



PROBLEMS OF SAFE AIRSPACE USAGE BY PILOTED AND REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS)

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Addressing **unmanned aviation**

ICAO is providing the **fundamental international regulatory framework** to underpin routine operation of UAS throughout the world in **a safe, harmonized and seamless manner comparable to that of manned operations.**



Concepts of certification, standardization and regulation of unmanned aircraft flights at the level of international governmental and nongovernmental organizations are developing within the **European RPAS Roadmap framework** (UVS, 2013).



The **safe integration** of RPAS into **non-segregated** airspace will be **impossible without new technologies for detecting and avoiding systems and frequency spectrum protection** from unintentional or unlawful interference.



**INTEGRATED APPROACH
TO THE RPAS
DEVELOPMENT
AT THE NATIONAL
AVIATION UNIVERSITY**



**The National Aviation University
(the UVS International Member)
was **one of the first** institutions in
Ukraine, which drew attention to
the use of RPAS for civil purposes.**



1

DESIGN AND PRODUCTION THE UNMANNED AERIAL VEHICLE (UAV)

In the **Research and Production Center of Unmanned Aviation "Virage"** at the National Aviation University the **line of domestic UAVs have been developed:** *one-engine M-3 "Border", M-6 "Skylark"; two-engine M-7, M-7D, M-7B5 "Sky Patrol" drones and UAV with an electric motor "Eye".*

Problems connected with integration, search, recognition, processing of satellite tracking, navigation and UAV-onboard avionics **were solved.**



UAV M-7B5 «Sky Patrol»

Purpose: designed for aerial photography, real-time video surveillance, patrolling line objects, and perform other types of aerial work including over populated areas.



Technical Characteristics:

Wingspan – 6.0 m;

Weight of special purpose load – up to 70 kg;

Launch weight – up to 200 kg;

Top speed – 250 km/h;

Engine power – 2 x 17 kW;

High flight altitude – up to 3000 m;

Method of launch and landing – as an aircraft;

Deployment time in the working position – 0.5 h;

Maximum take-off weight – 200 kg;

Empty weight – 100 kg;

Cruising speed – 200 km/h;

High flight altitude – 3000 m.

Variants according the special purpose load:

Weight of special purpose load – 70 kg / 20 kg;

Fuel weight – 30 kg / 80 kg;

Flight time – 5 hours / 14 hours;

The route distance – 1000 km / 2800 km.



UAV M-7D «Sky Patrol»

Purpose: mapping and aerial photography, real-time video surveillance, patrolling line objects and areas.



Technical Characteristics:

Wingspan – 5.1 m;
Weight of special purpose load – up to 55 kg;
Launch weight – up to 150 kg;
Top speed – 190 km/h;
Engine power – 2 x 12 kW;
High flight altitude – up to 2500 m;
Method of launch and landing – as an aircraft;
Deployment time in the working position – 0.5
Maximum take-off weight – 150 kg;
Empty weight – 80 kg;
Cruising speed – 190 km/h;
High flight altitude – 2500 m.



Variants according the special purpose load:

Weight of special purpose load – 55 kg / 20 kg;
Fuel weight – 15 kg / 50 kg;
Flight time – 3 hours / 10 hours;
The route distance – 450 km / 1500 km.



UAV M-6 "Skylarc"

Purpose: mapping and aerial photography (M-6K), real-time video surveillance (M-6P), patrolling line objects and areas (M-6CX).



Technical Characteristics:

Wingspan, – 1,6 m;

Weight of special purpose load – up to 7 kg;

Launch weight – up to 12 kg;

Engine power – 1,7 kW;

Top speed – 150 km/h;

Max. processing performance – 40 hectare/hour;

High flight altitude – up to 1000 m;

Method of launch – catapult;

Method of landing – aircraft / parachute.

Electric version:

Maximum take-off weight – 7.0 kg;

Empty weight – 5.2 kg;

Weight of special purpose load – 1.8 kg;

Flight time – up to 1 hour;

The route distance – 80 km;

Cruising speed – 80 km/h;

High flight altitude – 300 m;

Engine take-off power – 2,55 kW.

Petrol version:

Maximum take-off weight – 12.0 kg;

Empty weight – 5.5 kg;

Cruising speed – 110 km/h;

High flight altitude – 300 m;

Engine take-off power – 2.79 kW;

Fuel flow rate – 0.51 kg/h.



UAV M-10 "Eye"

Purpose: real-time video surveillance, patrolling the line objects and areas, the small objects security, the situation in small territories monitoring.



Technical Characteristics:

Maximum take-off weight – 3 kg;

Empty weight – 1.3 kg;

Cruising speed – 60 km/h;

High flight altitude – 300 m.

Variants according the special purpose load:

Weight of special purpose load – 1.5 kg / 1.3 kg;

Battery weight – 0.19 kg / 0.38 kg;

Flight time – 45 min / 1.5 hours;

The route distance – 45 km / 90 km.



UAV M-22 "Aerotester"

Purpose: practice training for external pilots; "flying laboratory".



Technical Characteristics:

Wingspan – 2.5 m;

Weight of special purpose load – up to 8 kg;

Launch weight – up to 18 kg;

Top speed – 120 km/h;

Engine power – 2.7 kW;

High flight altitude – up to 2000 m;

Method of launch and landing – as an aircraft;

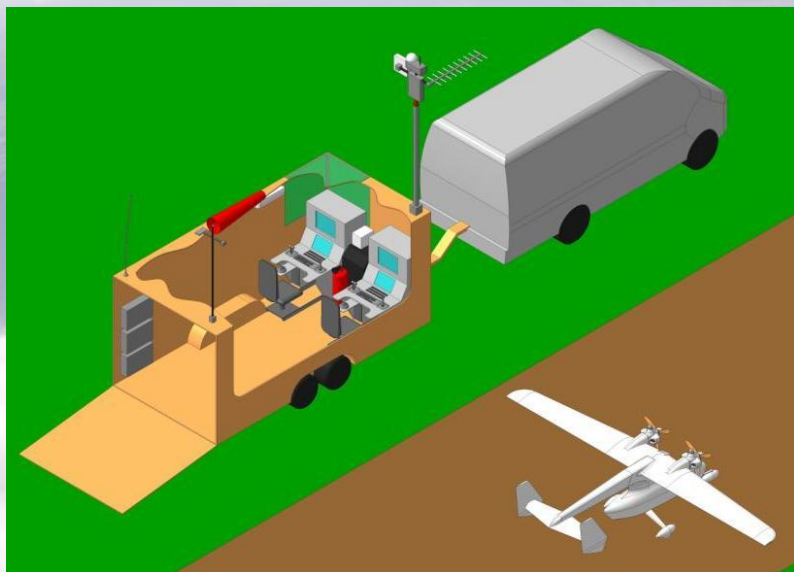
Deployment time in the working position – 0.5 h.



