Update to Ukrainian Aviation Emissions and Environmental R&D

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OUTLINE

- Aircraft noise investigation
- Local aircraft engine emission investigation
- Biofuels for aviation sector
- Concluding remarks
- Acknowledgements

New project funded by Ministry of Education and Science of Ukraine (2018-2019)

"Development of the GIS-platform with improved models for calculating the environmental impact factors of aviation to solve the tasks of monitoring, zoning and optimizing airport activities":

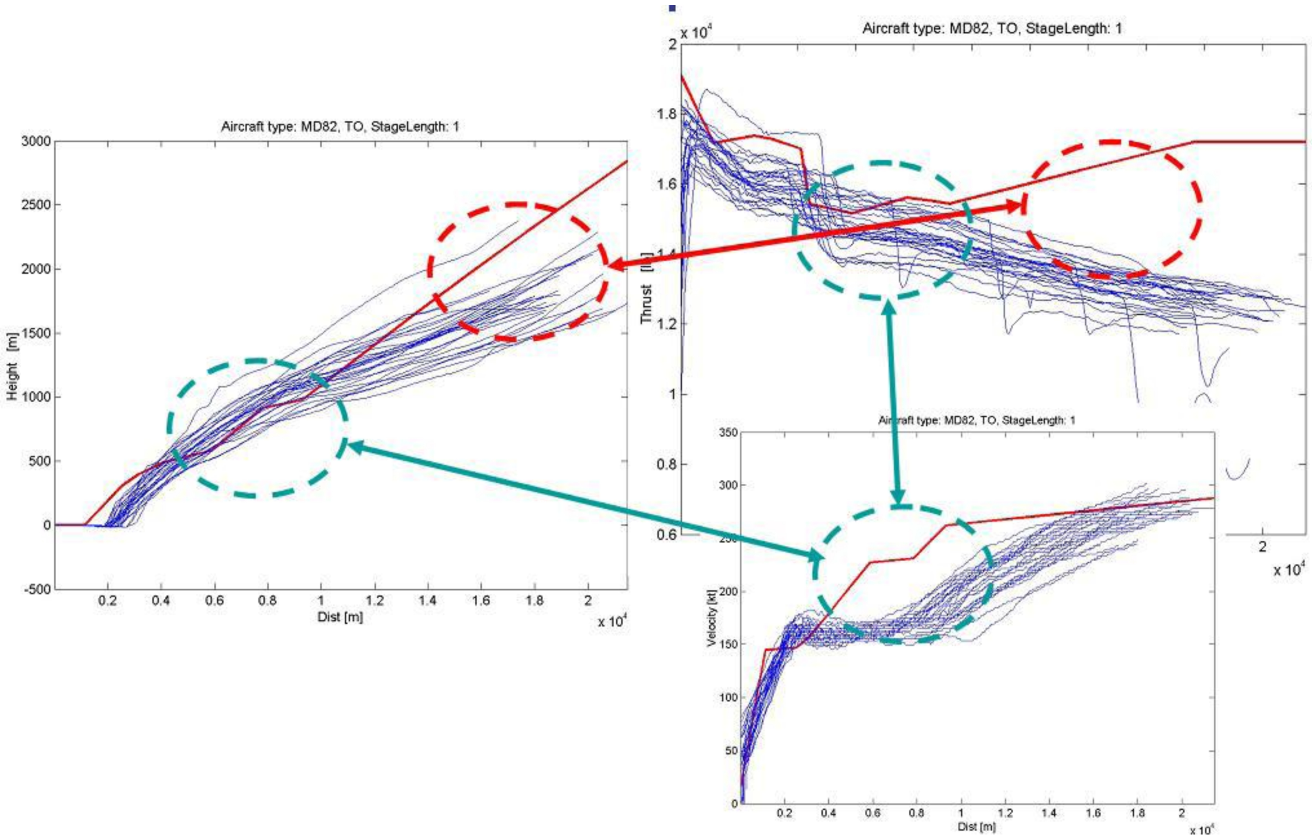
- Aircraft noise modelling – ***IsoBella*** calculation tool;
- Aircraft emission modelling (+ other ICAO Doc 9889 emission sources) – ***PolEmiCa*** calculation tool;
- Aircraft fuel consumption modelling – ***Fleming*** calculation tool;
- GHG-emission modelling for airport activities – ***Globus*** calculation tool

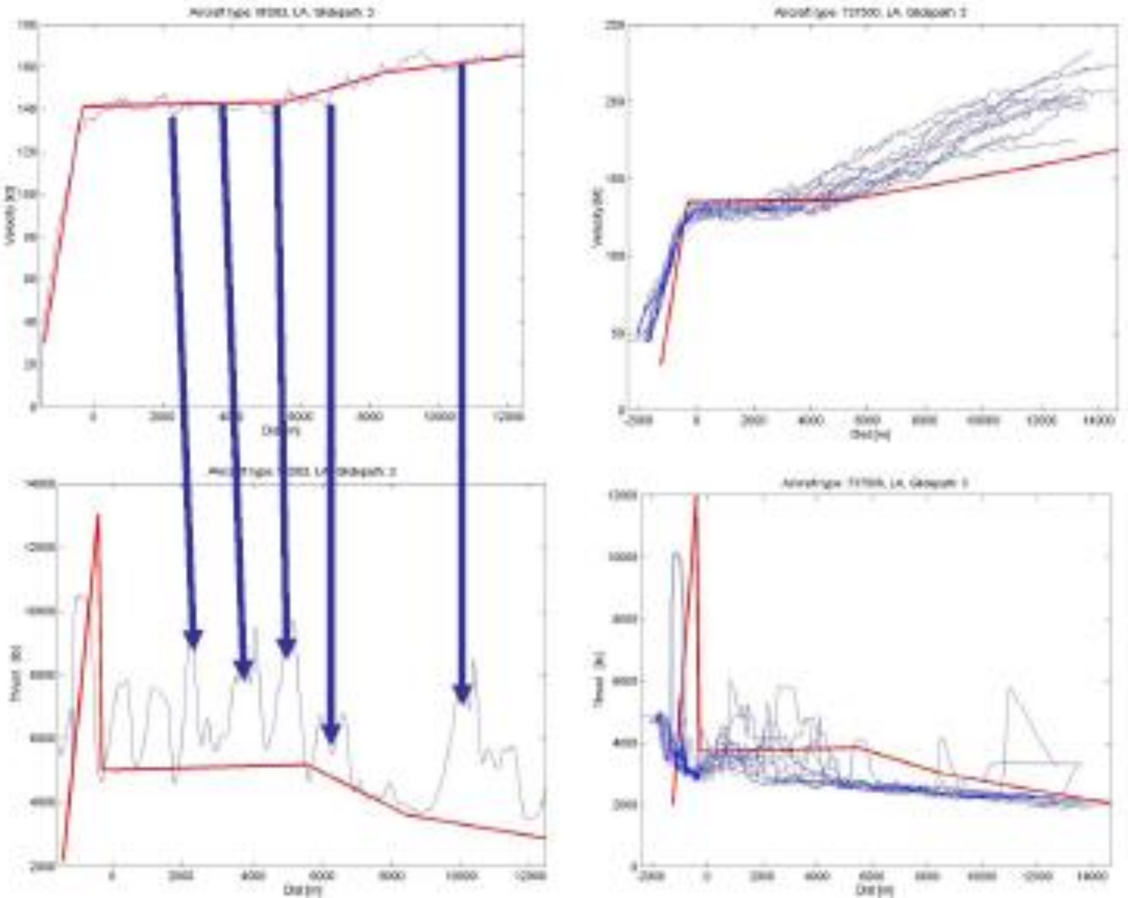
Expected improvement in aircraft noise modelling (coordinated with ASCENT activities):

Single aircraft noise event assessment – SEL, L_{Amax} at points and contours:

