Aeronautics Challenges & New Opportunities for International Cooperation

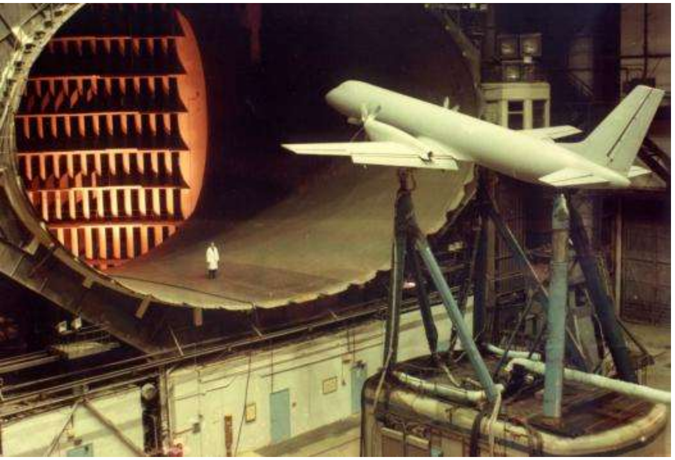
Sergey L. Chernyshev

Executive Director

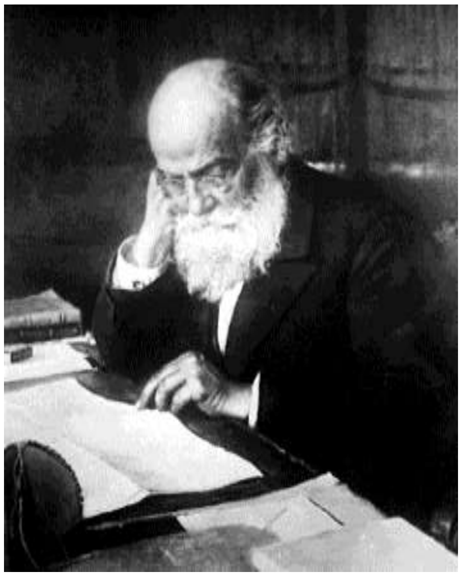
TsAGI

TsAGI: Central Aerohydrodynamic Institute
"ЦАГИ" — The Russian Abbreviation

- ✓ Russia's Leading Aerospace R&D Center
- ✓ Over 96 Years of Technology Excellence
- ✓ World Largest Testing Facility in Single Location
- ✓ Mother Organization for Many Russian R&D Institutes and Design Bureaus
- ✓ Training facility for top Russian Technical Universities
- ✓ Russia's ICAS Member since 1970



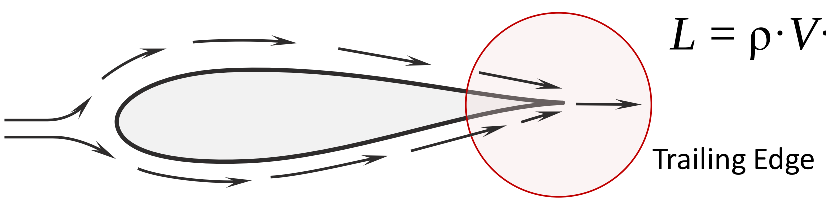
Aeronautics Early Days: Zhukovsky—Kutta Postulate



Prof. *Nikolay Zhukovsky*
1847–1921

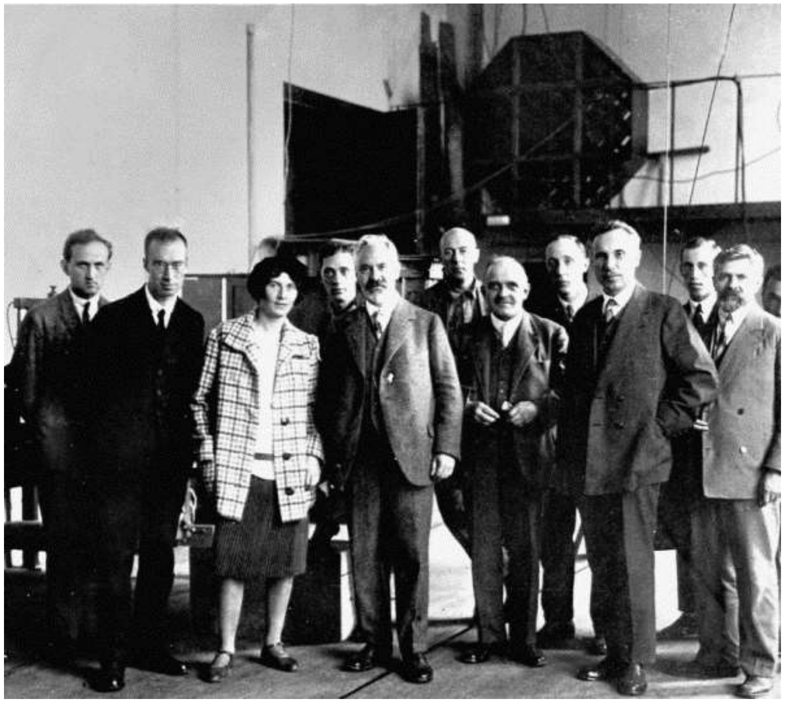
Prof. *Martin Kutta*
1867–1944

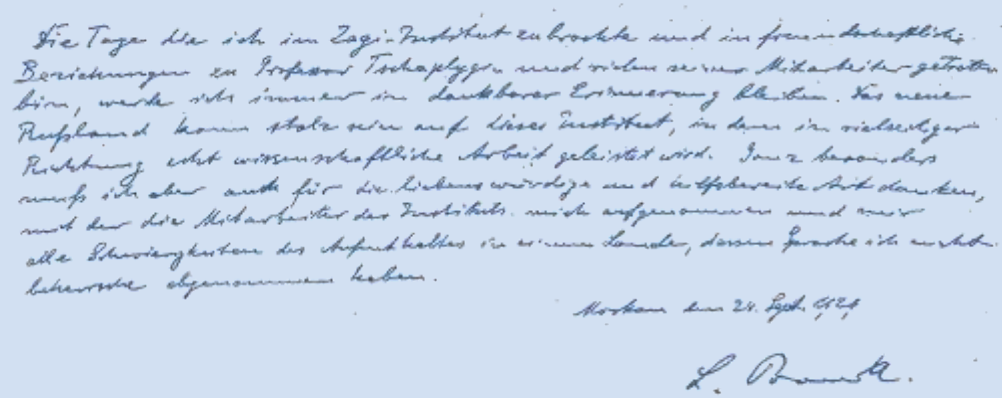
1904—1910 publications



$$L = \rho \cdot V \cdot \Gamma$$

Ludwig Prandtl at TsAGI, 1929





Die Tage, die ich im Zagi-Institut zubrachte und in freundschaftliche Beziehungen zu Professor Tschaplygin und vielen seiner Mitarbeiter getreten bin, werde ich immer in dankbarer Erinnerung behalten. Das neue Rußland kann stolz sein auf dieses Institut, in dem in vielseitigen Richtungen echt wissenschaftliche Arbeit geleistet wird. Ganz besonders muß ich aber auch für die liebenswürdige und hilfsbereite Art danken, mit der die Mitarbeiter des Instituts mich aufgenommen und mir alle Schwierigkeiten des Aufenthaltes in einem Lande, dessen Sprache ich nicht beherrsche abgenommen haben.

Moskau den 24. Sept. 1929

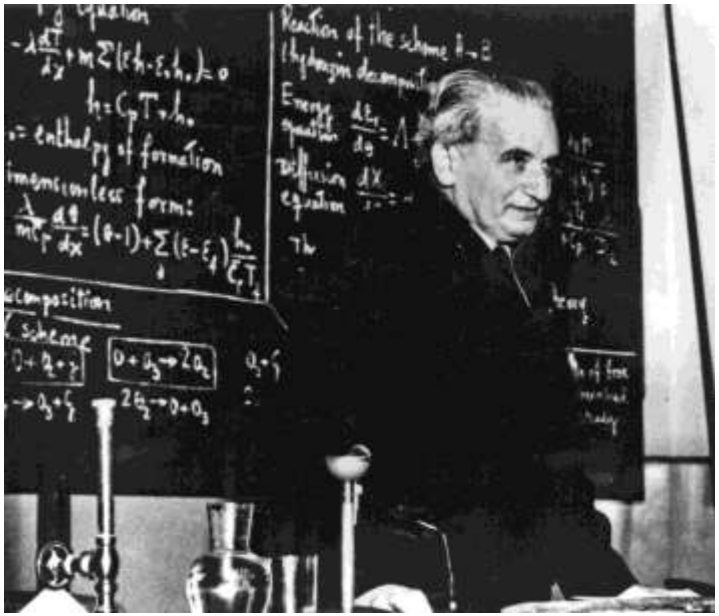
L. Prandtl.

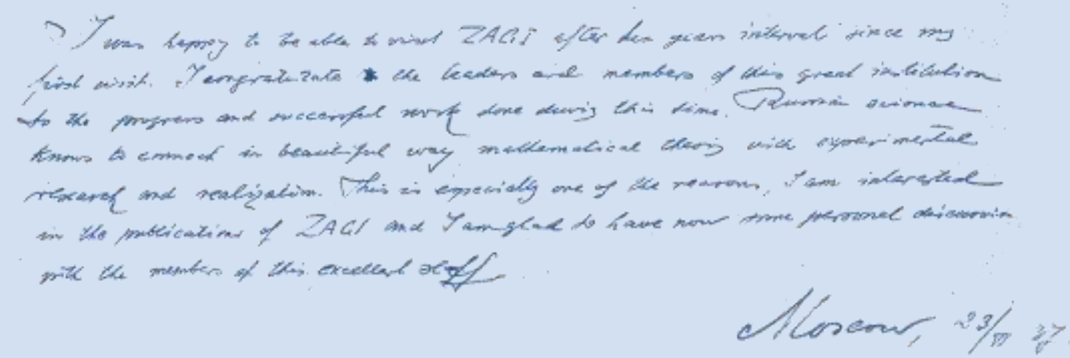
“I will always remember with thanks the days I spent in TsAGI. Young Russia can be proud of that Institute wherein serious scientific work in many areas is carried out...

Moscow, September 24, 1929
L. Prandtl”

L. Prandtl’s note in TsAGI Distinguished Guests Book

Theodor von Karman at TsAGI, 1927





I was happy to be able to visit ZAGI after ten years interval since my first visit. I congratulate the leaders and members of this great institution to the progress and successful work done during this time. Russian science knows to connect in beautiful way mathematical theory with experimental research and realization. This is especially one of the reasons, I am interested in the publications of ZAGI and I am glad to have now some personal discussion with the members of this excellent staff.

