIS OF AVIONICS SAMPLES AND COMPONENTS DUE TO DEVELOPING A METHODOLOGY OF THE UAV INTEGRATED AVIONICS SYNTHESIS

National Aviation University
Kosmonavta Komarova avenue 1, 03058, Kyiv, Ukraine
E-mails: [1]prusov@nau.edu.ua; [2,3]nvcba@nau.edu.ua

Abstract

The article is devoted to analysis of avionics components samples with a view to creating an integrated avionics synthesis methodology remotely piloted and unmanned Aerospace Dynamic Objects (ADO), which provides a comprehensive solution of problems of navigation and synergistic control ADO air navigation in space. ***Methods:*** *The analysis and setting objectives are the basis for the development of modern techniques for combining and processing primary data, methods to solve navigation problems, methods of solving problems in the management of complex integrated avionics ADO. In particular, this invariant compensation method for combining primary sources of information, complete correlation-extreme methods of navigation, control method synergistic ADO.* ***Results:*** *Using these techniques will increase the effectiveness of solving problems of navigation and control both civilian and military ADO, in terms of accidental and intentional interference, the failures of avionics.* ***Discussion:*** *Based on the provisions set a prototype integrated avionics for ADO navigation and control synergistic with current approaches has been developing.*

Keywords: navigation and control; integrated avionics system; unmanned aerial vehicles.

1. Introduction

The rapid development of aviation and space technology, which is observed in recent decades contributes fundamentally review the operation concepts of aerospace systems in the same space of Air Navigation [1, 2]. Formation of new fundamental concepts such as the concept CNS/ATM, Free Flight, A3 etc., leading to the nomination of the new requirements on the structure and principles of modern avionics ADO. Despite the fact that Ukraine is a state aircraft, aircraft industry domestic enterprises do not have sufficient experience developing and manufacturing advanced avionics systems. Usually avionics for unmanned aircraft Ukraine shipped from abroad, which were purchased in the leading European manufacturers of avionics. Research and development of such systems in Ukraine is spontaneous and decentralized. Along with that there are no domestic theoretical work on the synthesis of integrated avionics. Thus, in Ukraine there was a problem situation, which is the need to equip local ADO avionics systems of its own design and production system and lack of a unified methodology of hardware and software systems integrated avionics ADO [3].

2. Analysis of the latest research and publications

The staff of the National Aviation University have made a significant contribution to the development of the theory of synthesis of integrated avionics systems, particularly invariant developed the concept of integration of navigation aids - so-called invariant compensation scheme for integration of navigational aids based on nonlinear discrete filter; the method of complex correlation-extreme navigation compatible with processing information and navigation data evaluation; Energy-developed potential method for solving the poly-conflicts of aircraft in free flight conditions [4].

In this direction is planned to further develop and improve invariant compensation scheme through the use of special operation entry "acceleration" scheme based on regression algorithm using the device sensitivity theory; expansion methods correlation-extreme navigation. Requires further development and improvement of methods avionics system integration ADO for solving navigation and synergistic management on common methodological basis, in conditions of uncertainty, lack of information, intentional interference and random failures.

From the standpoint of the theory of complex dynamic systems in the work expected to address the problem at two levels of theoretical research: level navigation tasks solution to improve the accuracy and reliability of the definition phase coordinates ADO and synergistic management level synthesis formations ADO.

The basic idea of the first level investigation is to improve existing and develop new methods of primary processing, methods to solve navigation problems, methods of information integration and their system use in an integrated avionics [5].

The basic idea of the second level investigation is to create a virtual environment, giving it synergistic properties of objects real physical systems, determining parameters of traffic of objects in the virtual environment and use of derived parameters for the synthesis of synergetic self management group or traffic manned, remotely piloted and unmanned ADO in the CNS/ATM environment.

The relevance of confirmed new requirements for avionics systems ADO, due to the current global trends:

- increasing intensity of aircraft flight and increase the number of conflicts between them;
- nomination global aviation community requirements the transition from regulated flight trajectories to their free flight autonomy and board;
- simultaneous use of a single aeronautical space heterogeneous dynamic objects (manned, remotely controlled, unmanned);
- increasing use of remotely piloted and unmanned aerial vehicles to solve problems and civilians in areas of armed conflict.

The above trends impose strict requirements for methods of navigation and control their implementation in modern integrated complex avionics ADO. Complex solution of this problem is not only crucial, but in theoretical terms is classified as high complexity tasks.

3. Research tasks

The problem of designing prospective avionics today refers to the priority areas of the aviation industry. Basic scientific research in this area are carried out by experts of Aviation in the search for new concepts of designing hardware and software within the framework of the implementation of new technologies, materials and element base in the aviation product samples. The search for new concepts of designing hardware and software aimed at improving the structural organization of the on-board systems to meet the continuously increasing demand [6].

4. Integrated Modular Avionic concept

The introduction of new technologies, materials and element base in the aviation product samples aimed at changing technical and economic parameters of avionics in order to make on-board systems of the new qualities or to improve the quantitative performance of the existing equipment. At the present stage avionics developers some progress in addressing the particular problems of designing individual components due to the introduction in the development of promising functional technology, hardware and software integration equipment, but the problem of building integrated avionics computer systems remains unresolved fully up to date. The purpose of this article is to present a wide range of issues of design professionals integrated computer systems that make up the core of advanced computing systems avionics. The reader will find a brief overview of the results now achieved by developers and proposed for more detailed acquaintance modern approach to the design of the avionics perspective - an approach based on the introduction of on board UAV structures integrated modular avionics [6].

The main result of the international experts in the development of architecture and components of the avionics is now approved by ARINC (Aeronautical Radio Inc., USA) and developing the concept of integration of national experts on-board equipment - the IMA concept (Integrated Modular Avionic), the foundations of which are set out in the standard ARINC 651 «Design Guidance for Integrated Modular Avionic». The standard has defined a new direction in the improvement of aviation instrument and outlined the prospects for the development of the aviation industry for decades to come. ARINC 651 is a coherent and legally approved in the United States view the representatives of airlines, operators of aircraft, aircraft manufacturing companies and the US aviation equipment and a number of other countries on the approach to the systematization of avionics design.

IMA concept covers the following groups of design problems aircraft instrument:

– the establishment and implementation of IMA in the development of the avionics;

– used in the development of avionics technology;

– implementation of fault tolerance of onboard equipment;

– principles of the on-board network of information exchange (on-board data network);

– architecture of avionics;

– software architecture of avionics and its components;

– development certification (avionics hardware and software);

– testability and maintainability of avionics and object a whole;

– range of sources and data consumers (subscribers on-board local data network).

IMA concept involves the separation of the functional components of avionics into three hierarchical levels:

– the lower level of the hierarchy form a unified structural and functional modules for different purposes, with their own computing devices in a compact standardized design;

– the average level of the hierarchy form a multi-processor computer systems, modules created from the lower level and constructively performed in a standardized package;

– the highest level of the hierarchy is an onboard local area network based on the network interface of the central high bandwidth computing means integrating racks midrange.

