FAA Office of Environment and Energy (AEE) Research Overview

Presented to: ASCENT Advisory Committee Meeting

By: Jim Hileman, Ph.D.
Chief Scientific and Technical Advisor for Environment and Energy
Federal Aviation Administration

Date: April 26, 2016

Aviation Environmental Challenges

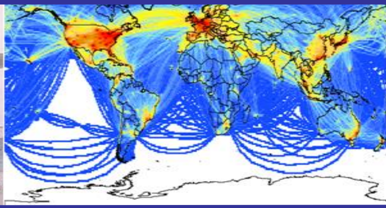
NOISE

AIR QUALITY

WATER QUALITY

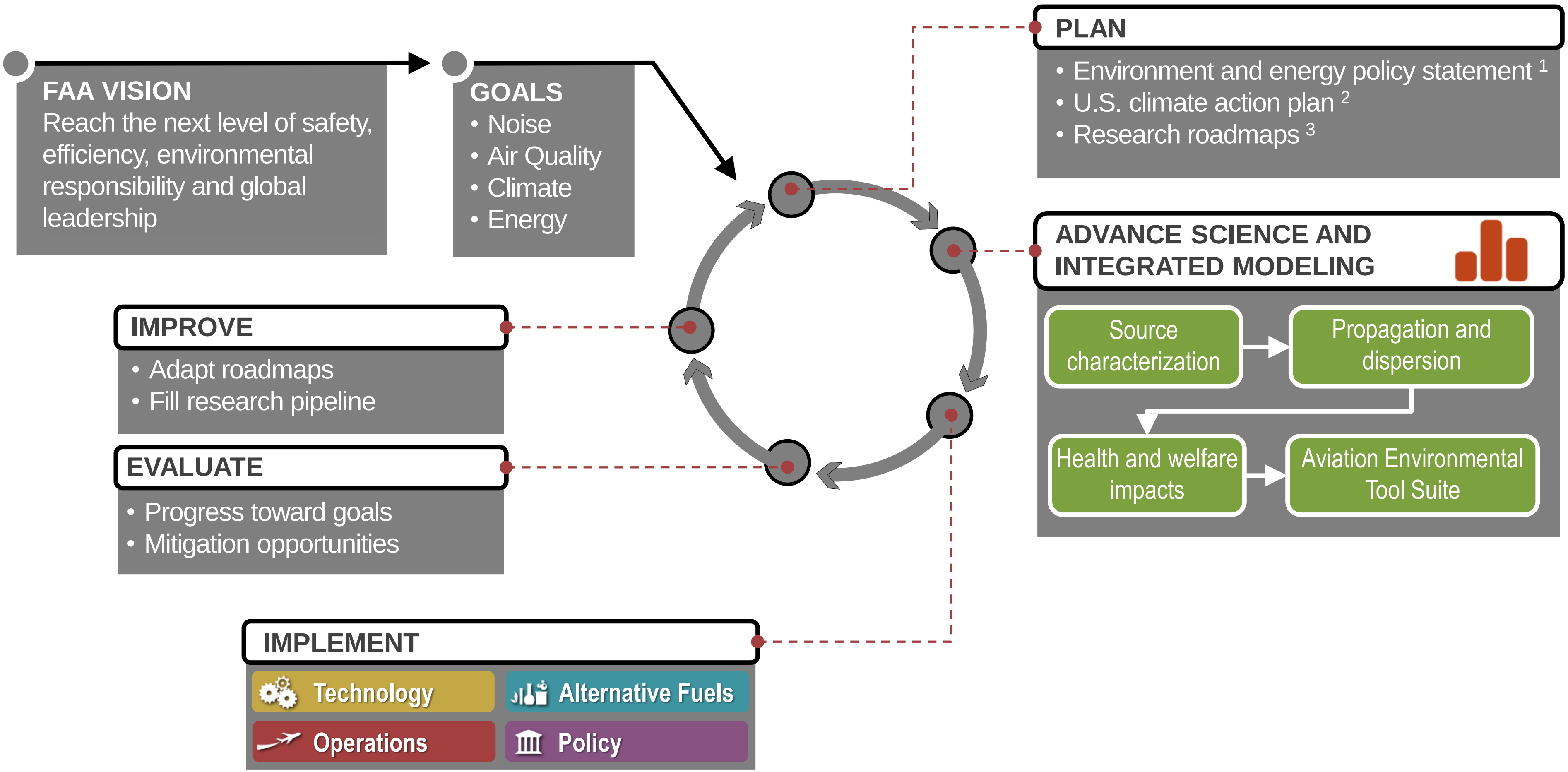
ENERGY

GLOBAL CLIMATE



- Aviation impacts community noise, air quality, water quality, energy usage, and climate change
- Environmental impacts from aviation could pose a critical constraint on capacity growth
- FAA are pursuing aircraft technology, alternative jet fuels, operations, and policy measures to address the environmental challenges facing aviation

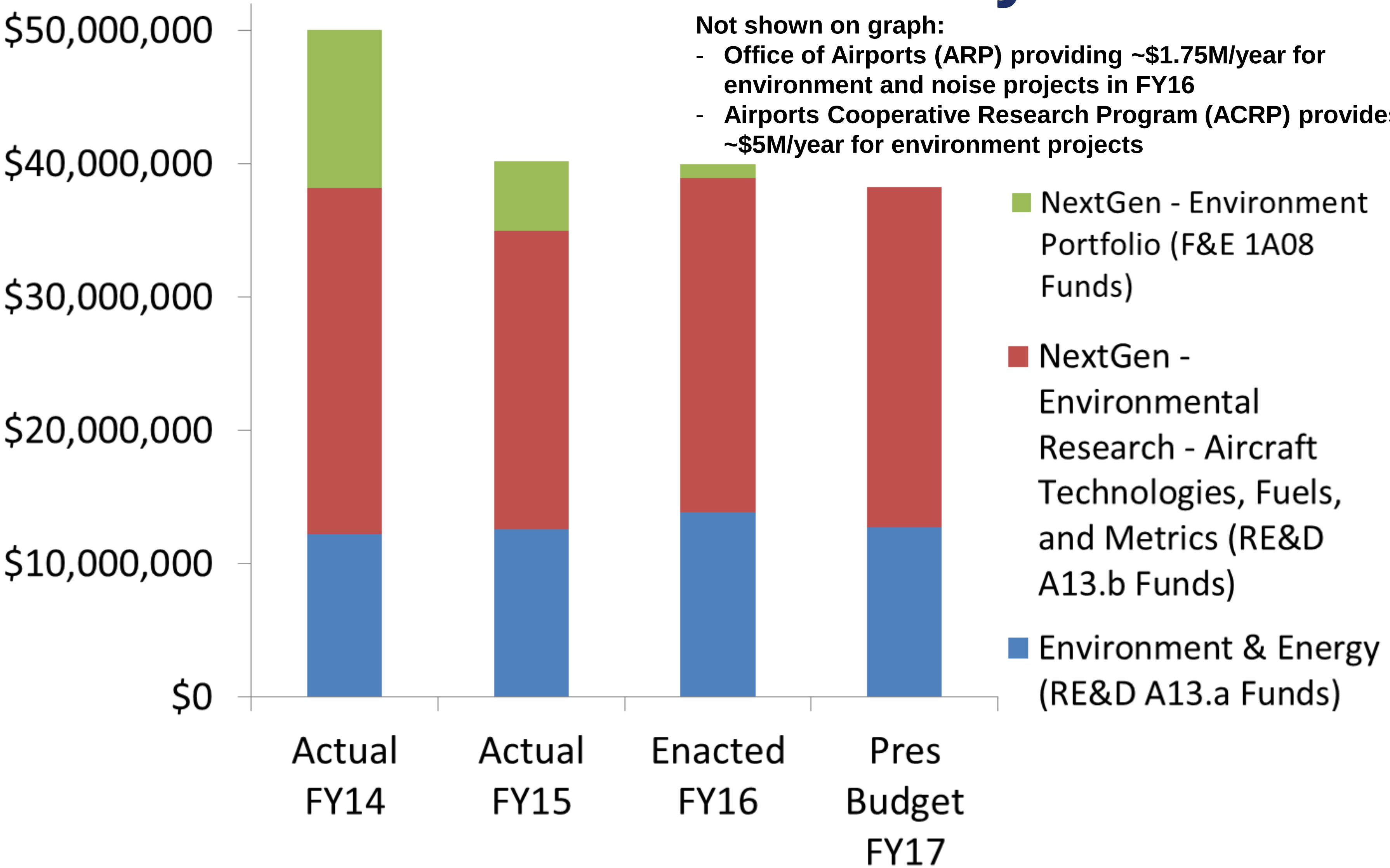
Environmental & Energy Strategy



Notes:

1. Aviation E&E Policy Statement (Federal Register 77-141, 2012): http://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/media/FAA_EE_Policy_Statement.pdf
2. U.S. Aviation GHG Emissions Reduction Plan: http://www.icao.int/environmental-protection/Pages/ClimateChange_ActionPlan.aspx
3. Environment and Energy Website: http://www.faa.gov/go/environment

FY14-17 Financial Summary



Not shown on graph:

- **Office of Airports (ARP) providing ~$1.75M/year for environment and noise projects in FY16**
- **Airports Cooperative Research Program (ACRP) provides ~$5M/year for environment projects**

ASCENT Funding

ASCENT Funding:

- **FY14 - $11.8M**
- **FY15 - $7.4M**
- **FY16 - $10.9M**

$30M investment over 3 years of operation

2016 Notice of Funding Opportunities (NFOs)

NFO	Project Title
2016-39	Naphthalene Removal Assessment
2016-40	Quantifying uncertainties in predicting aircraft noise in real-world situations
2016-41	Identification of noise acceptance onset for noise certification standards of supersonic airplanes
2016-42	Acoustical Model of Mach Cut-off Flight
2016-43	Noise Power Distance Re-evaluation
2016-44	Noise Reduction Analysis of Advanced Operational Procedures
2016-45	Takeoff/Climb Analysis to Support AEDT APM Development
2016-46	Surface Analysis to Support AEDT APM Development
2016-47	Background Noise Evaluation
2016-48	Analysis to Support the Development of an Engine nvPM Emissions Standard

ASCENT Projects Timeline

New Projects (based on NFOs)

- **Mar 25 –NFOs go out to COE**
- **Apr 15 – COE universities submit NFOs to AEE**
- **Apr 29 – AEE selects team**

Paperwork submission

- **May 15 – proposal submitted to grants.gov (all grants)**
- **Aug 1 – earliest start dates in the paperwork for new grants**

Some Recent Accomplishments

- ASCENT researchers were instrumental to the successes of the recent CAEP/10 meeting

- Under ASCENT Project 14, researchers from MIT and Georgia Tech provided technical support to the development of the aircraft CO_2 standard.

- Under ASCENT Project 2, researchers from MS&T were instrumental to the development of a Particulate Matter standard. They not only helped to develop the particulate matter (PM) measurement system that was used to gather the data to support the standard, but they used it extensively to quantify the PM emissions from a wide range of gas turbine engines.

- Under ASCENT Project 1, researchers from MIT and Purdue collaborated to conduct an analysis of the potential for alternative jet fuels to help the aviation industry meet its long-term goals to reduce CO_2 emissions. They also supported development of an LCA methodology to include alt fuels within the global market based measure for international aviation.

- Under ASCENT Project 7, researchers from Penn State supported preliminary efforts to examine a new supersonic noise standard that could allow for the resumption of supersonic commercial flights.

- Many ASCENT researchers provided input to the Impacts Science Group White Papers that summarize the state of the science on noise, air quality, climate, and climate adaptation.

For highlights of the CAEP/10 meeting, please visit:: http://www.icao.int/Newsroom/Pages/ICAO-Environment-Committee-Wraps-up-Landmark-10th-Meeting.aspx

Transport Canada Update to the ASCENT Advisory Board

Alec Simpson
Senior Director, Environmental Management Branch
Transport Canada

April 26 - 27, 2016

RDIMS 11815831

Canada

Purpose

- Outline Transport Canada's roles, responsibilities and activities related to aviation research.

Transport Canada's Responsibilities

- Ensures a safe, secure, efficient and environmentally responsible Canadian transportation system
  - Assess safety, security and economic implications in proposed environmental measures.

- Regulates all emissions from the aviation, marine and rail sectors – leads Canadian participation and involvement at the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO).

- Removes barriers to enable take-up of clean technologies – e.g., modernized and harmonized codes, standards, test protocols, targeted incentives, and research.

Clean Air and Climate Change Agenda

- Signed in 2011, the Clean Transportation theme under the Government of Canada's Clean Air Agenda, provides funding to various initiatives under three modes of transportation: Air, Rail and Marine.
- The aviation sector received $12.9 million over 5 years (ending in 2015/16). Budget 2016 extended funding for another 2 years.
- This initiative supports:
  - the development of new international standards and recommended practices that address air pollution and GHG emissions from aviation;
  - domestic aviation emission reductions through the development and implementation of new regulations;
  - the expansion of the voluntary Action Plan developed in collaboration with the Canadian domestic aviation sector; and
  - targeted research.

Canada's Action Plan to Reduce Greenhouse Gas Emissions from Aviation

- Publically released in June 2012, Canada's Action Plan on Climate Change was developed jointly between the Government of Canada and Canada's aviation industry.
- The Action Plan sets an aspirational goal to improve fuel efficiency by an average annual rate of at least 2 percent per year until 2020 measured against a 2005 baseline.
- Canada will also benchmark progress against the Air Transport Action Group's target of 1.5 percent.
- The Action Plan also highlights a second set of measures which are expected to have beneficial environmental results but are not expressed in quantitative terms.

Working Group on Aviation Emissions

- The Working Group has 5 main areas of focus:
  - Performance-based Navigation: improve Air Navigation Services (ANS) and air operator efficiency;
  - Surveillance: improved ANS, airport and air operator efficiency;
  - Airport Operations: identify and implement opportunities to reduce emissions from APUs and GSE, targeting data collection, push-back operations, ground crew availability, ground surveillance improvements and taxi infrastructure improvements; and
  - Alternative Fuels: identify opportunities to advance alternative fuels for aviation in Canada.

Working Group on Aviation Emissions Cont’d

- The Airport Operations sub-group has completed 3 studies:
  - In 2014, a study on best practices pertaining to APU and GSE use was undertaken, which looked at examples from airports, airlines and services providers in Canada and abroad.
  - In 2015, the purpose of this study is to identify specific steps airports and airlines have taken to convert traditional fossil fuel powered GSE to either alternative fueled vehicles (AFV) or electric vehicles (eGSE).
  - In 2016, a study was undertaken to look at alternative GPU connection configurations and operations at several Canadian airports.

Achievements

- Each year Canada produces an Annual Report on the Action Plan to highlight successes including:
  - Fleet renewal and upgrades;
  - Improved air traffic management;
  - International coordination; and
  - Research and development.

Air Quality Monitoring at Canadian Airports - Background

- Transport Canada has supported emissions assessments at airports since concerns were first raised regarding airport source impacts on ambient air quality in the early 1970's.
- TP 9606 “A Review of Ambient Air Quality at Major Canadian Airports” contains the results of 16 studies completed over a 15 year period.
- These studies were conducted as part of a commitment to ensure that national environmental objectives for air quality were being met.

Air Quality Monitoring at Canadian Airports - Background

- 26 National Airport System airports which account for 94% of traffic.
- Transport Canada partners with local airport authorities to complete air quality studies using the TC Mobile Air Quality Monitoring Laboratory.
- The Mobile Air Quality Monitoring Laboratory monitors various pollutants, CO, NO, Ozone, PM (10 and 2.5).

- Studies are completed over a year period encompassing all four seasons.
- Recent studies have been completed at Edmonton International Airport, Kelowna International Airport and Victoria International Airport.

The Airport Carbon and Emissions Reporting Tool (ACERT)

- The Airport Carbon and Emissions Reporting Tool was first developed in 2008 through a joint partnership with Transport Canada and the Canadian Airports Council. The tool was developed to assist airports in developing GHG inventories with reliable results at minimal cost.
- Utilizing available information, ACERT is an excel spreadsheet that can quickly run GHG calculations using inputted and assumed information.
- ACERT now forms part of the Airports Council International *Carbon Accreditation Program* as a recognized tool airports can use to develop a GHG inventory.

ACI | ACERT
AIRPORT CARBON AND EMISSIONS REPORTING TOOL

ACERT

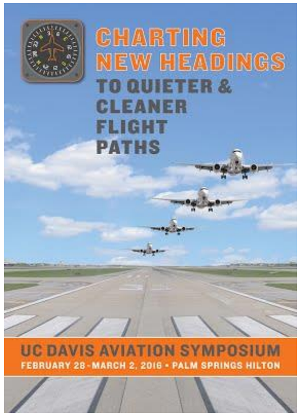
- ACI, in partnership with Transport Canada, has made the tool available to its 1600 members. ACERT has also been promoted to the International Civil Aviation Organization (ICAO) for use by all 191 member States.
- In June 2009, ACI-World launched the Airport Carbon Accreditation program, the first carbon mapping and carbon management standard specifically designed for the airport industry. There are four levels of accreditation, with the highest being “neutrality”.
- ACI-World has recently announced that ACERT can now be used by airports to develop emission inventories as part of the Airport Carbon Accreditation program.
- Results have indicated that using ACERT, Scope 1 and 2 emissions were within 5-10% of those from detailed inventories. Thus, making it an accurate tool for airports.
- In June 2015, ACI World released version 3.0.

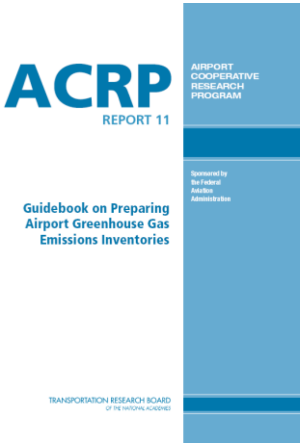
Moving Forward on Strategic Partnerships and Collaborative Research

ACI

CAC
CANADIAN AIRPORTS COUNCIL
CONSEIL DES AÉROPORTS DU CANADA

ICAO • OACI • ИКАО





ASCENT
AVIATION SUSTAINABILITY CENTER
FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

PARTNER
Partnership for AiR Transportation Noise and Emissions Reduction

An FAA / NASA / Transport Canada – Sponsored Center of Excellence

Canadian Aerospace Environmental Technology ROAD MAP

GARDN
Green Aviation Research & Development Network
Groupement Aéronautique de Recherche et Développement en eNvironnement

Transport Canada Transports Canada

NASA

NASA Aeronautics Update

Barbara Esker, Deputy Director
Advanced Air Vehicles Program
Aeronautics Research Mission Directorate
April 26, 2016

Contents

- Global Challenges
- Strategy
- FY 2017 Budget - New Aviation Horizons
- Summary

Global Growth in Aviation: Opportunities and Challenges

Global Air Passengers by Region (% of Total)

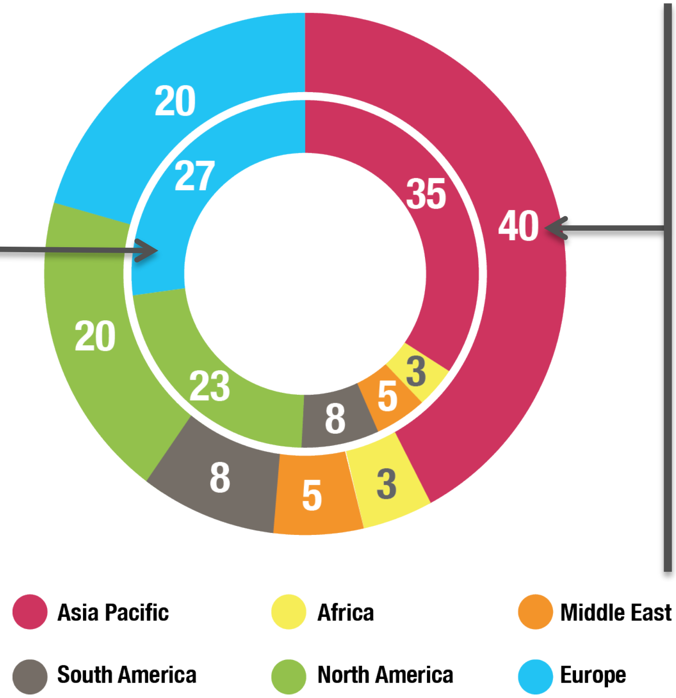
2014
Global Aviation Industry

3.3B Passenger Trips

North America and Europe combined is half of all Passenger Trips

58M Jobs

$2.4T GDP



2034
Global Aviation Industry, est.

7B Passenger Trips

Asia-Pacific Passenger Trips equal to North America and Europe combined

105M Jobs

$6T GDP

Over 36,000 New Aircraft required (replacement and growth) over the 20 year period ($4-$5T value)

Sources: International Air Transport Association, Air Transport Action Group, Boeing

Major Opportunities / Growing Challenges

Competitiveness—New state backed entrants, e.g., COMAC (China); Growing global R&D

Environment—Very ambitious industry sustainability goals; Large technology advances needed

Mobility—More speed to connect the worlds' major cities; Opportunity for commercial supersonic flight

U.S. Technological Leadership Required!

NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Innovation in Commercial Supersonic Aircraft
- Ultra-Efficient Commercial Vehicles
- Transition to Low-Carbon Propulsion
- Real-Time System-Wide Safety Assurance
- Assured Autonomy for Aviation Transformation

U.S. leadership for a new era of flight

ARMD Programs Aligned to Strategic Thrusts

NASA Aeronautics programs are aligned to the Aeronautics Vision and Strategy, working together to transform aircraft and operations for a safer, more environmentally sustainable, and higher mobility future.