Remotely piloted aircraft systems (RPAS) "Ukraine"

Function: mission assurance of the twin-engine aircraft M-7B5 "Sky Patrol" in a dedicated airspace to perform aerial work in the interests of the economy and national defense. Served by ALS "Ukraine" outside a crew of at least four persons.

RPAS based on the UAV M-7B5 "Sky Patrol" structurally consists of the one UAV M-7B5 on the trailer-platform in the container; and one land control station (HCK-1-7B5) on the trailer.

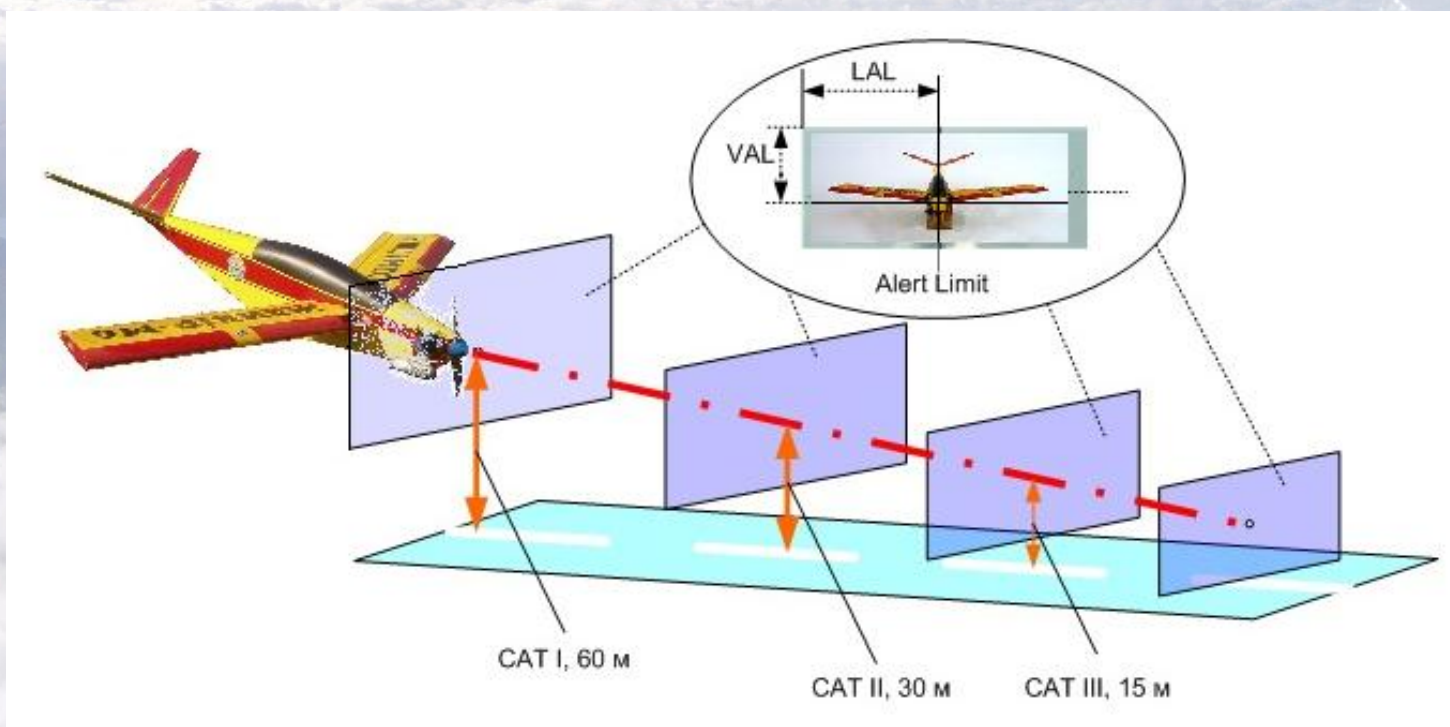




2

CREATION OF THE AUTOMATED SYSTEM FOR UAV LANDING

Methods and algorithms were developed and implemented for the **automation of UAV landing** using network signals of orbiting satellite systems.