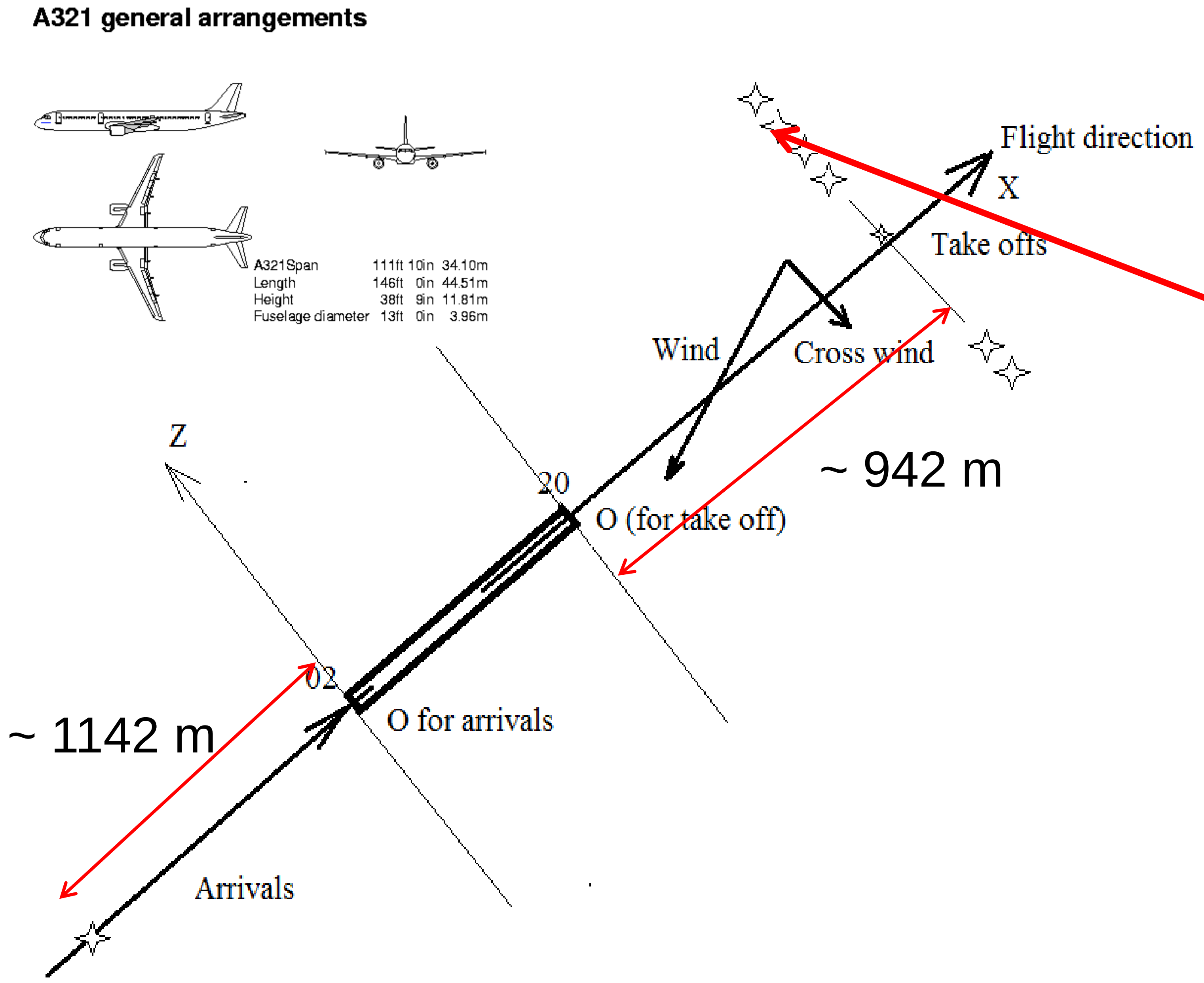
- Modelling variable aircraft configuration and speed
- Ground effect (Ground impedance), Airbus measurements to be used
- Ground (Taxiing) noise
- Reverse thrust and de-rated takeoff noise modelling (in cooperation with EU AIRMOD)
- Helicopter noise (in cooperation with EU AIRMOD)