For the organization of the central on-board network interface high bandwidth enterprises today aircraft instrument experts worked out a constructive and technological solutions for the implementation on the aviation and space ADO for new or existing:

– intersystem interface Fiber Channel (ANSI X3T11); Scalable Coherent Interface (ANSI / IEEE Std 1596-1992); Myrinet; Gigabit Ethernet; ARINC 664; Asynchronous Transfer Mode; FireWire (IEEE 1394) etc.;

– intrasystem interfaces Scalable Coherent Interface – SCI (ANSI / IEEE Std 1596-1992); Fiber Channel – ANSI X3T11; VME; PCI Compact; SKY Channel Packet Bus; LVDS (TIA / EIA 644) etc. [6]

Among foreign avionics projects carried out in accordance with the basic provisions of the IMA concept, deserve the attention of the following systems, a review is given below.

5. MicroPilot components

MicroPilot serves UAV manufacturers who maintain high standards for both the hardware they integrate into their systems and the software that drives them. Our customers require products that are reliable, scalable and customizable. MicroPilot has a solid reputation that supplies consistent products, services, and support [7]. Incorporated in 1994, MicroPilot has served over 850 clients in over 70 countries during its 20+ years in business. With such a stronghold and longevity in the industry, MicroPilot has maintained itself as the world leader in professional autopilots for UAVs and MAVs. MicroPilot serves small UAV manufacturers, large-scale defense and research enterprises, and all that exists between. Some of the organizations we serve include NASA, Raytheon, and Northrop Grumman.

Customizable Products.

MicroPilot offers a family of lightweight UAV autopilots that fly fixed-wing, transitional, helicopter, and multi-rotor UAVs. Some of our autopilots' popular features include:

- Airspeed and altitude hold;
- Turn coordination;
- GPS navigation;
- Vertical takeoff and landing (VTOL);
- Autonomous operation from launch to recovery.

Circuit Board Autopilots.

MP2x28 Series Autopilots

Since the company began in 1994, MicroPilot autopilots have been compact, lightweight, and powerful. They have flown everything from one-pound MAVs/backpacks to high-speed, turbine-powered drones. MicroPilot offers more flexibility and selection in autopilots than ever before to meet clients' needs, ranging from sophisticated data and imaging UAV systems to entry-level or single-use applications. From our single-use autopilot (MP2x28^{xp}) all the way up to our powerful VTOL autopilot (MP2128^{HELI2}), MicroPilot provides a seamless upgrade path. No other autopilot manufacturer offers such adaptable technology or such a range of autopilot options at quantity pricing. This makes MicroPilot the single-vendor solution for all autopilot hardware, software, and accessory needs. This also positions to grow and adapt at a fraction of the cost so that newly developed UAVs can get in the air faster with better autopilot control.

MP2128^{HELI2}. Incorporates all the functionality need to fly both VTOL and fixed-wing UAVs in an ultra-small autopilot. Based on proven MicroPilot autopilot technology, it flies fixed-wing and heli UAVs. Upward-compatible with the MP2x28^{g2} series of autopilots. Includes Ublox 4 Hz

GPS module and compass module. Supports fully autonomous flight from takeoff to landing.

MP2128^{g2}. Comparable in size to the MP2028^{g2} but with 50 times the processing power. Offering upward compatibility with the popular MP2x28^{g2}, MicroPilot's MP2128^{g2} provides a 50-fold increase in processor power, double the memory, and twice the input/output channels. The MP2128^{g2} is MicroPilot's premium autopilot and the autopilot of choice for high-performance miniature UAV.

MP2028^{g2}. The autopilot that will take miniature UAV from vision to reality. The MP2028^{g2} established a new benchmark for lightweight UAV autopilots. Weighing only 28 grams, including all sensors and a GPS receiver, this UAV autopilot is the smallest in the world. With a proven track record, the MP2028^{g2} packs everything need into one powerful UAV autopilot.

MP1028^{g2}. Bringing MP2028^{g2} performance to the entry-level UAV operator. The MP1028^{g2} is the lowest-cost member of the MicroPilot family of UAV autopilots. With the same small size and weight as the MP2028^{g2}, the MP1028^{g2} offers all of the reliability and the most important features of the MP2028^{g2}. The MP1028^{g2} autopilot is suitable for entry-level UAV applications where cost is the overriding consideration.

trueHWIL^{mp}. The highest fidelity available in UAV autopilot simulators. MicroPilot's new True Hardware-in-the-Loop (trueHWIL^{mp}) simulator offers UAV integrators and researchers the highest-fidelity UAV autopilot simulation available on the market today.

Existing quasi-hardware-in-the-loop simulators approximate a UAV's flight by exchanging sensor and control surface position information with the autopilot over a serial port or CAN bus. This form of simulation introduces inaccuracies as an autopilot in flight reads this information directly from its sensors instead of a serial port or CAN bus. MicroPilot's trueHWIL^{mp} offers a dramatic improvement in simulator fidelity by electrically simulating all sensor outputs using an analog-to-digital converter, signal conditioning, and PWM interface boards. MicroPilot's trueHWIL^{mp} allows our customers to replicate the conditions their UAVs experience in flight, offering superior on-the-ground validation of autopilot setup and integration.

MP2128^{3X} Triple Redundant. Three complete autopilots, advanced voting logic, carrier phase GPS, helicopter and fixed-wing. Triple redundancy (3X) gives autopilot technology the reliability necessary to safely carry out sensitive flight missions and transport valuable payloads. A triple redundant arrangement is comprised of three similar software and hardware systems. If any one of the three systems fails, the remaining two take over, offering a double redundancy arrangement. If one of the other two systems should fail, the third takes over. An additional mechanism is also included to oversee these three systems. Triple redundant systems are highly tolerant of autopilot hardware failures.

Triple redundant autopilots are not new. Military aircrafts such as the RAF's Trident fleet, used a triple redundant autoland system in the early 1960's. Ten years later, the Aérospatiale-BAC Concorde took advantage of 3X technology in its flight control system. Presently, triple redundancy is used in several manned military and commercial aircrafts.

Although triple redundant technology is established within the aviation industry, triple redundant autopilots are a relatively new addition to unmanned aerial vehicles (UAVs). MicroPilot, the leading UAV autopilot manufacturer, is setting the benchmark for triple redundant UAV autopilots. MicroPilot, based in Canada, has been designing autopilots for fixed-wing, transitional and helicopter UAVs since 1994. In 2006 MicroPilot started designing a triple redundancy autopilot for helicopter and fixed-wing UAVs.

The MP2128^{3X} is comprised of three MicroPilot MP2128^{HELI2} autopilots, mounted on an adapter board, or redundancy board. The three MP2128^{HELI2}s are prioritized. At the start, the autopilot in position one flies the airframe. If this autopilot should fail, the MP2128^{HELI2} in position two takes over, and so on. The redundancy board provides several input/output (I/O) ports. The board also includes two RS232 serial ports designed to communicate with a ground control system via radio modems. As a result of this design, users never need to work directly with bare circuit boards. Additionally, the autopilots do not have an individual casing, keeping overall weight to a bare minimum; however, the entire redundancy board is enclosed to protect the system.

Features:

- Fly both fixed-wing and helicopter UAVs.
- Multiple communication links for onboard devices such as cameras and aircraft transponders.
- Redundant datalinks to ground control station.
- Configuration, state and waypoint synchronization among all three autopilots.
- 11 serial ports including RS232 and RS485.
- 16 independently-generated servo signals.

• 8 high current drivers controlled independently by each autopilot.

• Pass or fail voting logic reliably selects the appropriate autopilot.

• HORIZON^{mp} ground control station software with built-in software in the loop simulator.

• Feedback loop synchronization ensures smooth transition when switching autopilots.