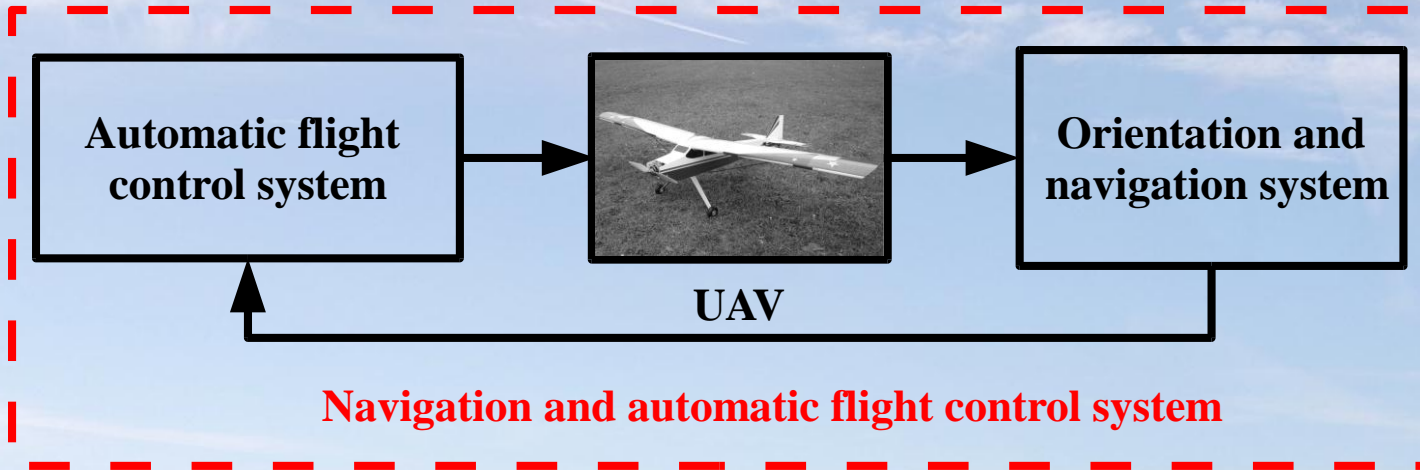




3

INTEGRATED NAVIGATION AND AUTOMATIC FLIGHT CONTROL SYSTEMS

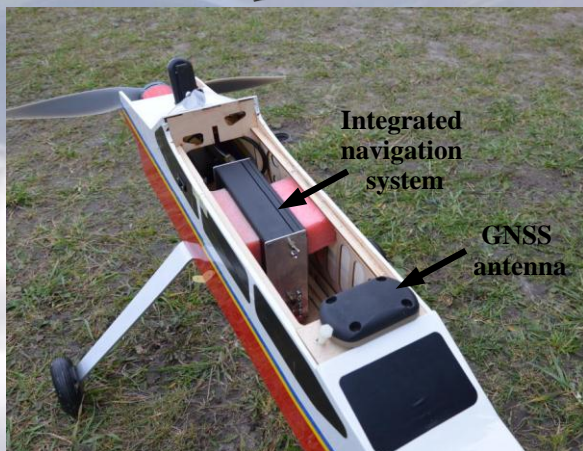
The **Scientific and Education Center**
"Aerospace Center" performs researches and
practical implementations of **global navigation**
satellite systems, information technology,
RPAS navigation and automatic flight control
systems.



The prototype of Integrated GPS/INS navigation system was created and implemented

Orientation angles (Range: roll $\pm 180^\circ$, pitch $\pm 90^\circ$, yaw $0^\circ \dots 360^\circ$;
Accuracy: roll, pitch – 0.5 - 1° ; yaw – 0.5 - 2°);

- **Ground speed** (Range: 0...400 m/s; Accuracy – 0.1 m/s);
- **Coordinates** (Accuracy: 5 m, depends on GNSS availability);
- **Angular Velocities** (Range: $\pm 450^\circ/s$; Accuracy: 0.16 $^\circ/s$);
- **Linear Accelerations** (Range: $\pm 18, \pm 10$ g; Accuracy: 1.5 mg);
- **Barometric height** (Range: 0...3500 m; Accuracy: 3 m);
- **UTC-time.**



Automatic en-route flight

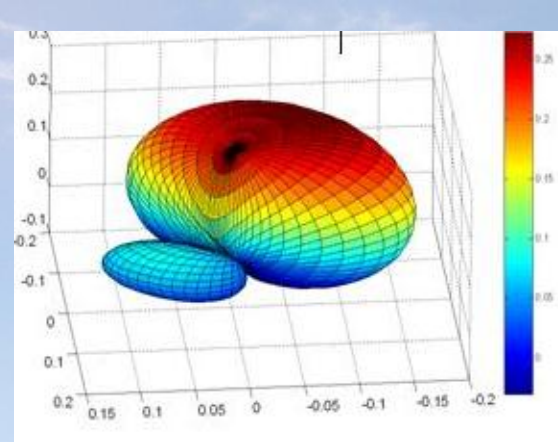
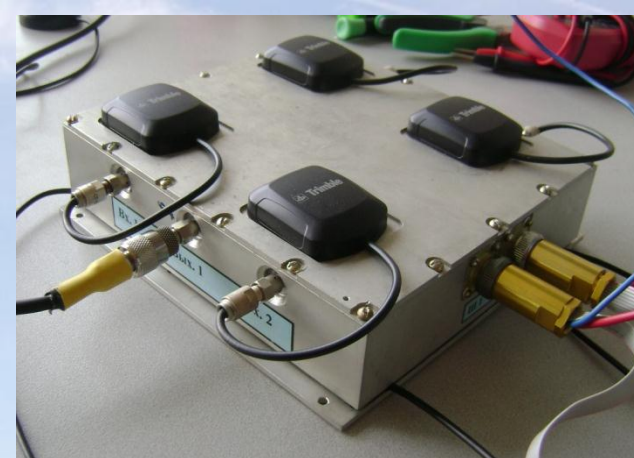
Automatic flight control system

allows:

- to perform automatic stabilization of UAV angular position regarding three main axes;
- automatic stabilization of UAV altitude;
- automatic stabilization and control of UAV flight true airspeed through the engine throttles control;
- to perform automatic en-route flight through the set of waypoints;
- to restrict the dangerous conditions of UAVs flight;
- to improve the stability and controllability characteristics of UAV;
- to record and transmit navigation and telemetry data through the radio-channel to the ground control station;



**Integrated GPS/INS
navigation system and
Automatic flight control
system
equipment**

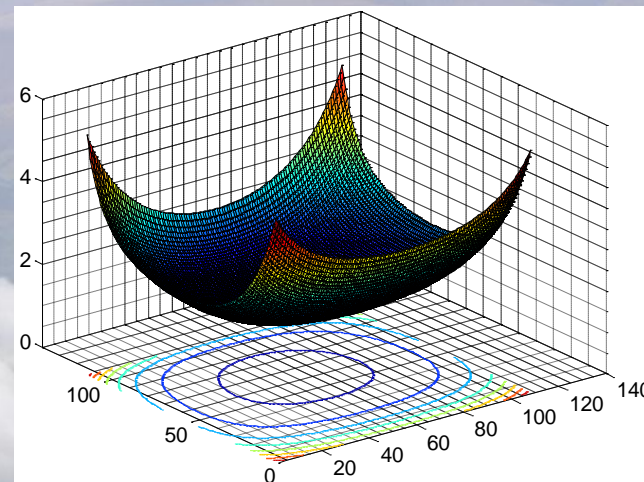


The prototype of adaptive antenna array

for **antijamming** in global navigation satellite system equipment provides the **possibility of excluding the jammed signal** and thus receiving reliable and accurate navigation solution

Automatic forecasting system of GNSS availability

This system allows to **plan optimal flight route** on the basis of predicted data of GNSS availability for solution of navigation task



Navigation field monitoring system

Base station



Antennas

According the Order from 28.08.2013 № 650 of the Cabinet of Ministers of Ukraine, the scientific object “**Global navigation satellite systems experimental monitoring complex of National Aviation University**” is in Ukrainian State register of objects that are National inheritance.