Modelling variable aircraft configuration and speed



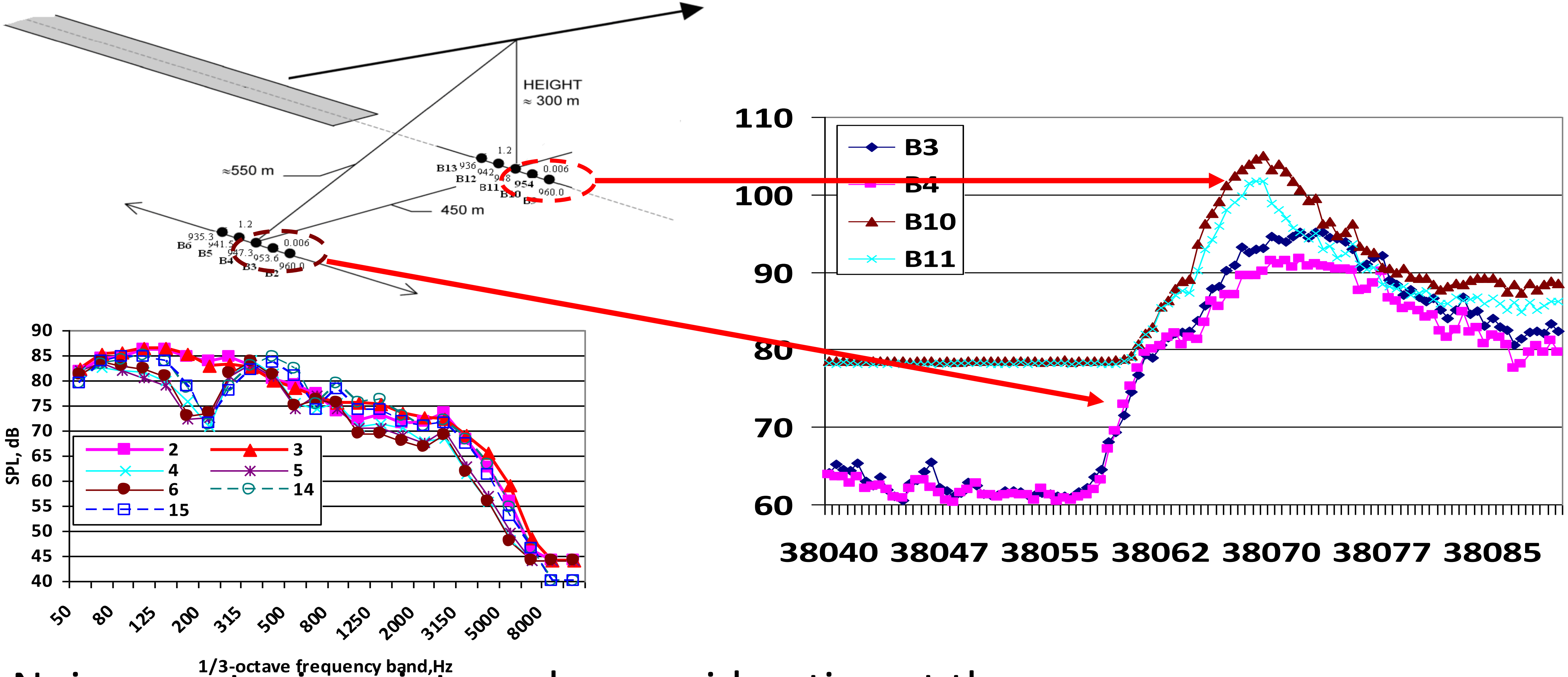


Airbus flight noise measurement scheme



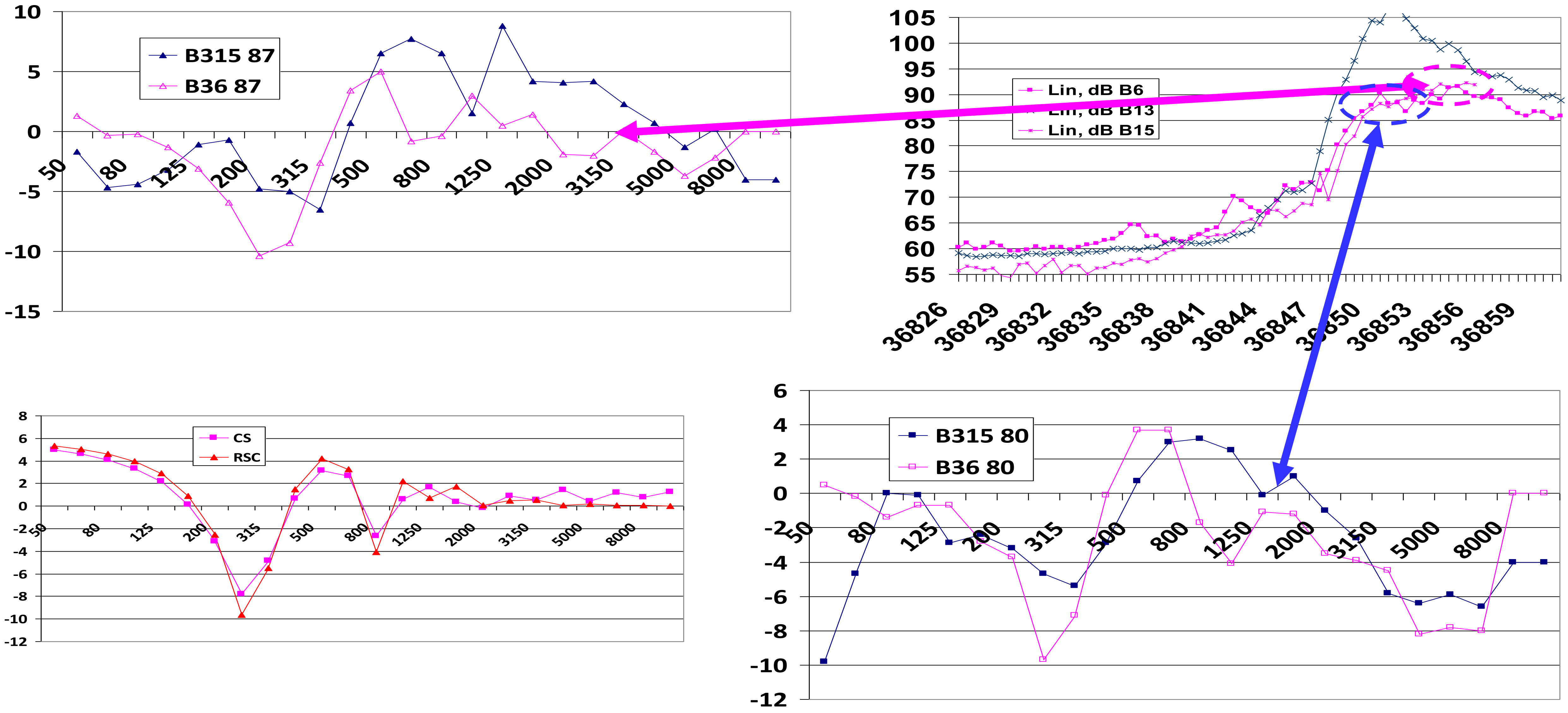
No of flight	No of microphone	No of measured spectra at control point	Abscissa of the control point, m	Ordinate of the control point, m	Altitude of the ground over the sea level, m	Height of the microphone over the ground, m
79	B1	100	925.0	592.5	6.0	1.200
79	B2	100	960.0	492.5	6.2	0.006
79	B3	100	953.6	492.7	6.3	0.006
79	B4	100	947.3	492.5	6.2	1.200
79	B5	100	941.5	492.5	6.3	1.200
79	B6	100	935.3	492.5	6.2	1.200
79	B7	100	925.0	392.5	6.0	1.200
79	B8	100	925.0	292.5	5.6	1.200
79	B9	100	960.0	42.5	6.4	0.006
79	B10	100	954.0	42.7	6.4	0.006
79	B11	100	948.0	42.5	6.3	1.200
79	B12	100	942.0	42.5	6.3	1.200
79	B13	100	936.0	42.5	6.2	1.200
79	B14	90	942.0	-407.5	5.7	1.200
79	B15	90	936.0	-407.5	5.5	1.200
79	B16	100	925.0	-479.5	5.5	1.200

Points under flight path and aside



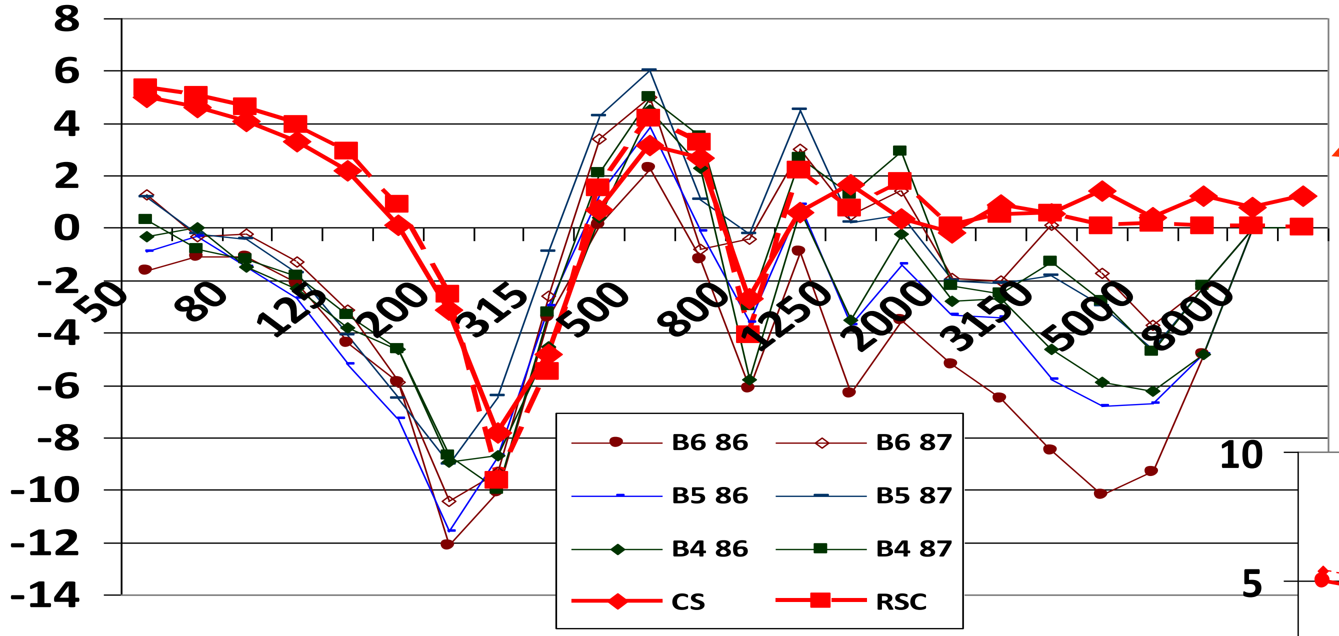
Noise spectra in points under consideration at the moment of maximum sound levels

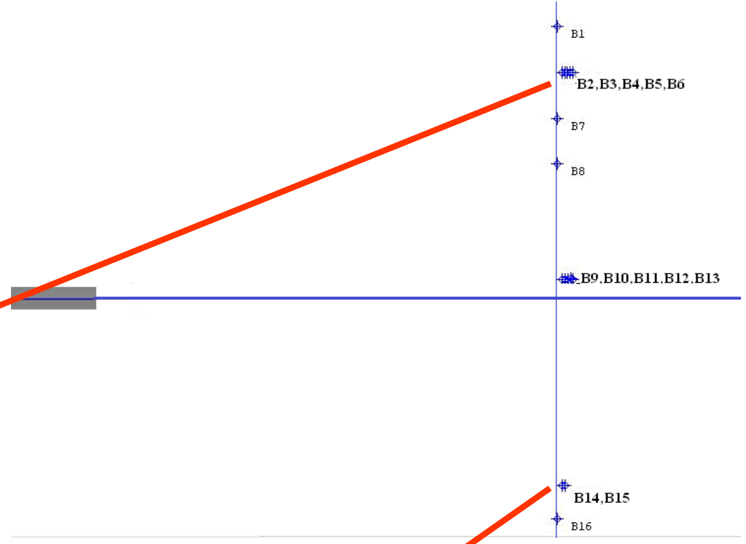
Ground effect at the moment of maximum sound level (point 87)



