AEROSPACE TECHNOLOGY CONGRESS 2019
SUSTAINABLE AEROSPACE INNOVATION IN A GLOBALISED WORLD
FT2019

Supersonic Transport: from the Tu-144 to the New Generation

Prof. Sergey Chernyshev
Chief Scientific Officer
TsAGI, Russia

8-9 October 2019, Stockholm, Sweden

ЦАГИ
1918–2018
TsAGI
100

TsAGI: 100 years of aerospace technology excellence

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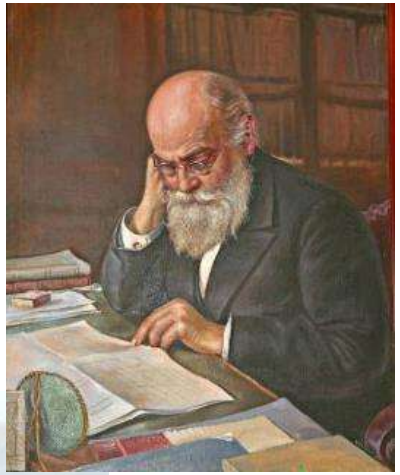
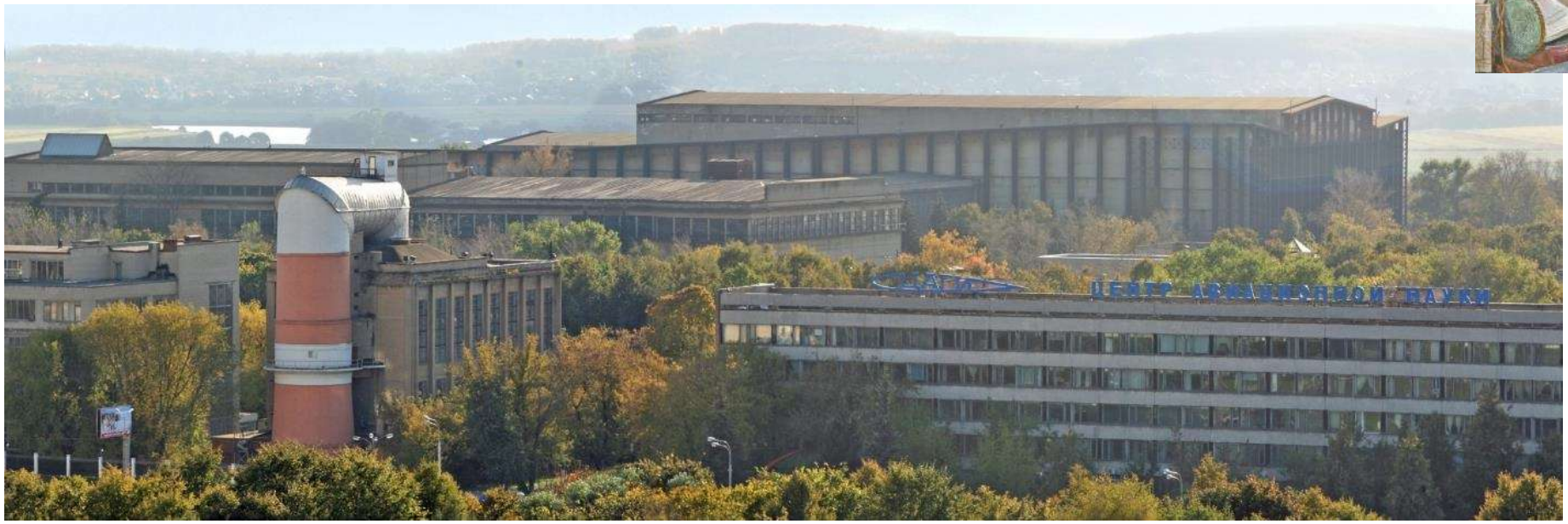
- ✓ Russia's Leading Aerospace R&D Center
- ✓ Founded in 1918
- ✓ World Largest Testing Facility in Single Location
- ✓ Mother Organization for Many Russian R&D Institutes and Design Bureaus (CIAM, VIAM, LII, GosNIIAS, SibNIIA, Tupolev, etc.)
- ✓ Training Facility for top Russian Technical Universities