Moscow, 23/VI 37

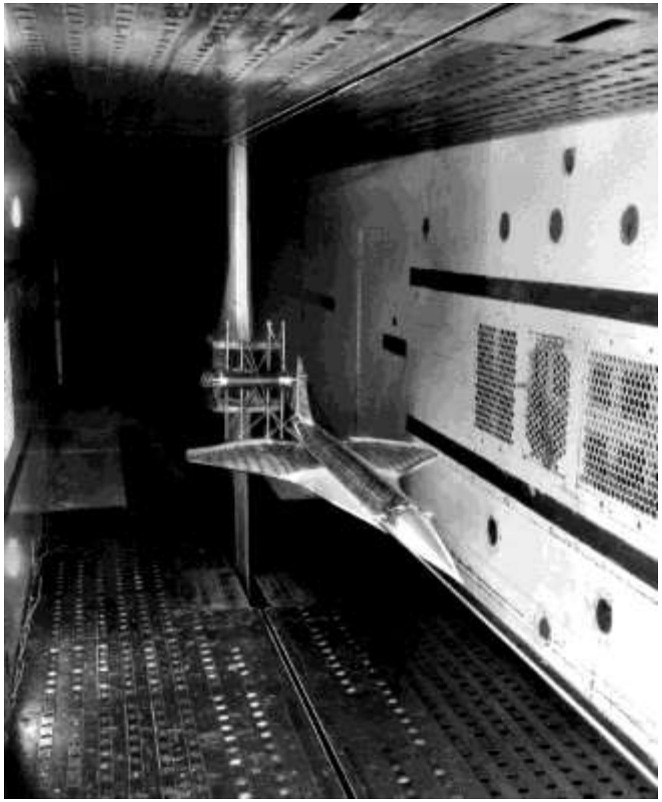
"I am glad to visit TsAGI 10 years after I visited it for the first time. I congratulate the leaders and collaborators of that big institution with the progress and successful work carried through that period of time. Russian scientists can excellently combine the mathematical theory with the experimental investigations and put them into practice. This, practically speaking, is one of the reasons for my interest in TsAGI Works and I am glad to have the possibility now to intercommunicate personally with collaborators of this excellent collective.

Theodore von Karman.
June 23, 1937"

Von Karman's note in TsAGI Distinguished Guests Book

1965 — Russian Top Level Aviation Delegation at ONERA

Back to Our History, 1967 — TsAGI-ONERA



Flatter test of scaled model of the Tu-144 at supersonic wind tunnel T-109

Tu-144 at descent
First flight in Dec 1968

High Speed Flight Research based on the Tu-144 Test Bed

NASA—TsAGI—Tupolev
Flight Test Program

- Overall & distributed aerodynamic characteristics
- Thermodynamics and surface temperature measurement
- Take-off and landing ground effect
- Stability and controllability
- Sound radiation and noise management
- In-flight structure aeroelasticity
- Sonic boom

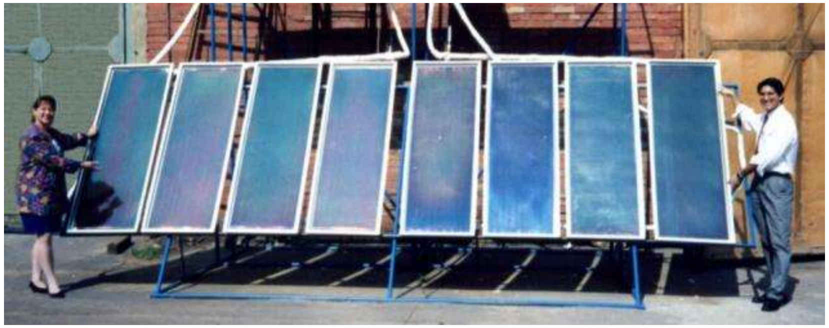
NASA — TsAGI Cooperation in Aeronautics

Dr. Wesley Harris (left)
NASA Associate Administrator
TsAGI, 1999

Mr. Richard Christiansen
NASA Associate Administrator
TsAGI, 1993

Political & Technical Exchanges — the 90s

Russia — US Student Exchange



ONERA — TsAGI Scientific Seminar

TsAGI — ONERA SEMINAR

2001 — Zhukovsky, Russia
2002 — Chatillon, France
2003 — Zhukovsky, Russia
2004 — Madan, France
2005 — Moscow, Russia
2006 — Paris, France
2008 — Moscow, Russia
2009 — Toulouse, France
2010 — Gelengik, Russia
2012 — Meudon, France
2012 — St. Petersburg, Russia
2013 — Palaiseau, France
2014 — Peterhof, Russia

TsAGI — ONERA Scientific Seminar

TsAGI — ONERA
SEMINAR

Scientific cooperation of TsAGI & ONERA

TsAGI — ONERA
SEMINAR

Denis Maugars Award for young researchers, established in September 2014

TsAGI–DLR Young Scientists Workshop
Moscow-2009, Berlin-2010

International Workshop
TsAGI–DLR:
Advanced Trends
in Aeronautical Research

TsAGI – CAE Scientific Conference on Aerodynamics, Flight Dynamics, Strength & Structures, Aeroacustics

Since 2001 held every year alternately in Russia and China

Participants:

Russia: TsAGI, SibNIA, VIAM, MAI, LII etc.

China: SADRI, ASRI, FAI, CFTE, Northwestern Polytechnical University etc.

International Forum for Aviation Research (IFAR)

- The world´s only aviation research establishment network established in 2008
- Aims to connect research organizations worldwide, to enable the information exchange and communication on aviation research activities

- The IFAR focus:
  non-competitive aviation research related to global technology challenges:
  - Emission
  - Noise
  - Safety & Security
  - Efficient Operations

EU—Russia Cooperation in Aeronautics Research

Technology Seminars - 2006, Brussels

- Russia's participation in the Framework Programmes
- Main areas of the EC–Russia cooperation in aeronautics
- Prospective joint projects

EU–Russia Cooperation in Aeronautics Research

Technology Seminar - 2007, Moscow

- The main topics of the EC-Russia cooperative research projects of FP7
- Organized by the Russian Agency for Industry with involvement of TsAGI, GosNIIAS, VIAM, CIAM and Sukhoi Civil Aircraft Co.

EU–Russia Cooperation in Aeronautics Research

Technology Seminar - 2010, Moscow

- Improvement of the EU–Russia cooperation in aeronautics research
- Support of the Russian participants involvement in FP7
- Support of the EU–Russia Coordinated Calls , the 3rd Call of FP7

FP Projects with TsAGI Participation

NATIONAL CONTACT POINT AERONAUTICS

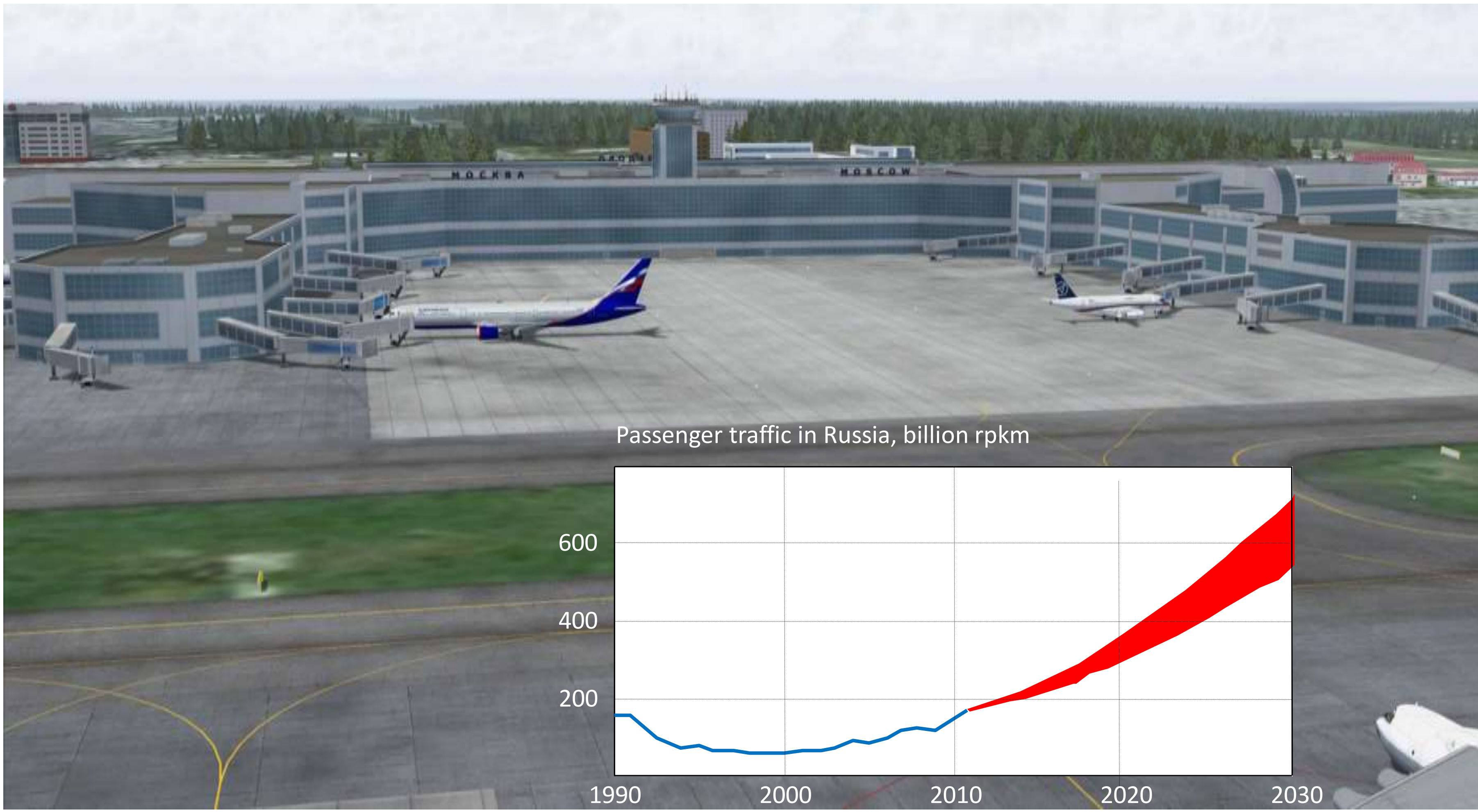
NACRE, FLY SAFE, FLIRET, SimSAC, Telfona, HISAC, ALCAS, QUANTIFY, MACE TRIP