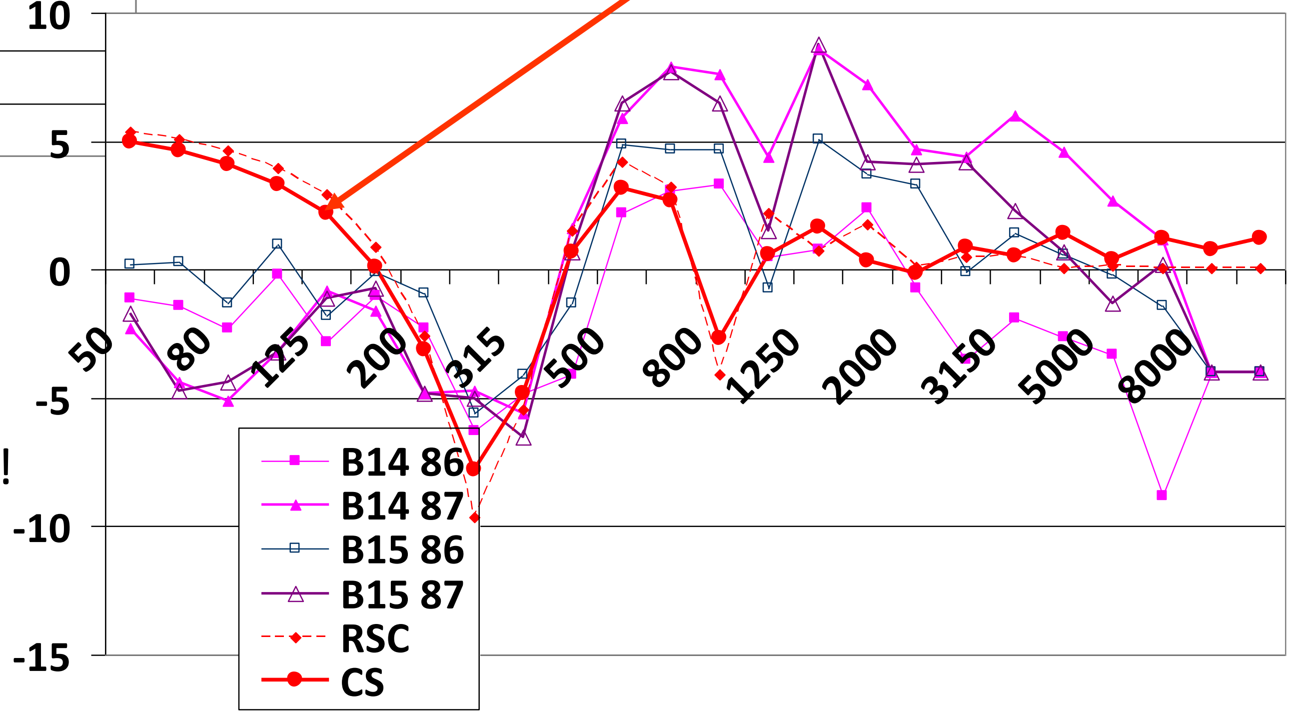
Calculated vies measured GE

points B4, B5, B6 are located upwind





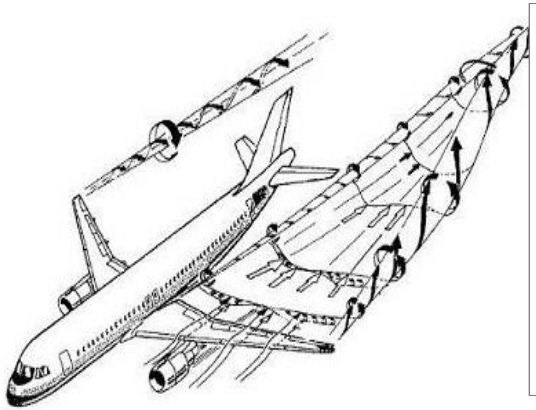
- **Points B14, B15** are located underwind

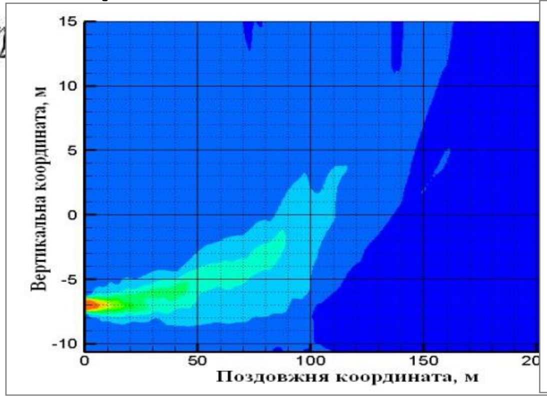


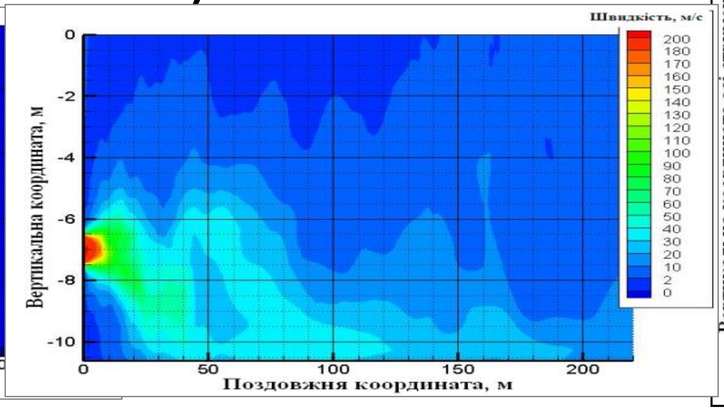
- At underwind points dip-effect is less pronounced!

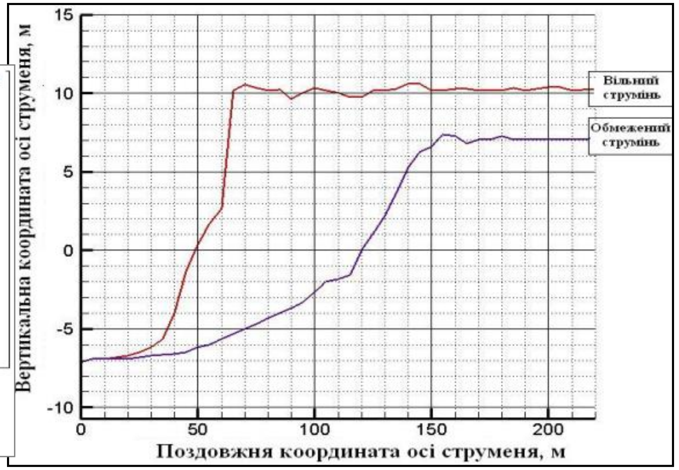
Expected improvement in aircraft emission modelling (coordinated with ASCENT activities):

- **nvPM polydispersity emission** modelling
- **nvPM (different fractions) pollution** modelling, including the effect of *particle sedimentation rate* (for all sources in airport mentioned in ICAO Doc 9889)
- Improvement of aircraft **engine jets and wing vortices interaction** (landing and take-off of the aircraft), including numerical simulations with CFD code (**FLUENT 6.3/Gambit**)