Roadmaps provide targets for long-term investment

January 19, 2016 Initial Approval

	2015	2025	2035
	Improved NextGen Operational Performance in Individual Domains, with Some Integration between Domains	Full NextGen Integration. Terminal, En Route, Surface, and Arrivals/Departures Operations to Realize TBO	Beyond NextGen Dynamic Autonomous Trajectory Services
	Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise	Introduction of Affordable Low-Boom, Low-Noise, & Low-Emission Supersonic Transports	Increased Mission Utility and Commercial Market Growth of Supersonic Transport Fleet
Transport	Aircraft Concepts & Technologies that Meet the Demands of Airlines and Flying Public with Necessary Fleet Level Efficiency Gains to Achieve Carbon Neutral Growth by 2020	Aircraft Concepts & Technologies with Revolutionary Improvements in Aircraft Efficiency to Reduce Carbon Output of the Fleet below 2005 Levels	Aircraft Concepts & Technologies with Transformational Capabilities to enable 50% reduction (by 2050) in fleet level Carbon Output below 2005 Levels
Vertical Lift	Increased Capability of Vertical Lift Configurations that Promote Economic Benefits and Improve Accessibility for New and Current Markets	New Vertical Lift Configurations and Technologies Introduced that Enable New Markets, Increase Mobility, Improve Accessibility, and Reduce Environmental Impact	Vertical Life Vehicles of all Sizes Used for Widespread Transportation and Services, Improved Mobility and Accessibility, with Economic Benefits and Low Environmental Impact

Roadmaps provide targets for long-term investment

January 19, 2016 Initial Approval for Stakeholder Vetting

2015	2025	2035
Introduction of Low-Carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems	Initial Introduction of Alternative Propulsion Systems	Introduction of Alternative Propulsion Systems to Aircraft of All Sizes
Domain Specific (Real-Time) Safety Monitoring and Alerting Tools	Integrated Predictive Technologies with Domain Level Application	Adaptive Real-Time Safety Threat Management
Supervised Autonomous Systems	Mission-Level Goal-Directed Autonomous Systems	Distributed Collaborative Autonomous Systems

Strategic Thrust Roadmaps will be Finalized for Presentation at the AIAA Aviation 2016 Conference in June and will Guide Long-Term ARMD Investment Planning

NASA Aeronautics Ready for Flight

Accomplishments and Planning

NASA Aero Vision and Strategy Established

Roadmaps Completed

2008-2013 | 2014/15 | 2016/17 | 2018-2026

N+3 Subsonic & Supersonic Concept/ Technology Studies

Ground Testing of N+3 configurations and technologies

LBFD PDR Completed

UEST PDRs Completed

N+2 Environmentally Responsible Aviation (ERA) Project Initiated

8 Integrated Tech Demos Completed, Tech transitioned to industry. HWB ready for Flight Dem/Val.

Ready for X-Plane Integration & Demonstration

NASA FAA NextGen Research Transition Teams (RTTs) Initiated

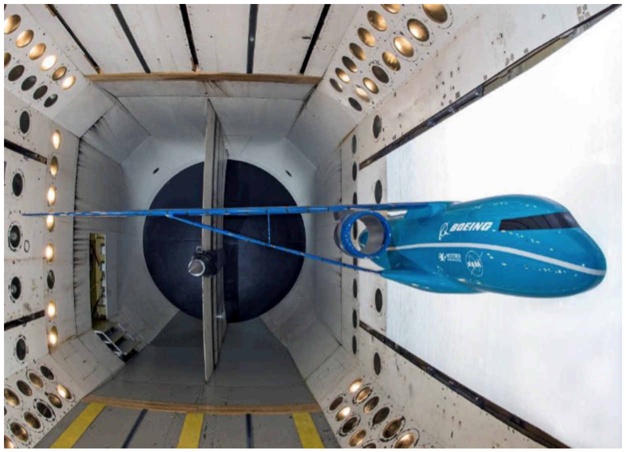
Technology Transitions to FAA: MSP, EDA, PDRC, TSAS

ATD-1 Completed and transferred to FAA

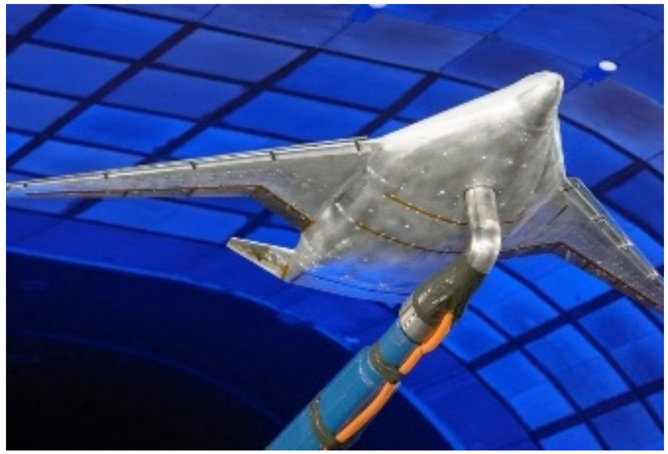
ATD-2, 3 Completed & Transferred to FAA

Ready for NextGen TBO Integration & Demonstration

Examples of Recent Progress in Developing Ultra-Efficient Subsonic Transport Concepts

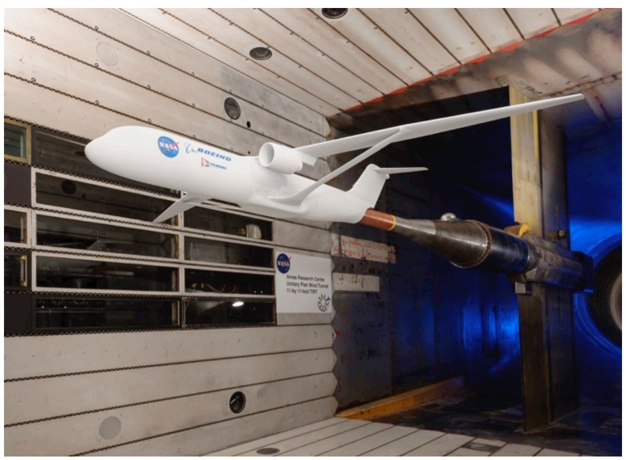


TTBW Aeroservoelastic • FY14
Langley Transonic Dynamics Tunnel



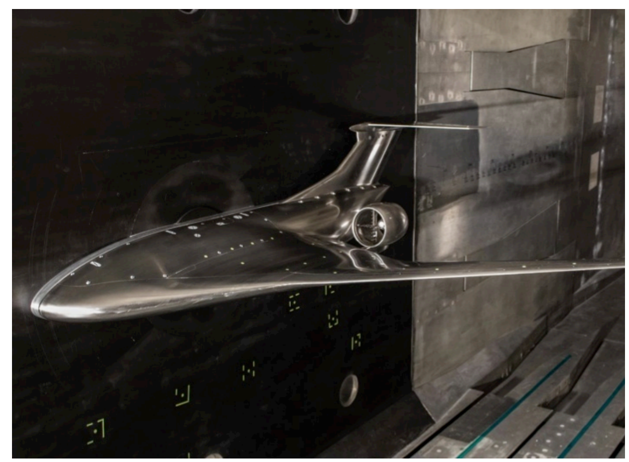
BWB/UHB Low Speed Operability • FY15
National Full-Scale Aerodynamic Complex at Ames

D8/BLI Integrated Benefit • FY13&14
Langley 14- By 22-Foot Subsonic Tunnel



TTBW Aerodynamic Integration • FY16
Ames 11-Foot Transonic Wind Tunnel

BWB Non-circular Fuselage • FY15
Langley Combined Loads Test System (COLTS)



HWB/OWN Performance • FY15
Langley National Transonic Facility

FY 2017 Budget

$ Millions	FY 2015	Enacted FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026
Aeronautics	**$642.0**	**$640.0**	**$790.4**	**$846.4**	**$1,060.1**	**$1,173.3**	**$1,286.9**	**$1,294.2**	**$1,307.6**	**$1,218.1**	**$829.7**	**$839.5**
Airspace Operations and Safety	154.0		159.4	159.2	176.2	189.1	221.5	198.7	200.9	193.2	175.5	167.8
Advanced Air Vehicles	240.6		298.6	277.4	308.8	311.6	312.6	321.3	315.0	318.9	317.7	326.7
Integrated Aviation Systems	150.0		210.0	255.4	381.4	493.0	556.7	591.5	612.2	525.0	203.8	210.6
Transformative Aeronautics Concepts	97.4		122.3	154.4	193.8	179.7	196.2	182.8	179.4	181.0	132.7	134.4

Aeronautics budget includes paid-for 10-year mandatory funding from the Administration's 21st Century Clean Transportation Plan. See appendix for additional detail.

Mandatory Budget Authority $ Millions	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	Outyears
21st Century Clean Transportation Plan	**100**	**200**	**400**	**500**	**600**	**1900**
Airspace Operations and Safety	*18*	*20*	*35*	*45*	*75*	*170*
Advanced Air Vehicles	*30*	*41*	*79*	*80*	*65*	*305*
Integrated Aviation Systems	*37*	*84*	*196*	*300*	*370*	*1170*
Transformative Aeronautics Concepts	*15*	*55*	*90*	*75*	*90*	*255*
Low Boom Flight Demonstrator	**56**					
Integrated Aviation Systems	*56*					

Ten Year Investment Plan—FY 2017 Budget Accelerates Key Components of NASA Aeronautics Plan

Fund the Next Major Steps to Efficient, Clean and Fast Air Transportation Mobility

New Aviation Horizons

Start a continuing series of experimental aircraft to demonstrate and validate high impact concepts and technologies. Five major demonstrations over the next 10+ years in the areas of Ultra-Efficiency, Hybrid-Electric Propulsion, and Low Noise Supersonic Flight

Major New Initiative within IASP

Enabling Tools & Technologies

Major series of ground experiments to ready key technologies for flight

Research and ground demonstration for an advanced small engine core for very high bypass engines and as a hybrid-electric propulsion enabler

Development of next generation physics-based models needed to design advanced configurations

Increases to AAVP and TACP

Revolutionizing Operational Efficiency

Accelerate demonstration of full gate-to-gate Trajectory Based Operations

Increase to AOSP

Fostering Advanced Concepts & Future Workforce

Increased investment in new innovation through the NASA workforce and Universities

Leverage Non-Traditional Technology Advances

Pursue challenge prizes in areas such as energy storage, high power electric motors, advanced networking and autonomy

Increase to TACP

UAS

Strong continued research leadership in enabling UAS integration into the National Airspace. Extending the UAS in the NAS project for an additional 4 years

Hypersonics

Increased investment to ensure a strong National fundamental research capability

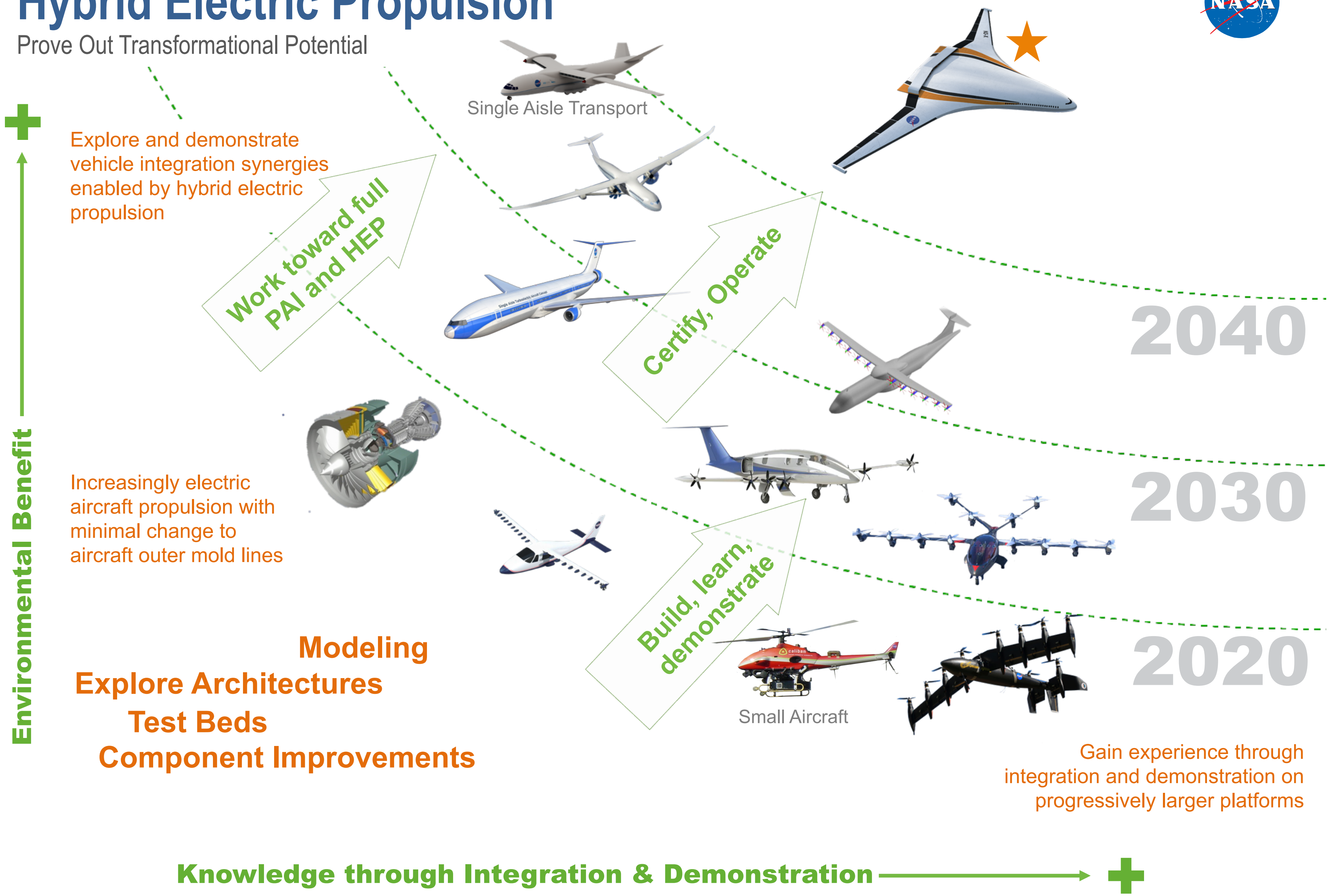
Increases to IASP and AAVP

Build off of major current developments and accomplishments

Continue to incentivize new innovation

Hybrid Electric Propulsion

Prove Out Transformational Potential



New Era For NASA Aeronautics

Investing In Our Future - Investments in NASA's cutting edge aeronautics research today are investments in a cleaner, safer, quieter and faster tomorrow for American aviation:

- A future where Americans are working in stable, well-paying jobs.
- A future where we fly on aircraft that consume half as much fuel and generate only one quarter of current emissions.
- A future where flight is fueled by greener energy sources.
- A future where our air transportation system is able to absorb nearly four billion more passengers over the next 20 years without compromising the safety of our skies.
- A future where our airports are better neighbors because aircraft noise is contained well within the airport boundary.
- A future where people can travel to most cities in the world in six hours or less in an airplane that can fly faster than the speed of sound on bio-fuels.

Thank you

Questions?

Ukrainian Aviation Emissions and Environmental R&D

Oleksandr Zaporozhets[1], Vadim Tokarev[1], Kateryna Synylo[1], Kateryna kazhan[1]
Jaroslav Movhan[2], Sergii Boichenko[3] , Yurii Bilokopytov and Grygorii Pop[4]

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[4]*Chair of Chemistry and Chemical Technologies*

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ASCENT Workshop, Washington, USA

April 26, 2016

OUTLINE

- MOTIVATION & Historical issues
- Aircraft noise investigation
- Local aircraft engine emission investigation
- Third party risk investigation
- Global aircraft engine emission investigation
- Aircraft noise&engine emission impact optimization
- Fuels and biofuels for aviation sector
- Concluding remarks
- Acknowledgements

Historical milestones

- **2000 – National Aviation University**
- **1994 – Kyiv International University of Civil Aviation**
- **1965 – Kyiv Institute of Civil Aviation Engineers**
- **1947 – Kyiv Institute of Civil Aviation**
- **1933 – Kyiv Aviation Institute**
- **1898 – Mechanical Faculty of Kyiv Polytechnic Institute**

Staff: Academicians 3

Professors and Doctors of Science~170

Assistant Professors and Candidates of Science>700

Assistants >900

Campus of the University

State Museum of Aviation (NAU educational airport center)

It is not an airport – it is an University!!!

Tens of thousands of engineers have been qualified for aviation and related activities during 83 years! Graduates are working worldwide (over the 130 countries!).

Backgrounds

Statute University

1.8. **University Structure**

...Institute for Environmental Safety...

Chapter 7. **Science**

In carrying out scientific researches, technological and innovation developments the priorities are following:

advanced aerospace technology;

aerospace systems for monitoring and navigation;

environmental protection;

information technology and data security.

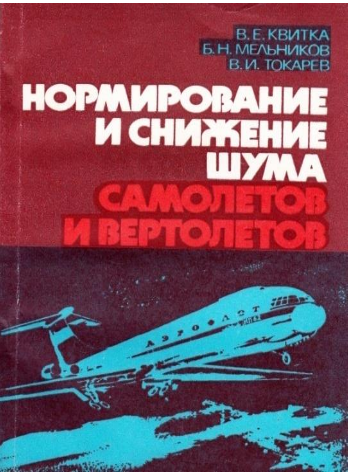
Scientific school **"Aviation acoustics"**

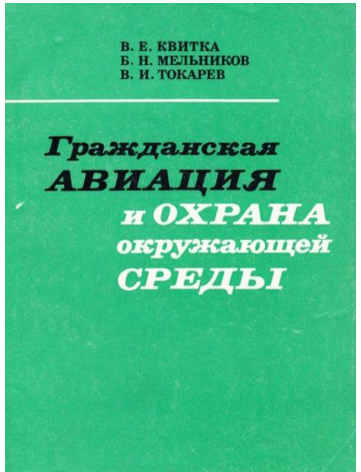
Head of the school - **Professor Vadim Tokarev**

Facilities and departments: **Acoustic Laboratory of the NAU & the Centre of Environmental Problems of the Airports**

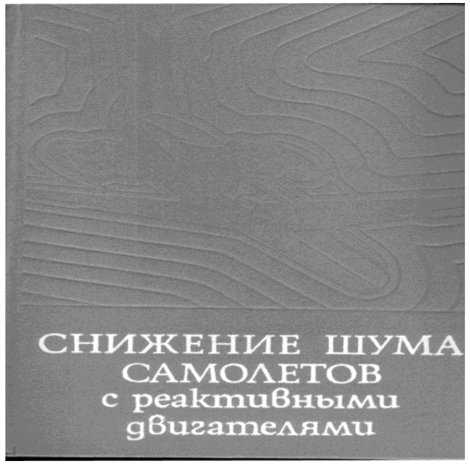
Defended thesis: **3 DrSc, 21 CdSc**

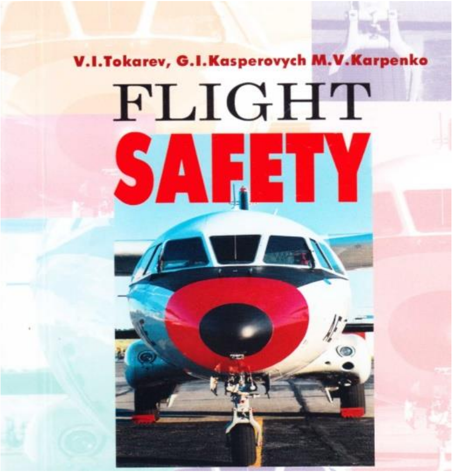
Publications: >10 monographs

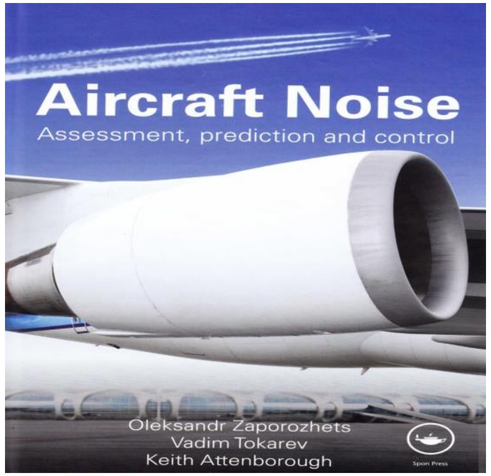




Institute of Environmental Safety of the NAU







Main publications of the scientific school "Aviation Acoustics"

Civil Aviation Authority of Ukraine

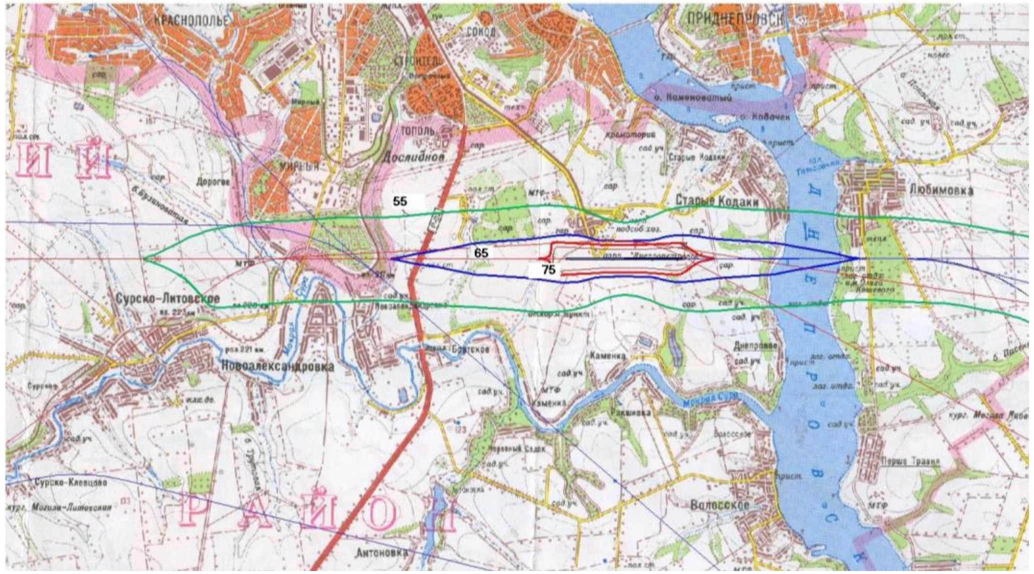
Air Code of Ukraine:

- Chapter X ENVIRONMENTAL PROTECTION

Air rules of Ukraine (АПУ):

Rules for noise zonning of residential development around the airports;

Method for aircraft noise contour calculation …



Calculation tools:

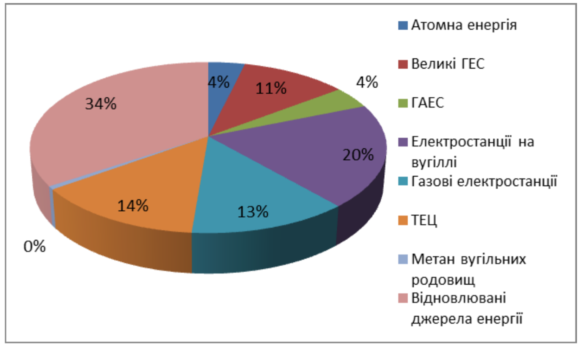
IsoBella, PolEmiCa, Fleming, 3PRisk, …

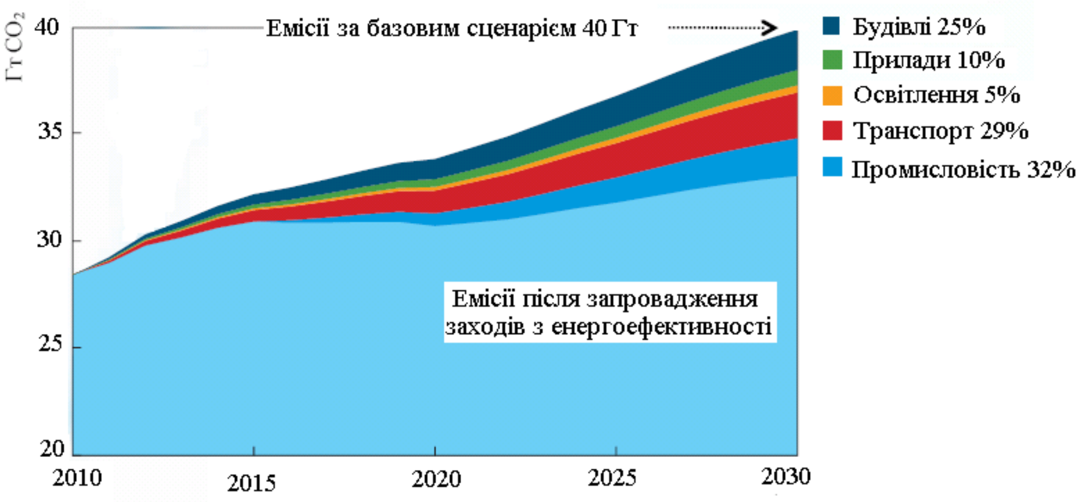
Ministry of Environmental Protection of Ukraine
State Agency on Energy and Energy Efficiency of Ukraine

Laboratory "EcoSafety"

- №1/1290/10/2 The impact of physical and biological factors on the environment
- №3/1290/10/3 Research of economic sectors vulnerability to climate change and determining the adaptation measures

- National Report on the implementation of the state policy in energy efficiency 2009: **Rethinking the degree of responsibility for the future**
- National Report on the implementation of the state policy in energy efficiency 2011: **Rethinking development strategy**

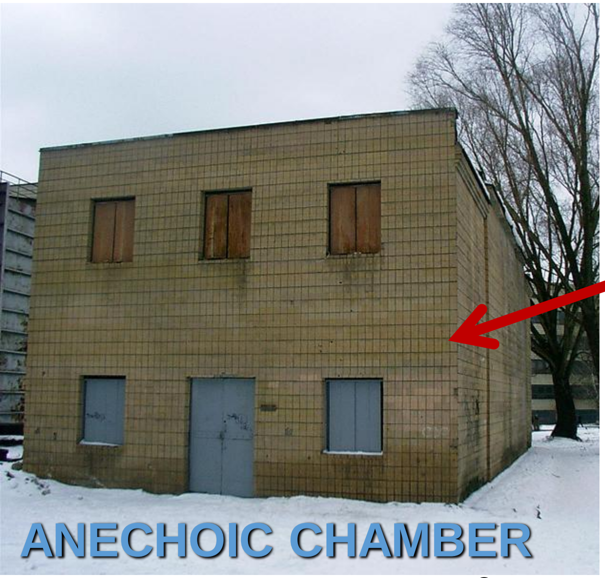




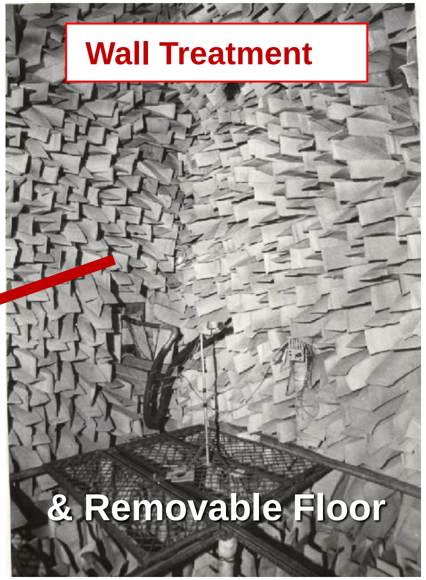
Potential reduction of CO2 emissions by implementing energy efficiency recommendations

Aircraft Noise Investigation

Acoustic sources
Sound propagation effects
Installation effects
Methods and tools to assess the noise
Methods and tools to reduce the noise



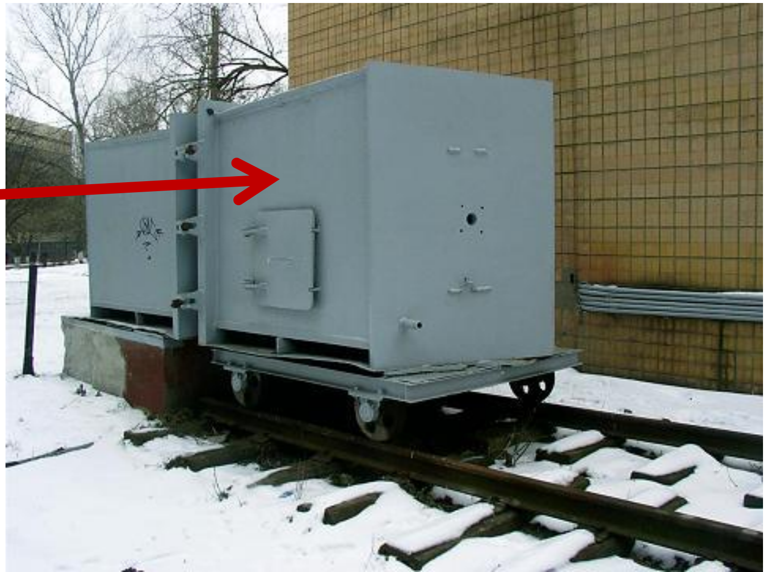
usable volume 330 m^3



Sound transmission performances
for Antonov-140, -148, -158

Small reverberation chambers

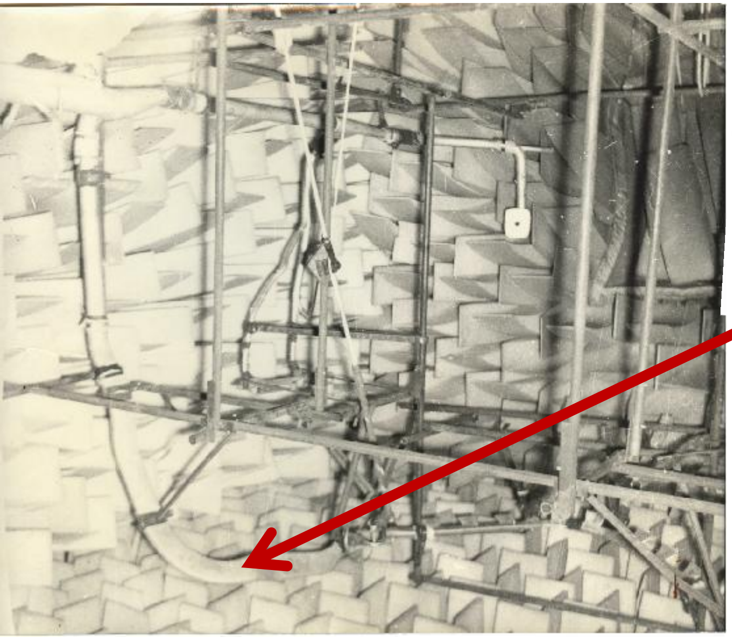
total volume = 4 m^3

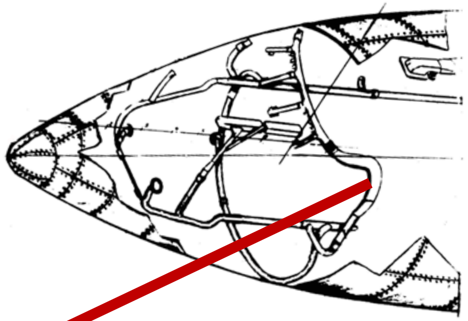


Large reverberation chamber

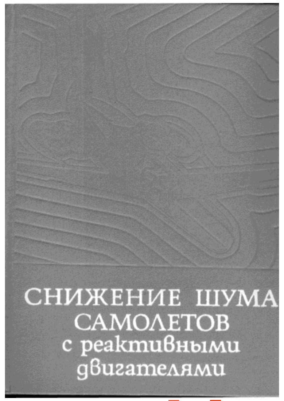
Investigation of aerodynamic noise sources

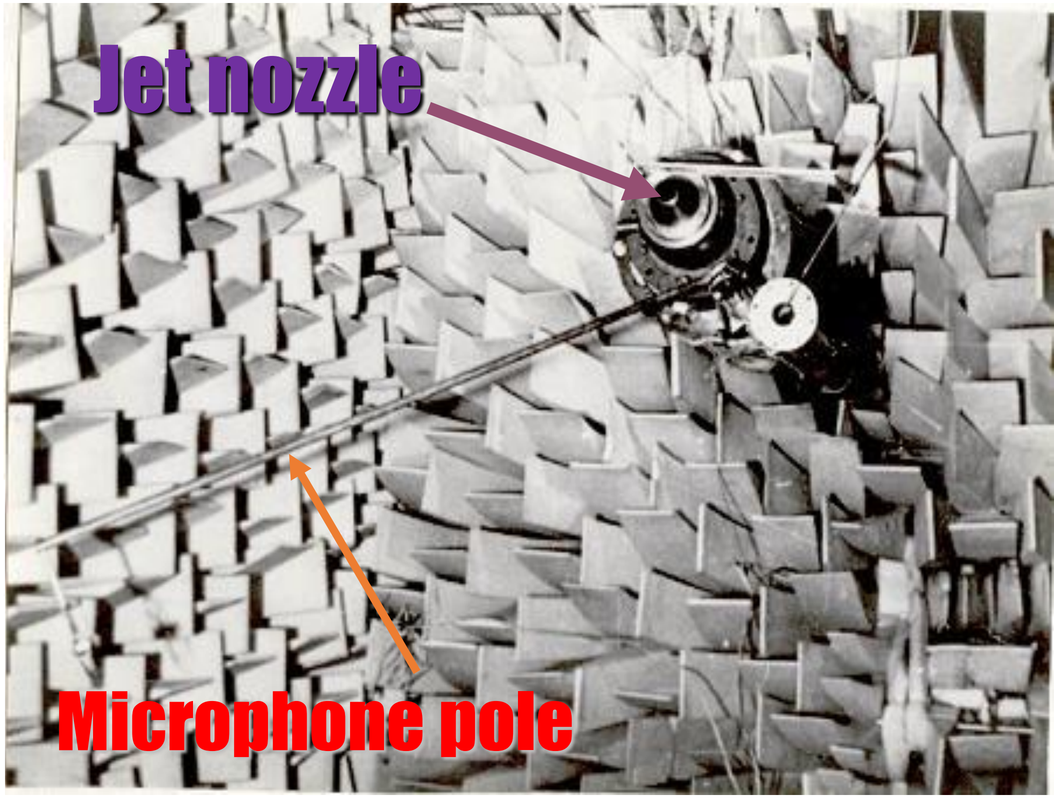
Noise generation by inboard ACS

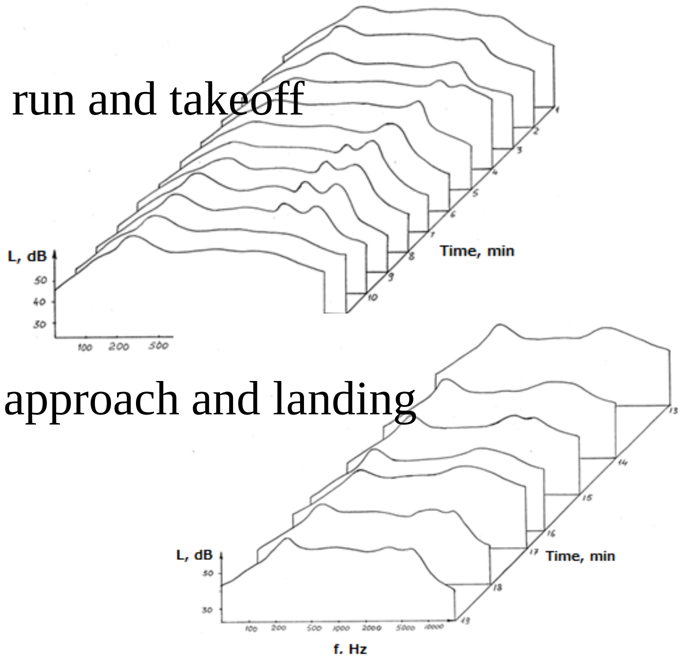


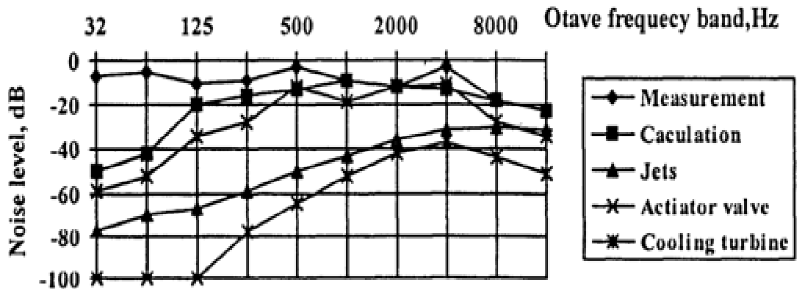


- jets;
- co-axial jets;
- jets leaking on screen;
- ejected jets;
- airflow around air wing/frame models

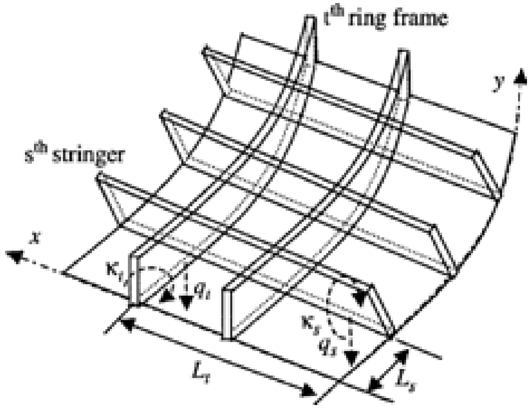


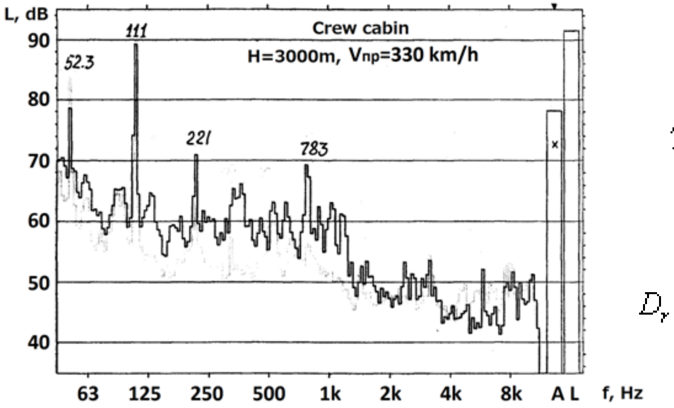






Sound transmission control through curved aircraft panel





Basic equations of bending and torsion displacements:

$$D_s \frac{d^4 w_s}{dx^4} - m_s \omega^2 w_s = q_s$$

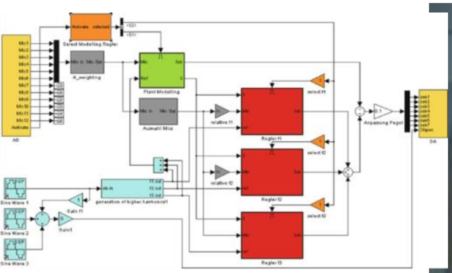
$$T_s \frac{d^2 \theta_s}{dx^2} - E_s C_{ws} \frac{d^4 \theta_s}{dx^4} + \rho_s I_{ps} \omega^2 \theta_s = \kappa_s$$

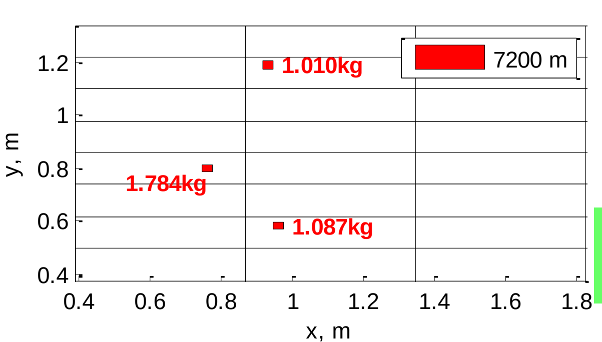
$$-m_k \omega^2 w_k = f_k$$

$$D_r \left(\frac{d^4 w_r}{dy^4} + \frac{2}{r^2} \frac{d^2 w_r}{dy^2} + \frac{w_r}{r^4} \right) - m_r \omega^2 w_r = q_r,$$

$$T_r \frac{d^2 \theta_r}{dy^2} - E_r \frac{I_{yr}}{r^2} \theta_r + \rho_r I_{pr} \omega^2 \theta_r = \kappa_r$$

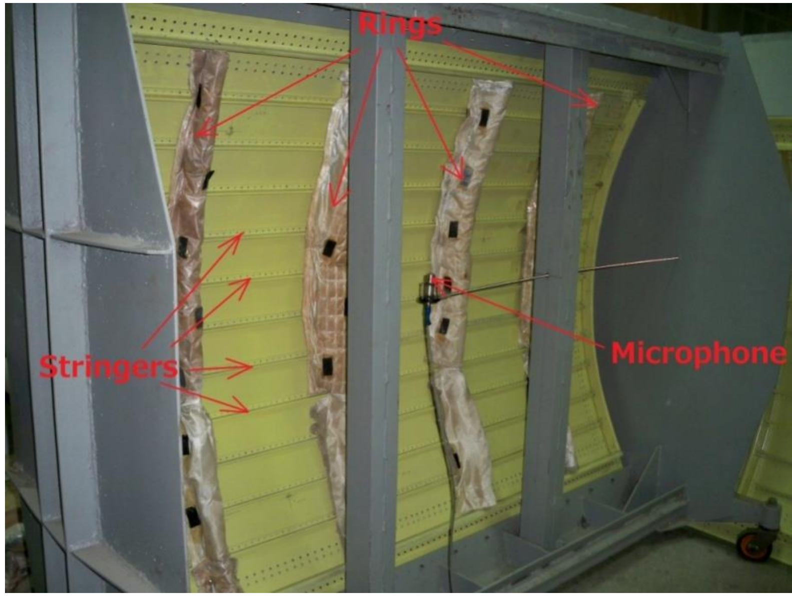
Optimal number and placement of damping material





From Vitalii Makarenko CdSc Thesis

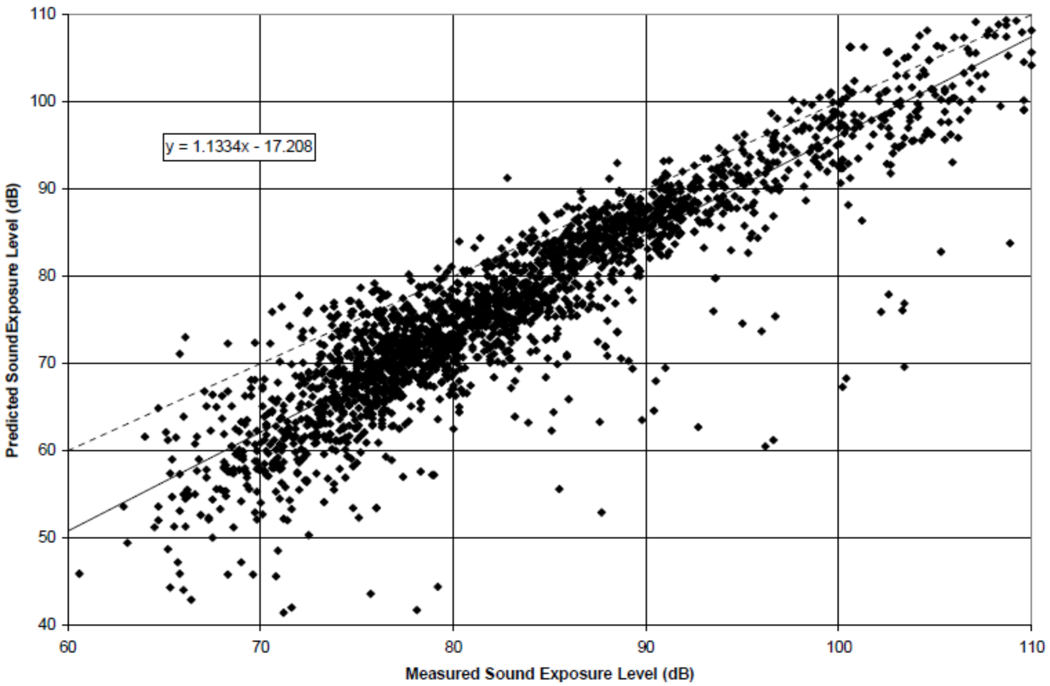
The increase of transmission loss at the fundamental propeller blade-pass frequency inside crew cabin of the **Antonov-140** using three distributed masses is equal to **9.7 dB**. The total weight of distributed masses is **16%** of the panel weight (dimensions 2.22 m x1.6 m).