HORIZON^{mp}

Ground control software that consistently takes UAV from the ground to the air. The choice of over 850 clients in 70 countries, HORIZON^{mp} ground control software offers a user-friendly, point-and-click interface. Developed by MicroPilot for the MP2x28 series of autopilots, HORIZON^{mp} runs on a Windows computer or laptop.

HORIZON^{mp} allows the operator to monitor the autopilot, change waypoints, upload new flight plans, initiate holding patterns, and adjust feedback loop gains all while the UAV is flying.

INFORMATIVE

HORIZON^{mp} allows both the UAV developer and the end user to access critical information in real time. Up to eight user-defined sensors can be configured and displayed in three formats:

• Current sensor values are displayed in an easy-to-read gauge format; warning and danger levels can be set for each gauge

• The Strip Chart graphs sensor-specific variations over time

• The Trace Route displays sensor data variations along the UAV's flight path

Data from the autopilot is also recorded for post-flight analysis.

MP2128^{LRC2} MP2128$^{HELI\text{-}LRC2}$

Providing the best MicroPilot 2128 series products in one convenient autopilot package. As world leaders in miniature UAV autopilots, MicroPilot continually develops dynamic new systems to serve RPAS, MAV, UAS, UAV, drone, and certain unmanned vehicles. The MP2x28 and MP2128 are the autopilots of choice for UAV operators who need a reliable, integrated system that performs in a variety of scenarios. Equipped with full airside and groundside UAV system components, the MP2128^{LRC2} is MicroPilot's premium UAV autopilot package. This long-range communication (LRC) autopilot provides an integrated, redundant, long-range data communication link. With this feature, operators benefit from greater distance and flexibility.

The LRC ground unit uses standard, off-the-shelf radio modems with three popular frequency band choices (see below), as well as versions for either fixed-wing or helicopter. This product adds RC control information to the existing GCS datalink and a second redundant datalink, which reduces possible failure modes. In addition, LRC units provide automatic emergency override. The LRC is lightweight, yet enclosed in a rugged aluminum housing that protects its sensitive electronics. What's more, these electronics are convenient to install on a variety of airframes.

XTENDER^{mp}

Take UAV to the next level with this power solution XTENDER^{mp} taps into the power of a world-recognized autopilot and expands it to fill the gap between standard autopilot functionality and specific requirements.

MP plug-ins are code modules that execute at the same time as the autopilot code and allow customers to add functionality to the autopilot to differentiate their products and close the gap between the standard autopilot functionality and their custom requirements

• MP plug-ins can access 64k RAM for data and 64k Flash for code

• MP plug-ins run under the autopilot simulator to simplify testing and speed development

• MP plug-ins can access all autopilot state fields

• MP plug-ins can provide customer-specific servo mixing

• Customer-defined control laws can replace any or all existing MP2x28 control laws

• MicroPilot plug-ins can access unused autopilot hardware for custom payload control and data collection

• Up to 9 I/O channels are available for MicroPilot plug-in. Each I/O channel can be configured as one of: serial input, serial output, PWM in, PWM out, single-bit input, or single-bit output

SIMULATOR

XTENDER^{mp} includes a "software in the loop" 6-DOF simulator linked to autopilot code.

• Simulator update rate: 150 Hz

• Accepts autopilot commands via PC serial port; speeds development of embedded payload/mission controllers

• Simulates communication, engine failure, loss of GPS lock, loss of RC signal, loss of communications, and low-battery failures

• Availability of simulator gives end-product training mode

XTENDER^{validate}

Build quality systems that meet high-level expectations. Develop high-level requirements and easily decompose them into appropriate lower level requirements with XTENDER^{validate}, the world's first available design life-cycle tool for UAVs. Systematically link flight, user, and simulator testing validation data to requirements. Likewise, link requirements to autopilot options and GCS settings. Additionally, XTENDER^{validate} incorporates a failure analysis tool that helps identify subsystem failure modes and links them to requirements. With XTENDER^{validate}, clearly satisfy requirements via autopilot options, ground control station options, UAV design, and more. Auto-generate electronic test cards, complete with descriptions for each test, indicators for severity, and schedule dates. Automate documentation for each requirement and its implementation, with this design life-cycle tool. XTENDER^{validate}offers a flexible means of satisfying requirements and provides progress and fulfillment reporting.

Features:

• Freeze and roll back requirements and implementation capability;

• Requirement linking to autopilot options and GCS settings;

• System and subsystem decomposition tool;

• Share requirement subsets among multiple UAVs capability;

• Integrated failure modes analysis and mitigation tool;

• Auto-generated electronic test cards from requirements;

• Validation data linking to requirements;

• Requirements and implementation change history;

• Progress tracking for satisfying and validating requirements [7].

6. RVOSD components

RVOSD6 Autopilot & Telemetry + LRS

RangeVideo RVOSD6 with RVLINK receiver module and airspeed sensor [8], includes:

• RVOSD6

• RVLINK Rx module + antenna

• GPS

• Current sensor

• IR remote

• Servo cables.

Requires: RVLINK Transmitter

Capabilities:

OSD: F16 style graphical OSD; Battery voltage & current; Airspeed; Ground Speed; Altitude; Variometer; Heading; AHI; 3 different OSD displays: F16, simple, or radar screen.

Autopilot:

– Variable throttle control based on airspeed and power.

– 16 waypoints (coordinates and altitude). Autopilot will fly the programmed path.

It can be override the mission at any time, with the following auxiliary modes:

– Position hold (circle flight path above any point– loiter diameter can be set);

– Fly-By-Wire (semi-automatic stabilized manual flight);

– Heading hold (maintain constant heading course);

– Return to home(return to take-off location and circle flight path at pre-set altitude).

Other Features:

Supports up to 6S battery; 100A current sensor with XT60 plugs; Filtered power supply for video camera and transmitter; 1A 5V PSU to power camera or vtx.

RVLINK UHF Control Relay (receiver is included in the RVOSD) 430MHz 800mW; 20-40km range; Spectrum analyzer mode.

RVGS(Optional)

Antenna tracker; Video diversity controller; Video splitter.

The RVOSD autopilot relies on a combination of gyros and accelerometers to sense the airplane's pitch and roll. The most important function of the autopilot is to return the airplane back home when R/C signal is lost. The RVOSD5 can also stabilize(fly-bywire mode) and autonomously(by waypoints) fly the aircraft.

Aircraft Compatibility. The RVOSD autopilot can control these types of aircraft:

– Stable trainer aircraft. Throttle, elevator, and rudder.

– Low wing Aerobatic aircraft. Throttle, elevator, and ailerons.

Autopilot Flight Modes RTH (return to home) This autopilot mode will engage automatically when R/C link lost is detected, and will fly the model back to the takeoff spot. Level flight The autopilot will keep the attitude of the model leveled on the pitch and roll axes. Heading hold The autopilot will keep the heading of the plane at the moment this of activation; it will also try to keep the actual altitude.

Position hold The autopilot will fly figure eight patterns around the GPS coordinates at the moment of activation; it will also try to keep the actual altitude. Fly-by-wire The control of the plane is given up to the OSD computer. It will check for user stick traffics and will translate to model desired attitudes. Control sticks are interpreted from 0 to full as 0-60° on each axis. Waypoint navigation (this mode is disabled outside of North America)

Hardware Overview.