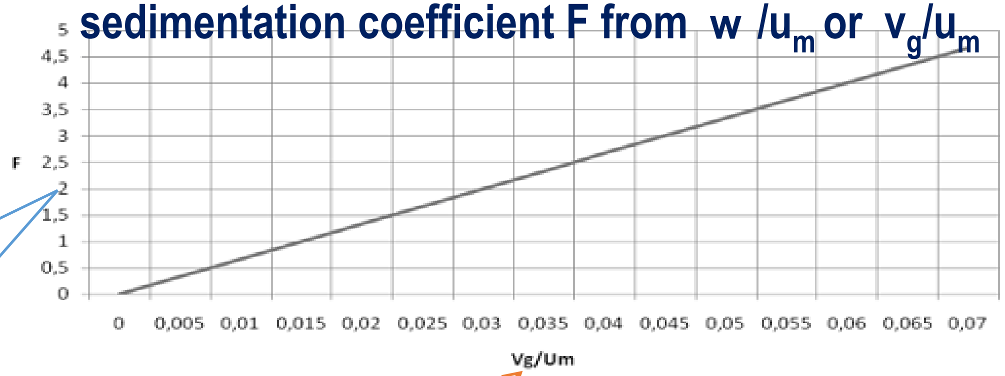








Modified method for PM



volatile

$$q_m = \frac{0,116\,(1+n)^2 M}{u_1 H^{1,5\,(1+n)}} \sqrt{\frac{k_1}{k_0 u_1}}$$

$$x_m = \frac{2}{3}\,\frac{u_1 H^{1+n}}{k_1 (1+n)^2}.$$

non-volatile

$$q_m = \frac{0,063\,(1+n)^2 M}{u_1 H^{1,5\,(1+n)}} \sqrt{\frac{k_1}{u_1 k_0}}\,\frac{(1,5+\omega)^{1,5+\omega}}{\Gamma(1+\omega)\, e^{\omega}},$$

$$x_m = \frac{u_1 H^{1+n}}{(1+n)^2 (1,5+\omega)\, k_1}.$$

The maximum value of surface concentration (mg/m^3) produced by emission of point source (round nozzle) under unfavorable meteorological conditions at distance X_M distance (m) from the source is determined by the formula:

$$q_M = \frac{A \cdot M \cdot F \cdot m \cdot n \cdot \eta}{H^2 \sqrt[3]{V_1 \cdot \Delta T}} \qquad x_м = \frac{5 - F}{4}\, d\, H\ , \qquad d = 2{,}48\left(1 + 0{,}28\sqrt[3]{f_e}\right)$$

- A - coefficient depending on the temperature stratification of the atmosphere; $A = a \frac{k_1}{u_1 \varphi_0}\Big|_{u_1 = 2\ м/с}.$
- *M* – emission rate, g/s;
- F – dimensionless coefficient that takes into account the rate of PM sedimentation; $v_g\,(\text{or}\,\omega) = \dfrac{10^{-8} \cdot d_g^2 \cdot \rho \cdot g}{18 \cdot \mu}$
- m, n – coefficients depending on output conditions of the exhaust mixture from the emission source;
- H – the height of the emission source above ground level, m;
- η – dimensionless coefficient that takes into account the effect of the terrain, in the case of flat terrain $\eta = 1$;
- ΔT – temperature difference between exhaust mixture and ambient air, °C;
- V_1 – exhaust mixture rate, m^3/s: $V_1 = \dfrac{\pi D^2}{4}\,\omega_0\ ,$

Among the goals of the project:

- Conditions will be created to include developed and improved tools in the EU and ICAO modeling structures, including within the framework of European projects (EU Horison 2020 program) and **cooperation with modeling research organizations in USA - the FAA program ASCENT):**
- **Noise**
- **Emission/pollution**
- **Biofuels**

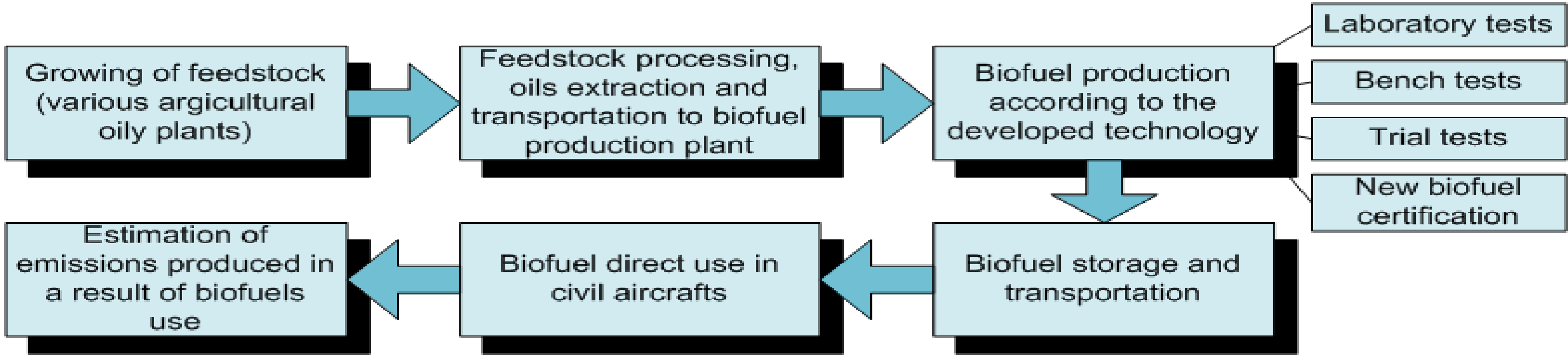
Development of environmentally safe alternative jet fuels

•Before the 2012 there is no practical experience in application of aviation biofuels in Ukraine.

•In 2012 the **Concept** was presented for **development and implementation of ecologically friendly biofuels into civil aviation of Ukraine**.

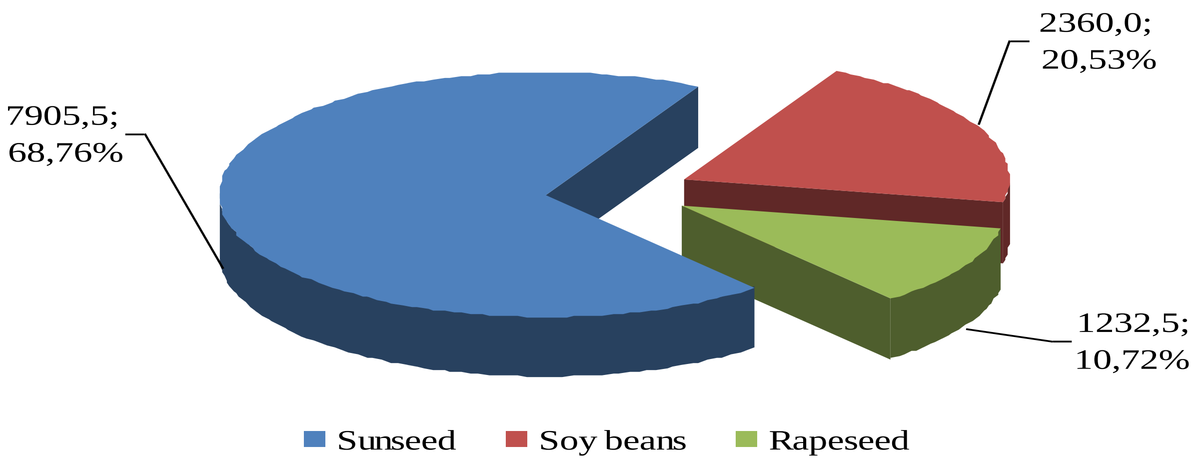
•**Concept** comprises the whole stages of alternative fuels production starting from feedstock growing and finishing with fuels certification and direct use by civilian aircraft.

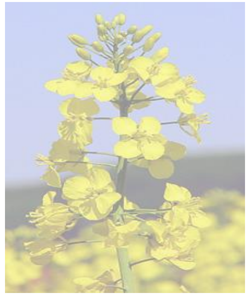
•**Concept** was included into the Action Plan of Ukraine for Reducing CO_2 emissions that was presented to ICAO by State Aviation Administration of Ukraine in 2012.