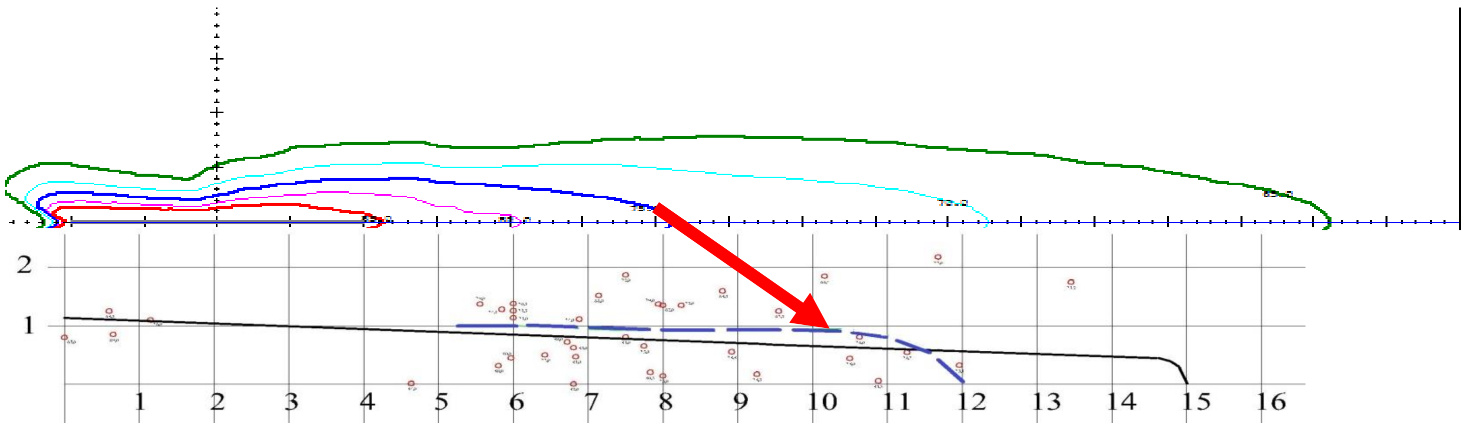
Measurements via calculations: Airport “Kharkiv”, L_{Amax} measurements 2012

Point 1			Point 2			Point 3		
L_{Amax}, meas	L_{Amax}, calc	**Δ**	L_{Amax}, meas	L_{Amax}, calc	**Δ**	L_{Amax}, meas	L_{Amax}, calc	**Δ**
дБ (A)	дБ (A)		дБ (A)	дБ (A)		дБ (A)	дБ (A)	
91,2	93,1	**-1,9**	80,1	86,5	**-6,4**	73,3	81	**-7,7**

Comparison between Measured and INM 5.1 Calculated SEL



INM Calculated via measured A-320 & B-737-400:
contours shorter on 3-4 km



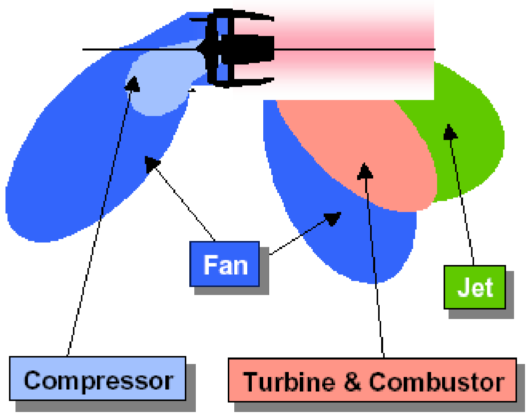
Main reasons for differences

- **Input data from balanced movement equations**
- **Noise sources performances (aircraft substitution concept)**
- **Propagation effects**

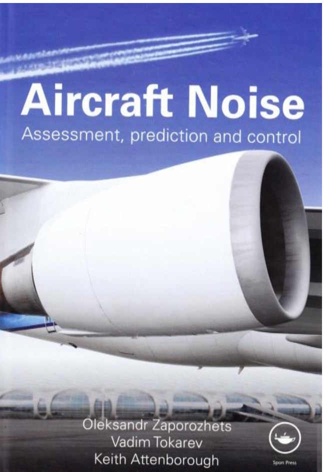
EU Project Silence®: ***Improving prediction models for noise footprint calculations in a part of sound propagation and installations effects in operating conditions (2002-2004)***

NOITRA: Flight Path + BELTASS - SPL calculations

Noise of a typical 1990s engine



High-bypass-ratio turbofans dominated by fan noise - whine, whistle - and lower jet exhaust noise - roar, rumble



Radiation sources

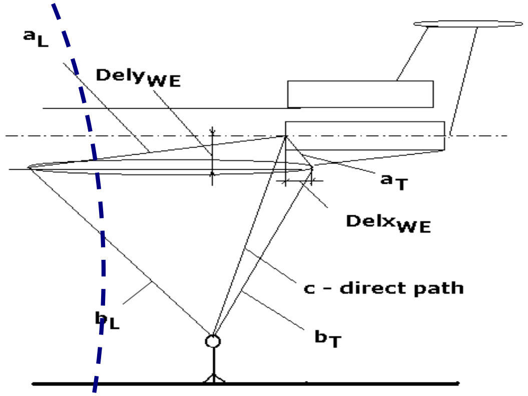
- **JET**
- **COJET**
- **FANIN**
- **FANOUT**
- **TURBINE**
- **COMCHA**

FRAME (wing, flaps, gears)

- **PROPEL**

Propagation+ Installation effects

- **DIVER**
- **ABSORP**
- **LATER**
- **REFLEC**
- **REFRAC**
- **SCREEN**
- **FUSELAGE**
- **GREENBLT**



Control point, contour, etc:

Total SPL

OASPL

PNL

L_A

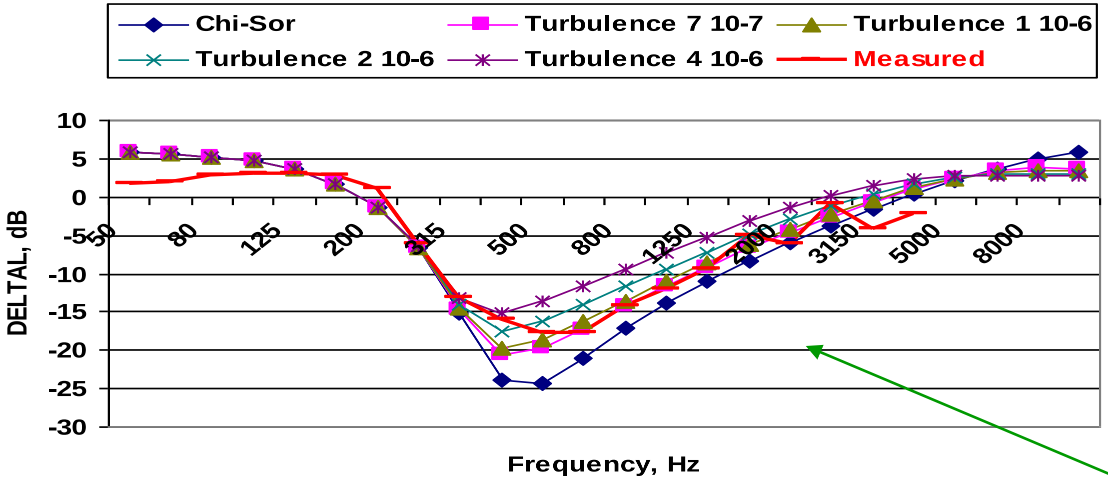
include the following effects:

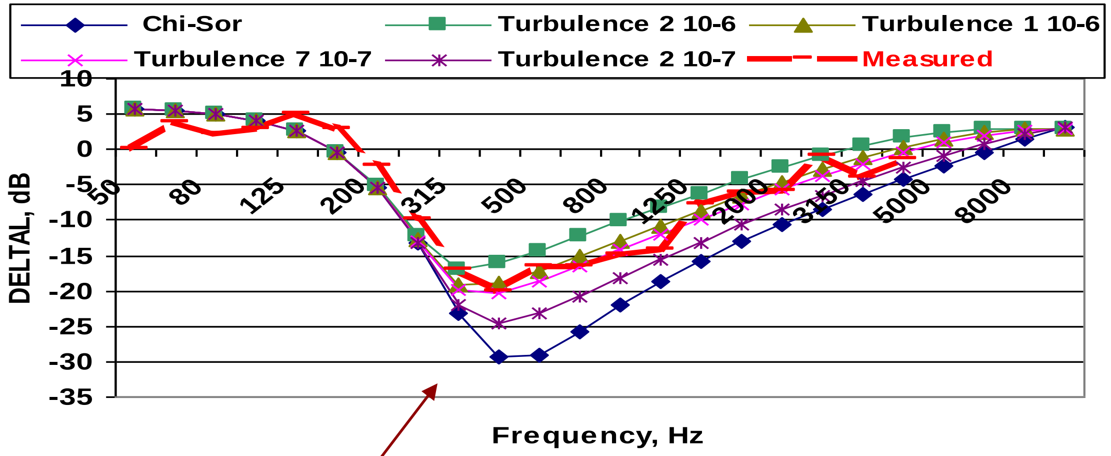
- geometrical divergence (spreading of sound);
- atmospheric absorption;
- ground effect (reflection from surface covering);
- meteorological effects (refraction in air),

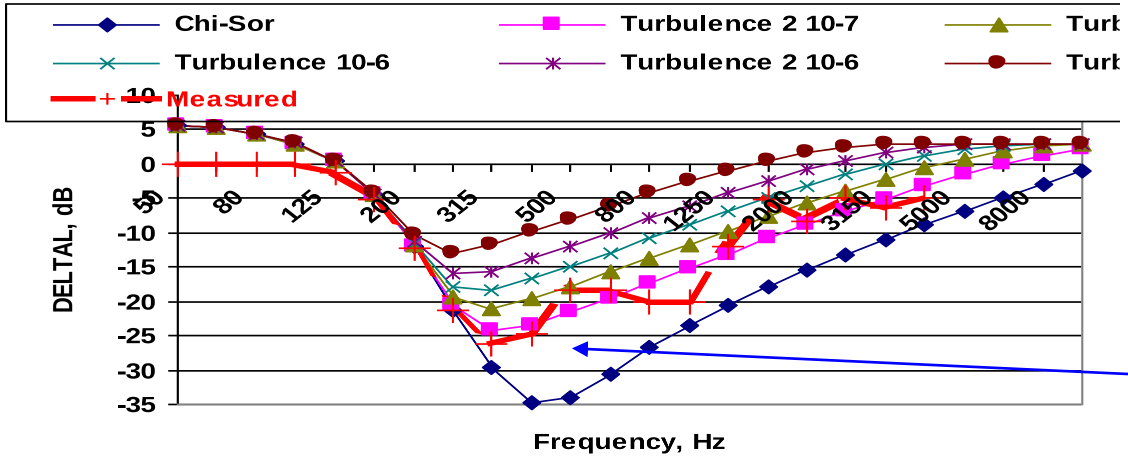
depending on conditions under consideration.

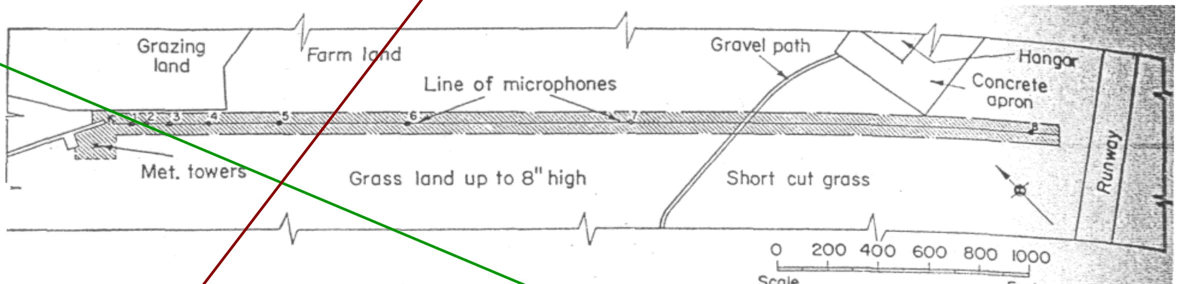
NAU & University of Hull, UK, NATO project:
Aircraft noise propagation modelling (1999-2000)

Ground effect with atmosphere turbulence influence (Parkin and Scholes, *Hatfield*)





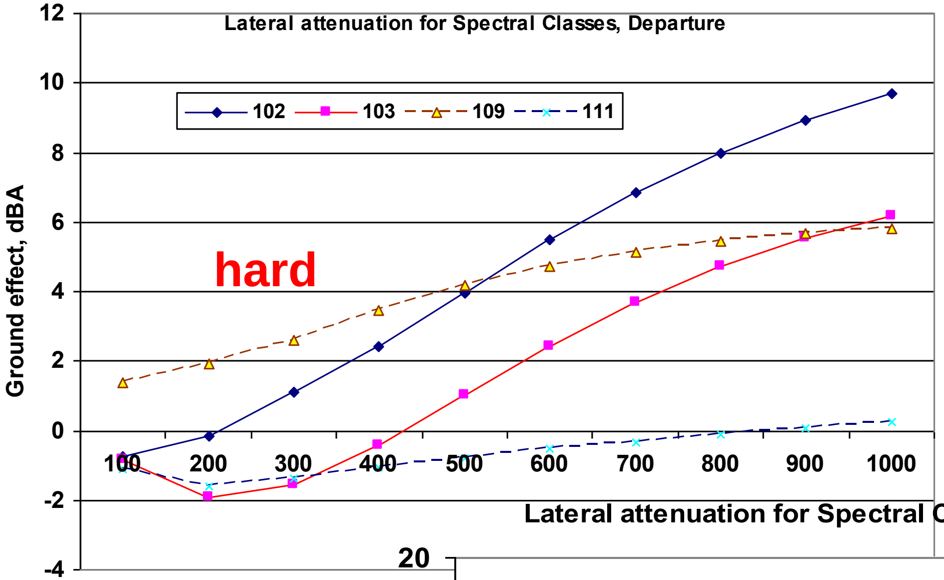




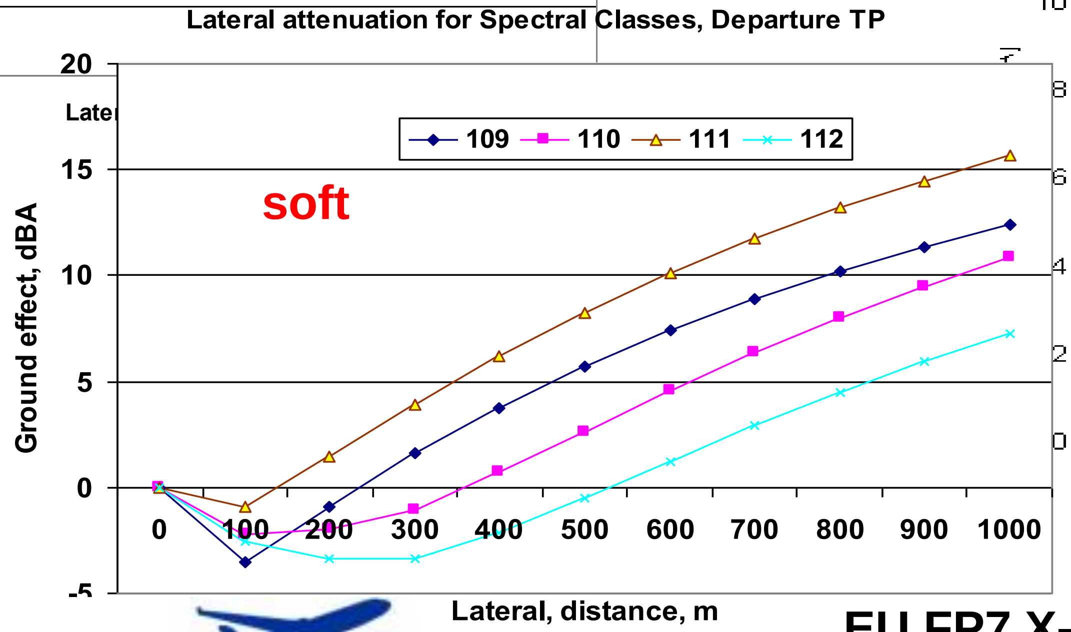
- microphones 19,51 m, 34,75 m, 61,57 m, 109,73 m, 195,07 m, 347,47 m, 605,7 m, 1097,28 m from the source

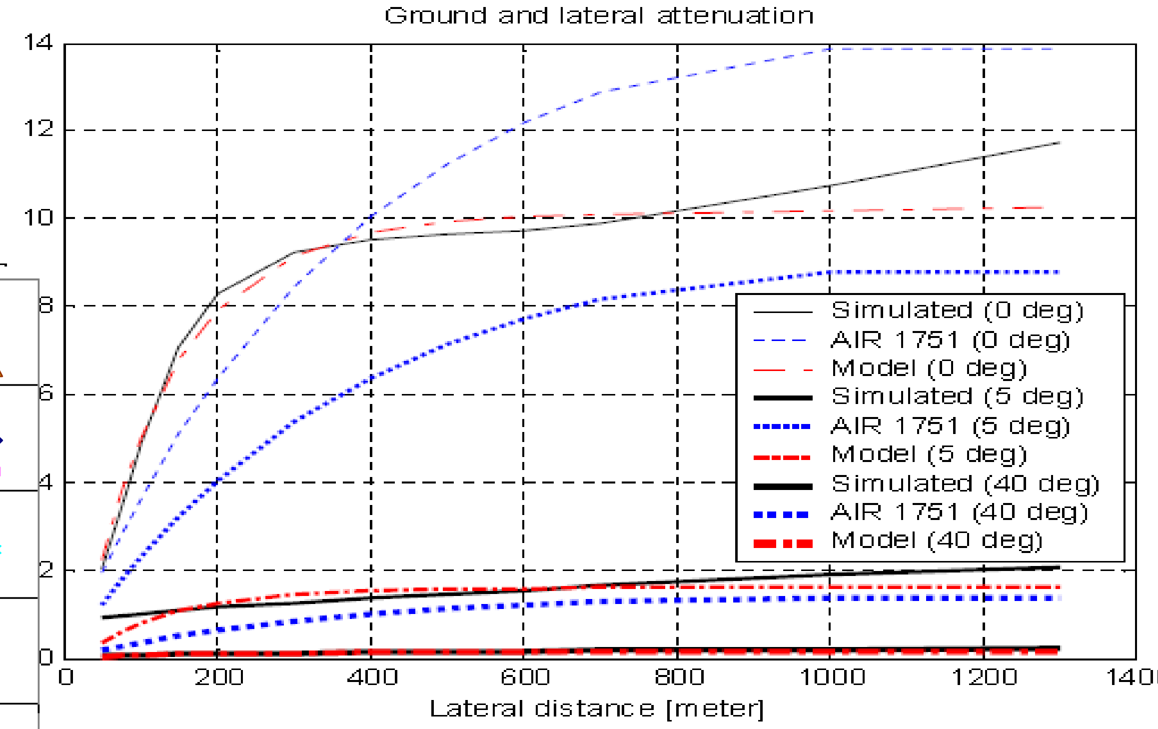
EU Project Silence®: ***Improving prediction models for noise footprint calculations in a part of sound propagation and installations effects in operating conditions (2002-2004)*** **+ NAU & University of Hull NATO project**: ***Aircraft noise propagation modelling (1999-2000)***

Ground effect for hard & soft covering of the surface, departure for all INM spectral classes