RVOSD5. The RVOSD performs all of the text and graphic overlay, navigation, autopilot control, and power management. A custom graphics engine draws a flicker free overlay. Two microprocessors handle all of the tasks. The RVOSD5 contains an onboard Barometric Pressure Sensor for measuring aircraft altitude.

GPS Receiver. The included 10Hz GPS with SAW filter is immune to jamming from video transmitters. It is WAAS enabled, and has an accuracy of < 2m. It has a lithium backup battery to retain GPS settings for quicker satellite acquisition times. GPS data provides ground speed, ground track, and latitude and longitude.

Current Sensor. The current sensor measures the current consumption of electric motor system from 6-25VDC, 70A maximum.

External Temperature Sensor. If the external temperature sensor is left disconnected, then RVOSD will display the onboard temperature sensor reading. Temperature sensor operating range:

onboard temp sensor MCP9700 -40 to +150 degrees Celsius.

Remote Control. The IR remote is used to navigate the RVOSD menus. The IR signal is powerful enough to penetrate foam and balsa; there is no need to remove the RVOSD from the model.

Wiring. Cables to connect video in, video out, GPS, current sensor, R/C receiver, are all included.

Video Camera. A video camera is not included with the RVOSD5. The RVOSD will not provide a video output without a valid video input. Use the included cables to connect camera to the RVOSD. There are cables for the KX131/KX191, KX171, and DX201. RVOSD is compatible with both PAL and NTSC composite video formats

Video Transmitter. A video transmitter is not included with the RVOSD5. The RVOSD5 will send the combined camera video and OSD to the connected video transmitter so the video can be sent down to on the ground for monitoring.

The video out connector is the video signal with the graphic/text data overlay. It can be connected directly to a TV monitor, DVR, or wireless video transmitter. Use the included male to male servo cable to connect the video out to a RangeVideo Aerial Video System transmitter.

Video Receiver. A video receiver is not included with the RVOSD. It will need a video receiver that operates on the same frequency as video transmitter. The video receiver will receive the transmitted video with RVOSD5 overlays. Connect the video receiver output to a video monitor to watch the video in real-time

Video Monitor. It will need a video monitor (not included with RVOSD5) to view the video being received by the video receiver.

Main Battery. The electric aircraft already has a battery to power the motor and electronics. The RVOSD5 and related components can use this existing battery as a power source. The Main Battery voltage and current can also be monitored and displayed on the OSD. A video transmitter and video camera can also be powered from the main battery via RVOSD5 connections.

Auxiliary Battery. The Auxiliary (Aux) Battery is optional and not included with the RVOSD5. The input range is 6-35 VDC [8].

7. Pixhawk Autopilot

PIXHAWK is a high-performance autopilot-on-module suitable for fixed wing, multi rotors, helicopters, cars, boats and any other robotic platform that can move. It is targeted towards high-end research, amateur and industry needs and combines the functionality of the PX4FMU + PXIO [9].

PX4 Autopilot. PX4 is platform independent autopilot software (or a software stack / firmware) that can fly or drive Unmanned Aerial or Ground Vehicles (UAV / UGV). It is loaded (flashed) on certain hardware and together with Ground Control Station it makes a fully autonomous autopilot system. PX4 ground control station is called QGroundControl and is integral part from the PX4 Autopilot System. QGroundControlcan run on Windows, OS X or Linux. With the help of QGroundControl it can load (flash) the PX4 on to the hardware, it can setup the vehicle, change different parameters, get real-time flight information and create and execute fully autonomous missions.

Today the PX4 Project and 3D Robotics announced Pixhawk — an advanced open-hardware autopilot design for multirotors, fixed-wing aircraft, ground rovers and amphibious vehicles. Pixhawk is designed for improved ease of use and reliability while offering unprecedented safety features compared to existing solutions.

Pixhawk is designed by the PX4 open-hardware project and manufactured by 3D Robotics. It features the latest processor and sensor technology from ST Microelectronics® which delivers incredible performance and reliability at low price points.

The flexible PX4 middleware running on the NuttX real-time operating system brings multithreading and the convenience of a Unix/Linux-like programming environment to the open-source autopilot domain. Advanced PX4 firmware layers ensure tight timing of operations and allow the addition of completely new functionalities like direct programmatic scripting of autopilot operations.

The flagship Pixhawk module will be accompanied by new peripheral options, including support for a digital airspeed sensor, external multi-color LED indicator and external magnetometer. All peripherals are automatically detected and configured.

PX4 is an open-source, open-hardware project aimed at providing a high-end autopilot to the academic, hobby and industrial communities at low costs with high availability. It is backed by volunteers of the Pixhawk Project hosted at the Computer Vision and Geometry Lab of ETH Zurich (Swiss Federal Institute of Technology) and supported by the Autonomous Systems Lab and the Automatic Control Laboratory of ETH as well several excellent individuals internationally.

3D Robotics is the leading open-source unmanned aerial vehicle technology company. It was founded in 2009 by Chris Anderson (founder of DIY Drones) and Jordi Muñoz. Today, 3D Robotics is a seasoned, venture-backed enterprise with more than 80 employees focused on delivering the most advanced, full-featured autonomous technologies at the most competitive prices.

3D Robotics and PX4 continue their partnership to mutually support the further development of the Pixhawk platform and provide all PX4 source code and hardware under BSD/Creative Commons licensing.

- Manufactured by 3D Robotics
- Aautopilot system designed by the PX4 open-hardware project
- Advanced 32 bit ARM Cortex® M4 Processor running NuttX RTOS

• 14 PWM/servo outputs (8 with failsafe and manual override, 6 auxiliary, high-power compatible)

• Abundant connectivity options for additional peripherals (UART, I2C, CAN)

• Integrated backup system for in-flight recovery and manual override with dedicated processor and stand-alone power supply

• Backup system integrates mixing, providing consistent autopilot and manual override mixing modes

• Redundant power supply inputs and automatic failover

• External safety button for easy motor activation

• Multicolor LED indicator

• High-power, multi-tone piezo audio indicator

• MicroSD card for long-time high-rate logging

Features

• 32 bit ARM Cortex® M4 Processor running NuttX RTOS;

• 14 PWM/servo outputs (8 with failsafe and manual override, 6 auxiliary, high-power compatible);

• Abundant connectivity options for additional peripherals (UART, I2C, CAN);

• Integrated backup system for in-flight recovery and manual override with dedicated processor and stand-alone power supply;

• Redundant power supply inputs and automatic failover;

• External safety switch;

• Multicolor LED visual indicator;

• High-power, multi-tone piezo audio indicator;

• microSD card for extended-time high-rate logging.

Specifications.

Microprocessor:

• 32-bit STM32F427 Cortex M4 core with FPU;

• 168 MHz/256 KB RAM/2 MB Flash;

• 32 bit STM32F103 failsafe co-processor.

Sensors:

• ST Micro L3GD20 3-axis 16-bit gyroscope;

• ST Micro LSM303D 3-axis 14-bit accelerometer / magnetometer;

• Invensense MPU 6000 3-axis accelerometer / gyroscope;

• MEAS MS5611 barometer.

Interfaces:

• 5x UART (serial ports), one high-power capable, 2x with HW flow control;

• 2x CAN;

- Spektrum DSM / DSM2 / DSM-X® Satellite compatible input up to DX8 (DX9 and above not supported);
- Futaba S.BUS® compatible input and output;
- PPM sum signal;
- RSSI (PWM or voltage) input;
- I2C®;
- SPI;
- 3.3 and 6.6V ADC inputs;
- External microUSB port.