It allows:

- **monitoring** of satellite radio navigation systems (**GPS, EGNOS, GLONASS**) navigation field;
- **analysis** of GNSS quality characteristics (accuracy, integrity, availability, continuity);
- providing **differential mode of GNSS**;



HARDWARE-SOFTWARE COMPLEX FOR SPECIAL MOVING VEHICLES MONITORING AND CONTROL

**Traffic
controller
workstation**



**Airborne
equipment**

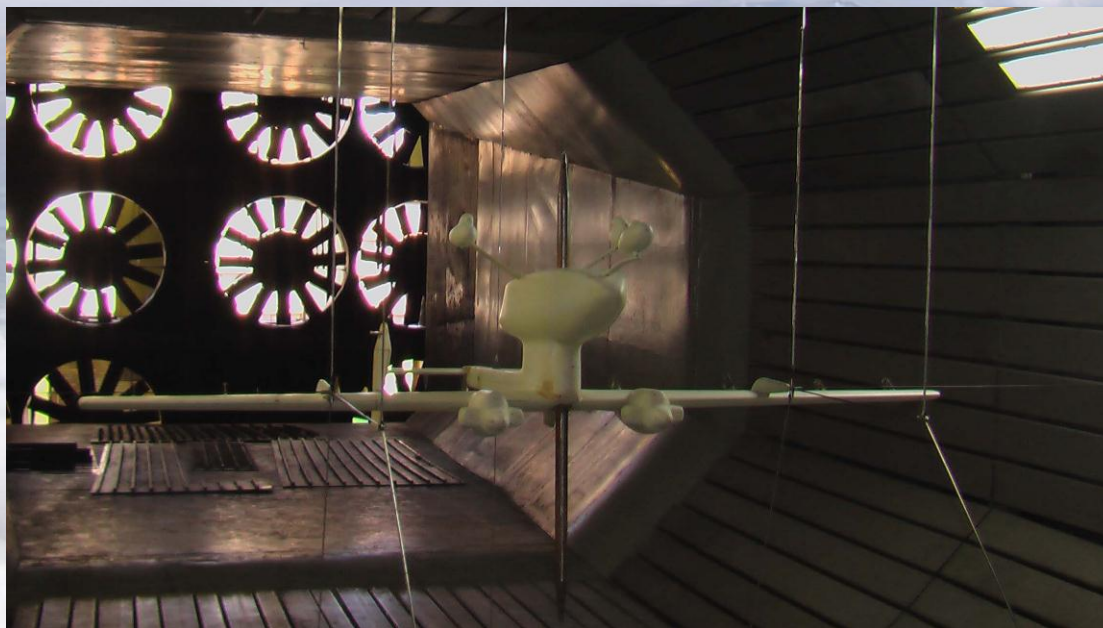
**This complex provides tracking of vehicles and other
moving objects of special destination in real time**



4

AEROMECHANICS AND UNMANNED AIRCRAFTS FLIGHT CHARACTERISTICS

Calculations of **longitudinal and lateral stability characteristics and limit parameters** of operational flights safe modes were realized.

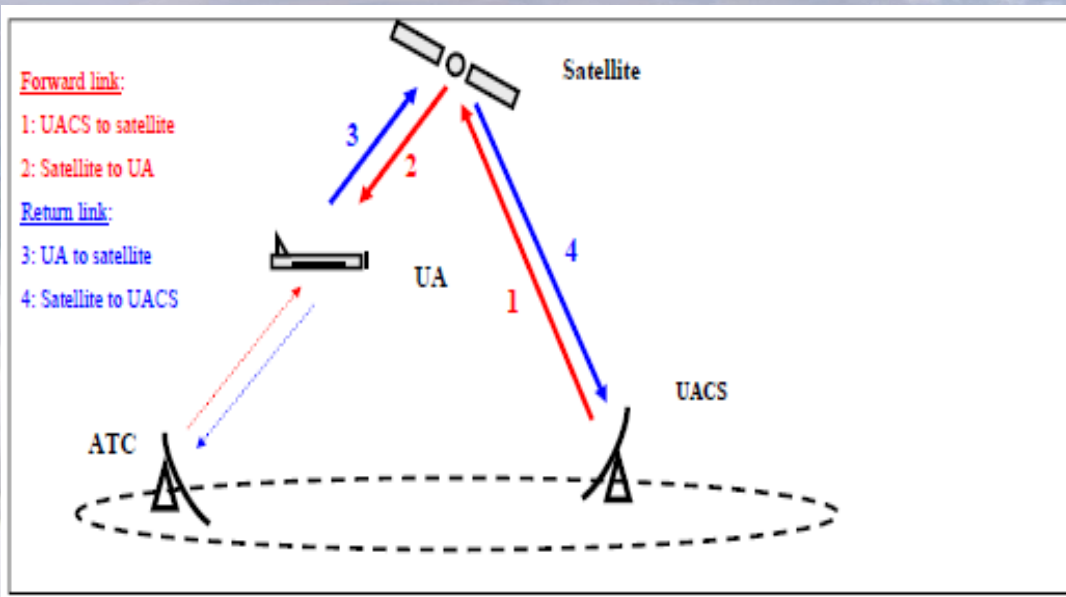




5

SECURE TRANSMISSION OF RADIO-TELEMETRY DATA AND VIDEO-SURVEILLANCE EQUIPMENT

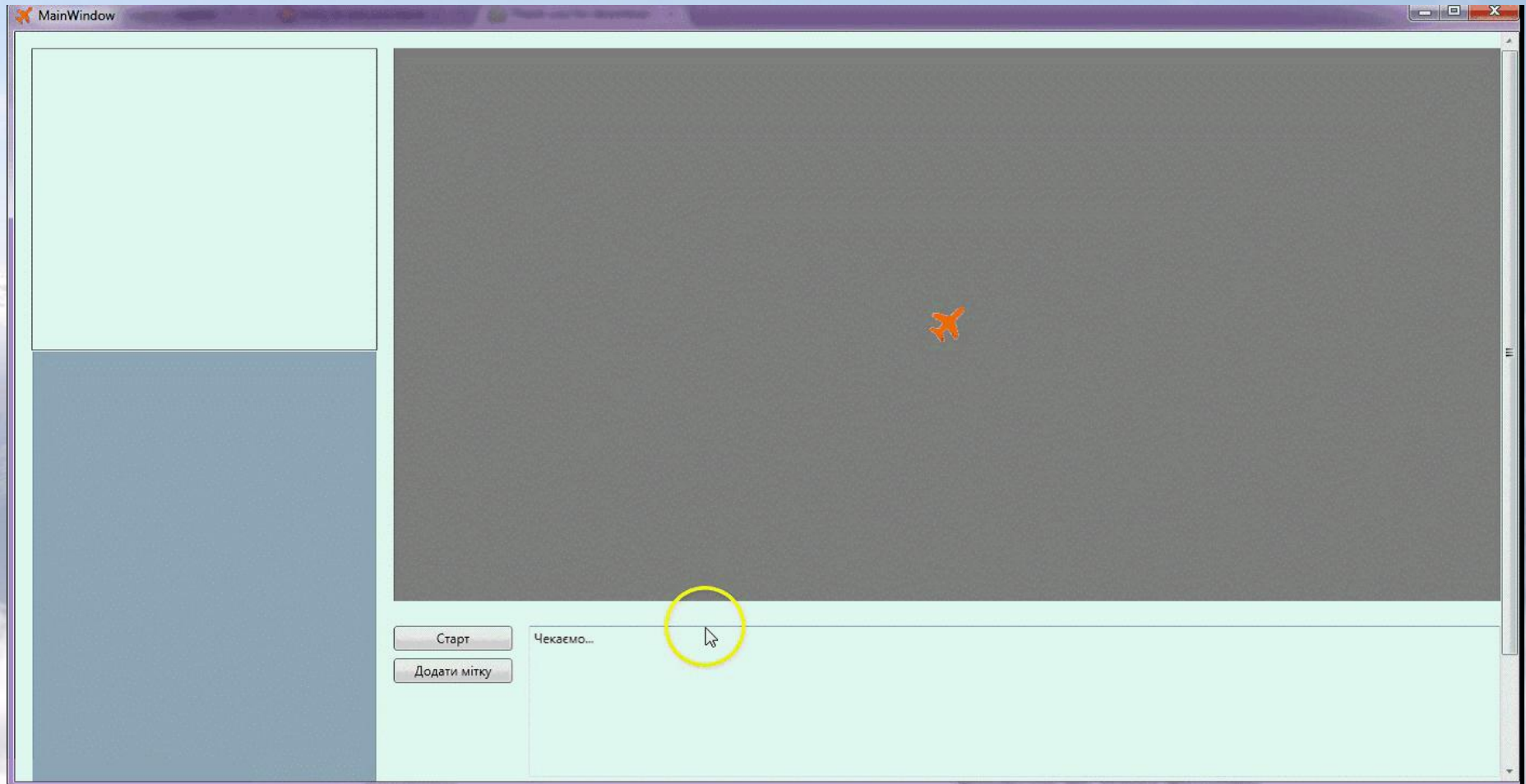
Protected data channel "Board-to-Land,
Land-to-Board" and flight control system were
designed. Standardization of protocols was realized.
Experimental prototype of equipment was produced.