Differences for lateral effect from ICAO Doc 9911 and ECAC Doc 29 between ±5 dBA





Corrective measures for the aircraft noise models

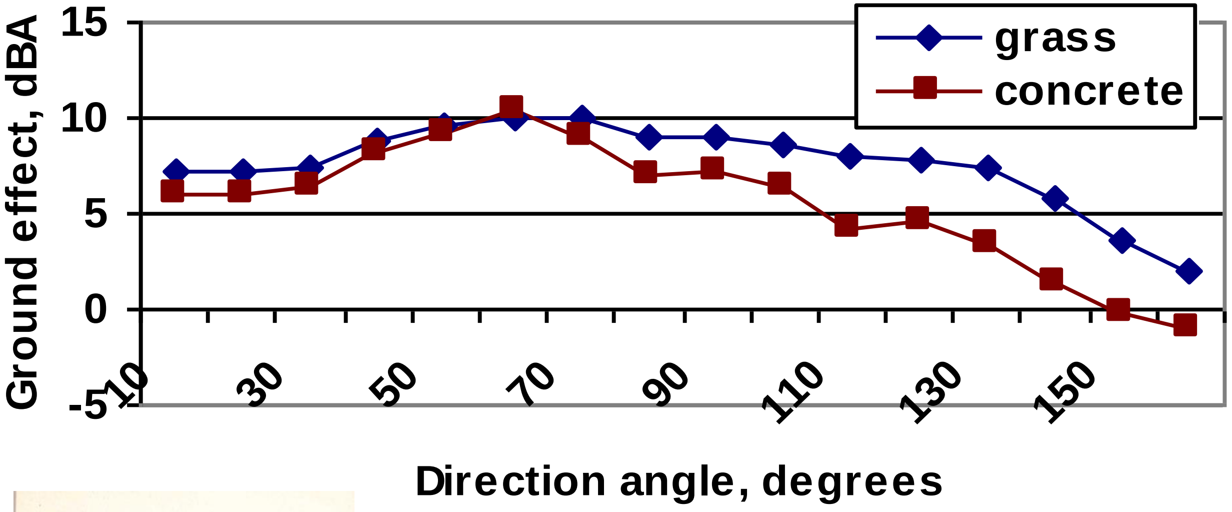
X-Noise

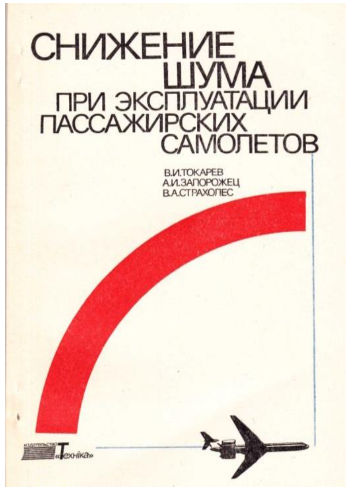
X-NOISE EV

EU FP7 X-NOISE EV: Aviation Noise Research Network and Coordination WP 2 Balanced Approach and Impacts

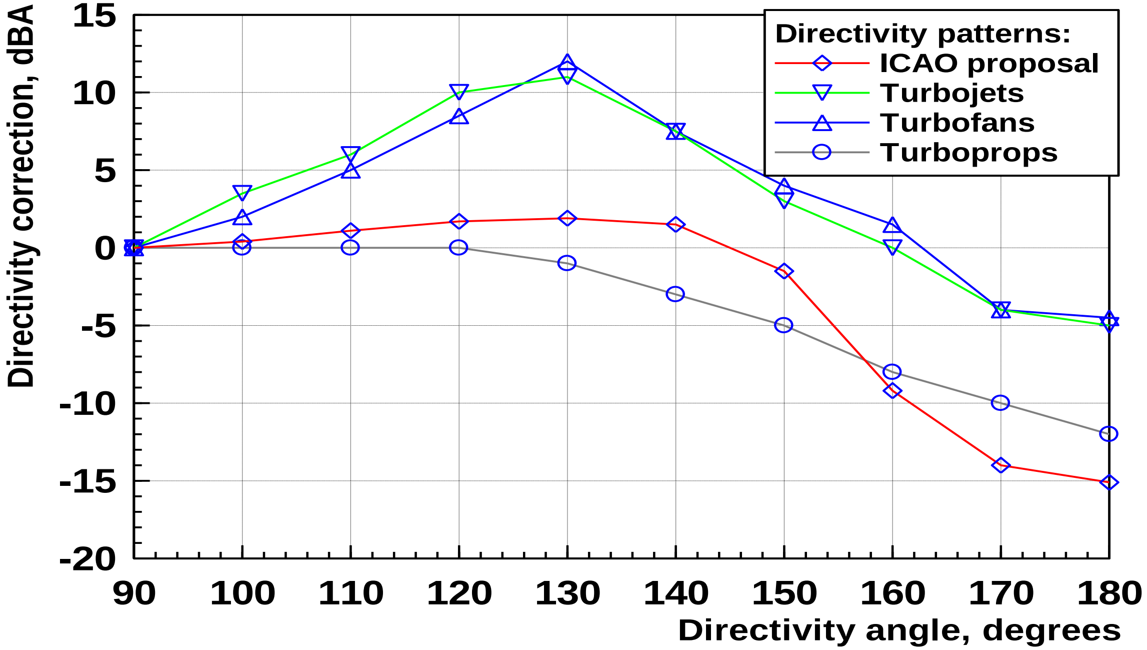
Aircraft noise directivity patterns

Ground effect as a function of the angle of engine noise generation





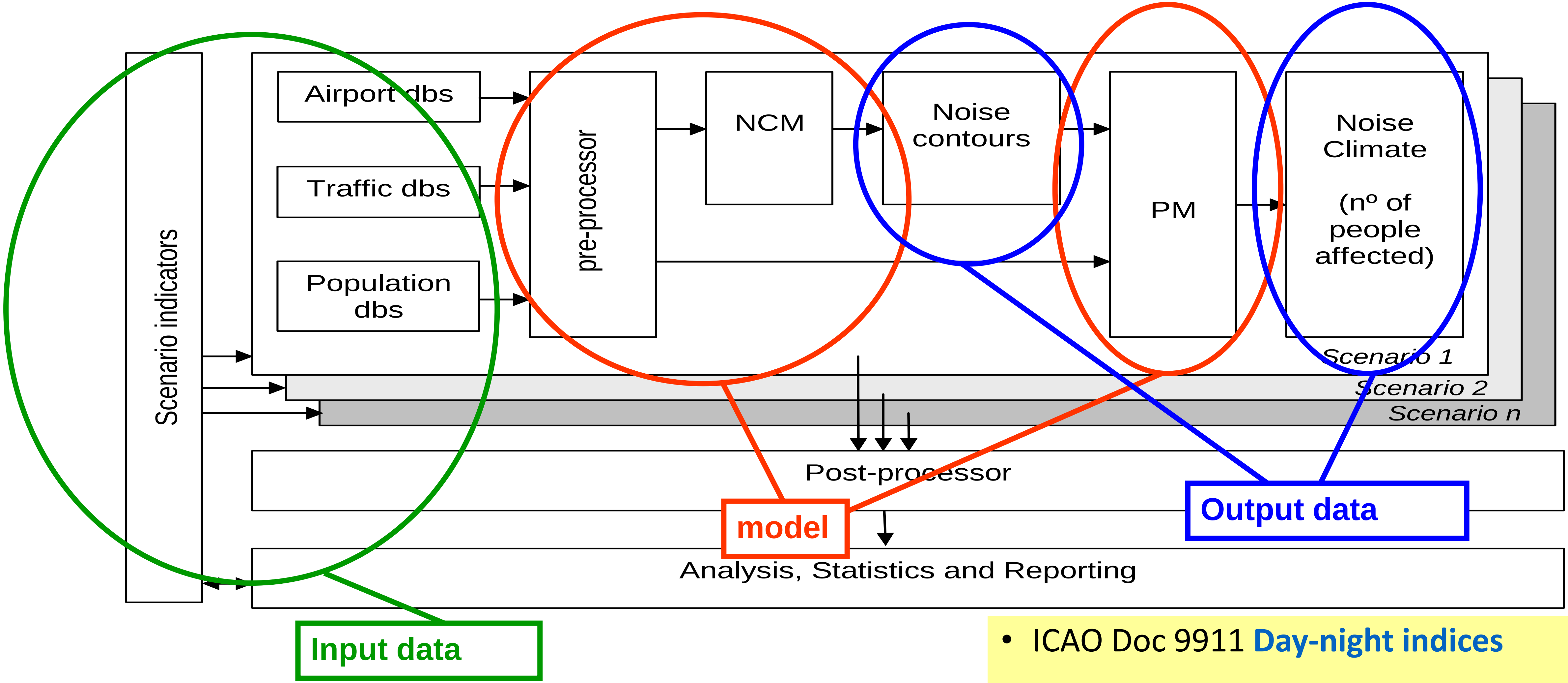
Different adjustment dL_{Θ}



EU FP7 X-NOISE EV: Aviation Noise Research Network and Coordination WP 2 Balanced Approach and Impacts

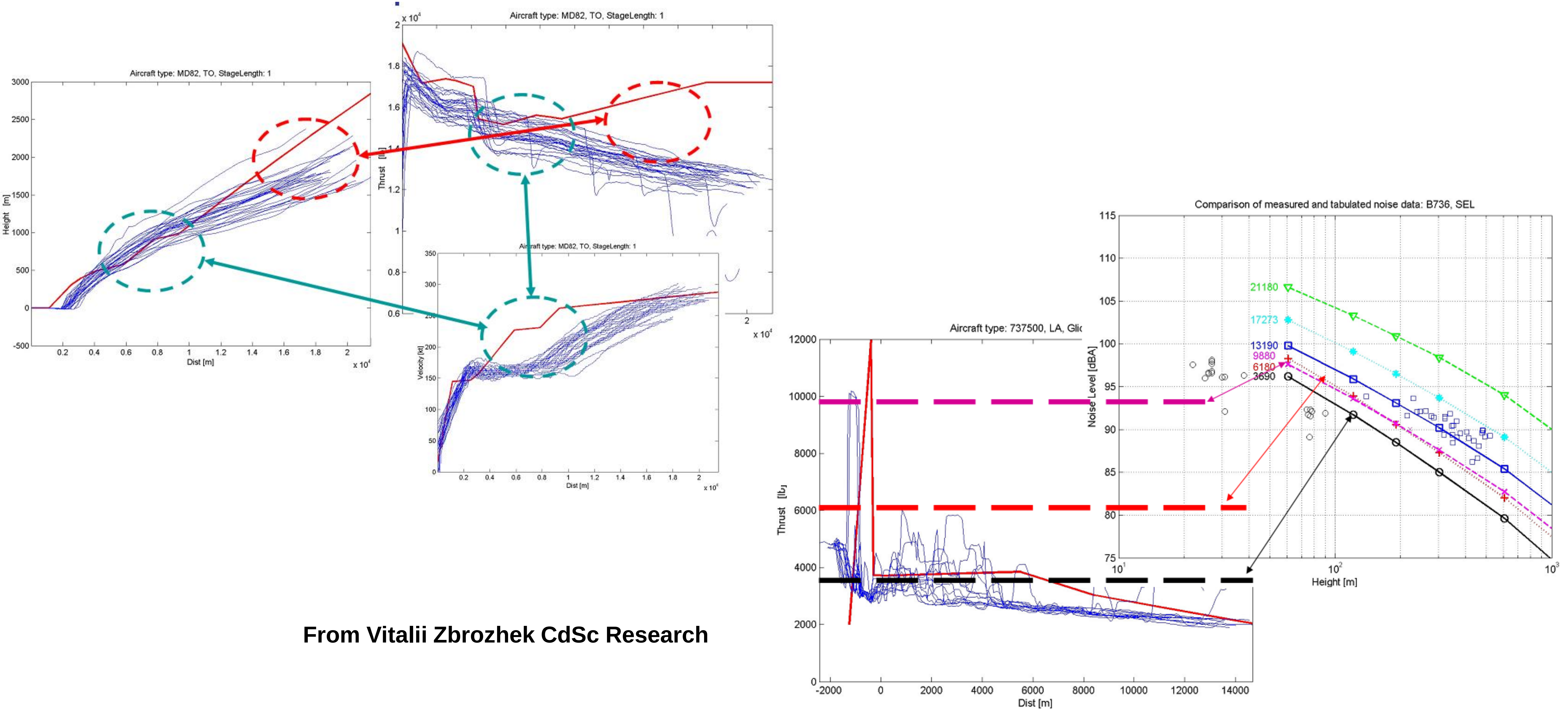
IsoBella calculation tool

✈ **Typical noise model process**



- ICAO Doc 9911 **Day-night indices**
- ECAC Doc 29 **Day-evening-night indices**
- GosNIIGA Method 1992 LAeq, LAmax

Comparison of observed in operation and balanced flight parameters & NPD curves

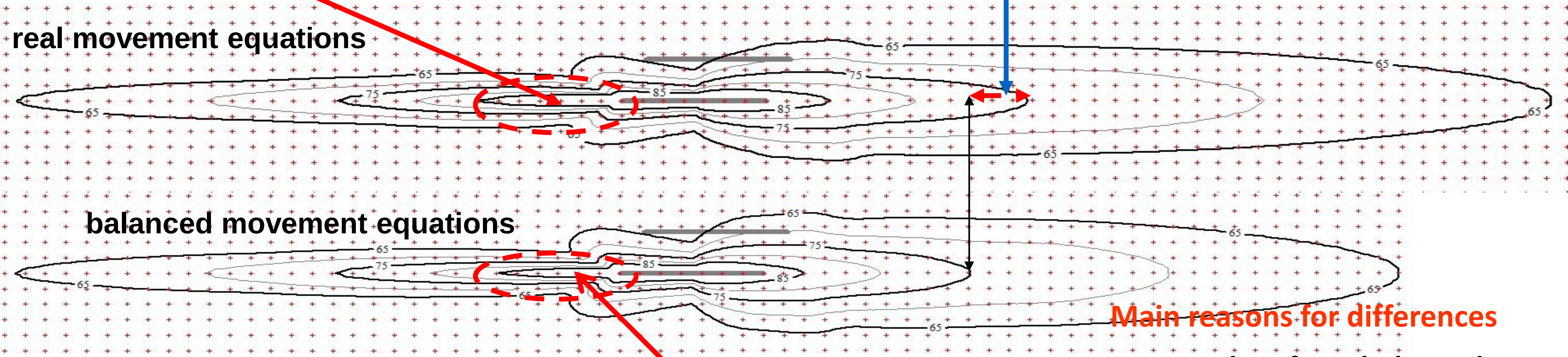


From Vitalii Zbrozhek CdSc Research

B737-400 comparison for balanced and observed in operation conditions (IsoBell'a calculations)

2 dBA difference!

1,5 km difference!



Main reasons for differences

- **Input data from balanced movement equations**
- **Noise sources performances (aircraft substitution concept)**
- **Propagation effects**

LAmax at distance 1000 m before RW end:

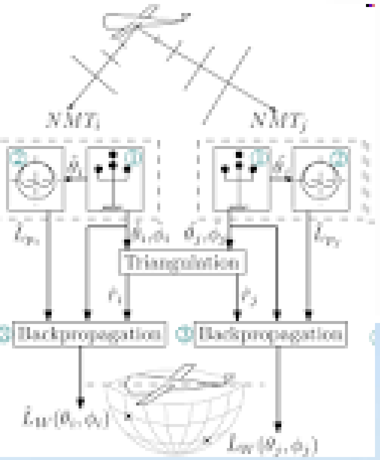
- **98** dBA for A – corrected thrust at glideslope+

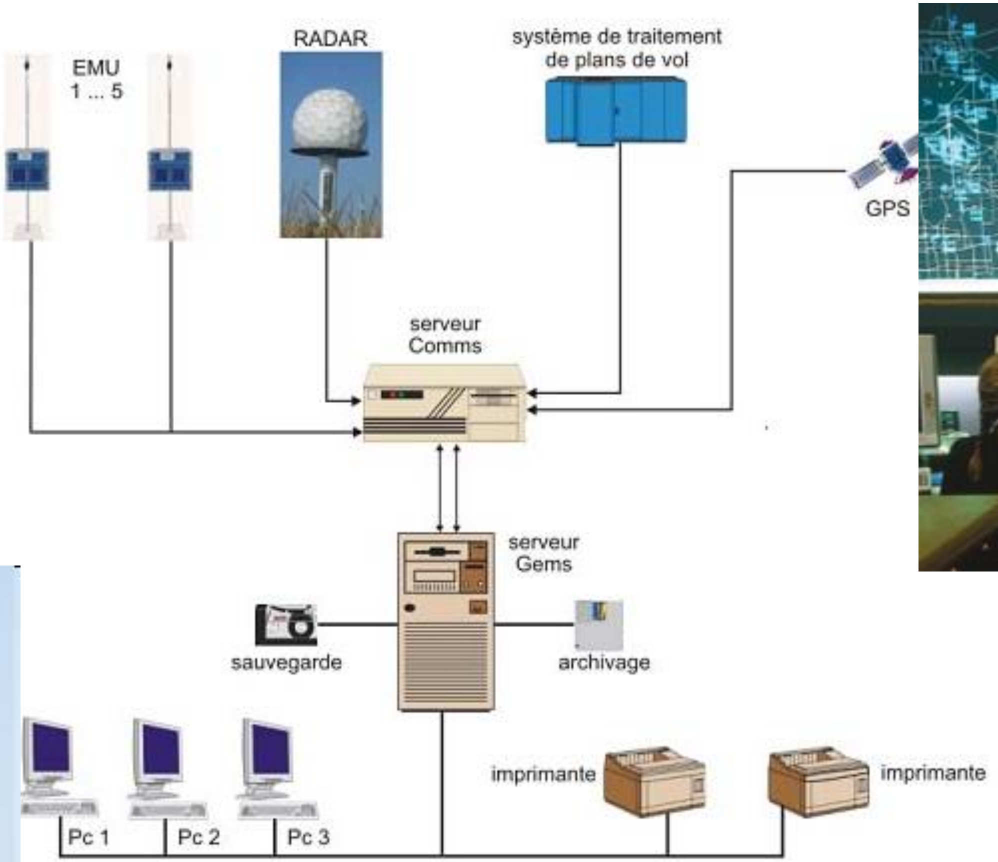
+ corrected thrust at climb out

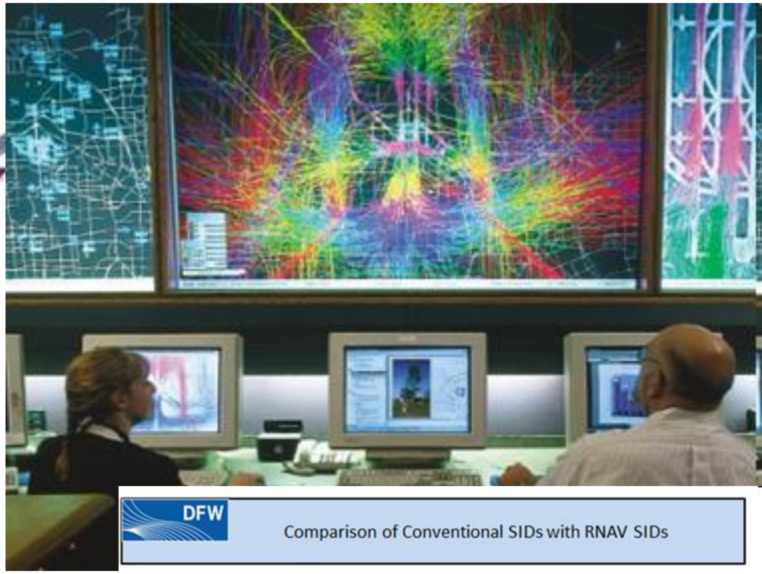
- **96** dBA for B – INM data base

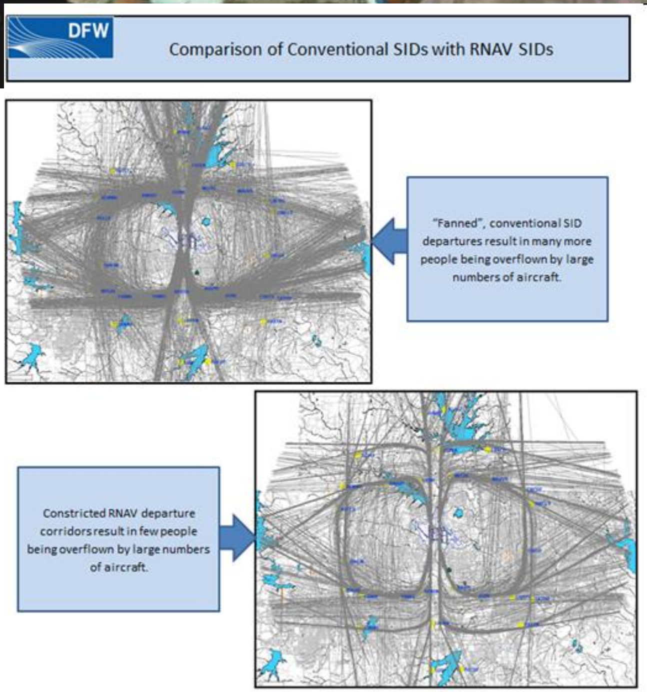
From Vitalii Zbrozhek CdSc Research

Noise measurement approach







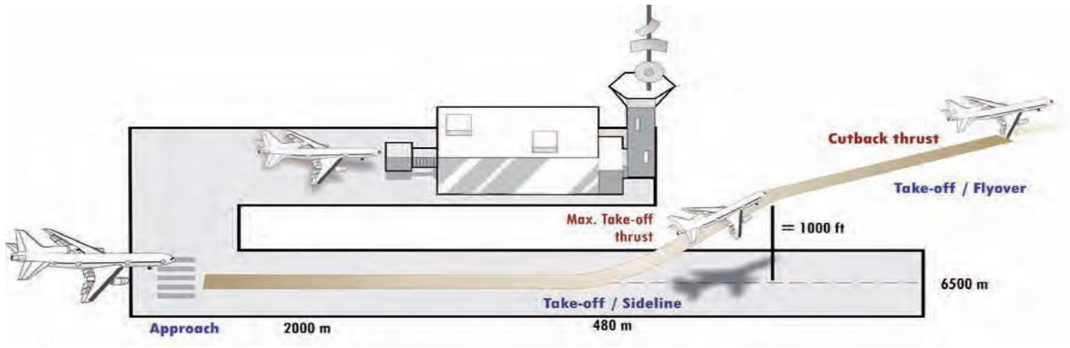


NON-ACOUSTIC FACTORS

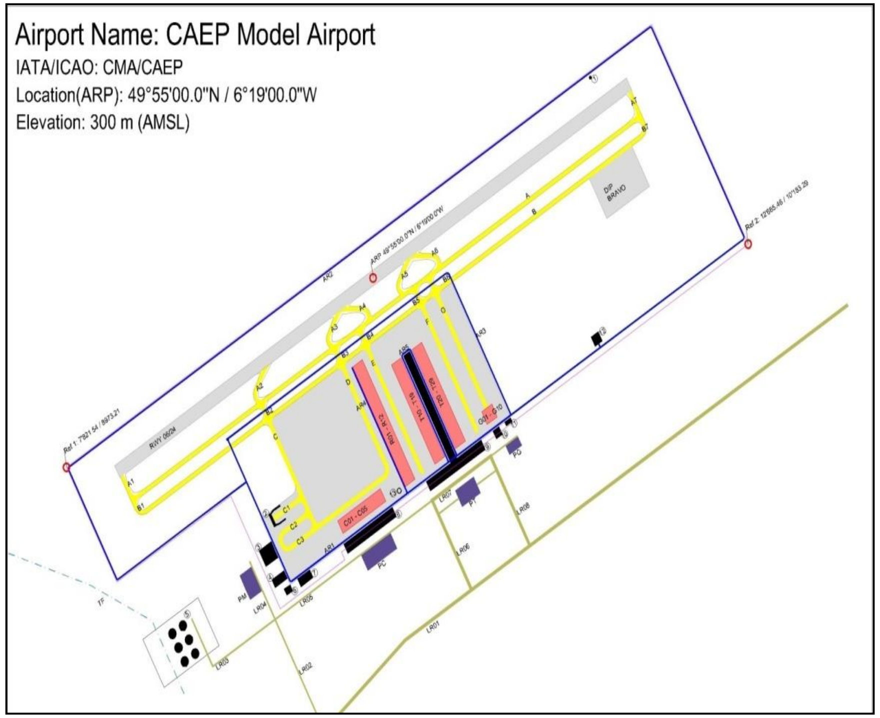
- From one point of view the **existing exposure-response curve**, used in any studies for impact assessments, **has to be updated**. From other point of view all the non-acoustical factors, influencing on annoyance, at any specific case need to be managed correctly, **providing less annoyance if it should be possible**.
- Approximately **one-third of the variation** (even only one-fifth by some results!) **in noise annoyance can be explained by acoustical factors!**
- The extent of noise annoyance is clearly influenced by numerous non-acoustic ... **ational factors** in add... et al., 2003].