Power System:

- Ideal diode controller with automatic failover;
- Servo rail high-power (7 V) and high-current ready;
- All peripheral outputs over-current protected, all inputs ESD protected.

Weight and Dimensions:

- Weight: 38g (1.31oz);
- Width: 50mm (1.96");
- Thickness: 15.5mm (.613");
- Length: 81.5mm (3.21").

Radio connections (range to 30km):

- Telemetry: 915 MHz;
- Digital video: 5.1-5.9 GHz [9].

8. Autopilots MNAV and Kestrel

Autopilot MNAV + Stargate has average size and not light enough for use on small ADO. Autopilot advantage of this is that the original software into the Linux open-friendly. In addition, Stargate is a powerful CPU and IO-ports MNAV Stargate and provide users with a great opportunity to install individual extensions.

Autopilot Procerus Kestrel has a much smaller size and weight that is acceptable for small ADO. Autopilot contains processor Rabbit 3000 with a frequency of 29 MHz, and a set of sensors, similar to the autopilot MNAV. All sensors are integrated with the processor, except for receiver GPS. In autopilot built to perform autonomous takeoff, landing and flight route, and provides pre-flight inspection of sensors. Autopilot algorithm is based on the traditional PID controller. Autopilot contains some controllers handlebar height, engine throttle and ailerons.

Autopilot provides automatic flight route as control points with three dimensions (latitude, length, height). Autopilot can use to ADO with bands such air speeds (km / h), the bottom 25 ... 150; normal 35 ... 250 the top 45 ... 450.

Apart from the autopilots, there are many commercial standard autopilots, such as the AP50 autopilot of UAV Flight Systems, 3400 the company UNAV autopilot, autopilot Microbot of Microbotics Inc. and others.

Mini ADO put strict requirements for autopilots for their physical size, weight and minimal power consumption. Comparison of these characteristics are given in Table 1. Information on the availability of sensors as parts of autopilots MNAV, Kestrel and MicroPilot are shown in Table 2.

Table 1

Specifications of autopilots

Parameter	MNAV	Kestrel	MicroPilot
Temperature, °C	-5 ... +45	-40 ... +85	–
The angular velocity, deg/s	±200	±300	±150
Acceleration, m/s2	±2	±10	±2
Magnetic induction, nT	±0,75	±1	–
Height, m	0 ... 5000	-13,7...3414	0 ... 12000
Air speed, mil/h	0 ... 180	0 ... 130	0 ... 311

Table 2

Comparing weight and dimensions performance and cost autopilots

Autopilot	Size, cm	Weight, g	Energy consumption	Cost, thous.doll.
MNAV	5.7×4.5×1.1	33	<0.8 W (5V)	1.5
Stargate	9.53×6.33×2.81	80.47	<500 mA	0.9
Kestrel 2.2	5.08×3.5×1.2	16.7	500 mA (3.3…5V)	5
MicroPilot	10×4×1.5	28	–	1.7…6
Piccolo LT	11.94×5.72×1.78	45	–	–
UNAV 3400	10.16×5.08×4.06	84	180 mA (5.5…7.5V)	5

Most commercial autopilots using PID regulators. Autopilot based PID controllers have a simple design and can easily be implemented to control the ADO. However, the autopilot is not optimal and have low reliability. In addition, some airplane mode settings PID controller can cause serious difficulties. Therefore, the current research is the application of modern methods of control theory for the synthesis of control laws ADO.

9. Development and production of integrated navigation system of unmanned aerial vehicles

Currently, the main and most common option is a navigation system UAV is the Inertial-Satellite Navigation System (ISNS), which is based Inertial System Platformless Type (ISPT). In ISPT sensors as the primary information used accelerometers and angular rate sensors. ISPT navigation systems are high, issuing evaluations of almost all parameters necessary for traffic control aircraft (components of linear and angular speeds, coordinates and orientation parameters) with high refresh rate information [10]. ISPT usually seen as the main source of navigation data and information coming from the receiver SNA, is used for correcting INS.

In evaluating parameters of spatial traffic of the aircraft should be aware that vertical channel INS unlike horizontal channels are structurally unstable, because it is no integrated contour correction. So usually expected to have an additional source of information – barometric altimeter that provides, first, linking the measurements to a reference level (to the average sea level), and secondly, a correction of this channel to restore the stability of the system.

Also note that in the SNA are no angular orientation, and ISPT error of course, as opposed to errors of calculation roll and pitch rapidly increasing. In this case, usually of the INS include magnetometer, which azimuthally adjusting channel ISPT, reduces error determination of the UAV.

So in addition to classic board sensors are more ISPT: magnetometer sensor and receiver static pressure, which provides the measuring barometric altitude. It is proposed to use these sensors to build an additional information system to improve reliability UAV flight navigation support.

Due to the different nature and different physical principles forming the navigation algorithm software ISPT and SNA well complement each other. Their sharing allows, on the one hand, to limit the increase in errors INS, and, on the other hand, to reduce the noise component errors SNA, increase the rate of delivery of information to consumers onboard, significantly raise the level of hurt-protection. But the real conditions of use Navigating consumers indicate that many gauges and, above all, the satellite radio navigation system, not always in working condition. In reality there is often failure tracking satellite signals, particularly because multi-beam action and other interference, and error signals capture etc.

In the article additional hardware devices without involving is proposed to create on the basis of existing equipment onboard the UAV navigation system that will support the work of SINS radio silence during the SNA, that is in turn ISSN integrated navigation system (INS). For truncated algorithms system of air signals, using information about the static and dynamic pressure, in addition to barometric altitude can be calculated true air speed.

Basically mode navigation system in calculators about the estimated components of the ground speed using the calculated value of the true air speed and the current rate is calculated and stored wind speed and direction. For short-range UAV flight parameters of the wind can be administered according to weather stations. Availability of information on the options wind allows aeromagnetic-metric calculation algorithm of navigation parameters.

To improve the reliability of measurements of angular orientations proposed use information not only on inertial system, but also from alternative sources not gyroscopic this information. Upon receipt of this information can be used magnetic-metric, aerodynamic, accelerate-metric measurement methods and pitch angles. The presence of additional flight and navigation information can significantly improve the reliability of the navigation software and the disappearance or noise signals SNS and continue further implementation of the flight mission, realizing inertial course-air method of infinite coordinates.

Thus, the main navigation tasks that will solve a navigation system is the problem of inertial and satellite navigation. The main mode of the complex is the mode of inertial-satellite navigation. The period of radio silence SNA complex moves to autonomous mode of inertial and aeromagnetic-metric systems [10, 11].

10. Automatic landing system of UAV

Tasks flight control automation is currently valid in connection with the global development of unmanned aircraft. The most responsible of all the list of tasks automation is the process of landing unmanned aircraft. Although you can find general information about individual achievements in this field in the world practice, however, this information does not include data on specific ways to solve this problem. The analysis of existing methods of planting the parameters guidance during the approach and landing. With the help of analytic geometry developed algorithms for calculating parameters guidance and control integrity. Based on algorithms developed software for mathematical modeling. To test the hypothesis to improve the accuracy of navigation based on an equipment navigation receivers leading manufacturers developed subsystem models and differential treatment for technology GBAS EGNOS [12, 13].

Requirements for the UAV landing systems.