Professor N.E. Zhukovsky
1847–1921,
founder of TsAGI



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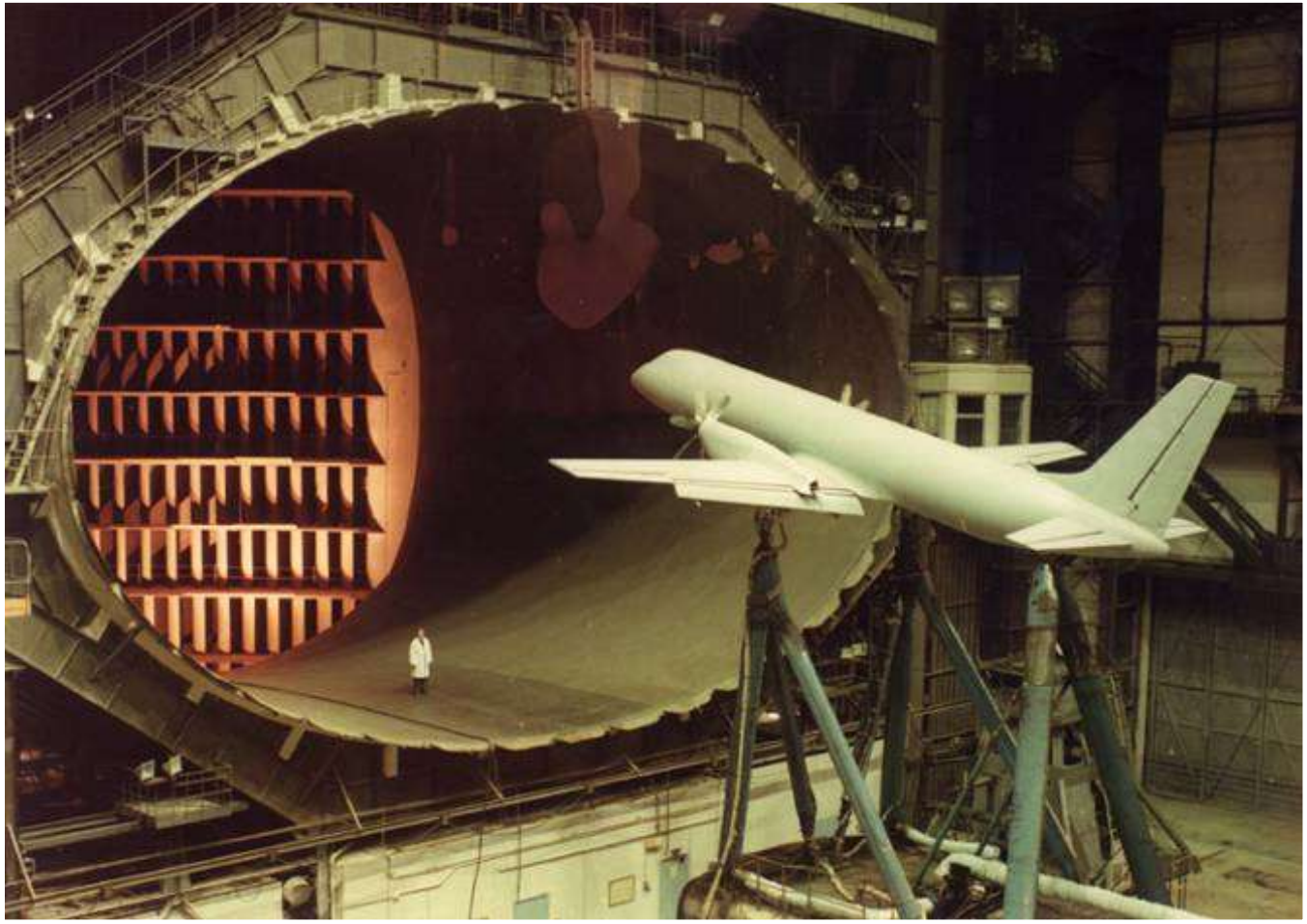
TsAGI: Main Areas of Expertise






- Aerodynamics & Hydrodynamics
- AeroThermodynamics & Gas Dynamics
- Aeroacoustics
- Aircraft Certification & Flight Testing
- Aircraft Propulsion
- Aircraft Strength & Structures
- Alternative Energy Sources
- Atmospheric & Environmental Research
- Air Traffic Management Research
- Experimental Facility Development
- Flight Dynamics & Control Systems
- Flight Simulation & Pilot Training
- Industrial Propellers & Fans
- Lasers & Optics
- Holography
- Microwave Technology
- Plasma Physics
- Precision Manufacturing

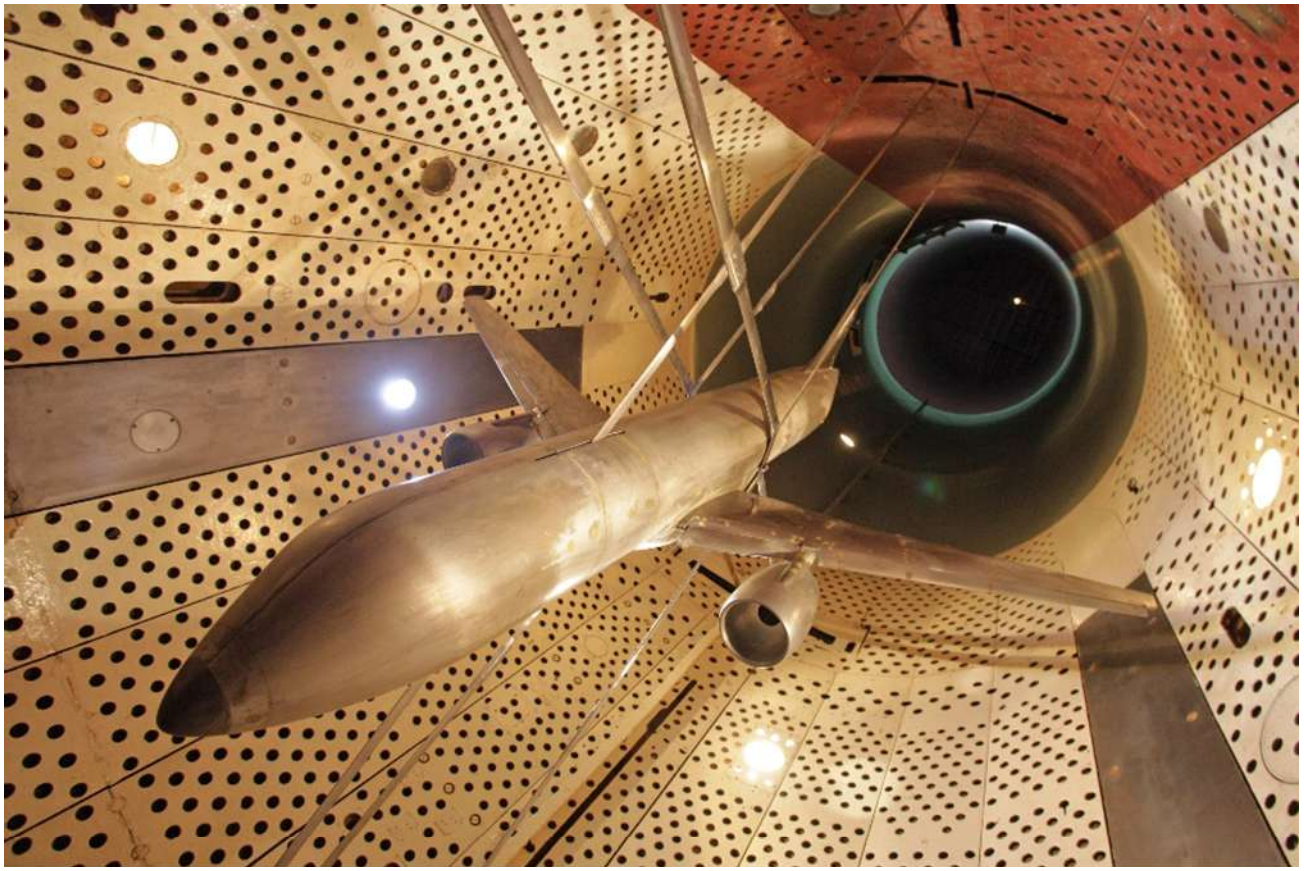
Large 24x14 m Subsonic Wind Tunnel



Subsonic Wind Tunnel T-101

Flow velocity	5…52 m/s
Test section	elliptic 24×14 m
Angles of attack range	–20°…+20°
Sideslip angle range	–180°…+180°