LAQ

- Local Air Quality is defined as the region in the atmosphere from 0 to 3000 feet above ground level



•Aircraft during LTO cycle; (ICAO Doc 9889)
•Start-up procedures, (ICAO Doc 9889)
•GSE; (ICAO Doc 9889)
•APU/GPU; (ICAO Doc 9889)
•Power plants *(Ukrainian national methodology)*
•Fuel farm *(Ukrainian national methodology)*
•Roadways vehicles *(Ukrainian national methodology)*



*The **following species** were selected for assessment:*

- *Aircraft Fuel Burn (can be used to calculate CO_2 respectively);*
- *Oxides of Nitrogen (NOx);*
- *Hydrocarbons (HC);*
- *Carbon Monoxide (CO);*
- *Particulate Matter (PM), as PM10 and PM2.5;*
- *Sulfur Oxides (SOx).*

- **ICAO Doc 9889**: **1-hour and/or daily concentrations**
- **EU: ALAQS, LASPORT, ADMS**
- **OND-86, PolEmiCA (UA): 20-30-minutes concentrations; daily concentrations non-mandatory**

Comparison of **PolEmiCa** emission inventory results with other CAEP tools

Species	Calculation tools, kg						
	LASPORT	EDMS	ALAQS	ADMS	ICAO	PEGAS	PolEmiCa
CO	273054	256163	208850	300359	419256	302395	**228767**
HC	48297	91541	54575	35789	57330	51815	**41787**
NOx	240720	238866	301880	279453	402509	309382	**333744**
SOx	16921	27058	20729	16 351	45544	96 103	**115009**
PM10	1788	2 827	1 961	4243	4365	2340	**2526**
PM2.5	1788	2 827	1 961	4243	4365	2340	**2526**
Fuel	21151038	19895750	20783565	20438419	33489839	19220622	**23001720**

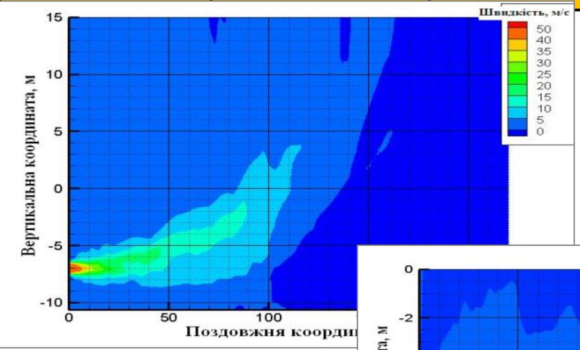
Initial dispersion parameters (σ_{0s}) of puffs and height of jet rise Δh_A are function of **the engine exhaust outlet parameters** (diameter, velocity and temperature).

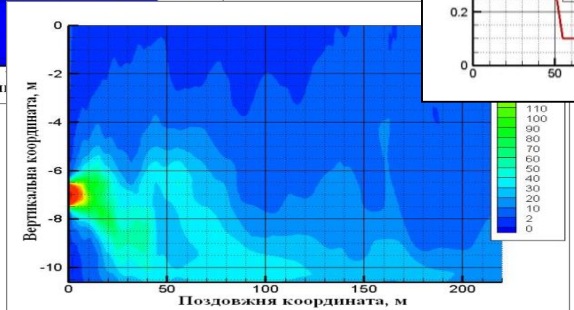
JET MODEL
for APU & aircraft engines

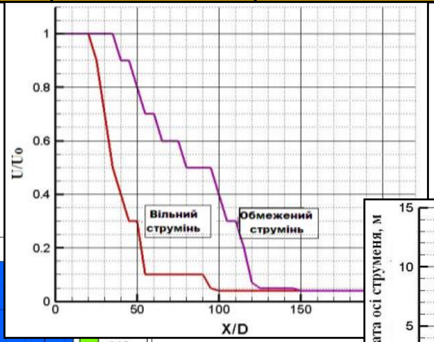
Height of jet rise due to buoyancy effect, the Archimedes number is used:

$$\Delta h_A = 0.013 \times Ar_0 \times \overline{X}_A^3 \times R_0$$

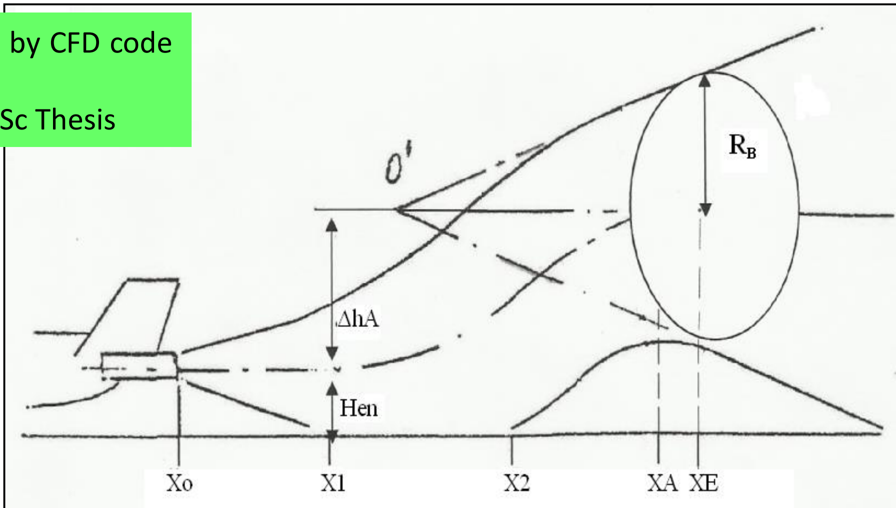
$$Ar_0 = \frac{2 \times g \times R_0 \times (Q_T - 1)}{U_0^2}$$



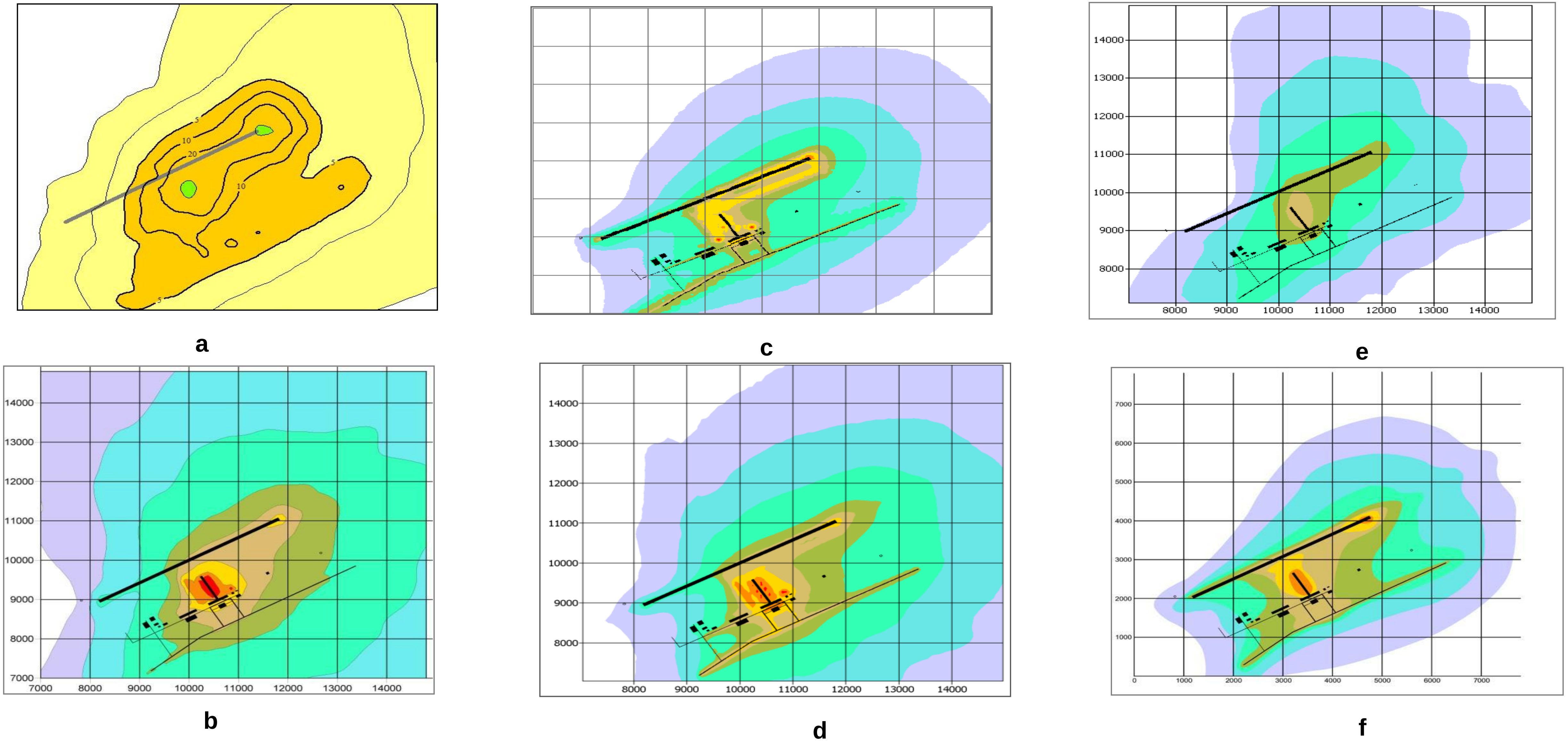




Jet model was improved by CFD code (**FLUENT 6.3/Gambit**),
From Kateryna Synylo CdSc Thesis



NOx dispersion results for CAEPort: PolEmiCa comparison with other verified LAQ tools



a – PolEmiCa; b – EDMS; c – ADMS; d – LASPORT; e) ALAQS; f) PEGAS

ICAO CAEP MDG verification task

OND-86 method for PM

volatile

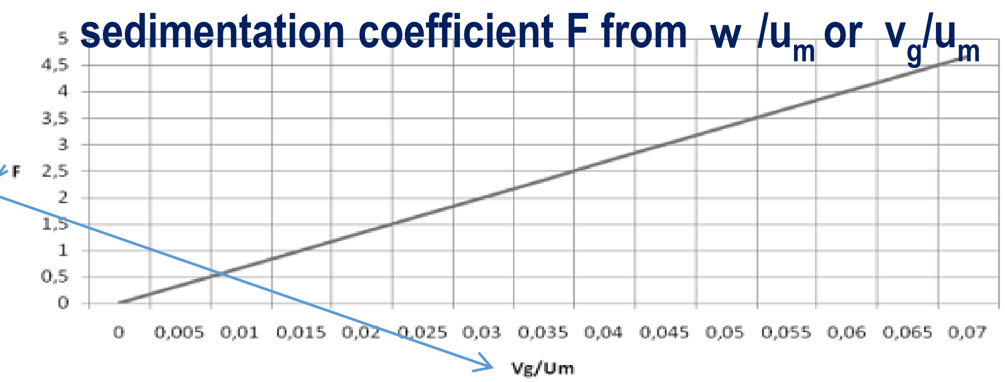
$$q_m = \frac{0,116\,(1+n)^2 M}{u_1 H^{1,5\,(1+n)}}\sqrt{\frac{k_1}{k_0 u_1}}$$

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

non-volatile

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

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



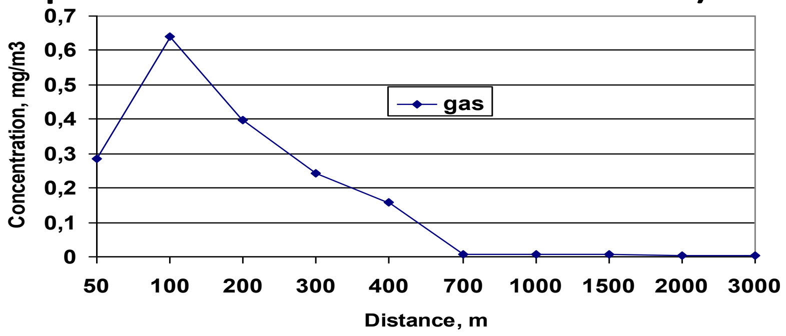
The maximum value of surface concentration (mg/m³) produced by emission of point source (round nozzle) under unfavorable meteorological conditions at distance X_M distance (m) from the source is determined by the formula:

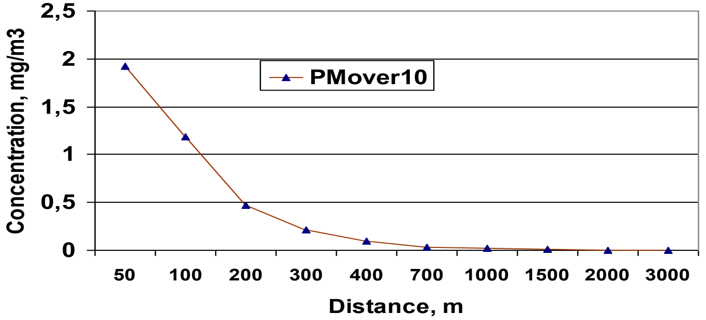
$$q_M = \frac{A \cdot M \cdot F \cdot m \cdot n \cdot \eta}{H^2 \sqrt[3]{V_1 \cdot \Delta T}} \qquad x_M = \frac{5 - F}{4}\, d\,H\,, \qquad d = 2{,}48\left(1 + 0{,}28\sqrt[3]{f_e}\right)$$

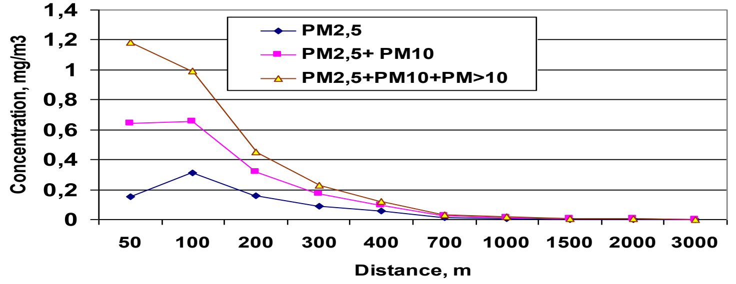
- A - coefficient depending on the temperature stratification of the atmosphere; $A = a\,\dfrac{k_1}{u_1 \varphi_0}\Big|_{u_1 = 2\ \text{м/с}}.$
- *M* – emission rate, g/s;
- F – dimensionless coefficient that takes into account the rate of PM sedimentation; $v_g\,(\text{or}\,\omega) = \dfrac{10^{-8} \cdot d_g^2 \cdot \rho \cdot g}{18 \cdot \mu}$
- 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 η = 1;
- ΔT– temperature difference between exhaust mixture and ambient air, °C;
- V_1 – exhaust mixture rate, m³/s: $V_1 = \dfrac{\pi D^2}{4}\,\omega_0\,,$

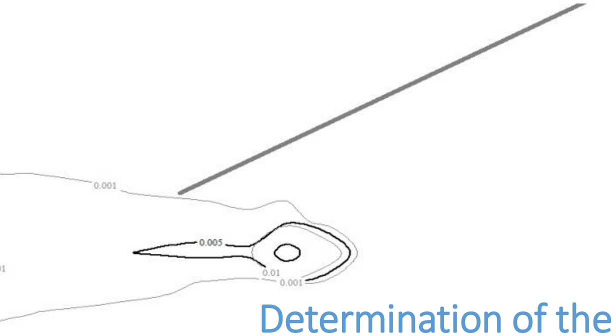
Pollution for gas and nvPM

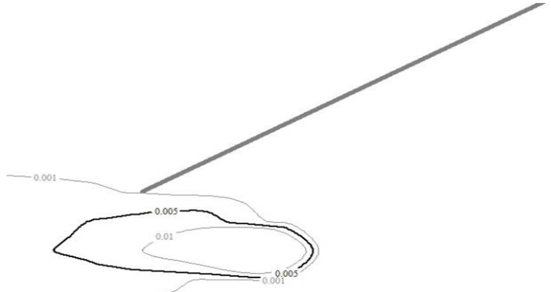
- APU, H=4,5m, concentration for gas, $PM_{>10}$ and polydispersed PM along the wind axis (emission parameters are the same):

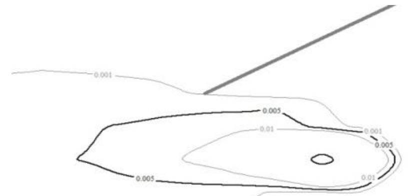






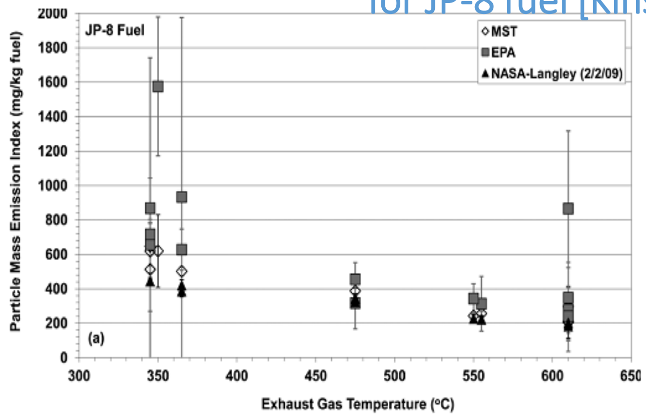


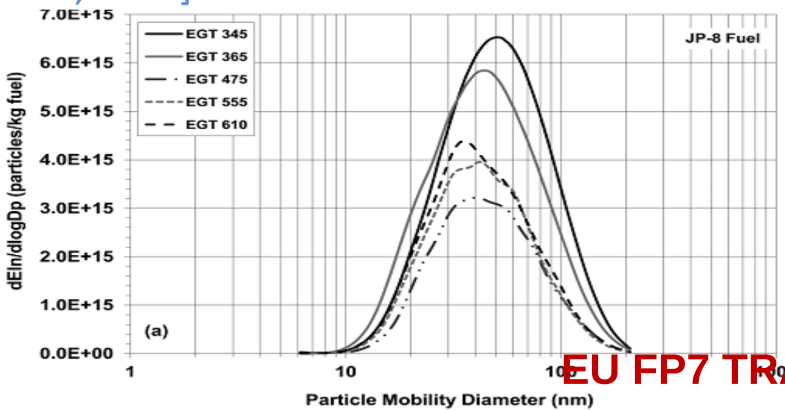




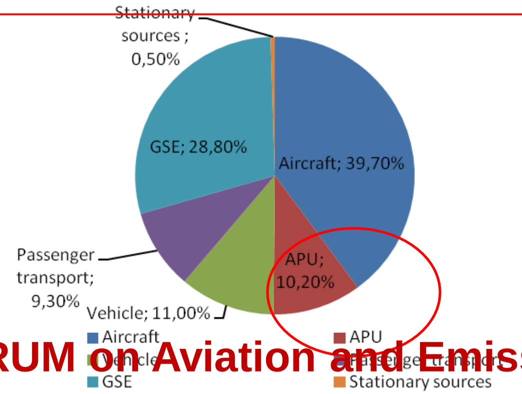
Polydispersed PM leads to the separation of maximums concentration in space