6

AUTOMATED SYSTEM FOR THE OPERATIONAL PURPOSES





IMPLEMENTATION OF DATA PROCESSING FROM UAV BOARD

Interpolation methods were developed based on local polynomial interpolation splines for **determining the current position** of objects and reference images to a digital map of the area.

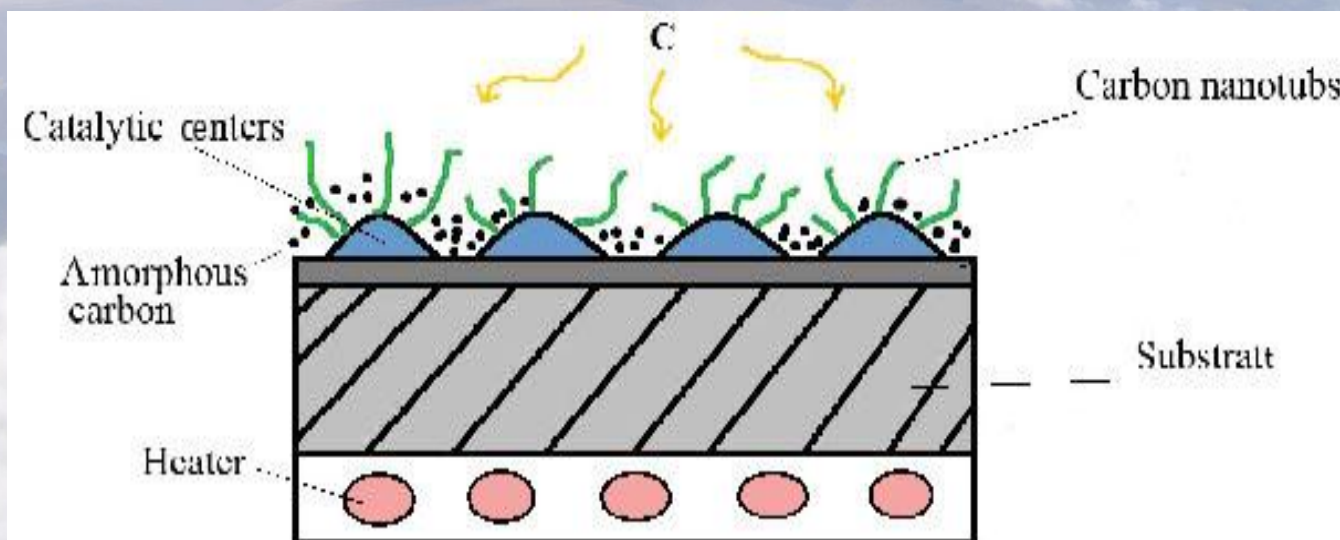


7

CREATION OF NEW MATERIALS FOR RPAS

New technology of **surface hardening** and **recovery** of aircraft parts was developed.

The fundamental mechanisms and the scientific basis for the control of **tribological processes** in **discrete nanostructured coatings** were investigated.