Ø2.5 m Transonic Wind Tunnel



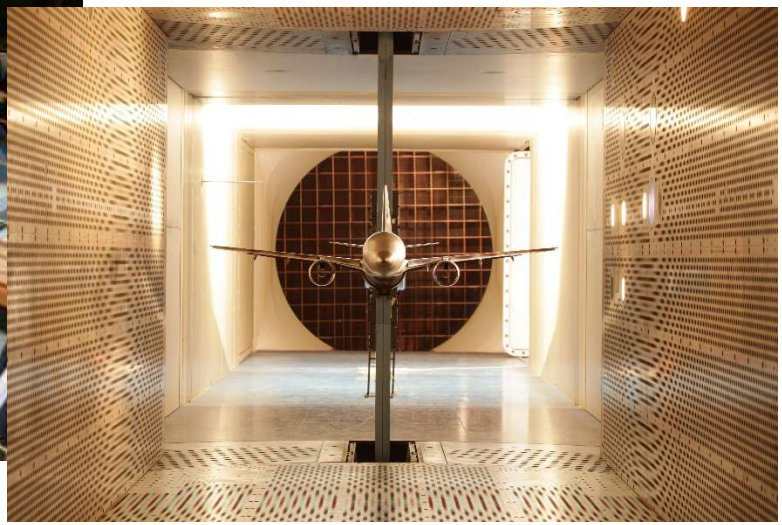
Transonic Wind Tunnel T-106

Flow Mach number	0.15…1.1
Re number per 1 m	up to $35 \cdot 10^6$
Dynamic pressure	up to 58 kPa
Test section section diameter	2.5 m

2.75 x 2.75 m Transonic Wind Tunnel

Transonic Wind Tunnel T-128

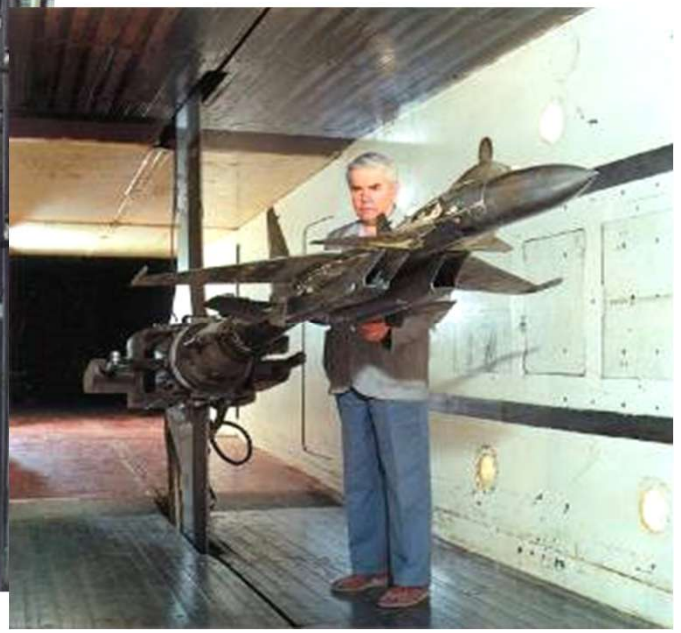
Test section: 2.75 × 2.75 m
Flow speed: M = 0.4…1.7
Adaptive wall perforation
Real flight Re numbers



2.25 x 2.25 m Supersonic Wind Tunnel

Supersonic Wind Tunnel T-109

Test section: 2.25 × 2.25 m
M = 0.4…4.0
$Re_{L=1m}$ = (16…60)·10^6
Variable nozzle