SADE, dream, Maaximus, ALICIA, OPENAIR, DeSiReH, SUPRA, VALIANT, IDIHOM

ARISTOTEL, SAR STU, X-Noise, 4DCo-GC, SACOMAR, TransHyBeriAN, ETNA, ESWI, HAIC

AFLoNext, ABSCA, ORINOCO, RESEARCH, PoLaRBEAR, Buterfli, HEXAFLY-INT

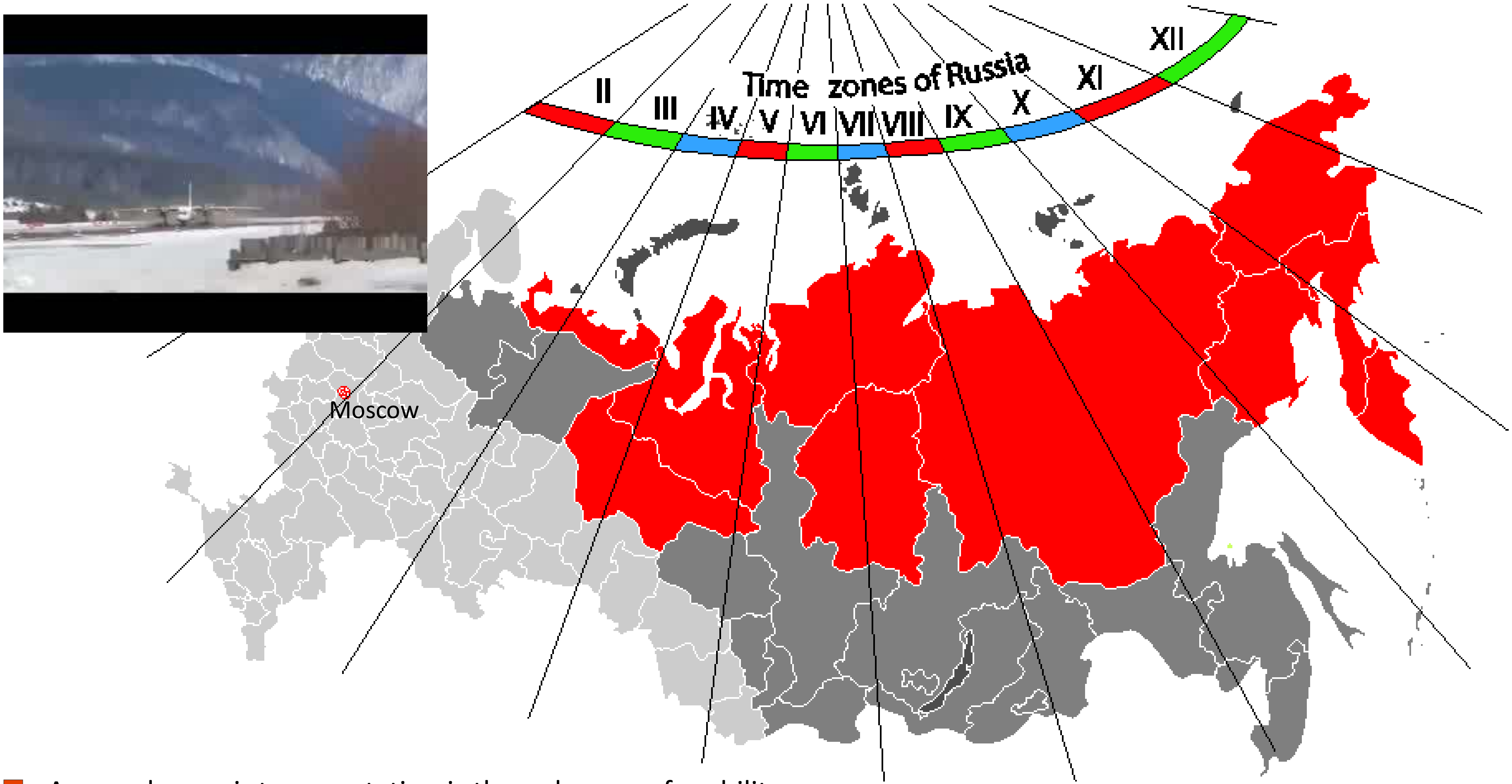
Air Transport System: Aircraft, Airport, ATM



National Plan for Aeronautics Research & Target Goals

	2015	2020	2030	2050
Safety		Fivefold accident reduction	Tenfold accident reduction	
CO_2	–33%	–40...–50%	–70% and more	–75%
NOx	–65%	–78...–80%	–78% and more	–90%
Noise (relative to Chapter 4 ICAO)	–32 dB	–30...–42dB	Commeasurable to average city noise level	–65%

Russia: Infrastructure and Climate Challenges

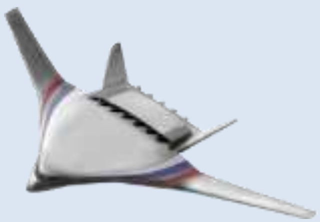


- Areas where air transportation is the only way of mobility
- Area where limited ground transportation is available

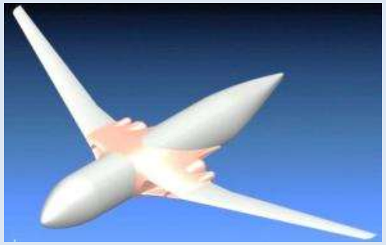
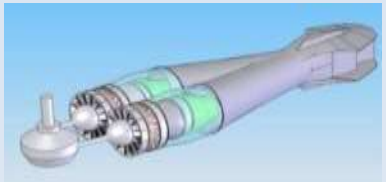
Russian National Aeronautics R & T Plan 2025

Total funding — $6 B till 2025, Including $ 200 M for international cooperation

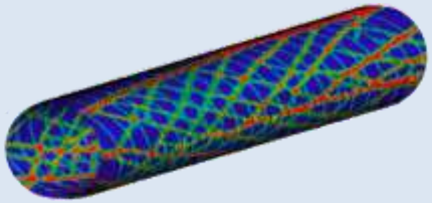
- New configurations
- Better airframe-engine integration, Higher L/D, Lower weight

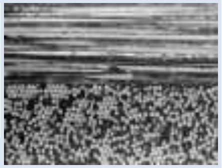


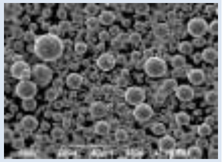
- UHBR Engines and Integration
- Open rotor
- Alternative fuels

- Pro-composite structures with new structural designs
- Active aeroelasticity
- “Smart” structures







- NG IMA
- Smart cockpit
- NG Systems
- More electric aircraft


AIRCRAFT 2020

Aircraft 2020: Integrated Technology Demonstrators Higher TRL

New configurations

Wide body A/C

Green regional aircraft

Low boom supersonic business jet

STOL transport aircraft

NG Aerodynamics High lift system

- Advanced wing with higher aspect ratio
- Laminar flow
- Ultra high aspect ratio braced wing
- Blended wing body
- Active flow control
- Natural/hybrid laminarization
- High lift system for STOL
- Low noise & low sonic boom configuration

Engines & integration

- Turbofan:
  - UHBR
  - Mixed thermodynamic cycle
  - High thrust to weight ratio
  - Distributed Power Plant
- Turboprop:
  - Open rotor
  - Low noise propellers
- Engine/airframe integration:
  - Over the BWB
  - In the fuselage tail
  - Over the wing
- Distributed air intakes
- Low noise nozzles

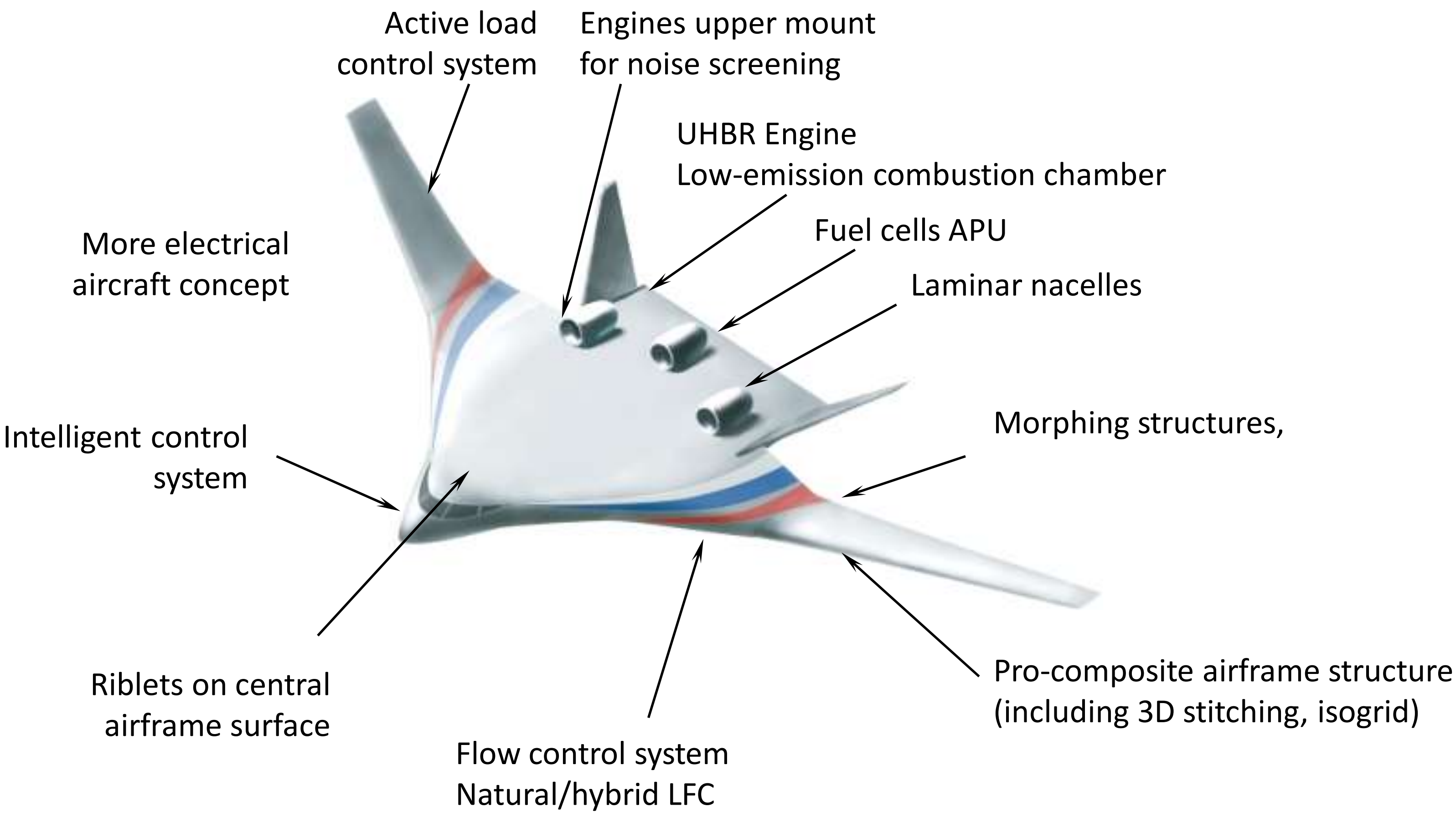
Advanced materials & structures

- Pro-composite structure
- Active aeroelasticity
- Hybrid metal/composite structure
- Ultra high aspect ratio braced wing
- Morphing structures