Determination of the emissions from APU (GTCP-98CK) for JP-8 fuel [Kinsey, et al., 2012]





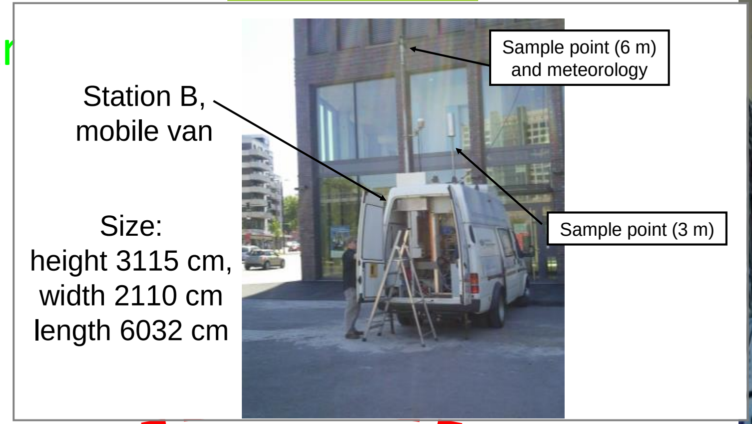
Emission inventory analysis highlighted on sufficient APU contribution to total emission:

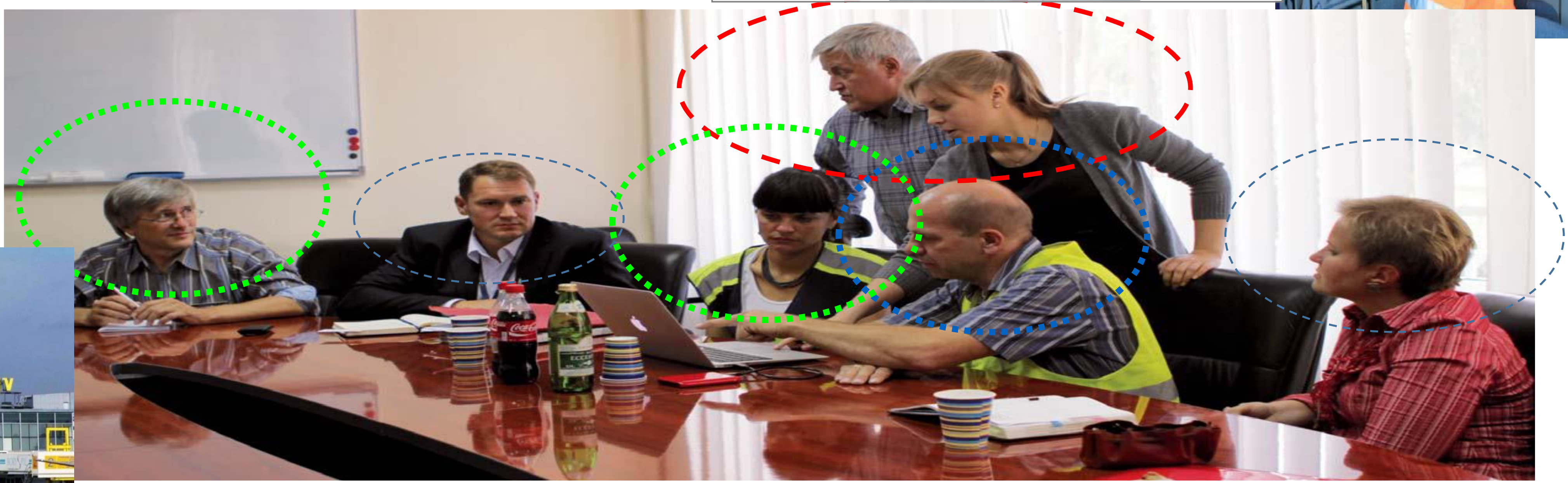


International cooperation in International Boryspol airport

Monitoring of air pollution produced by aircraft engine emissions in the vicinity of the airport

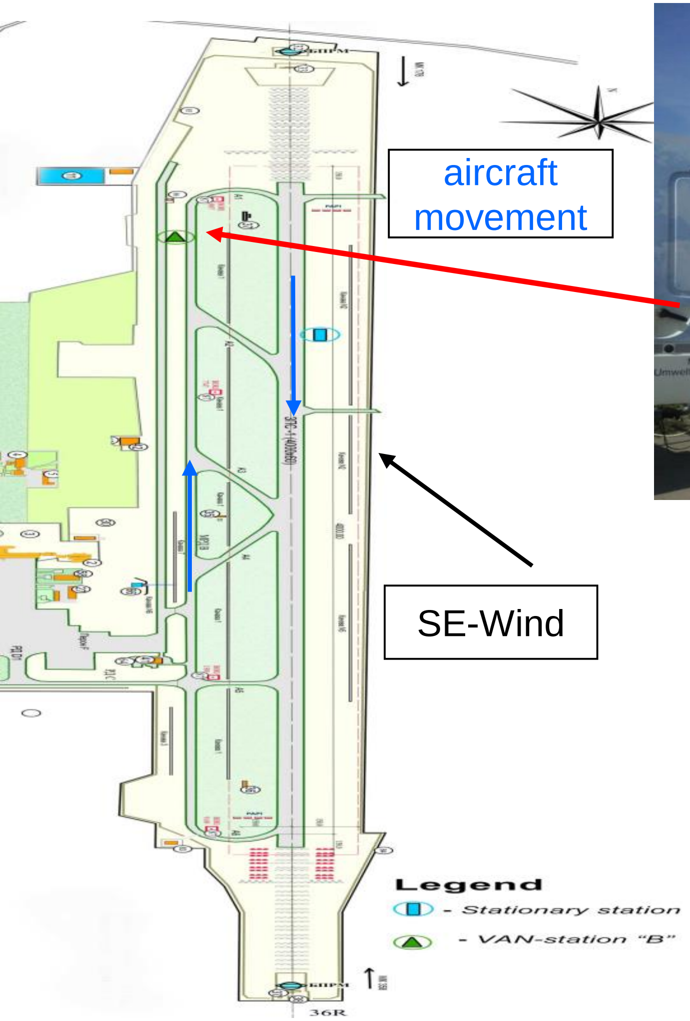
- University of Wuppertal (Wuppertal, Germany)
- National Aviation University (Kiev, Ukr
- Boryspol Airport (Kiev, Ukraine)
- Center of Ecological Safety (Moscow,



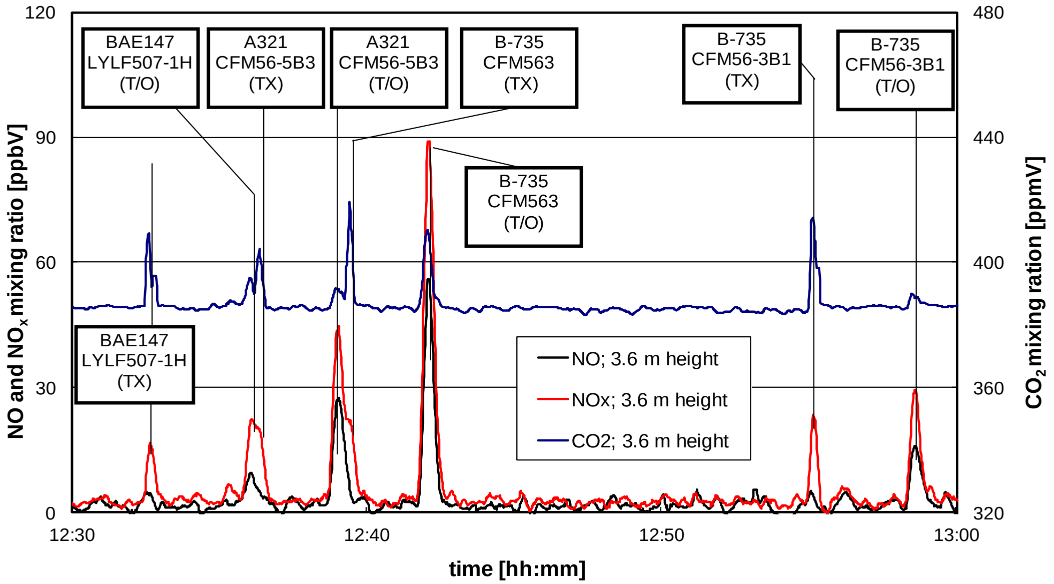


UA-DE bilateral project 2011-2012

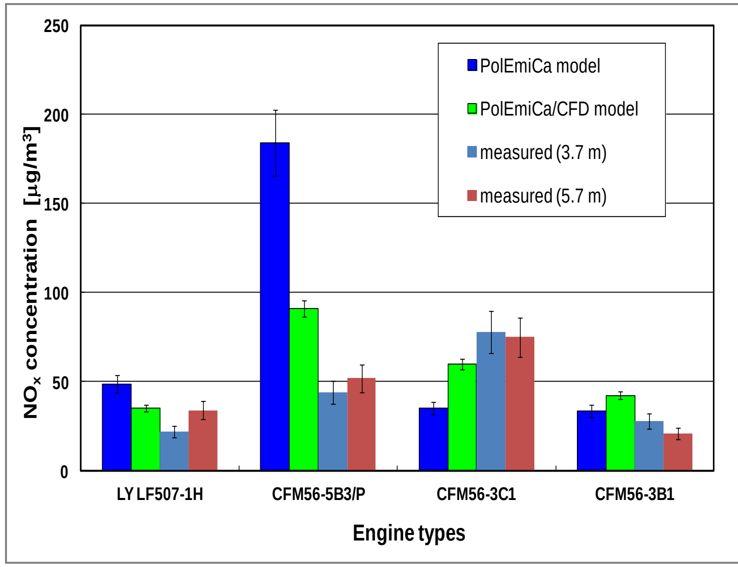
Measurement campaign at International Boryspol airport – Location set up 1:



Measurement sites **A** und **B**: stationary station A is located close-by the runway (30 m for sample mast) and mobile station B at 110 m from the runway due to prevailing wind direction (south-east).



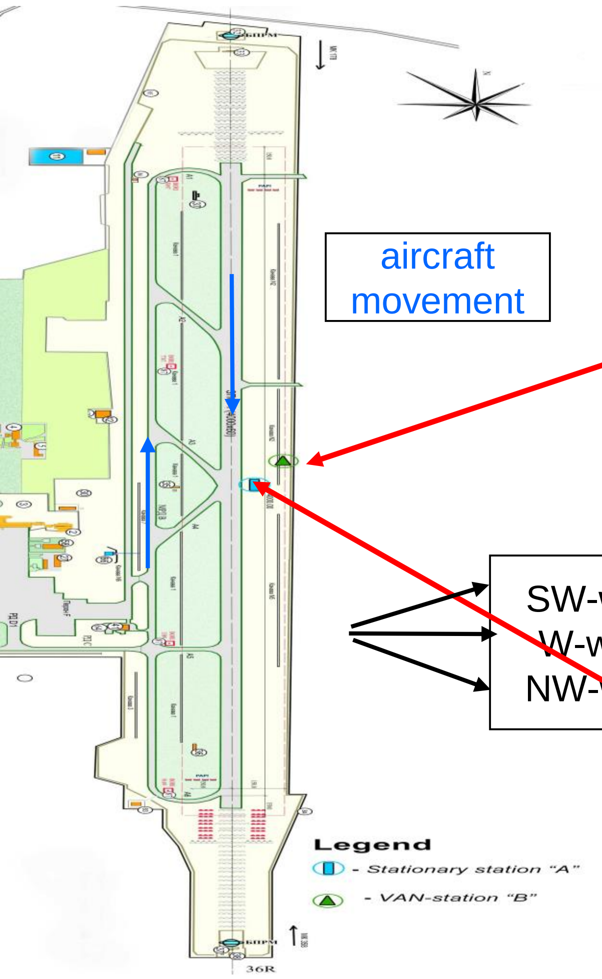
Background and the plume concentration for NO, NOx and CO2 at 3.6 m height (mobile station B) for different aircraft conditions: take-off (T/O) and taxi (TX)



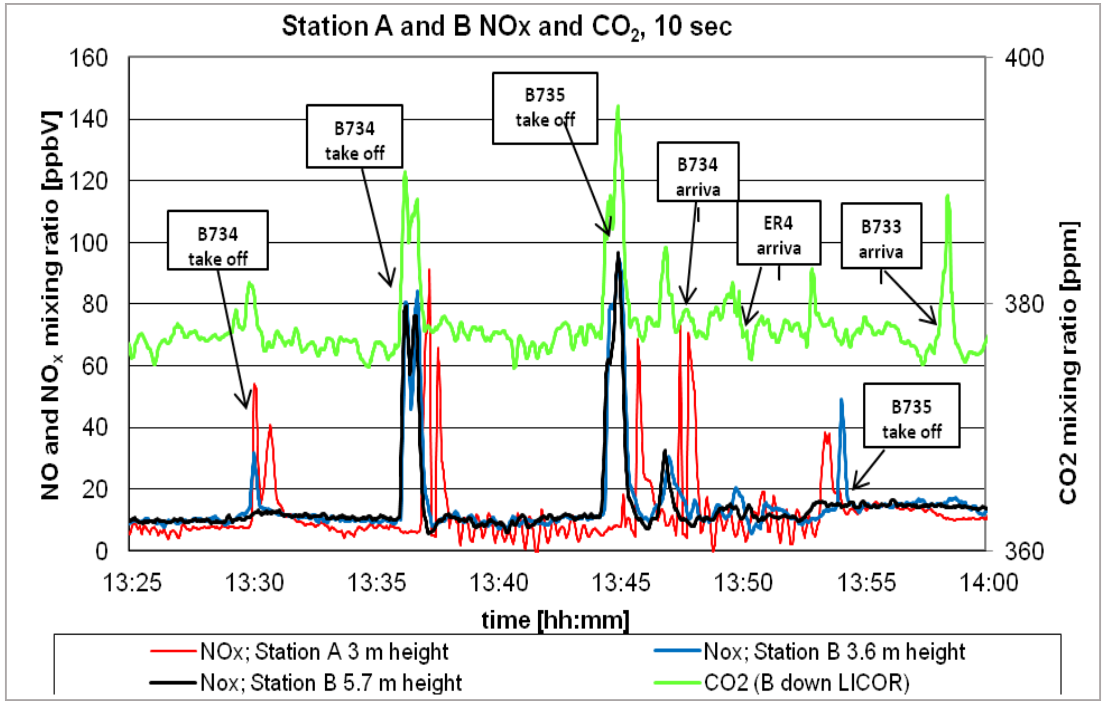
Comparison of measured and modeled averaged concentrations (3 s) of NOx in plume from aircraft engine for maximum operation mode

UA-DE bilateral project 2011-2012

Measurement campaign at International Boryspol airport – Location set up 2



SW-wind
W-wind
NW-wind

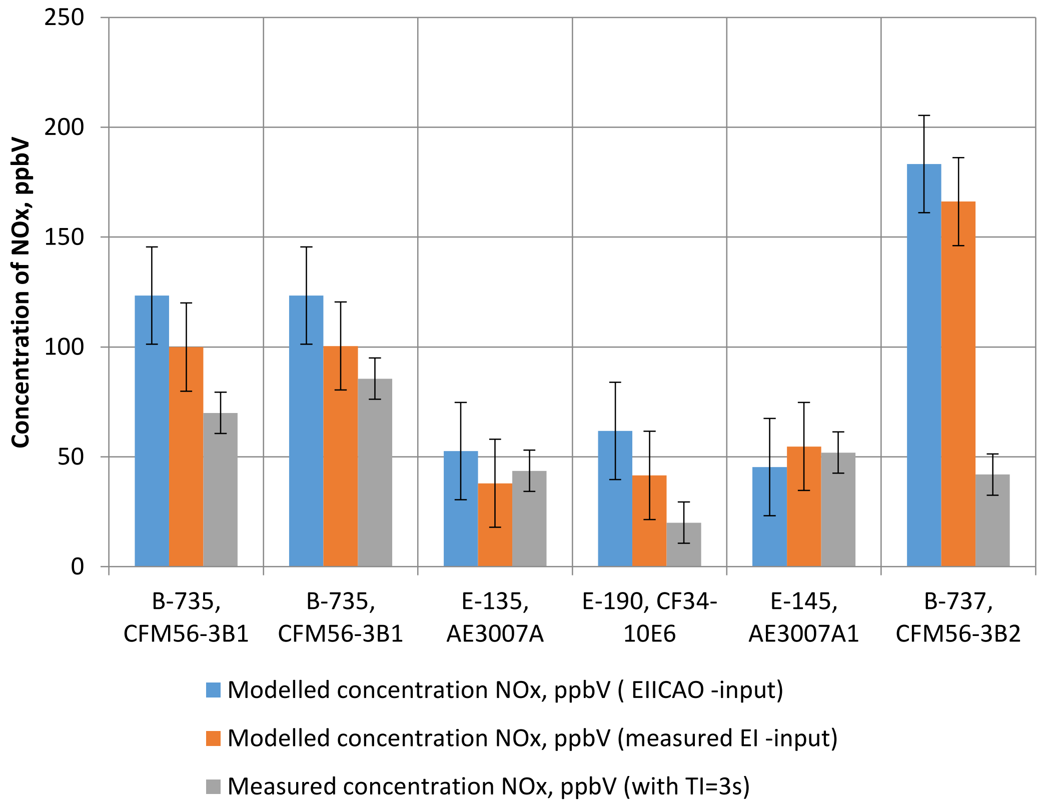


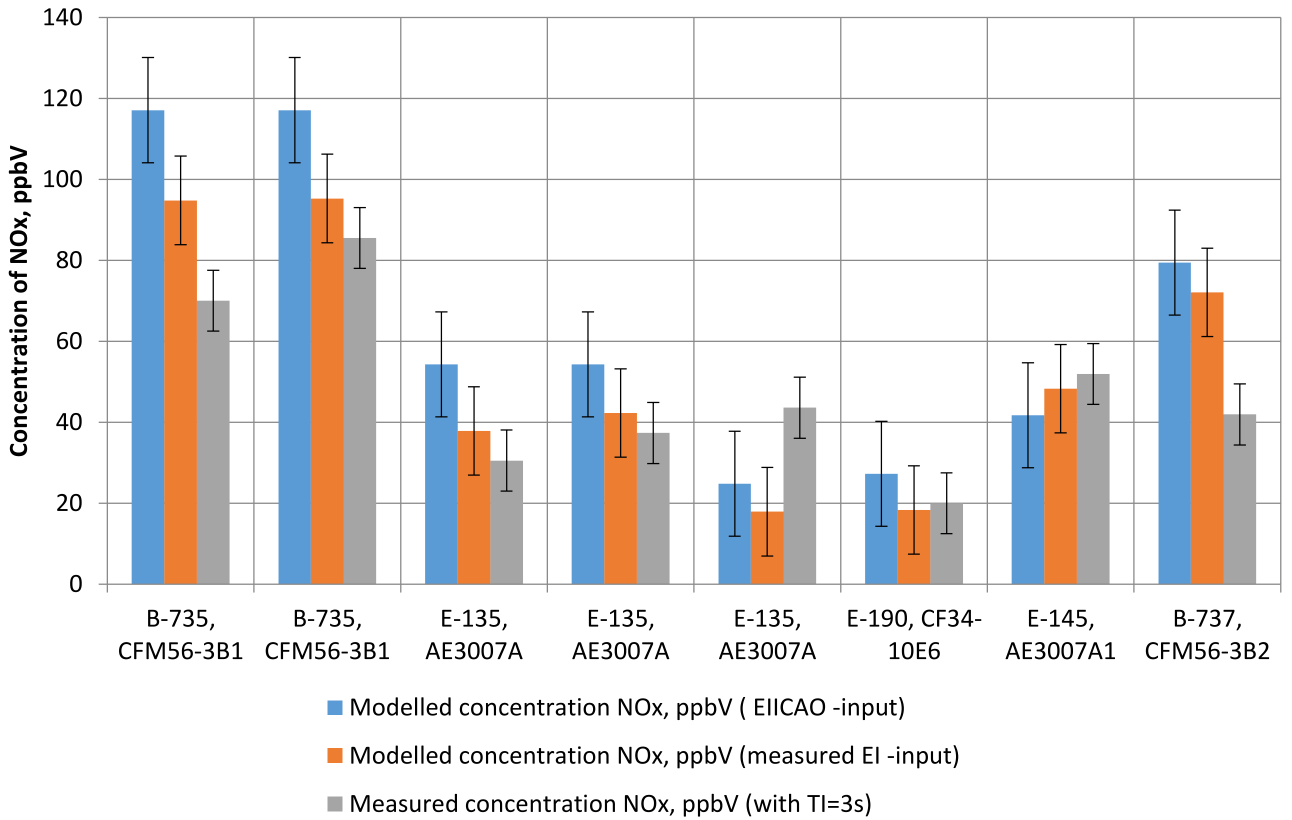
Measurement sites **A** und **B**: stationary station A is located close-by the runway (30 m for sample mast) and mobile station B at 110 m from the runway due to prevailing wind direction.