1.0 x 1.0 m, M = 10 Hypersonic Wind Tunnel

Hypersonic Wind Tunnel T-116

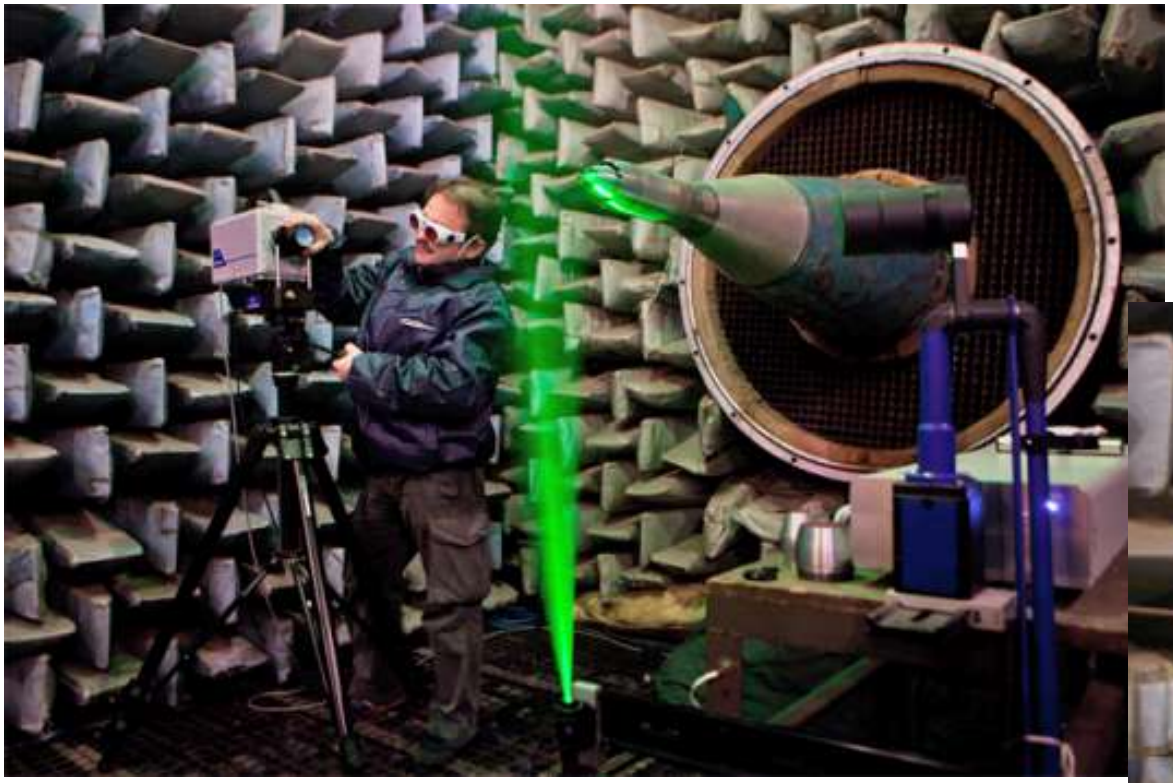
Flow M number	1.8…10
Cross section area	1×1 m
Total pressure	110…8000 kPa
Dynamic pressure	8…120 kPa
Stagnation temperature	290…1075 K
Run duration	up to 300 s
Angle of attack (α)	–6°...+30° (60°)
Side slip angle (β)	–4°...+9°

Ø1 m, M=20 Hypersonic Wind Tunnel

Hypersonic Wind Tunnel T-117

Flow M number	7.5...20.0
Nozzle diameter	1 m
Re number per 1 m	$(0.15...8.5)\cdot10^6$
Total pressure	0.8...20 MPa
Dynamic pressure	up to 12 kPa
Stagnation temperature	600...3400 K
Run duration	30...180 s
Angle of attack (α)	–25°...+80°
Side slip angle (β)	±30°

Acoustical Anechoic Chambers



Anechoic Chamber

Hot/Cold Air Jets Noice
Fans & Air Frame Noise
Acoustical Sources Study

Full Flight Engineering Simulator

PSPK-102 Flight Simulator

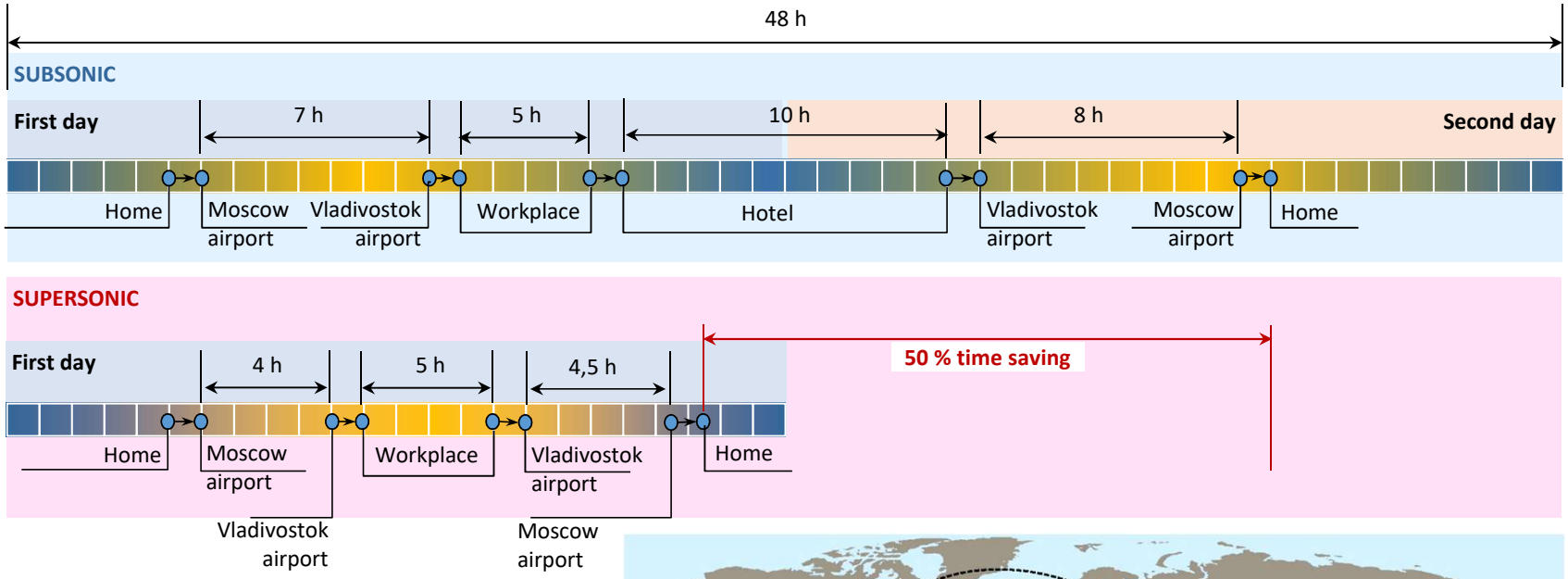
Flexible configuration control system
Control side-sticks
4-channel collimating visualization system
6-degree hydraulic motion system
Graphic instrument panel

Global Air Transport System

- Air Traffic doubles every 15 years
- Demand for faster travel
- Business and time critical shipments

Supersonic Flight — a New Horizon of Aviation Mobility

Moscow–Vladivostok Flight



The one-day trip flight range for subsonic aircraft is limited to 3,500 km

Supersonic aircraft expands the one-day trip flight range up to 7,500 km and halves the flight time and better