Development of environmentally safe alternative jet fuels

- Ukraine possesses a great variety of feedstocks, which can be used for alternative jet fuels production: **rape, sunflower, soy, corn, camelina, sorghum and some others**.
- The main concept for choosing biofuel feedstock is:
- **Feedstock** have to be of **domestic origin**, feedstock yields should be enough to **provide Ukrainian internal needs** in biofuels and biofuel feedstock **must not conquer with food industry**.



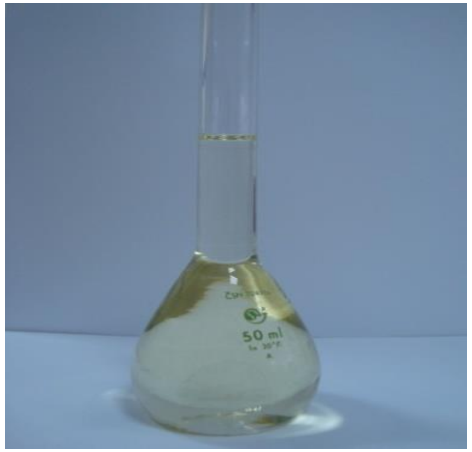


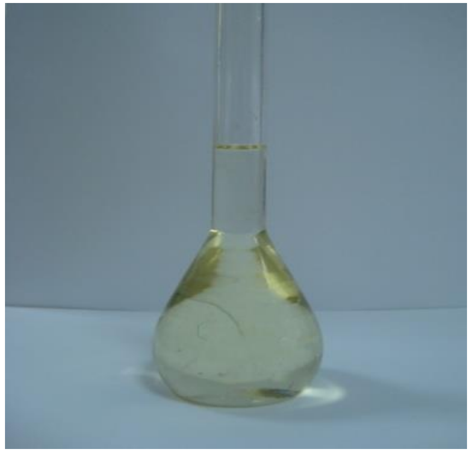
Development of environmentally safe alternative jet fuels

orientation on the international specifications, which determine quality parameters of conventional and synthetic jet fuels:

- Def Stan 91-91 Turbine fuel, Kerosene type, Jet A-1;
- ASTM D1655 Standard Specification for Aviation Turbine Fuels;
- ASTM D 7566 Standard Specification for Aviation Fuel Containing Synthesized Hydrocarbons.

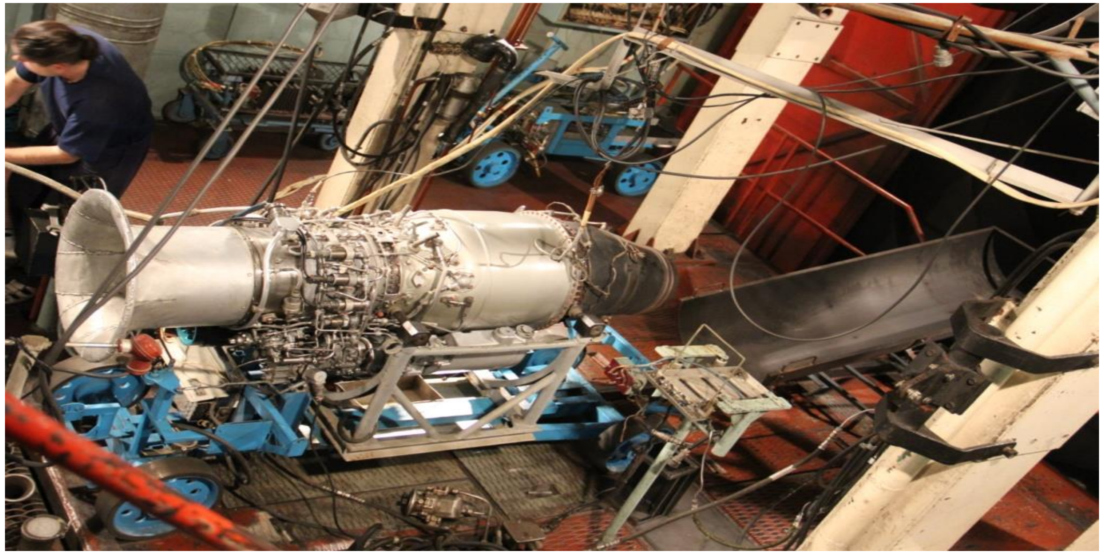
Complex laboratory studies of physical-chemical properties and quality parameters of alternative jet fuel blended with rapeseed oil biofuel. The results have shown that today the content of rapeseed oil biofuel in conventional jet fuel may be up to 30%.





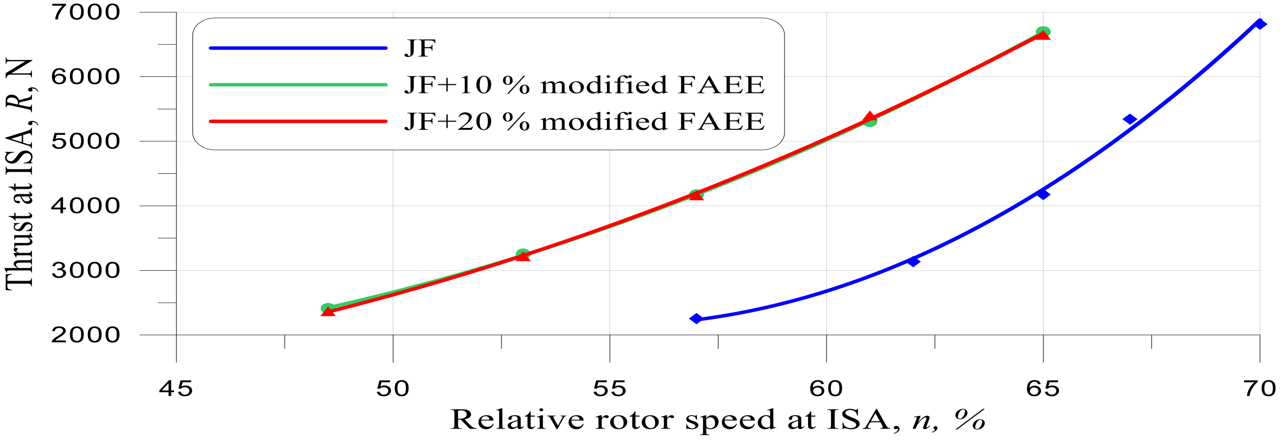
Engine testing facility usage for trials of alternative jet fuels

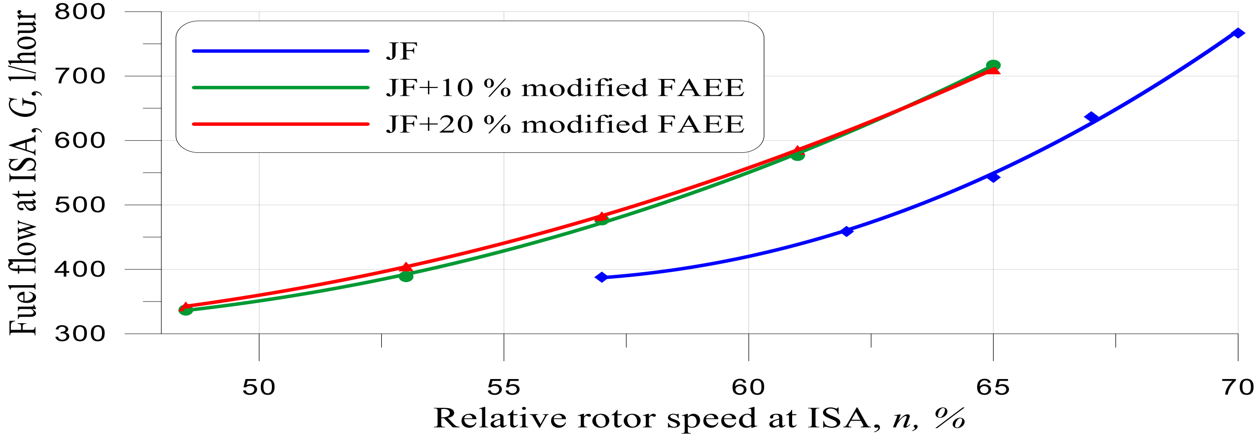
The bench tests of new alternative jet fuels, containing rapeseed oil derived biofuels, were fulfilled on certified engine-test facility with specific stand at State Enterprise of Civil Aviation 410 (Kyiv).