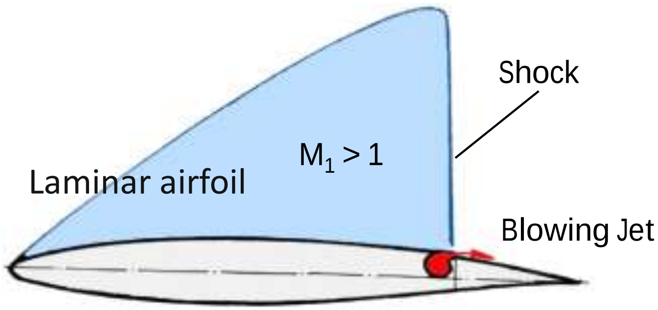
Avionics & systems

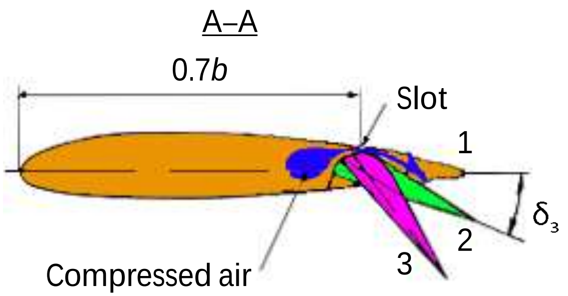
- Advanced avionics, IMA-2
- Smart control system
- More electrical aircraft
- Heat & energy balance

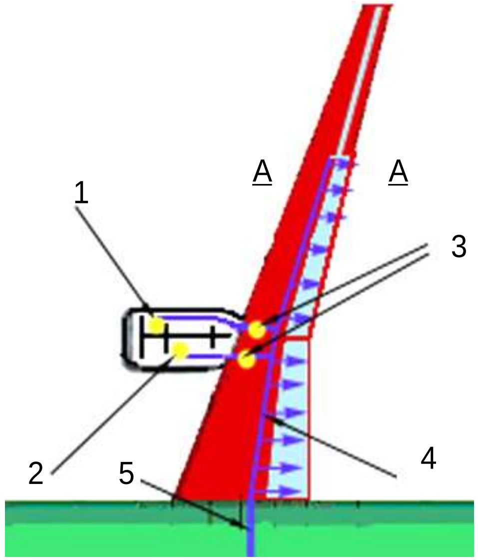
Innovations for BWB Aircraft

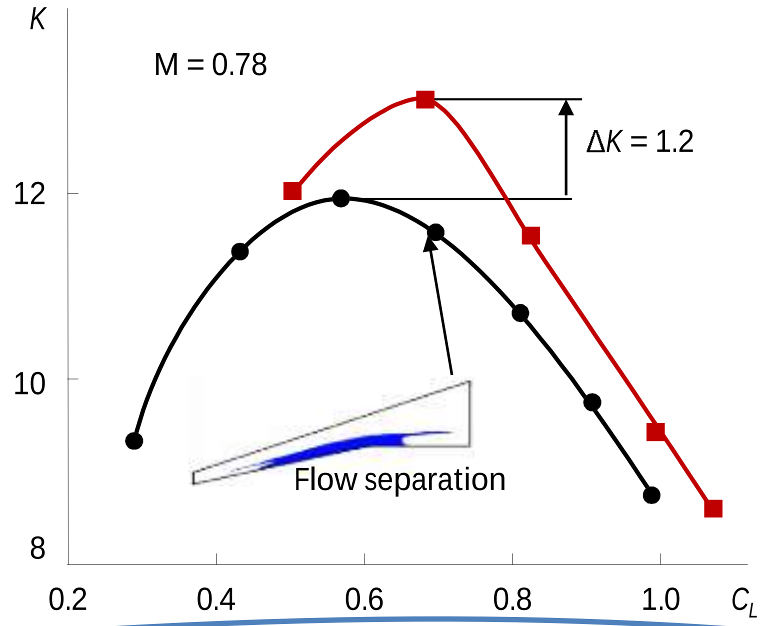


Wing Active Flow Control System





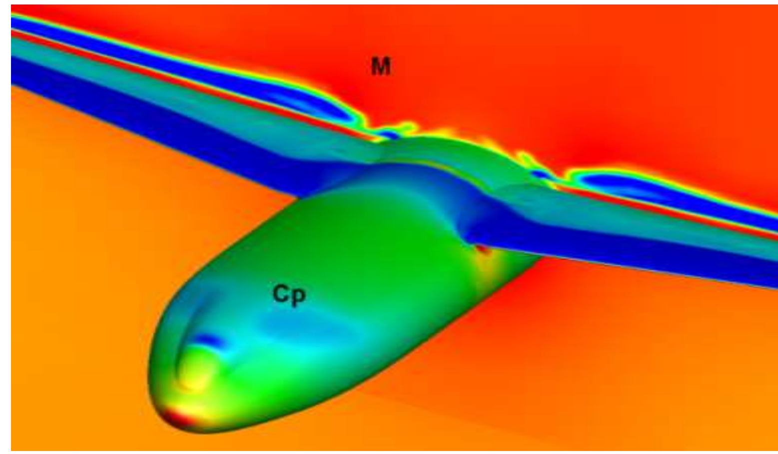


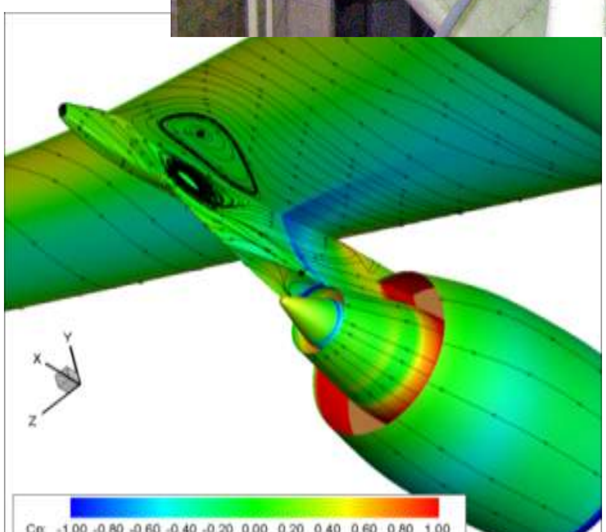


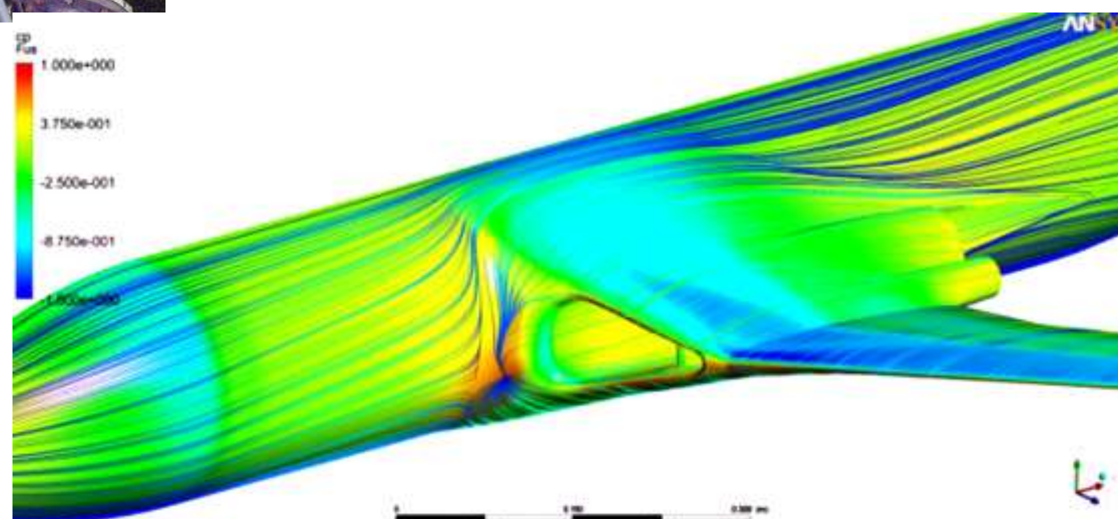
Using jet blowing system provides:

Speed and range increase	8–10%
Fuel burn reduction	–(5–7)%
Take-off and landing speeds reduction	–(10–15)%
Runway length reduction	–(30–35)%

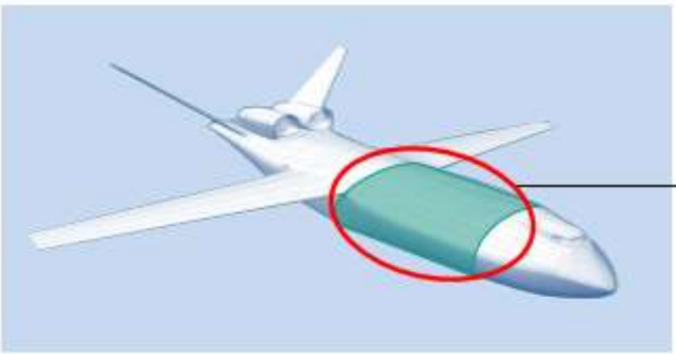
Numerical and Experimental Research of Power Plant Integration