First Generation of Supersonic Transport

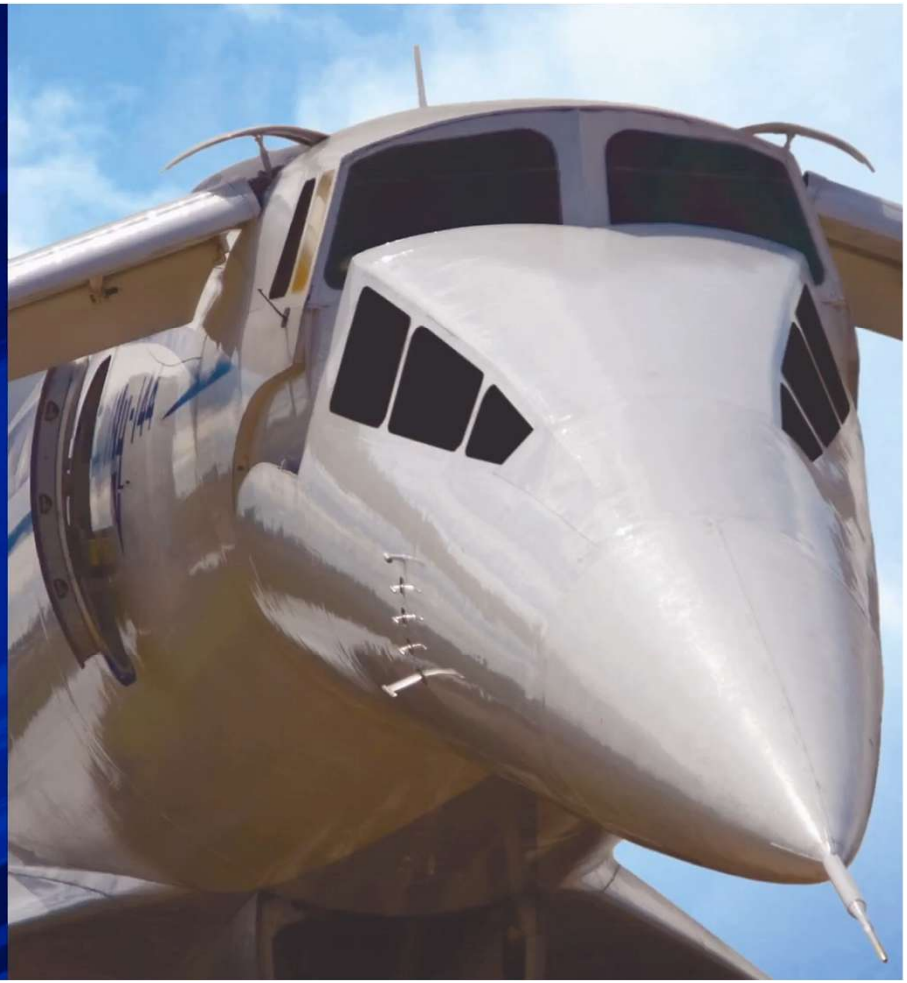
Tu-144 (USSR, 1968—1978)


Concorde (Great Britain—France, 1969—2003)

Key Problems	Tu-144, Concorde	Current Requirements
Unacceptable level of sonic boom, dBA	96—106	Less than 72
High level of initial shock overpressure, Pa	120—140	7—10 times less
High level of noise near airport, exceeding current standards, EPNdB	By 25 and more	–3 / –5 (to margin)
High level community noise, EPNdB	Chapter 3 ICAO + 30	less 20 EPNdB to Chapter 3 ICAO
High level LTO NOx EI, g/kN	50, CAEP6	60%—75% reduction
High level NOx EI, g/kN	≥ 20	≤ 10

TsAGI 100 SINCE 1918

FIRST FLIGHT of the RUSSIAN SUPERSONIC JET TU-144



Supersonic Flight Research based on the Tupolev-144

NASA – TsAGI — Tupolev test program

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

World Projects of Supersonic Business Jets

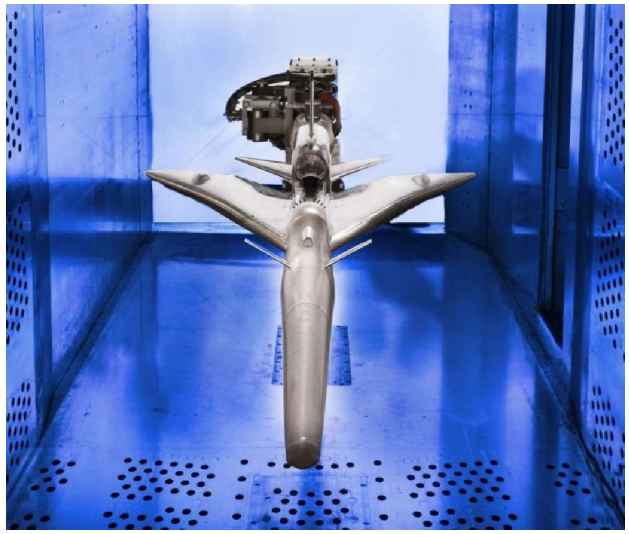
	Flight Mach Number	Range, km	Q-ty PAX	First Flight
Aerion AS2, USA	0.95 — 1.4	9300	9	First flight in 2023
Gulfstream QSJ, USA	1.6	7500	8	
SAI & LM QSST, USA	2.0	7500	8	
SpikeAerospace S-512, USA	1.6	10300	18	First flight in 2021
Boom Supersonic, USA	2.2	8800	55	Demonstrator in 2021
Sukhoy / TsAGI Russia	1.8	7500	12	First flight — late 2020's






World Technology Demonstrator Aircraft - USA

X-59 NASA, USA



Model in WT

Flight Mach Number	Flight Altitude, km	Propulsion	Project start	Current status	Lead time
1,4	17	from F-18	2016	In progress	2023