8

THE **DECISION MAKING SUPPORT
SYSTEM TO JUSTIFY THE FLIGHT
PLAN OF RPAS DIVISION**

9

THE **TRAINING PROGRAMS
DEVELOPMENT FOR UAV OPERATORS
AND RPAS LAND PERSONNEL**

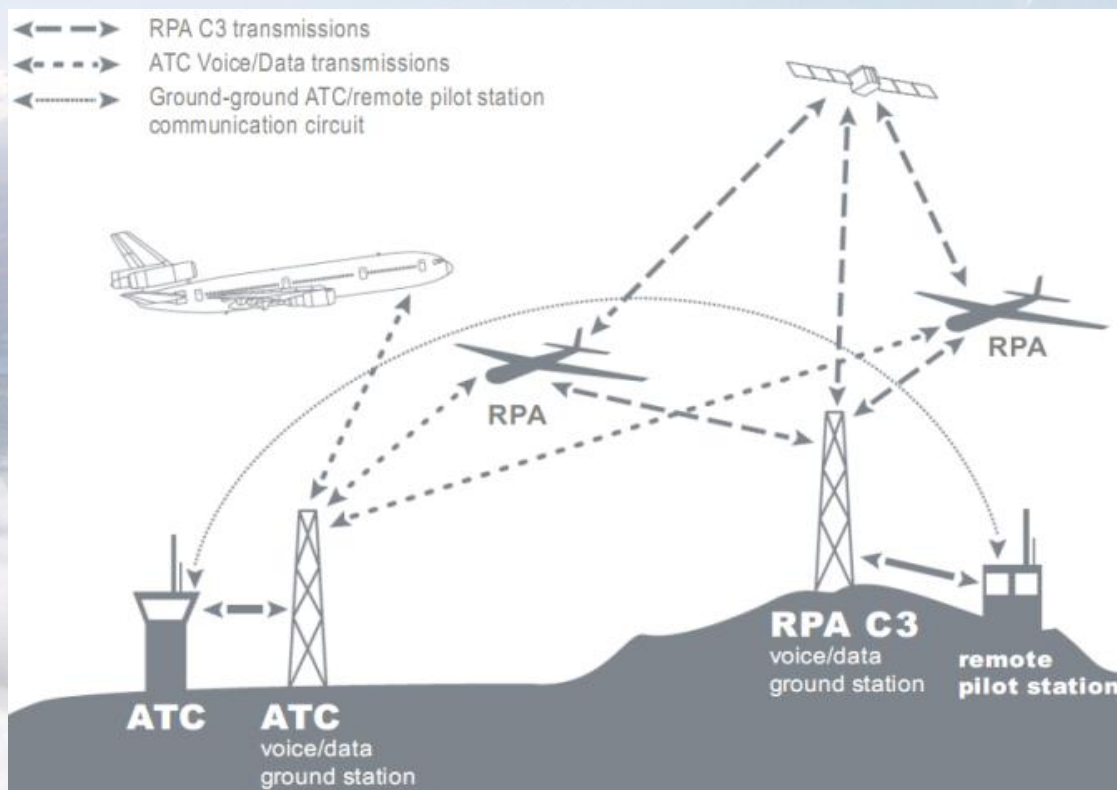
10

**THE NORMATIVE AND TECHNICAL
DOCUMENTATION DEVELOPMENT
FOR **RPAS CERTIFICATION****

11

MODELING OF RPAS SELF-SEPARATION

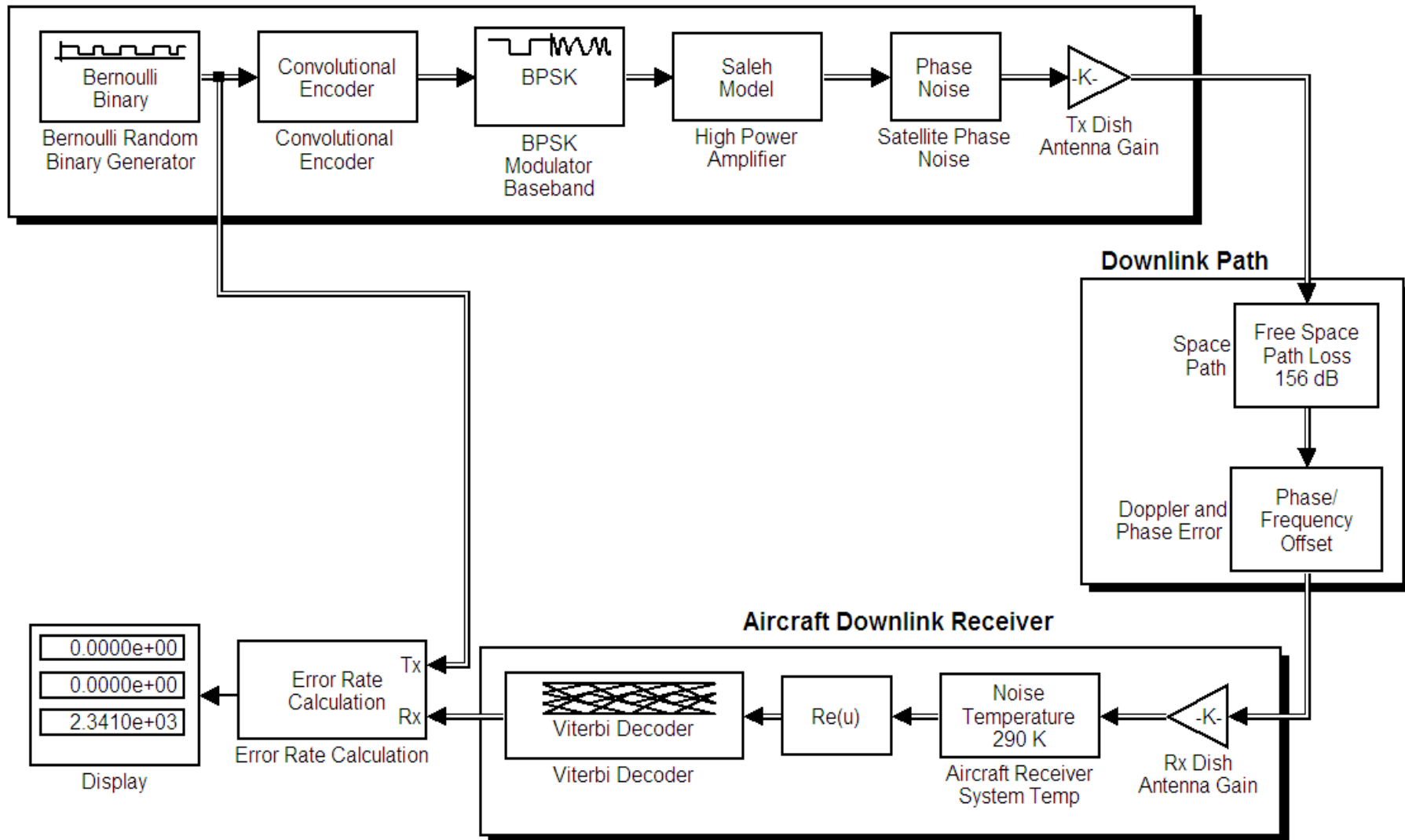
The models with **error-correcting coding** for RPAS communication with satellites during **self-separation** were created in MATLAB Simulink.





“SATELLITE – RPAS” LINK

Satellite Downlink Transmitter





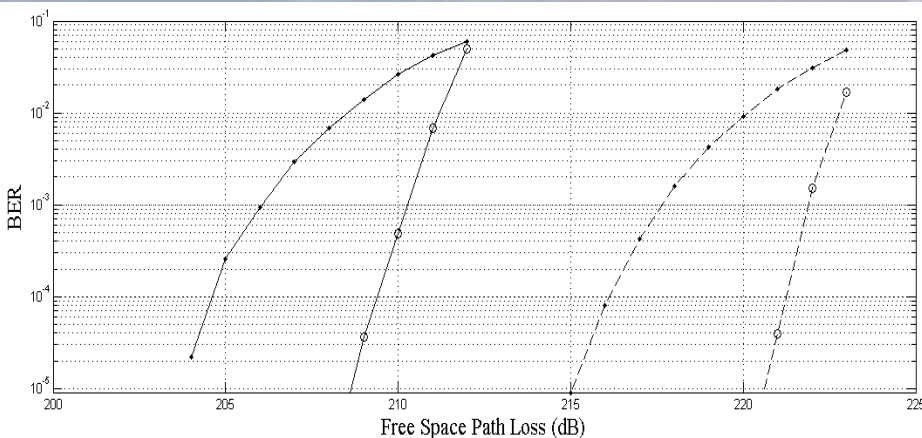
“SATELLITE – RPAS” LINK CHARACTERISTICS

Dependence of Error Probability for BPSK Modulation Scheme on Satellite HPA Nonlinearity