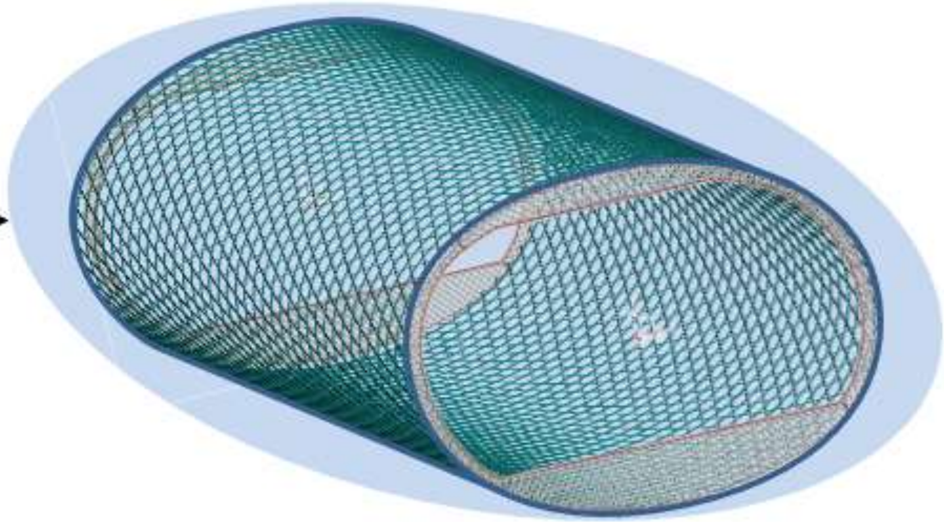




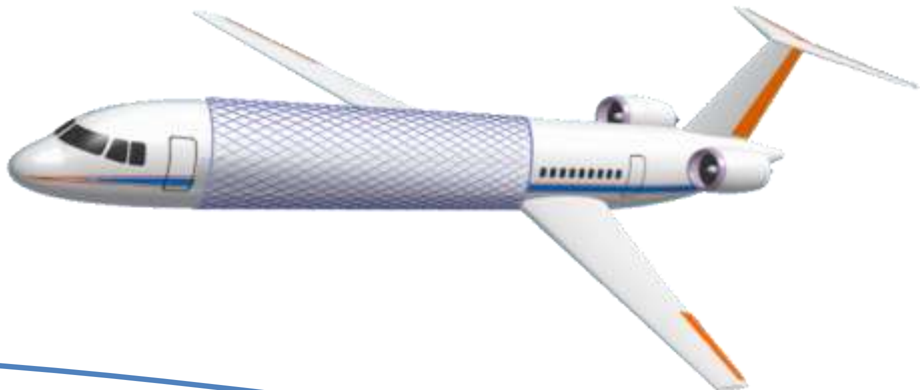


Advanced Aircraft Structures

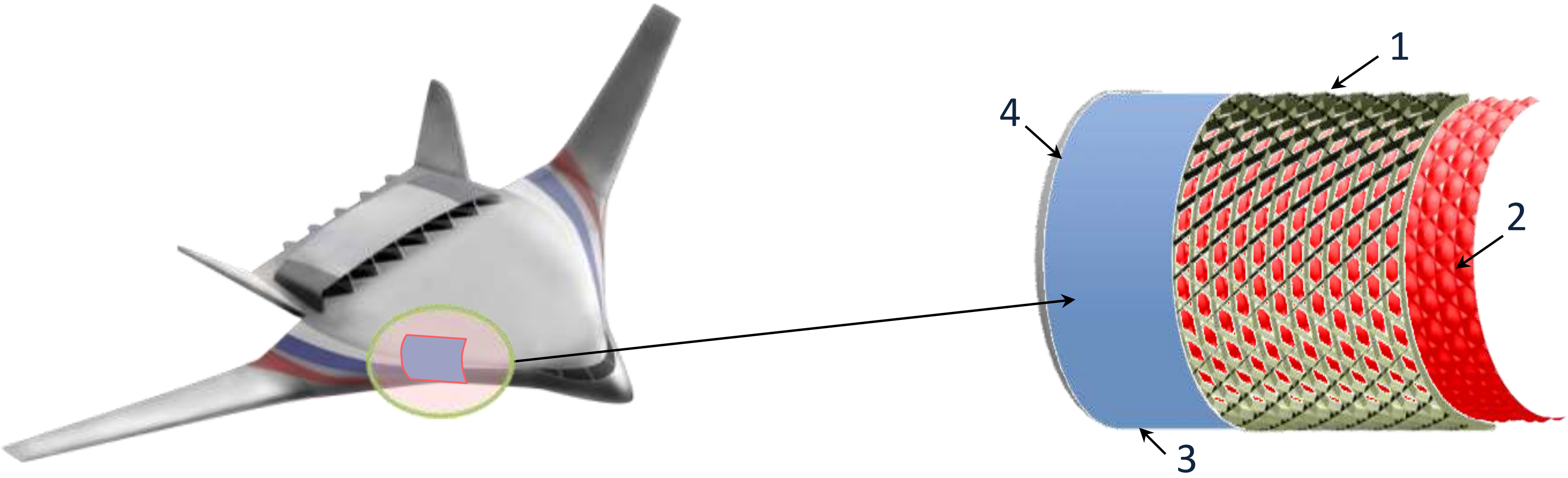




- Light and reliable discrete designs for Integral airframe structure
- New generation hybrid structures for critical units
- Integrated active load control and comfort improvement system
- Individual loading and health monitoring in real operation condition
- Adaptive morphing structures using “smart materials”



Composite Geodesic (Isogrid) Integrated Structures



Benefits of the new structures

- Up to 10-12% weight reduction.
- Long lasting reliable FOD protection
- Up to 40% less junction weight compared to "black metal".

Main structural elements

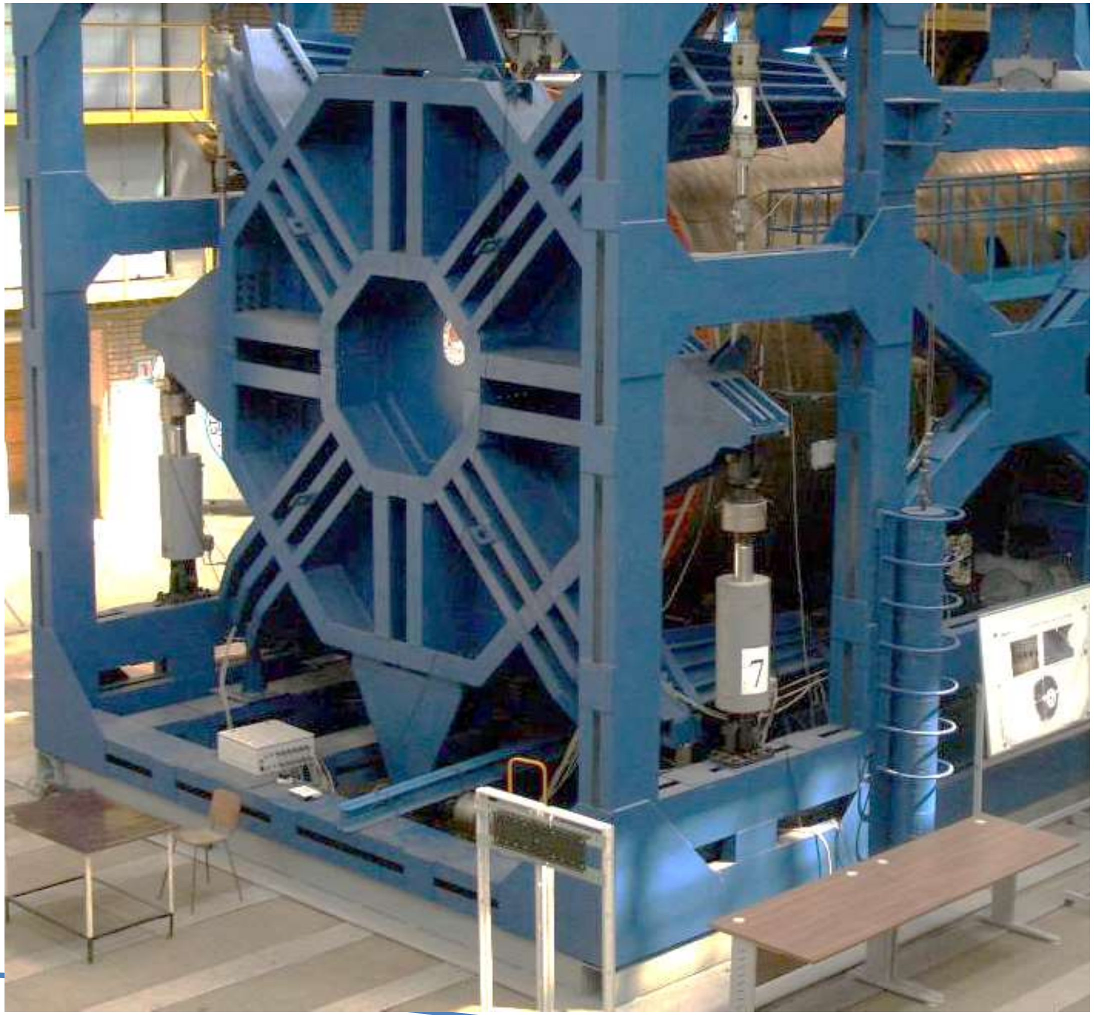
1. Lattice structure instead of traditional skin panels.
2. Elastic internal skin for pressurization.
3. Elastic external skin forming aerodynamic surface.
4. Stiff frames with strong and reliable junctions.

EU FP-7 Projects: Alasca & PolarBear

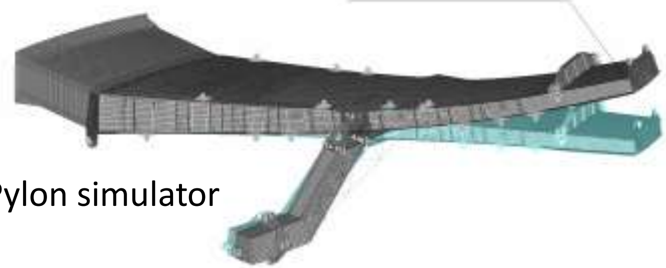
Test Facility for Composite Fuselage Barrel

Lattice fuselage barrel (inside view)

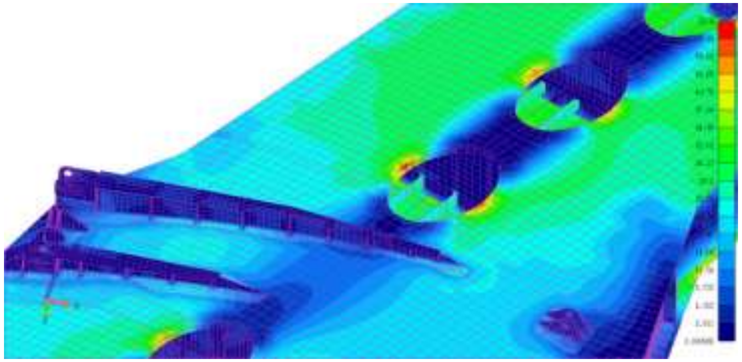
Validation of the structural modeling at the TsAGI test facility



High Aspect Ratio Composite Wing-box Prototype Testing



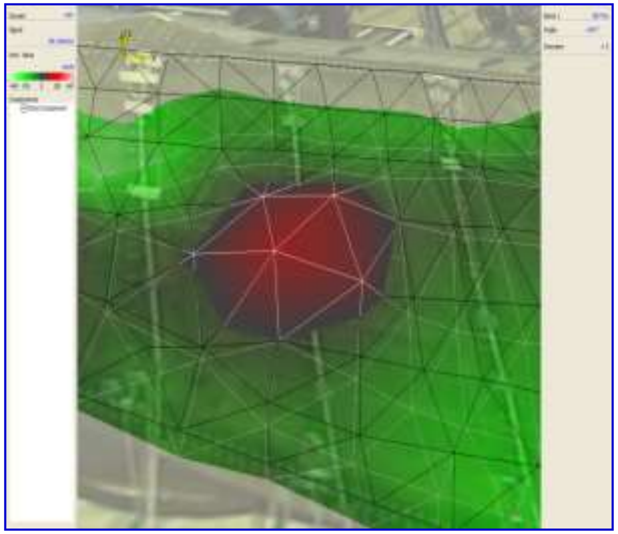
Finite element model of the wing-box
(169373 nodes, 192644 elements)