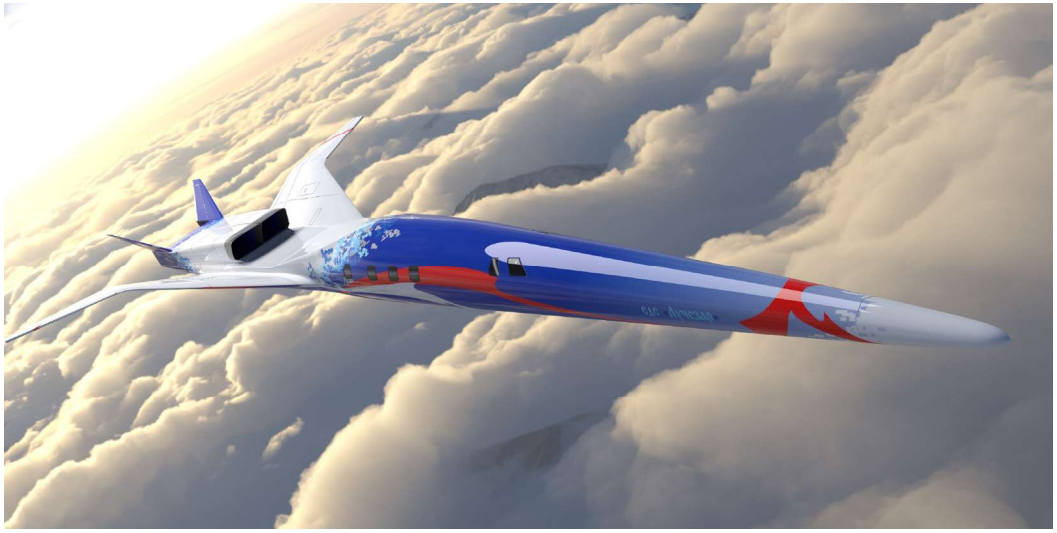
World Technology Demonstrator Aircraft – Japan

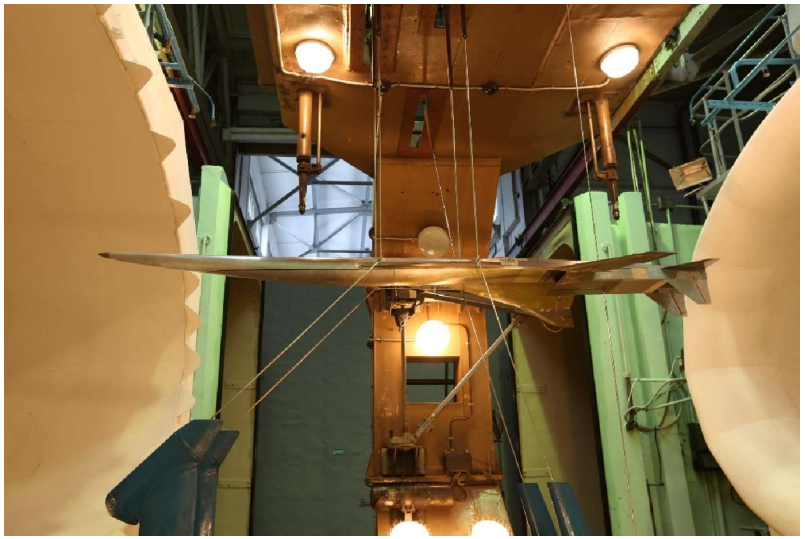
JAXA SST Scaled Model

Flight Mach number	Flight altitude, km	Propulsion	Project start	Current status
2.0	15	—	2011	Flight Testing Campaign 2014 — up to date

World Technology Demonstrator Aircraft - Russia

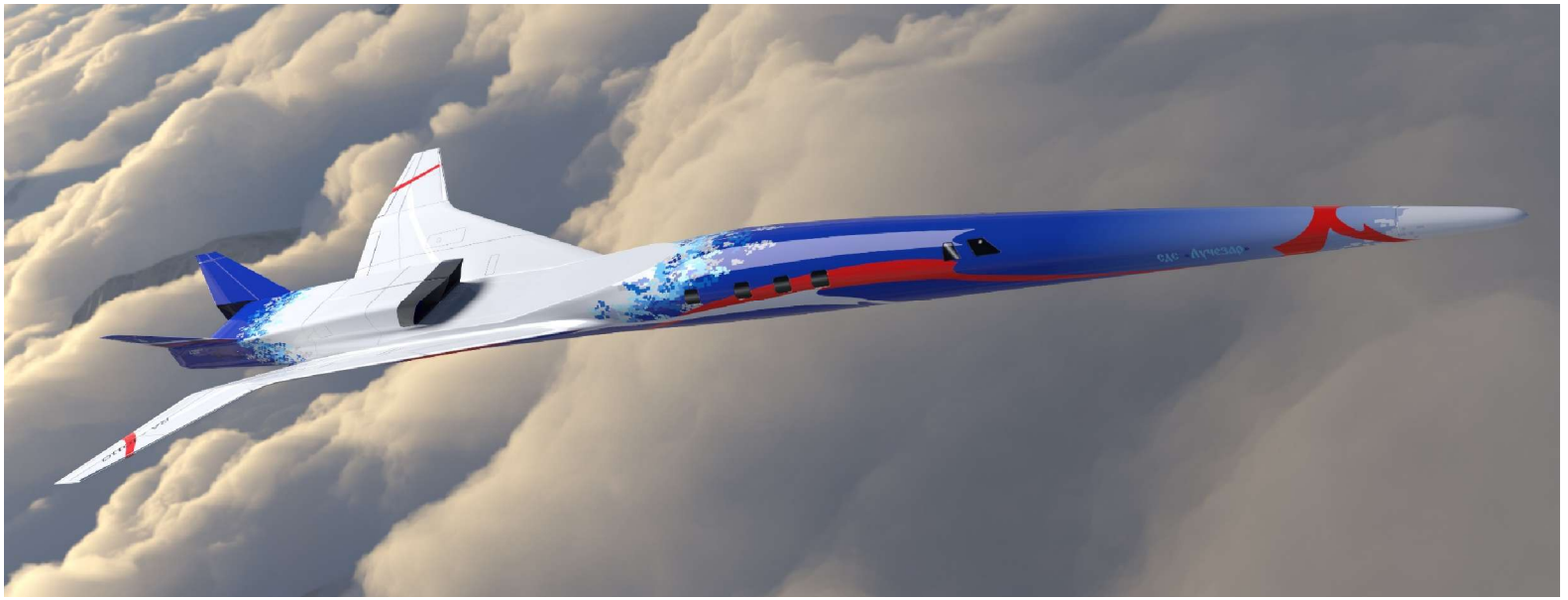
Sukhoy / TsAGI concept of low sonic boom supersonic business jet