According to the general concept of UAV flights should operate in accordance with the standards of ICAO, which are designed to fly with a pilot on board. Thus, UAVs, carrying out direct flights visibility must meet the requirements that apply to of systems communication, navigation and surveillance in the airspace.

According to the navigation strategy states of the European Conference on Civil Aviation for the European region has further development:

- gradual extension of area navigation (RNAV);
- heavy use of GNSS navigation;
- gradual decommissioning of navigational aids NDB and VOR.

The most promising landing UAV systems should be considered landing system using area navigation and satellite navigation systems, as evidenced navigation strategy states of the European Conference on Civil Aviation, which involves increasing the accuracy of satellite landing the third category (GBAS Cat I/II/III).

It should be noted that the use of GNSS and RNAV involve the use of algorithms receiver autonomous integrity monitoring (RAIM or FDE). In order to meet a specified level of continuity of operation should apply a system of functional additions: GBAS and / or SBAS with ABAS. When landing using GNSS must perform separate RAIM - forecast. Application of GNSS systems, along with functional supplement allows you to perform operations on the basis of appropriate type RNP.

The base receiver GNSS must comply to the requirements of Volume 1 Annex 10 ICAO and specifications RTCA DO-208 (Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System) and EUROCAE ED-72A (MOPS for Airborne GPS Receiving Equipment used for Supplemental Means of Navigation) with amendments TSO-C129A (Airborne Supplemental Navigation Equipment Using the Global Positioning System). These documents define the minimum requirements to be met by the receiver GNSS (integrity control, prevent reversals, the use of electronic navigation data bases).

The board equipment SBAS must comply to the requirements of Volume 1 Annex 10 ICAO and specifications RTCA DO-229C (Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment).

Standards for SBAS avionics features include three levels of approach:

- LPV (the approach beacon on the course with a vertical input);
- LNAV/VNAV (side / vertical navigation);
- LNAV (side navigation).

There are four separate classes onboard equipment SBAS. Different classes of equipment provide different functionality. Minimum functionality is Class I. This equipment provides flights on routes near the airfield and landing LNAV. Class II SBAS equipment in a position to Class I and provides Approaches LNAV / VNAV. Class III and IV has the capabilities of the hardware and Class II SBAS provides Approaches LPV.

Basic requirements for SBAS equipment onboard during landing formulated as follows. Board equipment SBAS calculates the exact location and provide information about the integrity of the calculated provision for this type of approach. The required level of integrity for each of the types of approaches specific set alarm thresholds in the horizontal and vertical planes, called HAL and VAL. These thresholds similar control limits for ILS. These alarm thresholds form a region of maximum error that meets the requirements of integrity for this type of approach.

SBAS-board equipment ensures the integrity of information intended location for this type of approach via continuous calculation of levels of protection in the horizontal and vertical planes (HPL and VPL) and comparing the calculated values according to HAL and VAL. If HPL or VPL exceeds the limits alarm (HAL or VAL) for a specific type of approach, the pilot warned of the need to interrupt at this point performed the operation. The pilot takes only warning and does not perform the function of monitoring VPL or HPL.

The board equipment GBAS must comply to the requirements of Volume 1 Annex 10 ICAO and specifications RTCA DO-253A (Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment) and DO-246B (GNSS Based Precision Approach Local Area Augmentation System Signal-in-Space Interface Control Document).

At minimum requirements for onboard equipment GBAS no provisions relating to RNAV. GBAS can produce vector position, velocity and time (PVT). In cases where the GBAS ground station provided this service, it is called GBAS service to determine the location. PVT vector is intended for introduction into an existing board navigation equipment. However, the requirements for RNAV equipment computer equipment available. No demand and to provide onboard equipment GBAS pointing out at the second round. Minimum display functionality similar to ILS deviations and provide an indication of the rate indication deviation in the vertical plane, about the distance to the runway threshold and flags signaling failures. With no navigation equipment on board the pilot not provided information on the spatial position of the PC. Its provided only information that provides guidance for the course and glideslope on final approach phase.

Monitoring the integrity of navigation information performs receiver GNSS, using RAIM function.

UAV, equipped with facilities multisensory RNAV, can and using sensors monitoring the integrity of GNSS, with built-in algorithm RAIM. The implementation RAIM integrity monitoring functions based only on satellite signals. Interruptions RAIM may occur due to insufficient number of satellites or their unfavorable location, which leads to a very large error determining spatial position. The loss of the satellite signal and a warning given by the RAIM, may also occur due to traffic. Installation antennas for UAV, satellite positions relative to the horizon and spatial position UAV can affect reception of signals of one or more satellites. Since the relative position of the satellites are constantly changing, resulting in this airport's previous experience does not guarantee the sustainability of signal reception, and in this regard should always check the readiness RAIM. In the absence of minimal conditions for RAIM must use a different type of navigation and approach, choose another destination or delay the flight until as predicted will be provided willingness to RAIM the arrival. In carrying out long flights should provide pilots during flight of revalidation RAIM prediction of destination. It can advance to obtain information that after takeoff, there was an unexpected break in satellite signal. Interruptions in readiness mode RAIM approach will have a greater frequency compared with the flight route as a result of more stringent threshold alarm. Since factors such as spatial position and UAV antenna location may affect reception of signals from one or more satellites, and also due to unplanned outages satellites willingness to RAIM predictions can not be 100% accurate.

GNSS receiver has three modes: the flight route, flight in the terminal area and approach mode. Limits RAIM alarm automatically brought into line with the modes of the receiver and are ± 3,7 km (2,0 m. Mile) route mode, ± 1,9 km (1,0 m. Miles) area of the airfield mode and ± 0.6 km (0.3 m. miles) mode precision approach.

Sensitivity indicator deviation Exchange automatically consistent with the mode of operation of the receiver. Sensitivity is: ± 9,3 km (0,5 m. Mile) route mode, ± 1,9 km (1,0 m. Miles) area of the airfield mode and ± 0,6 km (0,3 m. Miles) mode approach.

Approach on GNSS traditional event like the landing and is a flight with guidance on appropriate terms and is independent from any terrestrial navigation aids, except accurate approach in which the use GBAS.

The following are excerpts from the Doc. 8186, describing the features of the implementation approach for satellite navigation systems.

Approach can be performed if the database onboard equipment:

- includes all points the way indicated in the diagram future approach;
- presents them in the same order in which they are marked on the map scheme;
- contains updated information for the current AIRAC cycle.

To ensure the accuracy of mapping databases GNSS pilots should check the admissibility of data displayed for an approach based on GNSS after loading scheme in the current flight plan and flight performance under this scheme.

The main modes and functions of the system's hardware landing UAV, turn on and initialization, the creation of-flight (FPL), navigation (NAV), the choice of types of navigation points procedures (WPT), calculation (CALC), enter additional information (AUX), the approach (APP) [12, 13].

11. Automated system for optimal control of remotely controlled aircraft system

The main requirement is that the current development of aviation technology refers to traffic control facilities for different purposes, is the greatest attainable accuracy of the object it designated traffics in each normal mode of operation. That object precision traffics necessary quality control is the equivalent of the specified object and determines its level of competitiveness of the developed or the modernizes my moving object. How to view moving objects of aircrafts (airplanes, missiles, unmanned aerial vehicles, etc.), various ground transport tools and moving simulators and training devices, which are equipped with the above items [14].