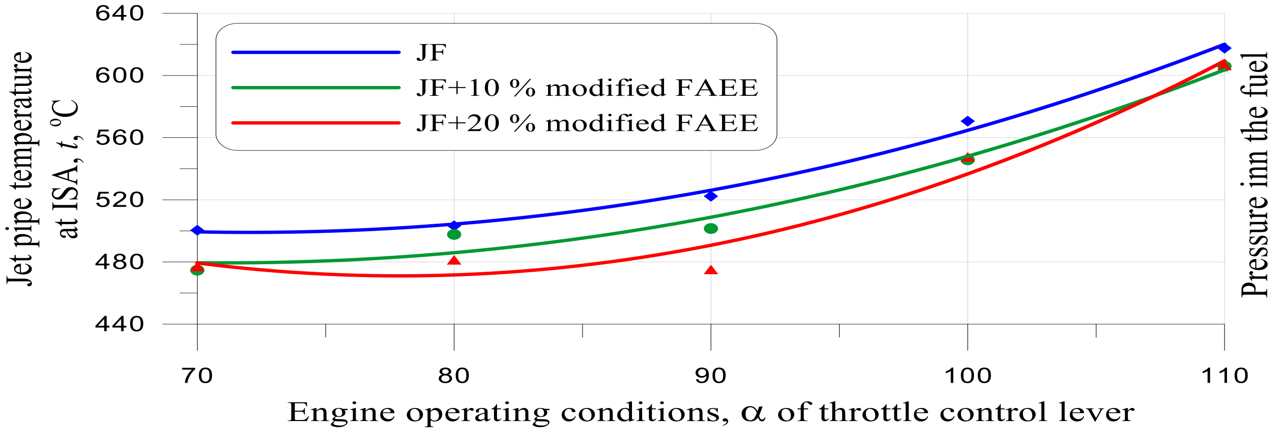


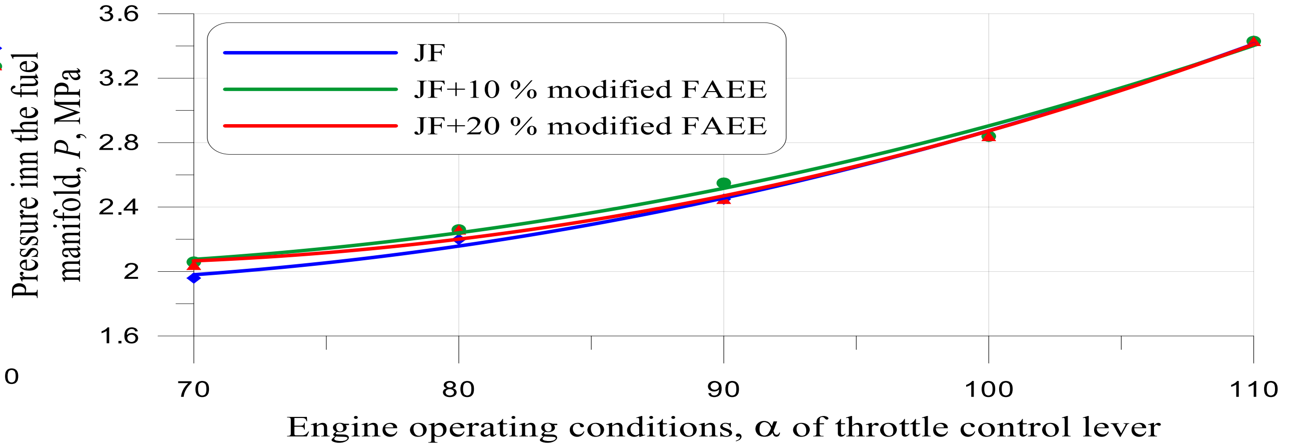
Main technical characteristics were tested:
relative rotor speed n, %,
engine inlet temperature $t_{e.in.}$, °C,
barometric pressure, B_{atm}, mm Hg
thrust, R, N
pressure in fuel manifold, $P_{f.m.}$, MPa,
jet pipe temperature, $t_{j.p.}$, °C,
fuel flow, G, l/hour,
acceleration response time, s.

Results of bench tests of alternative jet fuels with 2 types of rapeseed oil biofuels in quantities 10% and 20%