Flight Mach Number	Flight Altitude, km	Weight, t	Sonic Boom	Current Status	Lead Time
1.8	15…17	55	69 dBA	Government Contract **2017—2019**	Demonstrator Technical Proposal **2019**

Low Boom Supersonic Business Jet Concept



Flight Mach Number	Flight Altitude, km	Weight, t	Sonic boom, dBA	Current status	Lead time
1.8	14…16	27	Less than 65	Acting contract for Technology Demonstrator Aircraft Concept Design Development	Dec **2019**

Key Technologies

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- ✓ Low sonic boom & low noise technologies
- ✓ High fuel efficiency in all flight regimes
- ✓ External environment artificial vision system
- ✓ Variable-cycle power plant design
- ✓ Composite isogrid structure airframe
- ✓ Artificial intelligence

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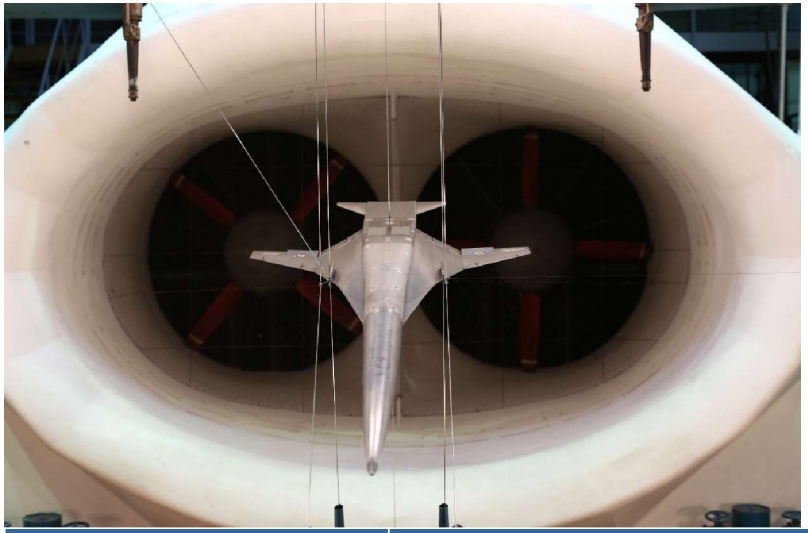
International Supersonic Technology Projects



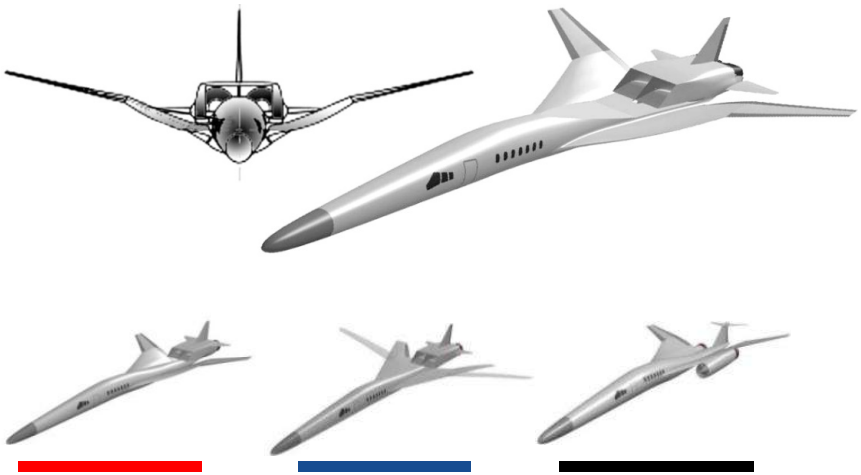
HISAC

Acronym:	HISAC
Project Title	Environmentally-friendly high-speed aircraft
Objective	Research on supersonic business jet providing low sonic boom and noise near airport areas
Coordinator	Dassault Aviation (France)
Time Frame	01.05.2005 — 31.10.2009
Partners	38 partners, incl. TsAGI, Alenia Aeronautica, ONERA, EADS, SNECMA, Rolls-Royce, Sukhoi Civil Aircraft Company, CIAM and others

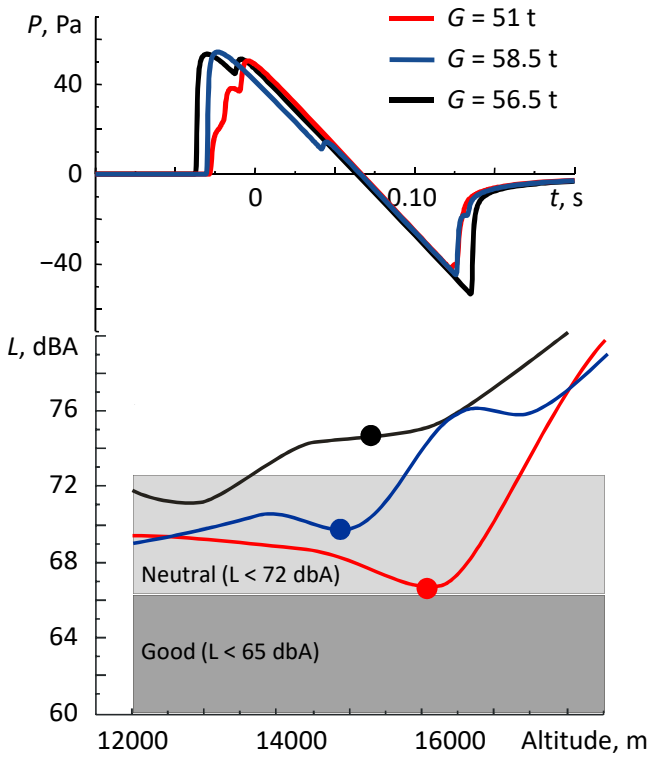
HISAC – Low Sonic Boom Supersonic Business Jet