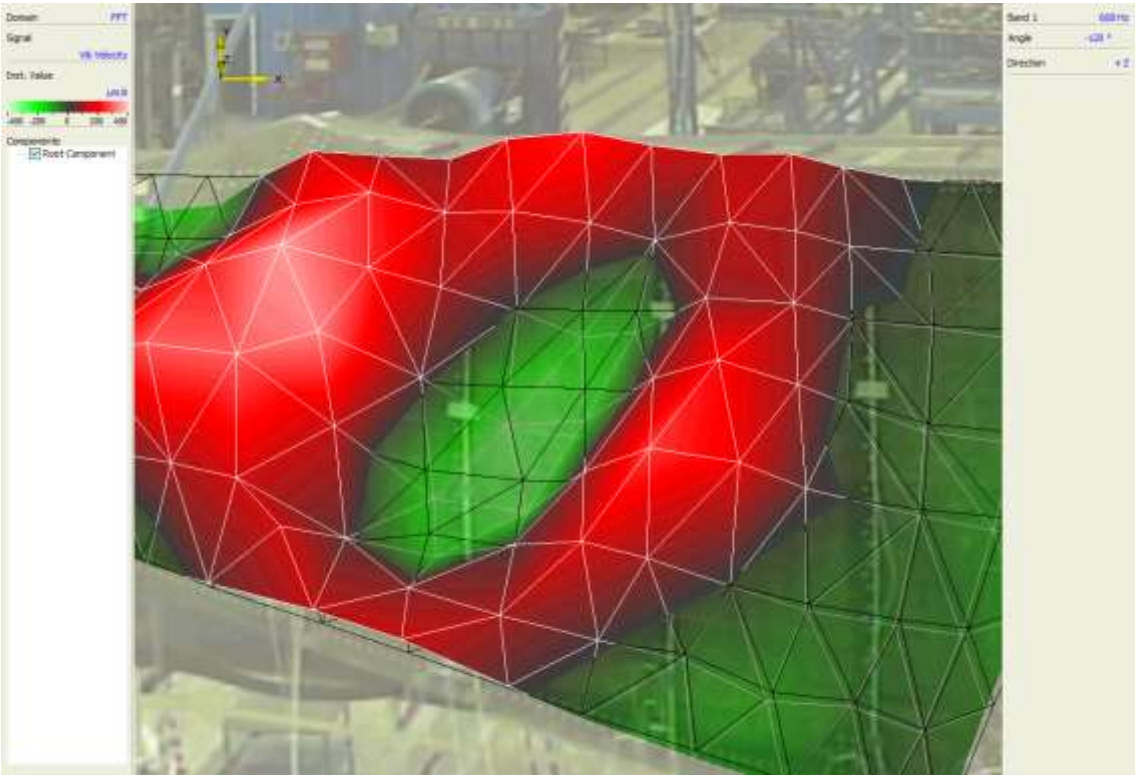


Stress and deformation on the lower panel

FEM modeling of the Composite Wing-box Stress & Deformation

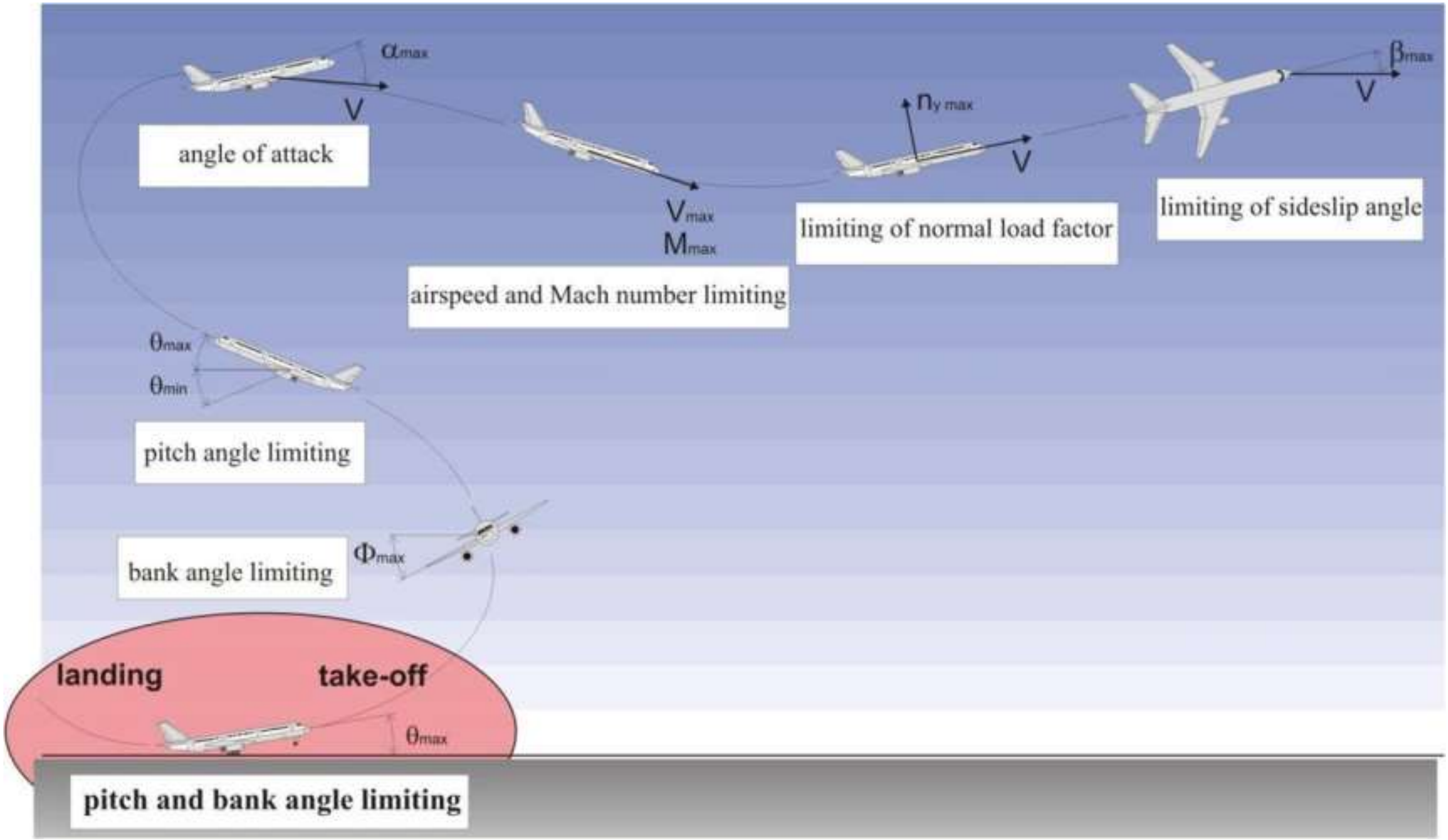
Modeling foreign objects damage on the upper wing surface



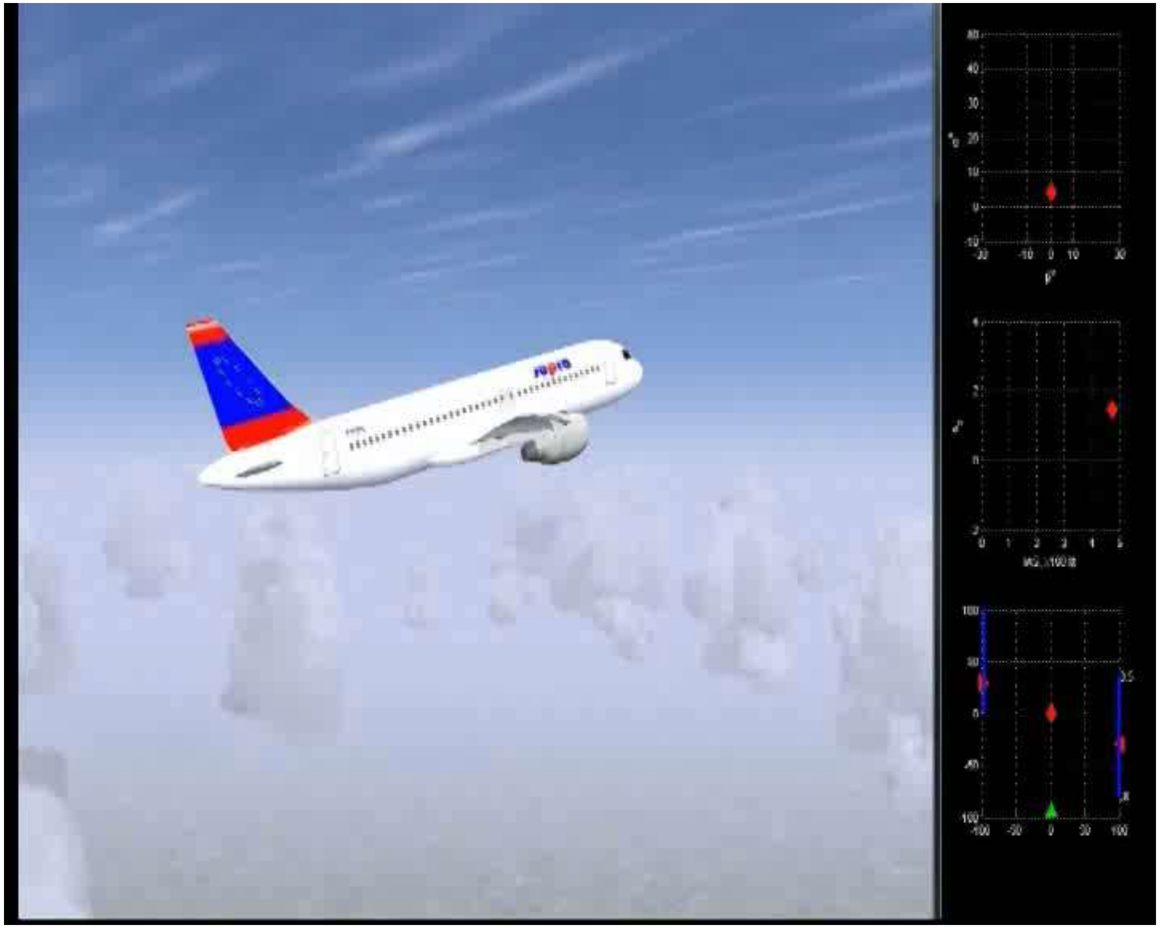


Mathematical modeling visualization

Flight Safety



Upset Recovery in FP7 SUPRA 2010—2012



- Loss of control in upset conditions.
- To improve pilot training for upset recovery
- Pilot training based on flight simulator

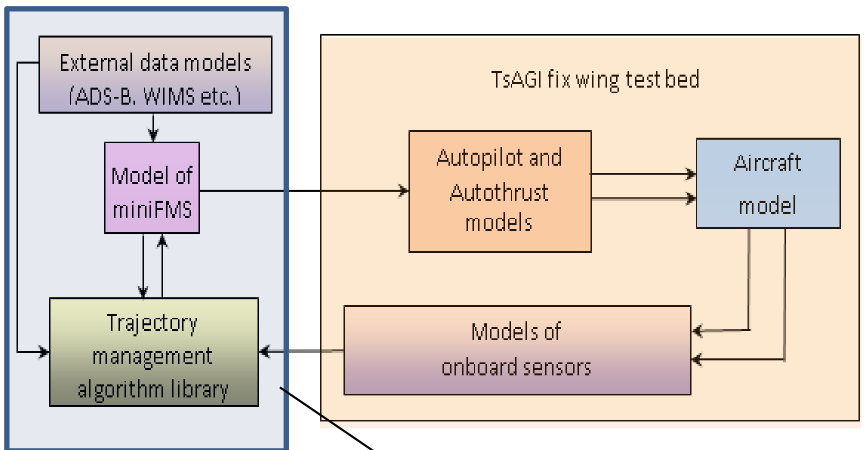
SUPRA achievements:

- New A/C dynamic mathematical models in extended flight envelope.
- Motion cueing concept to extend the capabilities of hexapod flight simulators

ALICIA: 4-D Trajectory Management & Optimization

- 4-D navigation with minimum fuel consumption
- Mostly vertical maneuvering ($n_z \leq 1.2$)
- Continuous descent profile of the type *"CAS-M-CAS"*

Integration of trajectory algorithms



ALICIA segment

Re-planning due to thunderstorm on the route

Simulator cockpit with ND imitator

Pre-planned & Re-planned routes on ND imitator.