The successful use of unmanned aerial aircraft is extremely important so-called stabilization modes. In the process of stabilizing one of the basic and complex types of motion control, object held in the space in a state close to the set for a sufficiently long time. When given of the facility means a series of software components values of the state vector object. These components can be not only constant, but also deterministic or random functions of time with known statistical characteristics. Automated tools that keep the object in a state close to the set (software) called Stability and they're the regulators that are normally in the feedback to stabilize the object. When the program is a function of time, the system of "object-regulator" called tracking system. Typically, the formation of law stabilization using only information about the current and / or past state of the object. This mode is called stabilization system for deviation. When in the formation of law stabilization using, in addition, information on external disturbing factors act to stabilize the facility, then it is for the stabilization and disturbance rejection.

Stability intended, first, to ensure the stability of the system "object-regulator" with unstable or no-minimum-phase facility, and, secondly, to parry the impact of disturbing factors and obstacles that are in the loop stabilization . Disturbing factors and disturbances in the circuit are stabilizing as deterministic and random. In many cases, the impact of deterministic factors may fully compensate, for example, from the standpoint of the theory of invariance.

Linear stochastic optimal control stand-simulator known traffics can be solved as the problem of multidimensional dynamic stabilization facility taking into account only random measurements in famous productions using the so-called theorem section and without. The task of designing analytical and objectives of sustainable stabilization facility at the disturbance of the "white noise" and perfect measurement vector of the facility are identical. However, the task of stabilization allows you to get the best solutions for arbitrary dynamic properties of the object, but also take into account interference and perturbation measurements.

In practical formulation of the problem of synthesis of stabilizing traffics UAV must also take into account the fact that the waste traffic UAV created not only the initial conditions of work, but also deterministic and random disturbances constantly acting on the UAV in flight, deterministic and random obstacle of measurement conditions UAV. Such measurements are often incomplete and facilities management systems or meters can be volatile. Often management system moving objects that are being developed, and to include the so-called adaptation contours [14].

Thus, the problem of ensuring efficiency, safety, regularity and quality of UAV flight accompanied by major scientific and technical challenge. One of the main ways to solve this problem, obviously, is full automation of mission control. The accuracy depends on the quality control tasks on flights performed. In many cases of practical importance the concept of "accuracy" can be the equivalent of the concept of "quality" and the accuracy rate system could be a criterion of quality. For example, the average square error criterion adopted to determine the quality mode navigation and stabilization of different types of UAV flight.

Thus, the problem of maximizing precision motion control is one of the basic side problems of efficiency, safety, regularity and quality of flights and can be solved in a complex where motion control is optimal for accuracy, the impact of disturbing factors and quality control will be constantly assessed a special board system and using a special system update (adaptation) quality is maintained at extreme values.

Performance Based Navigation Area navigation (RNAV) is a method of Instrument Flight Rules (IFR) navigation that allows an aircraft to choose any course within a network of navigation beacons, rather than navigating directly to and from the beacons. This can conserve flight distance, reduce congestion, and allow flights into airports without beacons. RNAV began as a means of navigation on a flight path from any point, or fix, to another. These fixes could be defined by a latitude and longitude, and an airplane's position relative to them could be established using a variety of navaids. RNAV facilitated a type of flight operation and navigation in which the flight path no longer had to be tied directly to overflight of ground navigation stations. Performance Based Navigation concept specifies that aircraft RNAV system performance requirements be defined in terms of accuracy, integrity, availability, continuity and functionality required for the proposed operations in the context of a particular airspace concept, when supported by the appropriate navigation infrastructure. Performance Based Navigation concept identifies three components: – the NAVAID Infrastructure; – the Navigation Specification; – the Navigation Application [15].

European aviation community is currently looking for the right steps in order to increase airspace capacity and airspace flexibility along with enhancement of operator's efficiency.

12. Conclusions

Based on the provisions set a prototype integrated avionics for ADO navigation and control synergistic with current approaches has been developing [16, 17].

The further implementation of scientific research and development work activities include such tasks:

1. Improve existing and develop new concepts and methods of system integration of avionics ADO for solving navigation and synergistic management, namely:

- to develop a new compensation invariant concept and method for combining primary sources of information in an integrated ADO avionics;
- to develop new methods for complex correlation-extreme ADO navigation;
- to develop a new concept of synergistic motion control ADO formations;
- to improve energy-potential method guaranteed solution of poly-conflict dynamic objects for solving synergistic control ADO formations;
- to improve methods of ensuring reliability ADO avionics;
- to improve methods of communication and information transfer between elements ADO avionics.

2. To develop algorithmic software integrated ADO avionics, namely:

- algorithms implementing basic operations invariant compensation scheme combining treatments based on nonlinear filtering theory and sensitivity;
- allocation algorithms characteristics of real-time and their comparison with the standards;
- algorithms for tracking target image characteristics of the video sequence;
- processing algorithms compatible data inertial navigation system and the correlation extreme navigation system using nonlinear models and Gaussian filter point.

3. To create a prototype integrated avionics ADO and evaluate the effectiveness of the its operation in a high probability of operational and intentional failures, the suppression of radio subsystems.

In the course of further work must be obtained new results:

- invariant compensation concept and method for combining primary sources of information in an ADO integrated avionics;
- complex methods of correlation-extreme ADO navigation;
- concept synergistic traffic control ADO formations;
- advanced ENERGY-potential method guaranteed solution of poly-conflict dynamic objects for solving synergistic control ADO formations;
- improved methods of ensuring reliability ADO avionics;
- improved methods of communication and information transfer between elements ADO avionics;
- algorithms implementing basic operations invariant compensation scheme combining treatments based on nonlinear filtering theory and sensitivity;
- mapping algorithms base reference surface and image processing methodology for the selection of the characteristics, the characteristics allocation algorithms in real time and their comparison with standard algorithms for tracking target image characteristics of the video sequence;
- methodology compatible data processing inertial navigation system and the correlation extreme navigation system using nonlinear models and Gaussian filter point;
- assessment methodology required amount of computation depending on hardware configuration ADO avionics;

- method of improving reliability models integrated ADO avionics;
- algorithms of systems connection between ADO elements avionics;
- axioms and laws synergistic motion control in a single ADO limited navigation environment;
- stand for ADO avionics testing;
- testing methods elements integrated avionics ADO, methods of testing complex integrated avionics ADO, methods of evaluating the effectiveness of the proposed compensation invariant concept of integration of navigational aids ADO, methods of assessing the effectiveness of laws synergistic management of extreme correlation navigation system of channels that are resistant to intentional interference.

References

[1] Kharchenko V., Prusov D. Basic principles for the modern classification of unmanned aviation systems. *Proceedings of National Aviation University*, 2012, vol. 4 (53), pp. 5-12.

[2] Kharchenko V., Prusov D. Analysis of unmanned aircraft systems application in the civil field. *Transport*, 2012, vol. 27 (3), pp. 335-343. (http://dx.doi.org/10.3846/16484142.2012.721395)

[3] Kharchenko V., Chepizhenko V., Pavlova S., Wang Bo. Innovative concept of synergetic air traffic management under polyconflicts. *Aviation*, 2014, vol. 18, iss. 4, pp. 185-192.

[4] Kharchenko V., Chepizhenko V., Pavlova S., Tunick A. *Avionika bezpilotnykh litalnykh aparativ: Monohrafiia* [Avionics of Unmanned Aerial Vehicles: Monograph]. Kyiv: Abris-print, 2012, 506 p. (in Ukrainian).