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



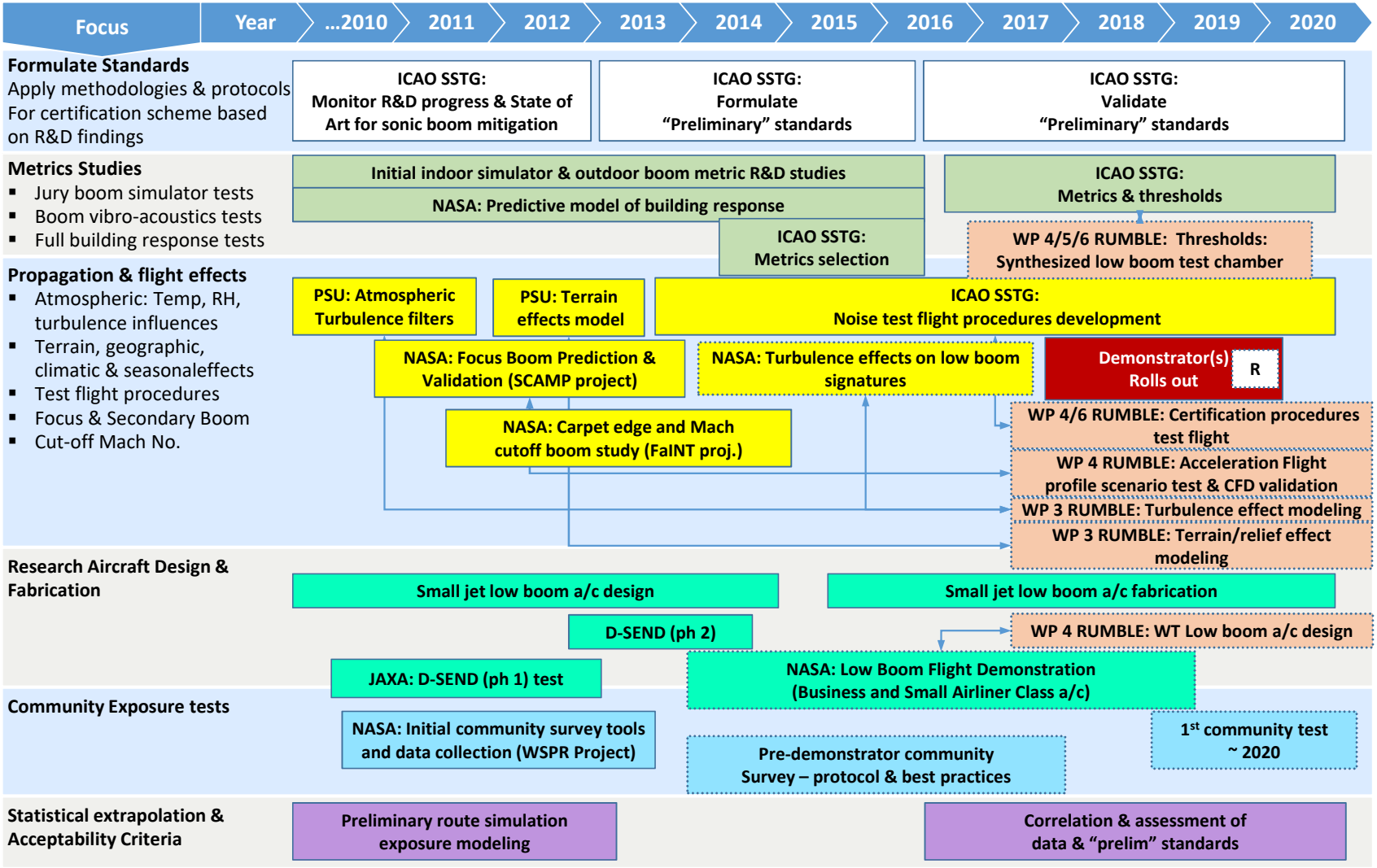
International Supersonic Technology Projects

RUMBLE

Technic Museum
Sinsheim, Germany

Acronym:	RUMBLE
Project title	Regulation and norm for low sonic boom levels
Objectives	Formulation of proposals to determine the permissible overland sonic boom level and the corresponding measurement methods
Coordinator	Airbus Group Innovations (AGI)
Time frame	2017—2020
Partners	18 partners, incl. ONERA, Dassault Aviation, TsAGI, Gromov Flight Research Institute, MAI, CIAM, SCAC, GosNIIAS, GkNIPAS

RUMBLE Contribution to the ICAO Supersonics Research Roadmap



Main Challenges for the New Generation Supersonic Transport

- Lack of international norms on acceptable sonic boom levels for over populated area flight
- Lack of ready-to-use jet engines that provide required aircraft range and conform with ICAO Noise Standards near airport areas
- Difficult trade-off between high performance and low environmental impact
- Aircraft operation requirements and SST integration into the existing ATM system

Concluding Remarks

The Success of New Generation Supersonic Passenger Aircraft Program Depands on:

- Technology and low sonic boom demonstration in real flight for aviation authorities and general public
- Advanced high efficiency supersonic variable-cycle engines development
- ATM upgrade to accept supersonic transport flights
- Strong cooperation of aviation leading organizations worldwide to address existing challanges, i.e. IFAR

EU Research Projects with TsAGI Participation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СССР
SARKISYAN
since 1978

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Thank you for your attention!

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