Route Fragment : Amsterdam – Clermont-Ferrand

This poster is produced under the EC contract ACP8-GA-2009-233682

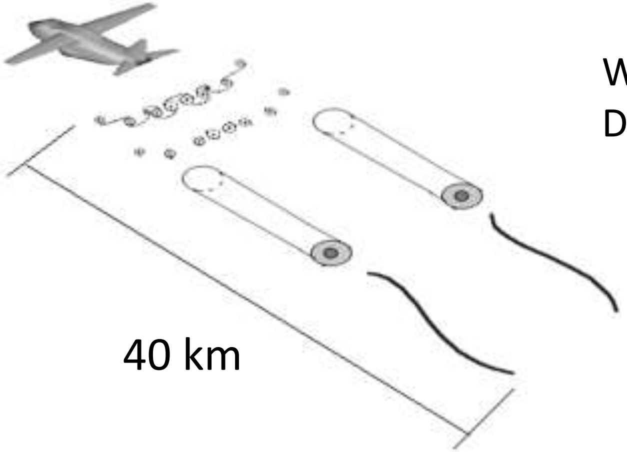
SimSAC: Stability & Flight Control Analysis

SimSAC

TsAGI tasks in the project:

- Software to assess the stability and controllability of A/C
- Wind tunnel tests four aerodynamic stability analysis
- Software for flight control system synthesis

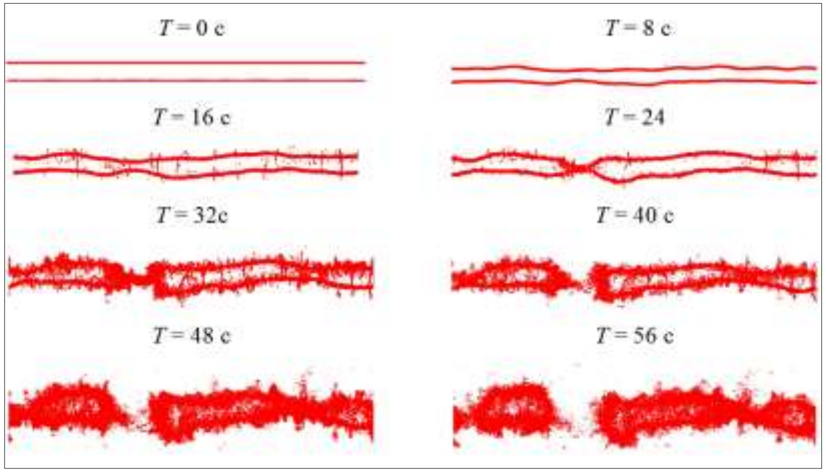
Wake Vortex Safety / ICAO WTSG



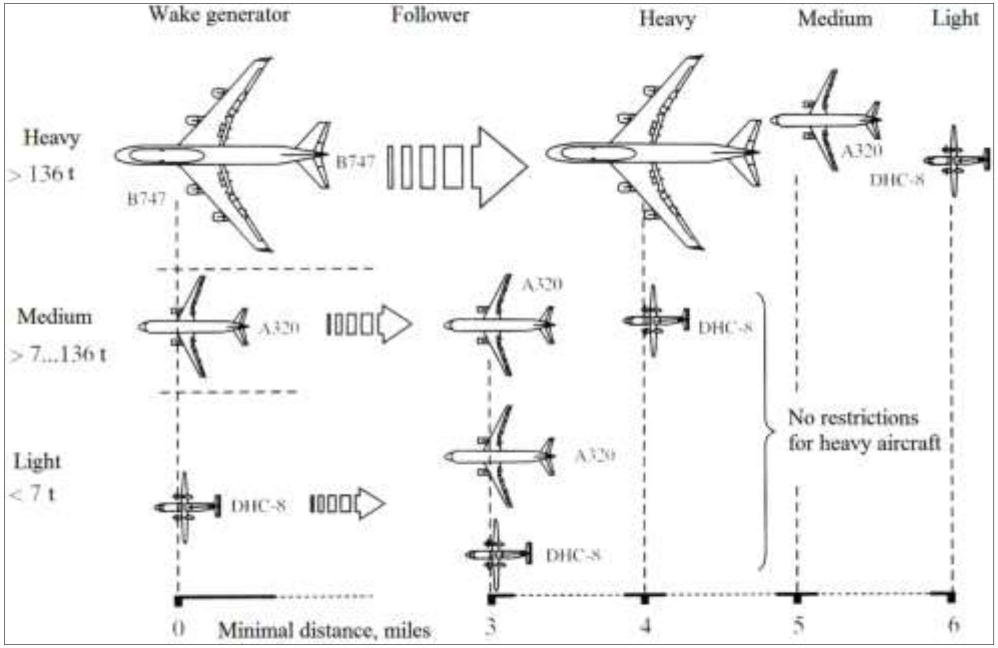
Wake length - 40 km
Duration - 3 minutes

Separation Distance Due to Wake Vortex Safety

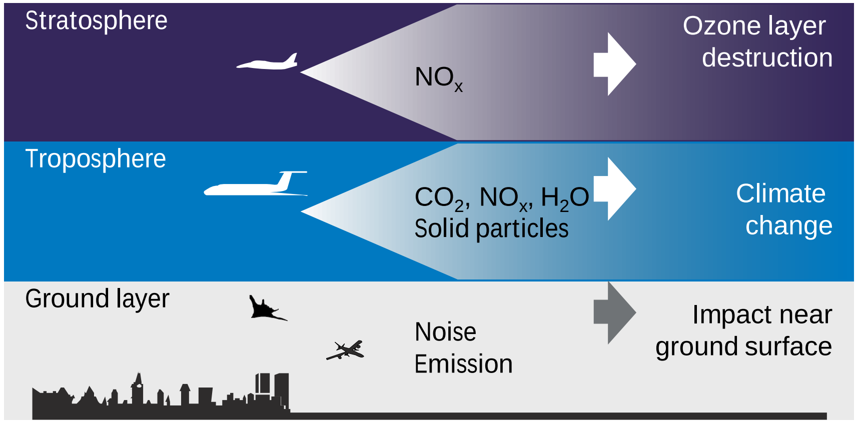
Flight experiment CFD calculations

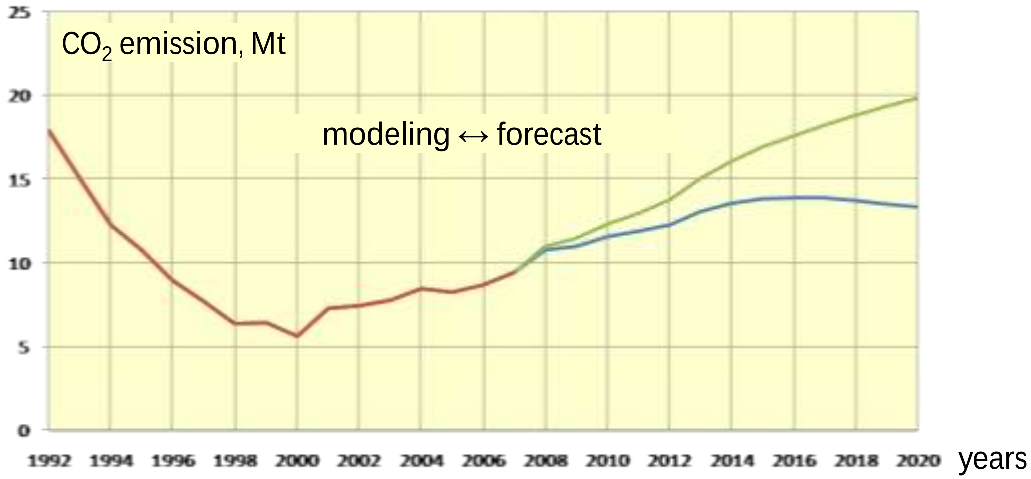


Safety matrix (ICAO)