[5] Kharchenko V., Kuzmenko N., Mykhatsky O., Savchenko O. Experimental unmanned aerial vehicle flight data measurement and their post-processing analysis. *Proceedings of the National Aviation University*, 2014, vol. 1 (58), pp. 11–16. doi: 10.18372/2306-1472.58.6632

[6] Paramonov, P., Zharinov I. Integrated Onboard Computing Systems: Review of Current Status and Analysis of the Development Prospects of the Aviation Instrument. *Scientific and Technical Messenger of Information Technologies, Mechanics and Optics*, 2013, vol. 2 (84), pp. 1-17.

[7] A family of lightweight UAV autopilots of MicroPilot. Available at: https://www.micropilot.com

[8] *RVOSD6 Autopilot & Telemetry*. Available at: http://www.rangevideo.com/rvosd/117-rvosd6-autopilot-telemetry-lrs.html

[9] *Pixhawk advanced open-hardware autopilot*. Available at: https://3dr.com/px4-and-3d-robotics-announce-pixhawk/

[10] Zakharin, F., Samoylenko, O., Karnaukh, T. Metodolohichni aspekty unifikatsii intehrovanyh inertsyalno-suputnykovi navihatsiini systemy dlia litakiv obiektiv [Methodological Aspects of Unification Integrated Inertial-Satellite Navigation Systems for Aircraft Objects]. *Proceedings of Scientific Works. State Research Institute of Aviation*, 2012, vol. 8(15). pp. 59-64. (in Ukrainian).

[11] Filyashkin M., Mukhina M. Gyro-accelerometric method of determination of angular orientation parameters. *Proceedings of Scientific Works. Systems of control, navigation and communication*, 2014, vol. 2 (30), pp. 45-52.

[12] Konin V., Shyshkov F. European Geostationary Navigation Overlay Service in Ukraine. *Proceedings of the National Aviation University*, 2015, vol. 2 (63), pp. 23-26. doi: 10.18372/2306-1472.63.8829)

[13] Konin V., Pogurelsky A. Investigation the Positioning Accuracy with Minimum Combined GPS and GLONASS Configurations. *Proceedings of the Engineering Academy of Ukraine*, 2011, vol. 1, pp. 35-39.

[14] Azarskov V., Blokhin L., Ermolaeva O. Structure Identification of Non-Linear System "Moving Object and Servo Drive" under Stochastic Disturbances. *Proceedings of the National Aviation University*, 2015, vol. 4 (65), pp. 34-41. doi: 10.18372/2306-1472.65.9818

[15] Pavlova S., Zadorozhnia A. Analysis of free route airspace and performance based navigation implementation in the European air navigation system. *Proceedings of the National Aviation University*, 2014, vol. 4 (61), pp. 20-31. doi: 10.18372/2306-1472.61.7583)

[16] *Implementing of the Performance Based Navigation*. Ukraine strategy and roadmap 2013-2015. Kyiv, 2013.

[17] *European Airspace Concept Handbook for PBN Implementation*. EUROCONTROL. Ed. 3. 2013.

Received 20 November 2016

Д.Е. Прусов[1], М.П. Матійчик[2], О.Ю. Михацький[3]

Порівняльний аналіз зразків авіоніки і їх компонентів стосовно до створення методології синтезу інтегрованої авіоніки БПЛА

Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03058.
E-mails: [1]prusov@nau.edu.ua; [2,3]nvcba@nau.edu.ua

Мета: Метою цієї роботи є аналіз зразків авіоніки та їхніх компонентів з огляду на створення методології синтезу інтегрованої авіоніки дистанційно-пілотованих та безпілотних аерокосмічних динамічних об'єктів (АДО), яка забезпечує комплексне розв'язання завдань навігації та синергетичного управління АДО в аеронавігаційному просторі. **Методи дослідження:** Аналіз та постановка завдань є основою для розробки сучасних методів комплексування та обробки первинної інформації, методів розв'язання навігаційних задач, методів розв'язання задач керування в комплексах інтегрованої авіоніки АДО. Зокрема це неінваріантний компенсаційний метод комплексування первинних джерел інформації, комплексні методи кореляційно-екстремальної навігації, метод синергетичного управління АДО. **Результати:** Використання цих методів дозволить підвищити ефективність вирішення задач навігації і управління як цивільних так і військових АДО, в умовах дії випадкових і навмисних завад, при відмовах елементів авіоніки. **Обговорення:** Виходячи з наведеного аналізу, можна встановити вимоги до прототипів інтегрованої авіоніки, що розробляється для навігації і управління АДО.

Ключові слова: безпілотні літальні апарати; інтегрована система авіоніки; навігація і управління.

Д.Э. Прусов[1], М.П. Матийчик[2], А.Ю. Михацкий[3]

Сравнительный анализ образцов авионики и их компонентов применительно к созданию методологии синтеза интегрированной авионики БПЛА.

Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03058.
E-mails: [1]prusov@nau.edu.ua; [2,3]nvcba@nau.edu.ua

Цель: Работа посвящена анализу образцов авионики и их компонентов с учетом создания методологии синтеза интегрированной авионики дистанционно-пилотируемых и беспилотных аэрокосмических динамических объектов (АДО), которая обеспечивает комплексное решение задач навигации и синергетического управлиния АДО в аэронавигационных пространстве. **Методы исследования:** Анализ и постановка задач является основой для разработки современных методов комплексирования и обработки первичной информации, методов решения навигационных задач, методов решения задач управления в комплексах интегрированной авионики АДО. В частности это неинвариантны компенсационный метод комплексирования первичных источников информации, комплексные методы корреляционно-экстремальной навигации, метод синергетического управления АДО. **Результаты:** Использование этих методов позволит повысить эффективность решения задач навигации и управления как гражданских так и военных АДО, в условиях действия случайных и преднамеренных помех, при отказах элементов авионики. **Обсуждение:** Исходя из приведенного анализа можно установить требования к прототипам интегрированной авионики, разрабатываемой для навигации и управления АДО.

Ключевые слова: беспилотные летательные аппараты; интегрированная система авионики; навигация и управление.

Prusov Dmitry. Doctor of Technical Sciences (Prof.Dr.Habil.Eng.), Associate Professor.
Senior Research Analyst,, Scientific Research Administration, National Aviation University, Kyiv, Ukraine.
Education: Kyiv National University of Construction and Architecture (1997).
Research area: Development the new concepts, creation of theoretical principles and new methodologies for objects research and processes mathematical modeling.
Publications: 121.
E-mail: prusov@nau.edu.ua

Matiychyk Mykhailo. Candidate of Technical Sciences (Ph.D.), Associate Professor.
Director of the Scientific and Production Center of Unmanned Aviation "Virazh".
Education: Ternopil National Technical University (1985).
Research area: development and designing of modern competitive unmanned aerial vehicles and unmanned aircraft systems.
Publications: 71.
E-mail: nvcba@nau.edu.ua

Mykhatskyi Oleksiy. Candidate of Technical Sciences (Ph.D.). Senior Researcher.
Senior designer of the Scientific and Production Center of Unmanned Aviation "Virazh".
Education: The National Technical University of Ukraine "Kyiv Polytechnic Institute" (1985).
Research area: development and designing of modern competitive unmanned aerial vehicles and unmanned aircraft systems.
Publications: 50.
E-mail: nvcba@nau.edu.ua