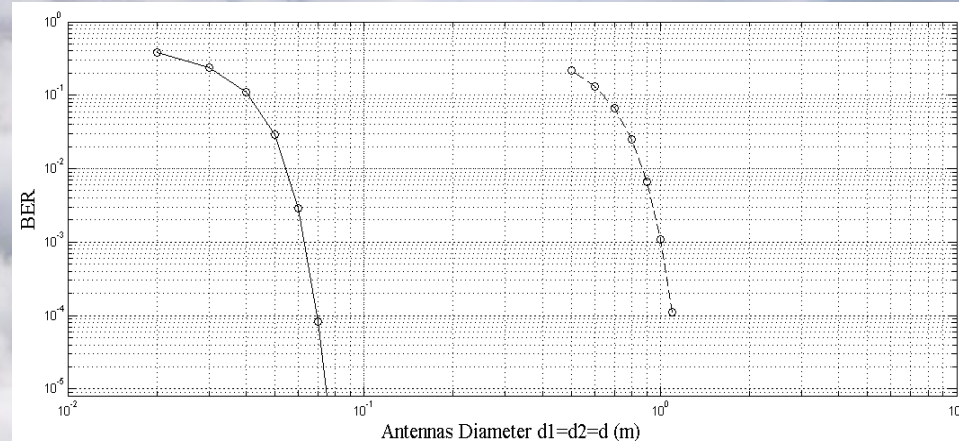
| HPA backoff level | BER (Aircraft Receiver Noise Temperatures T=20K) | | | BER (Aircraft Receiver Noise Temperatures T=290K) | | |
|------------------------------------|--|----------------------|----------------------|---|----------------------|-----------------------|
| | Free Space Path Loss | | | Free Space Path Loss | | |
| | 210 dB | 214 dB | 225 dB | 203 dB | 206 dB | 212 dB |
| 30 dB (negligible nonlinearity) | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 7 dB (moderate nonlinearity) | 0,0 | 0,0 | $2,78 \cdot 10^{-1}$ | 0,0 | 0,0 | $5,43 \cdot 10^{-2}$ |
| 1 dB (severe nonlinearity) | 0,0 | $1,89 \cdot 10^{-2}$ | $4,93 \cdot 10^{-1}$ | $5,98 \cdot 10^{-2}$ | $4,26 \cdot 10^{-1}$ | $4,980 \cdot 10^{-1}$ |

Note: Antennas gain G=1; with convolutional coding (rate $\frac{3}{4}$, constraint length K=7); without phase and frequency offsets.

FREE SPACE PATH LOSSES



ANTENNAS DIAMETERS





12

CONFLICT RESOLUTION

The most important problem of RPAS implementation in **non-segregated** airspace – **is the absence of an universal method for the conflict resolution.**

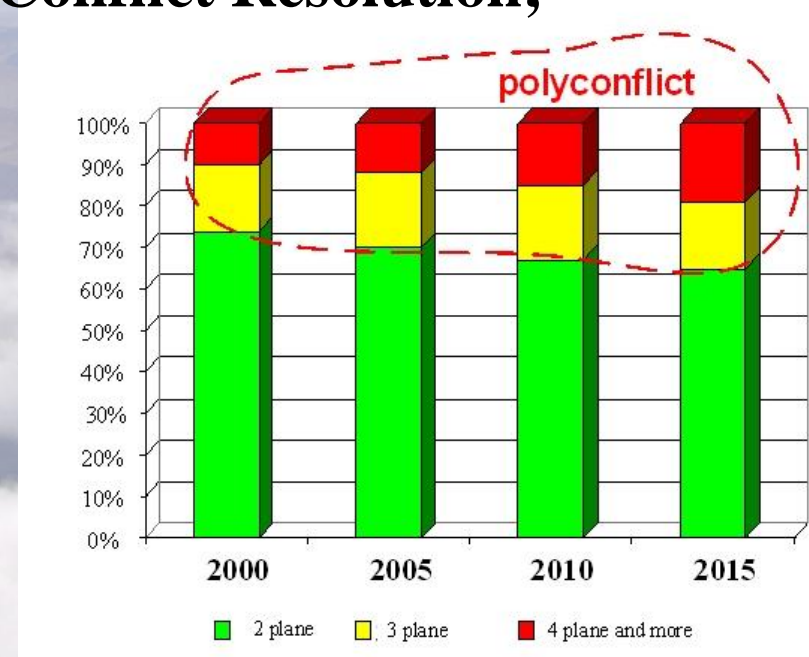


Problem solution:

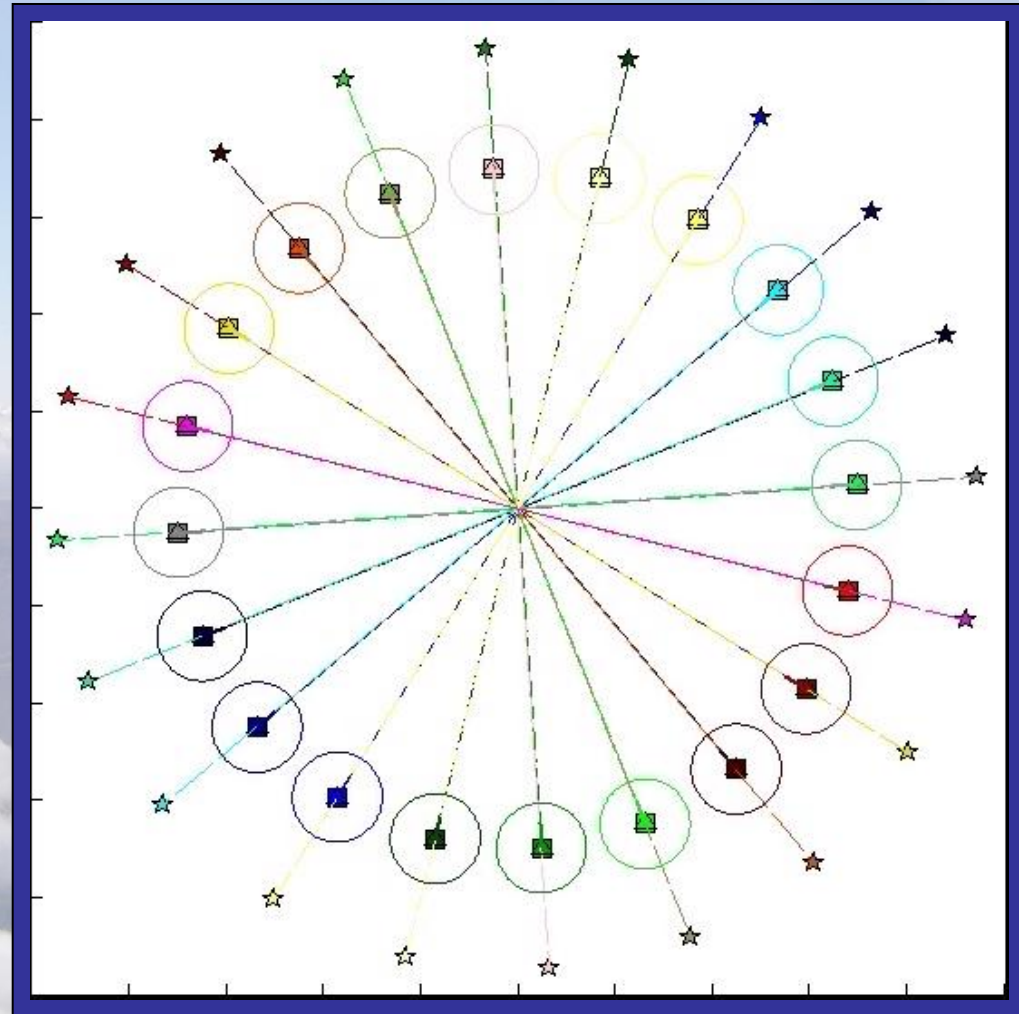
Innovative polyconflict resolution method has been **developed** at the **National Aviation University**.

The method provides:

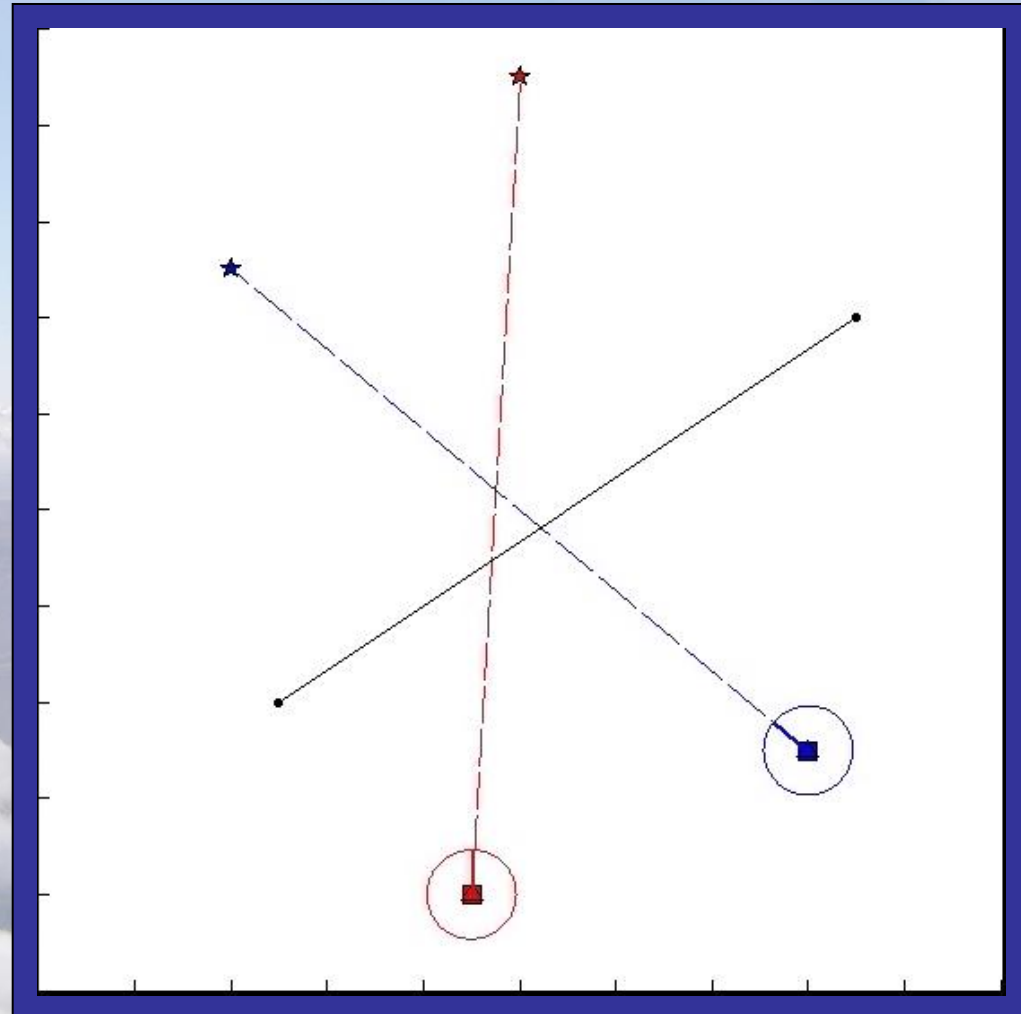
- synthesis conflict-free trajectories for any quantity of airplanes which take part in the polyconflict;
- synthesis in real time effective, safe and free 4D-trajectories in Long, Middle and Short Term Conflict Resolution;
- guaranteed conflict avoidance;
- solving a problem of "damnation dimension" and avoiding "domino effect" during polyconflicts;



- self-organizing of planes safe movement in “Free Flight” mode;
- taking into account priority of planes;
- conflict resolution between piloted or (and) pilotless aircraft in an automatic mode;
- using as system for support of decision-making in an automatic or manual mode;
- undertaking collision avoidance autonomously;
- preventing contact with wake turbulence zones;



- **safe bypass of static and dynamic forbidden zones (special use of airspace, convective weather zones and others airspace constraints);**
- **support for innovative technical solutions, such as ADS-B & Airborne Separation Assistance System (ASAS);**
- **effective solutions in the field of revolutionary approaches to UAS autonomy and collaborative operations.**





The National Aviation University has **a scientific and technical base, and all the necessary resources** to create effective Remotely Piloted Aircraft Systems (RPAS).



The National Aviation University has created **theoretical principles, concepts, technical and technological solutions for the implementation** of unmanned aircraft systems into the civil aviation practice.

The National Aviation University **is interested in collaboration in all kind activities** on the promotion and development of RPAS.



**THANK YOU FOR
ATTENTION**