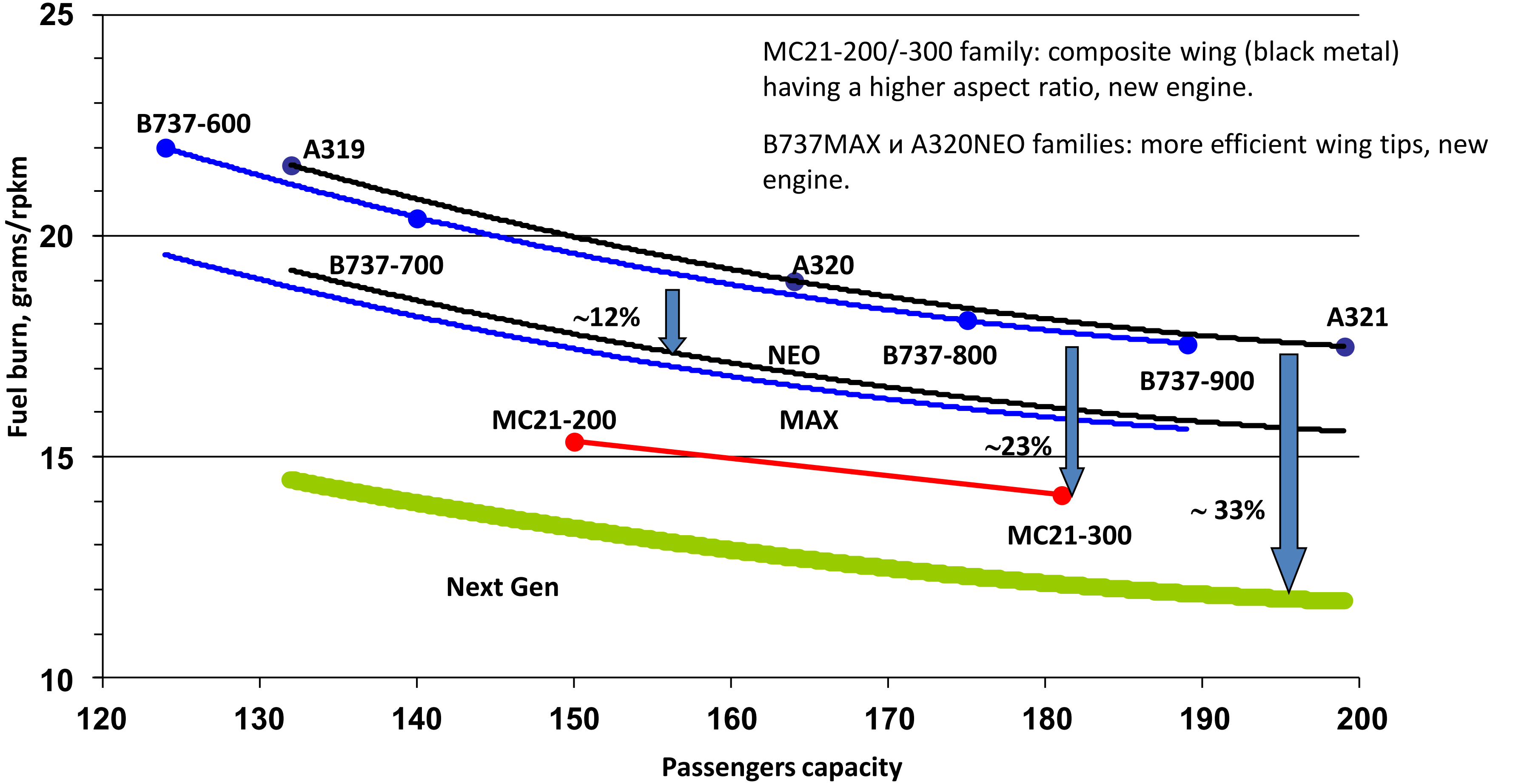


Modeling Emission over Russian Territory





Fuel Burn Target Goals for Narrow Body Aircraft

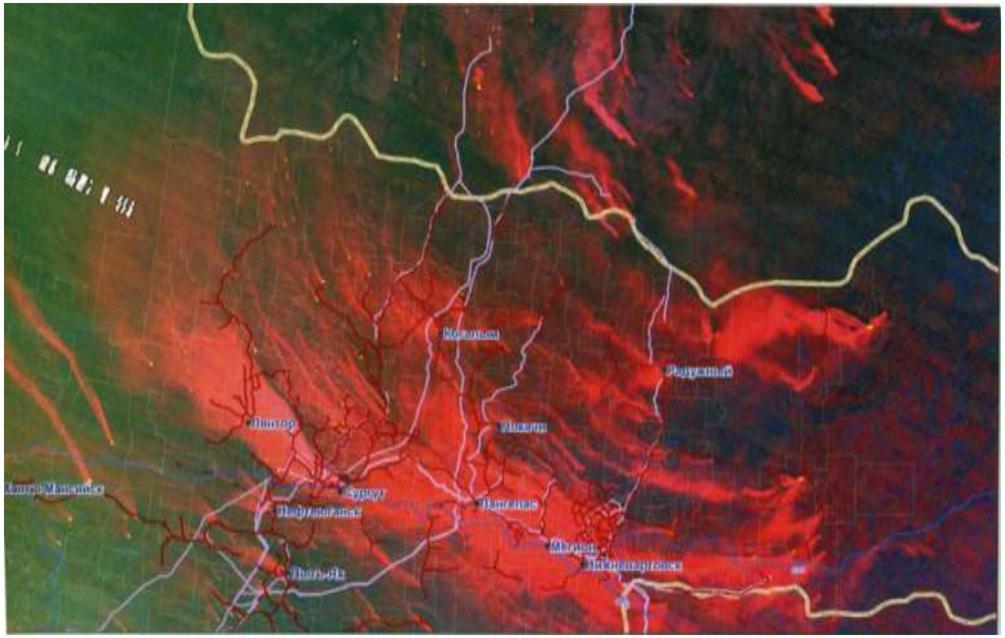


Innovations introduced in re-engined versions of narrow body families are not sufficient to meet the fuel burn target goals for N+1 generation.

“Alternative” Fuel: Gas-to-Liquid (GTL)

GTL fuel is «greener» compared to conventional kerosene:

- 5–10% less CO_2 emission
- less NO_x & CO emission
- Much less soot



Thermal wakes from torches

Existing GTL Fuel Demonstrators & Future Projects

Mil-8GTL

Ilyushin-114

Tupolev-206

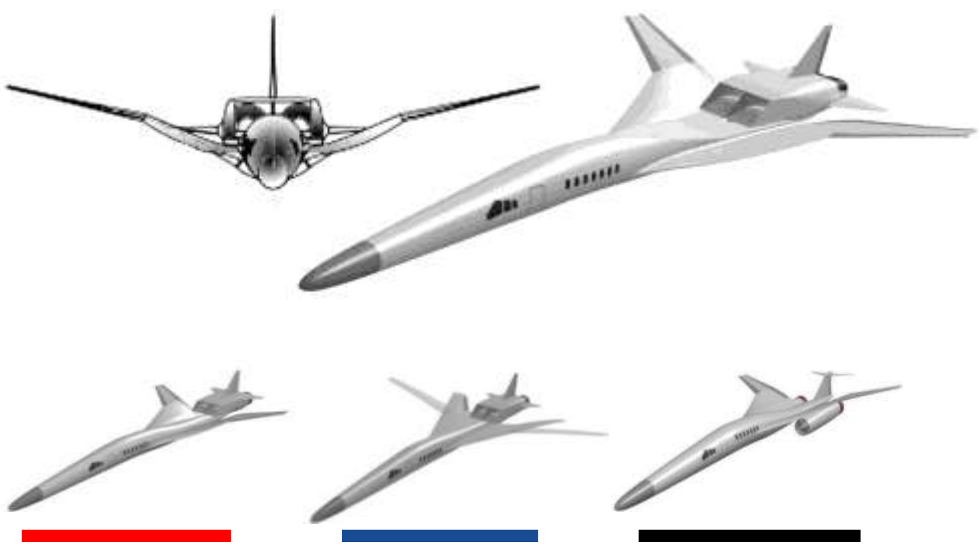
Tupolev-336

HISAC — Low Boom Supersonic Business Jet

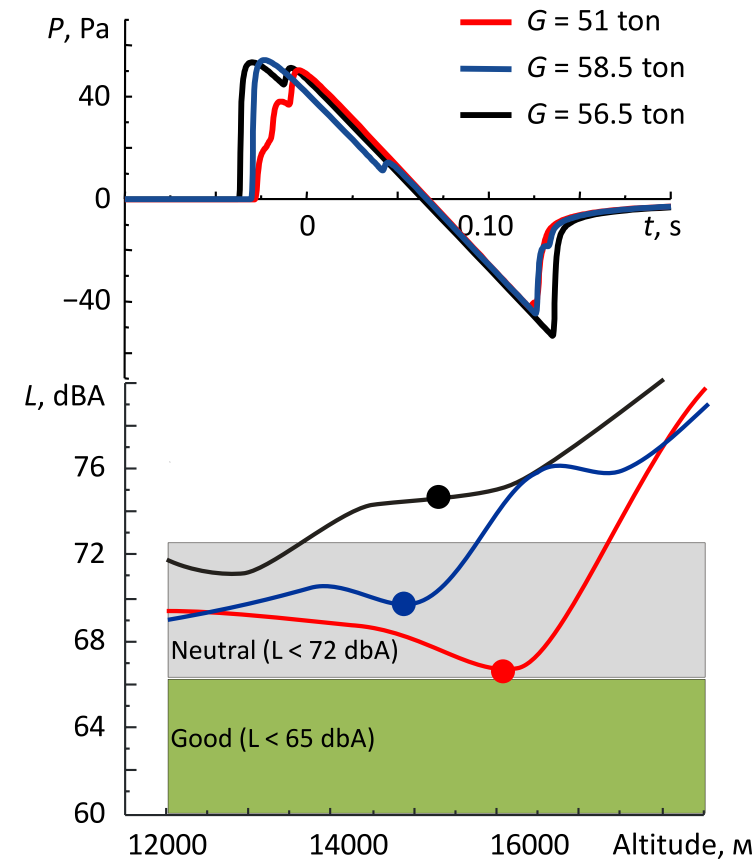
Low Sonic Boom Supersonic Business Jet

Contribution of TsAGI:

- sonic boom criteria
- sonic boom and aerodynamic modeling
- design of low-boom a/c configuration;
- MDO analyses



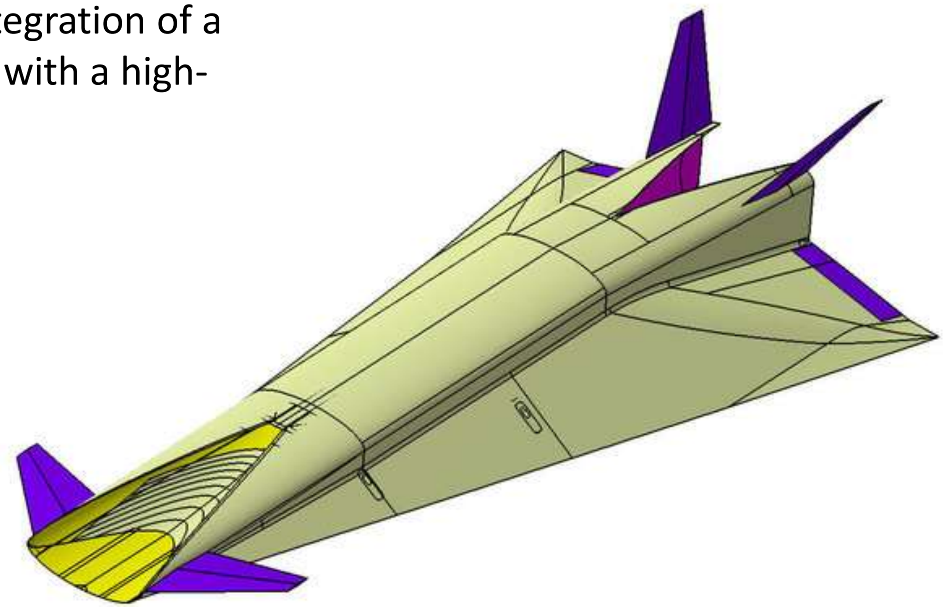
Pressure Signatures and Sonic Boom Loudness



HEXAFLY-INT — High Speed Experimental Fly Vehicle

Main objective:

Free flight demonstration of radically new conceptual design of hypersonic vehicle based on integration of a highly efficient hydrogen propulsion unit with a high-lifting concept .



TsAGI: Minding the Future of Flight