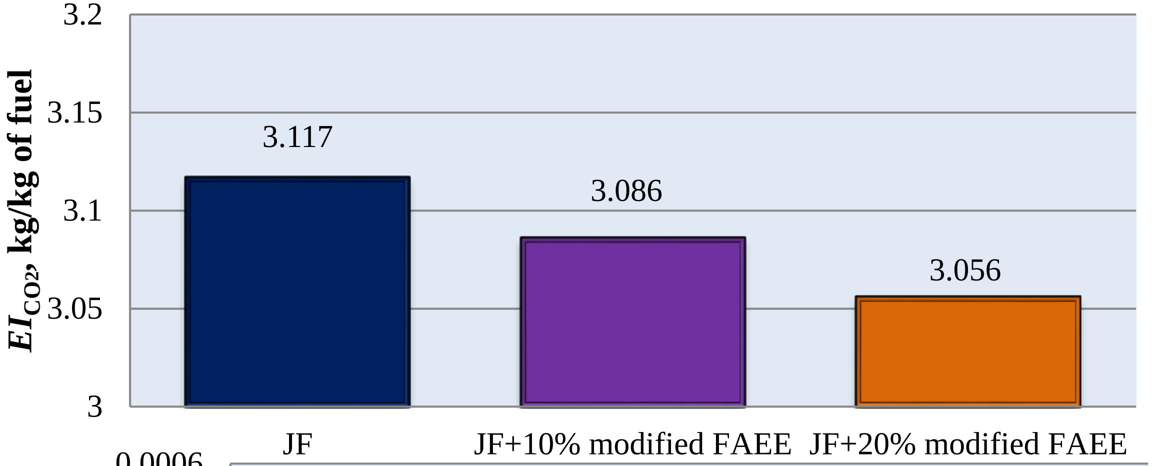


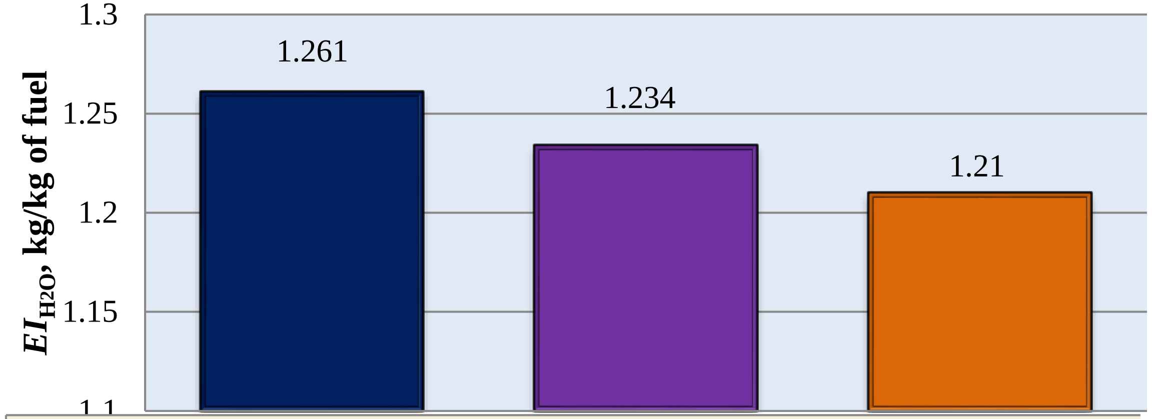


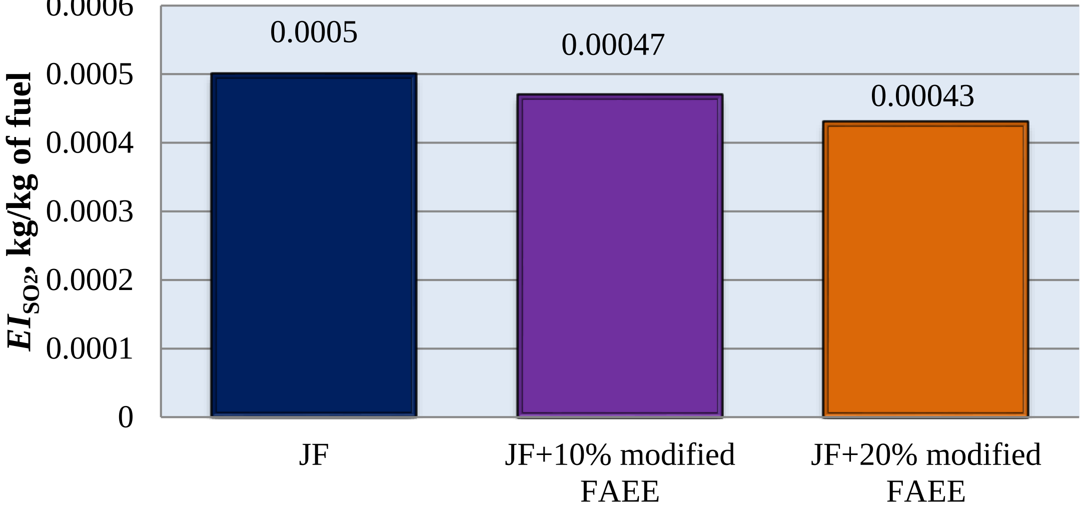


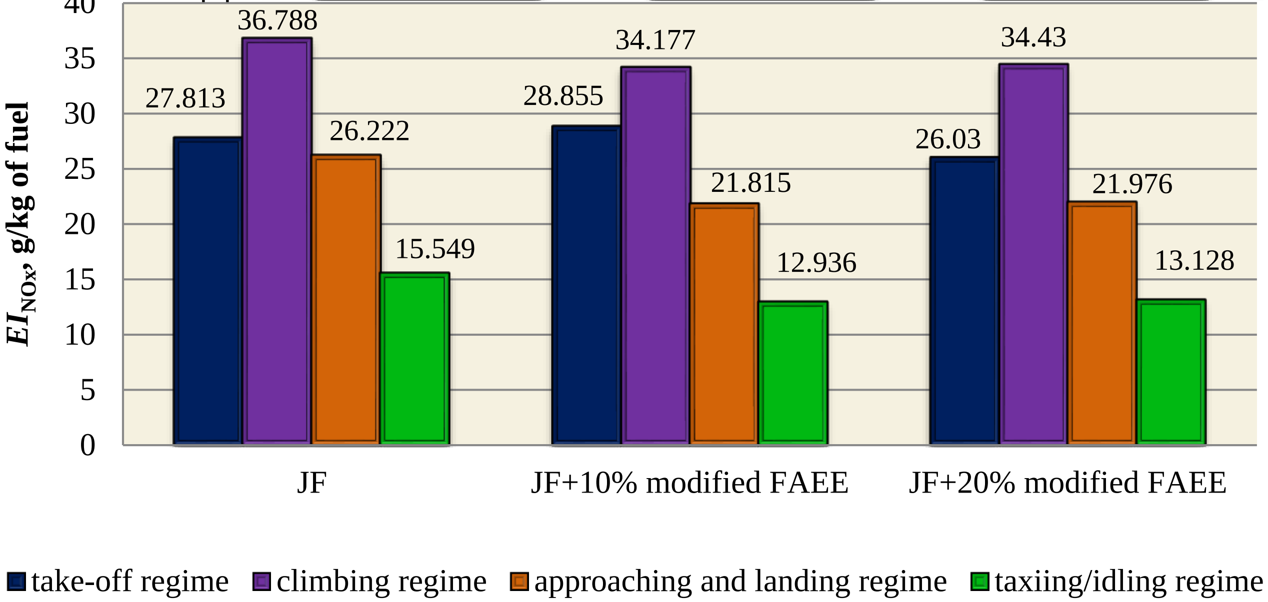


Results of calculations of emissions of alternative jet fuels with 2 types of rapeseed oil biofuels in quantities 10% and 20%



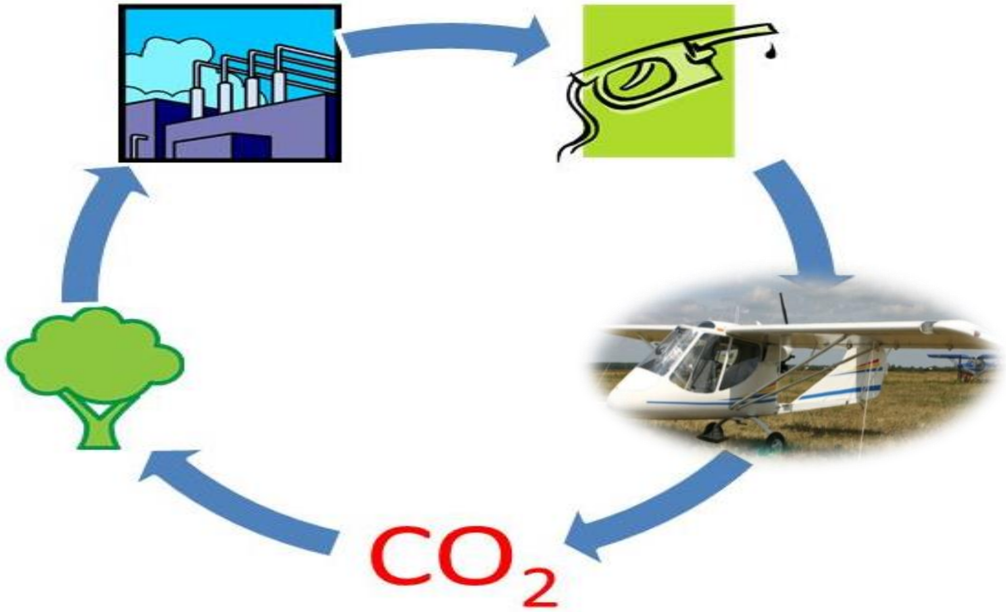






Development of environmentally safe alternative ***aviation gasoline***

The reciepts of reformulated clean aviation gasoline include a complex of domestic production components, which include biocomponents - oxygenates - **aliphatic alcohols** (eg ethanol) that meet the technical requirements for aviation gasoline of international standards.



It is proposed to change from the traditional reciepts of gasoline composition , which avoids the use of toxic tetraethyl lead and at the same time provide the necessary technical parameters and environmental cleanliness.

New concept for Research funding in Ukraine beginning from 2019

- Introduction of so called basic research funding from the Government in accordance with priorities in Ukraine and in an University:

1) Environment protection is of highest priority in National Program of fundamental researches in Ukraine

2) Environment protection in sectors of Transportation and Energy is a priority of Researches in National Aviation University

3) NAU with connection to US ASCENT and EU Horison-2020 is top ranking for new Research funding in UA

Concluding remarks

- ASCENT Program is considered as a highest priority cooperation between US FAA and UA CAA
- It is a good support to contribute in our CAEP activities
- It is a good starting point before 2019 new approach for financing of the researches in Ukrainian Universities
- **We ready for bilateral cooperation** between NAU and US Universities in Civil Aviation & Environment Protection areas

ACKNOWLEDGEMENTS

- **FAA Office of Environment and Energy**

for inviting the Environmental Safety Institute of the NAU

to participate in ASCENT Advisory Committee Meeting