Background and plume concentration for NO, NOx, CO_2 at stationary station A and mobile station B at landing, take-off conditions and the prevailing wind direction

UA-DE bilateral project 2011-2012

COMPARISON MEASURED AND MODELED CONCENTRATION OF NOx IN THE JET FROM AIRCRAFT ENGINE AT DOWN STATION B (sample height of exhaust gases jet = 3.6 m)





Concentration of NOx were calculated by PolEmiCa model with taking into ground impact on the jet structure and its behavior

Concentration of NOx were calculated by PolEmiCa model including the interaction of the jet with wing trailing vortexes during the take-off stage

Combined approach for aircraft activities impact evaluation by measurement campaign and modelling techniques (from CdSc Thesis of Kateryna Synylo)

EI, C

- Moving monitoring station measures concentrations (C) in exhaust gases jet under real operation conditions;
- Moving monitoring station allow to determine emissions indexes (EI) under real operation conditions;

C

- Dispersion model calculates concentration field inside and around the airport on the ground of measured emission and concentration of contaminant s under real operation al conditions of aircraft;

Output

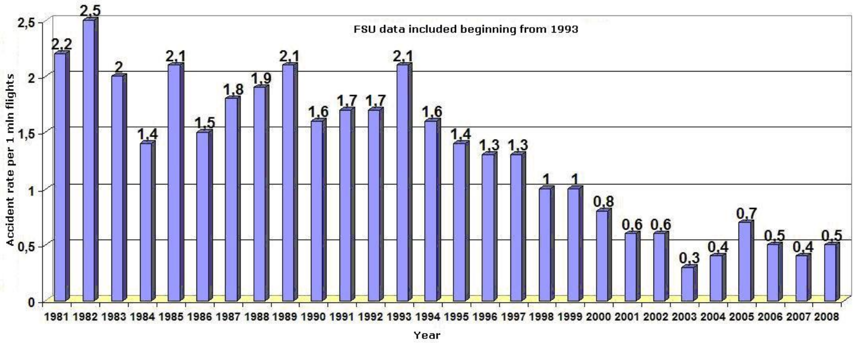
- Improvement of emissions inventory of aircraft s;
- Improvement of procedure of sanitary-hygienic zoning around the airports;
- Assessment and control /regulate of aircraft engine emissions ;
- Validation and improvement of air quality modeling systems

- Using obtained results from CFD simulations of aircraft engine jet dynamics to improve local air quality modeling and assessment of aircraft emission contribution in to total air pollution of airport;
- Investigation of properties and mechanisms of interaction between jets/plumes from double engines for different meteorological and operational conditions;
- Using obtained results from CFD simulations of aircraft engine jet dynamics for monitoring tasks, because dispersion process are in a time scale of a few minutes and properly incorporate with in the most commonly used monitoring software;

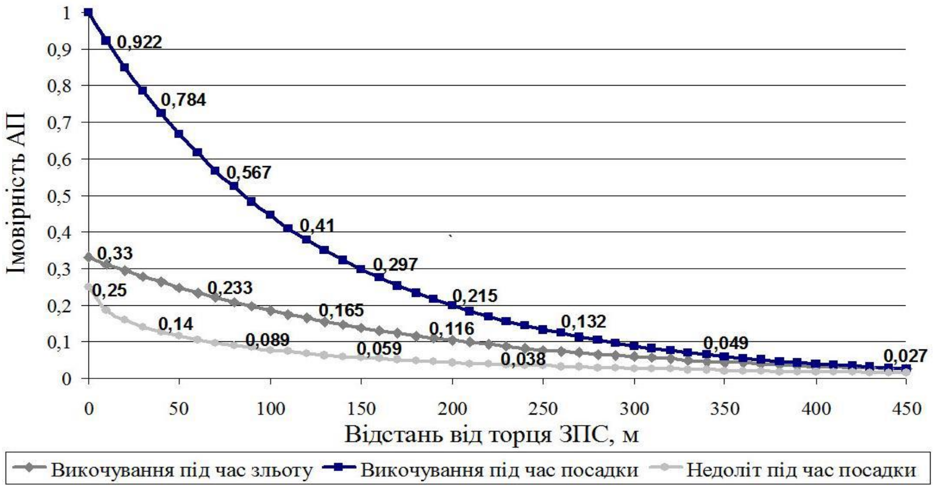
Proposed method for control aircraft engine emissions is cost effective, because it requires only one-two monitoring stations at specific points relatively to runway and main taxiway.

Third Party Risk

- **A methodology to assess Third Party Risk (TPR) around airports has been developed and recommended by CAEP for usage in grounding of Public Safety Zones (PSZ) around specific runways**

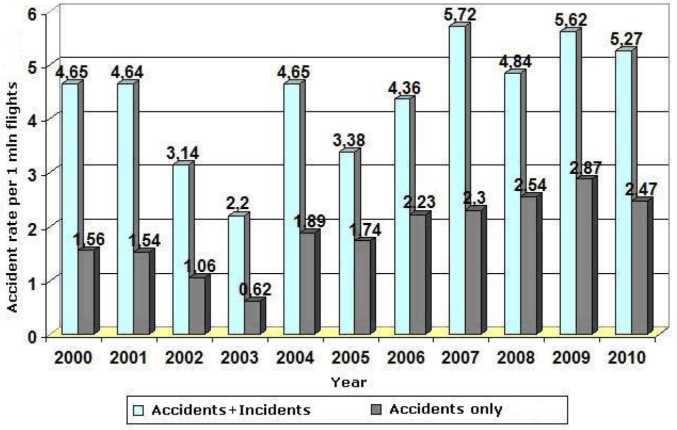


Averaged AR for aircraft movements (per 10^6 movements) in the world in total



Probability per 10^6 flights relatively the beginning and end of the runway

From: CdSc Thesis Inna Gosudarska



Averaged AR for aircraft movements (per 10^6 movements) in FSU countries

- ICAO Doc. 9184
- EU: NL, UK, DE
- 3PRisk (UA tool)

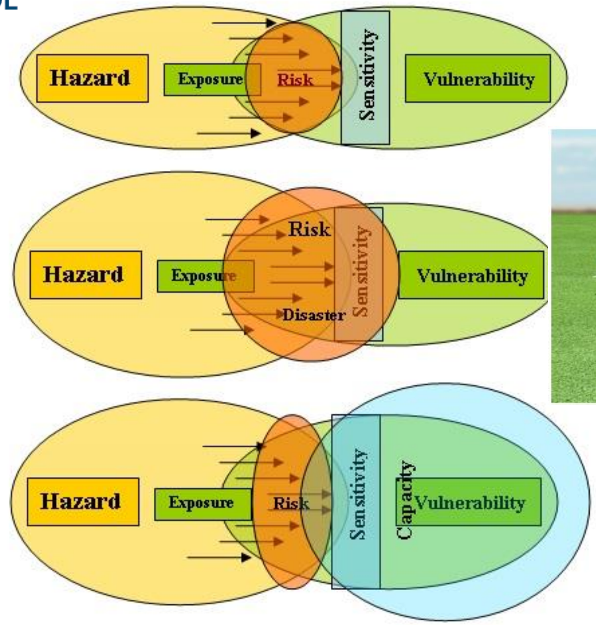
TPR calculation tool: 3PRisk

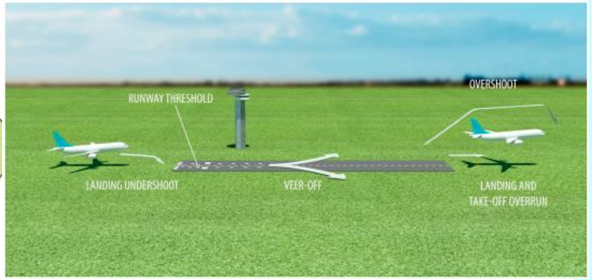
EUROCONTROL

envisa

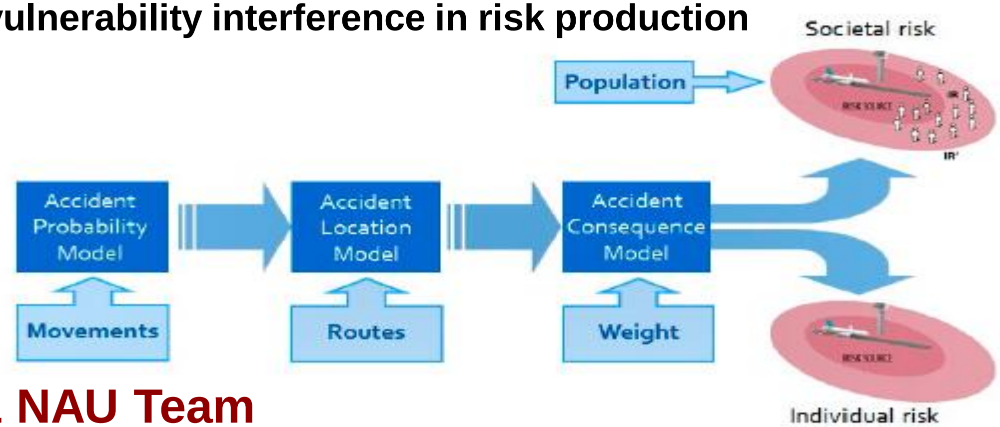
TEAM Play

SEVENTH FRAMEWORK PROGRAMME



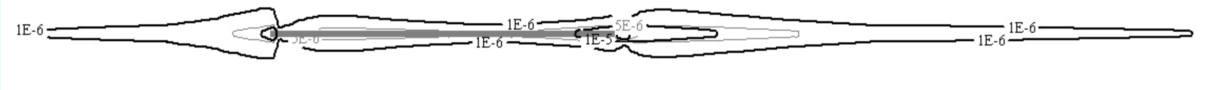


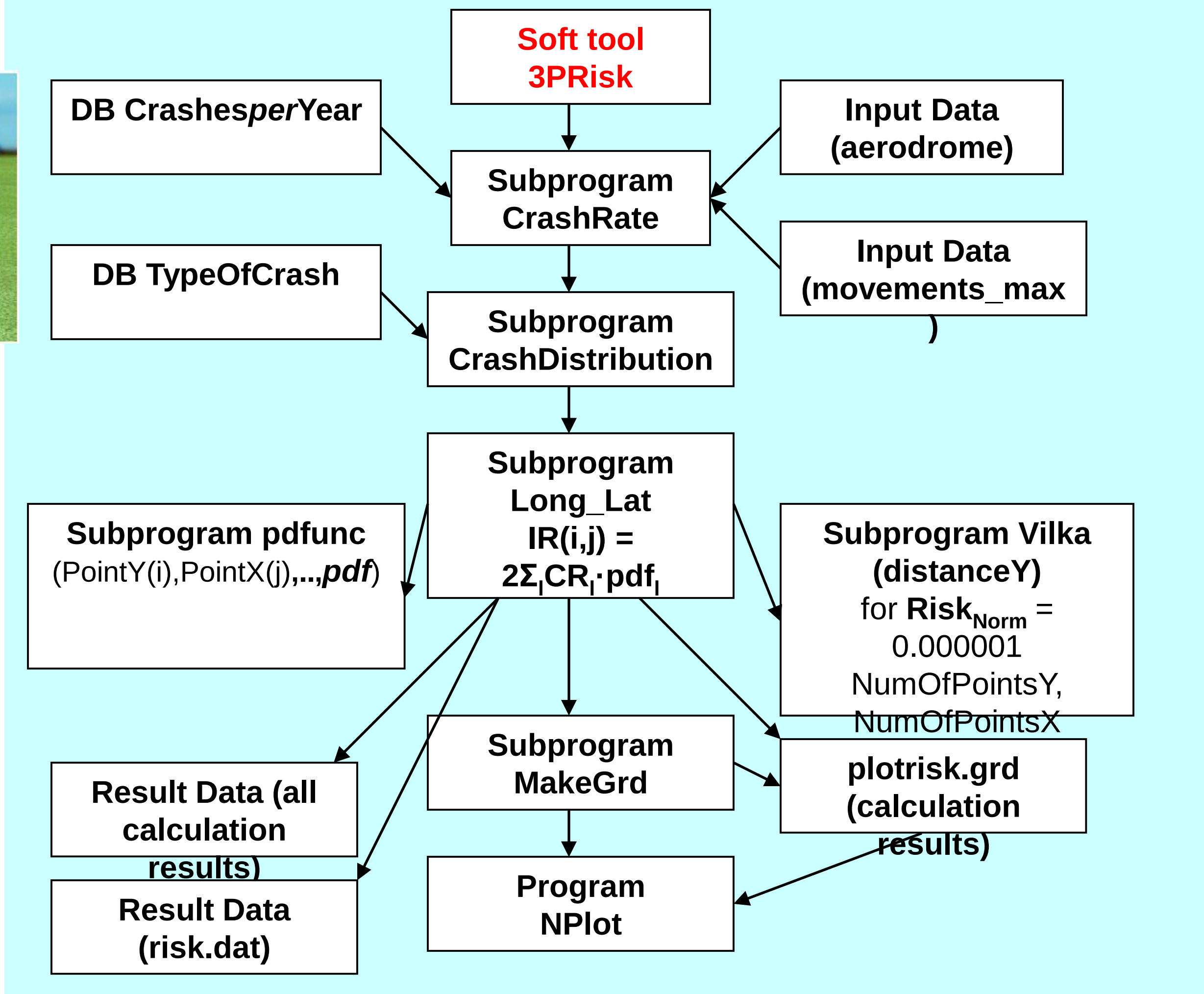
Hazard and vulnerability interference in risk production



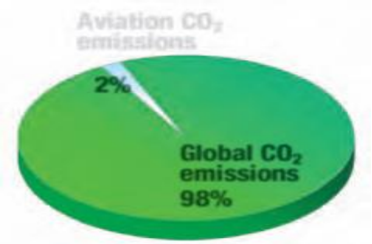
Envisa & NAU Team

Feasibility study on the integration of third party risk near airports into IMPACT (Eurocontrol, 2015)



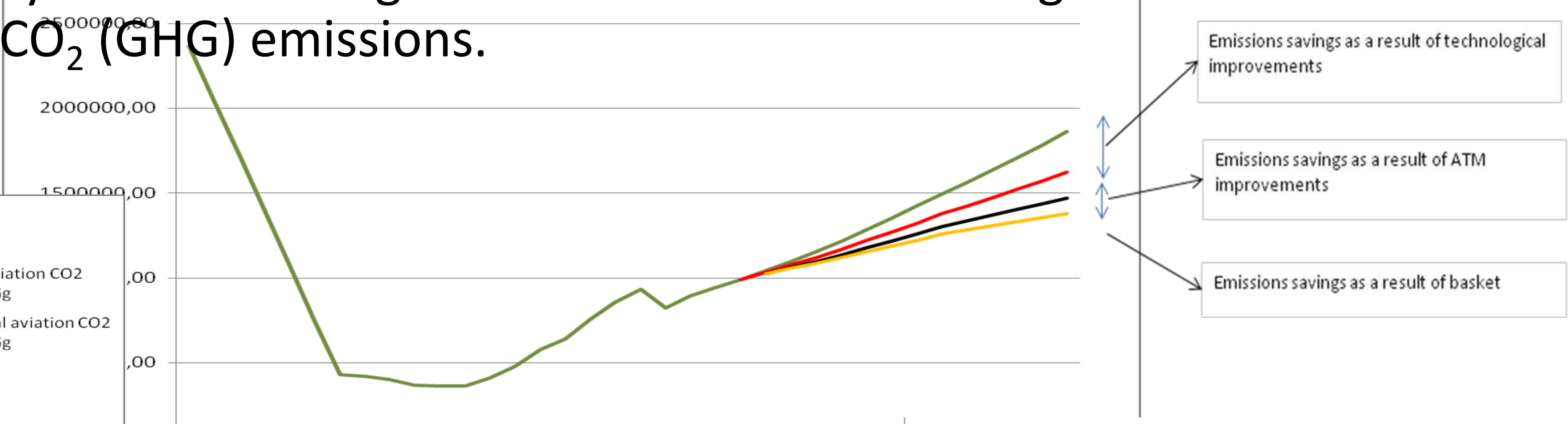


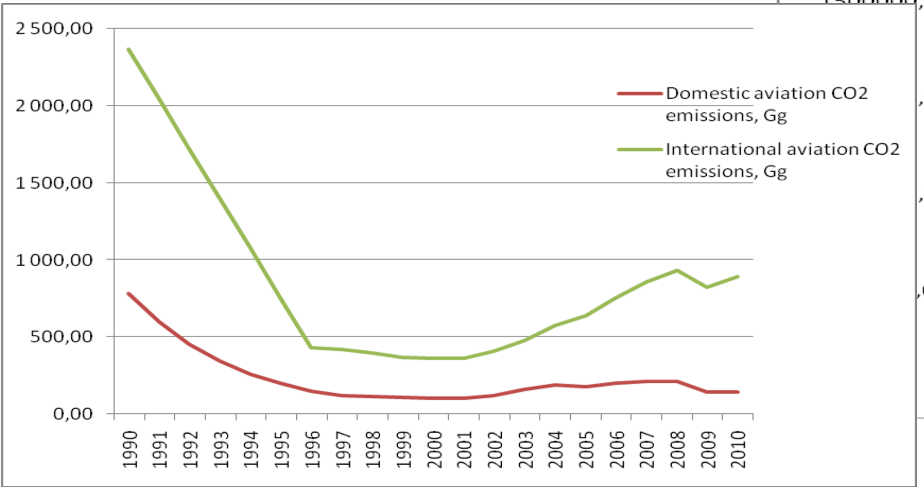
Tool Suite for Environmental and Economic Aviation Modelling for Policy Analysis (FP7, 2010-2013)

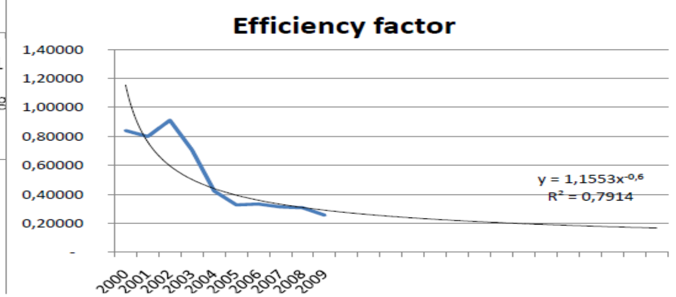


Climate Change
National Action Plan 2012

- The ICAO Programme of Action on International Aviation and Climate Change, agreed in 2009, set a goal of 2% annual fuel efficiency improvement through the year 2050.
- It is the first and only globally-harmonized agreement from a sector on a goal and on measures to address its CO_2 (GHG) emissions.







in collaboration with Spain and in coordination with EU (EU Twinning Project)

To execute the Environmental Impact Statement of implementation of the CNS/ATM systems in countries-members of the RADA

- Calculated aircraft fuel burned and emission for flight traffic scenarios in RADA-member States in 2015

(NAU Flight Fuel and Emission calculator: Fleming, CORINAIR Emission Inventory Guidebook)

ICAO's CAEP has developed a methodology and tool for estimating global emissions and fuel usage and evaluating the impact of various CNS/ATM enhancements:
indirect routings,
non-optimal flight profiles,
congestion resulting in airborne holding and queuing,
delays and other factors

Customer:
Robinson Aviation (RVA), Inc, USA, 2005

State		Fuel consumption, t	NOx, t	CO, t	HC, t	CO2, t	H2O, t	SO2, t
Ukraine	2015	468739.84	4680.40	8005.29	3830.31	1587667.25	623474.43	504.02
	CNS saving	35281.49	352.28	602.54	288.30	111136.71	43643.21	35.28
Armenia	2015	23170.227	333.064	295.797	80.264	72986.219	28661.570	23.170
	CNS saving	1158.511	16.653	14.790	4.013	3649.311	1433.078	1.159
Azerbajan	2015	90255.930	918.985	856.773	237.593	284306.188	111646.586	90.256
	CNS saving	4512.796	45.949	42.839	11.880	14215.310	5582.330	4.513
Georgia	2015	51134.016	801.073	724.841	336.127	161072.156	63252.777	51.134
	CNS saving	2556.701	40.054	36.242	16.806	8053.608	3162.639	2.557
Moldova	2015	7281.161	80.361	79.561	33.275	22935.656	9006.795	7.281
	CNS saving	364.058	4.018	3.978	1.664	1146.783	450.340	0.364

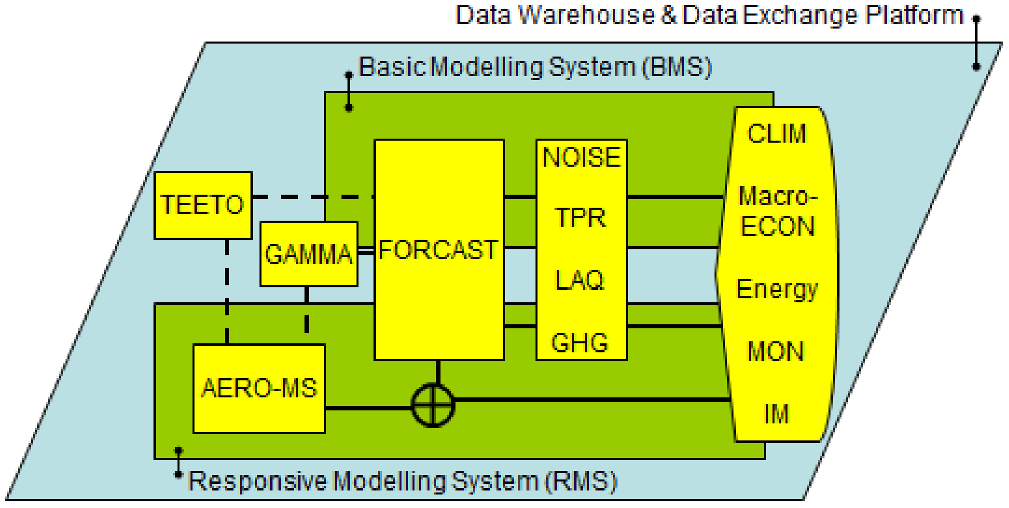
EU Strategic modelling approach + ALFA:

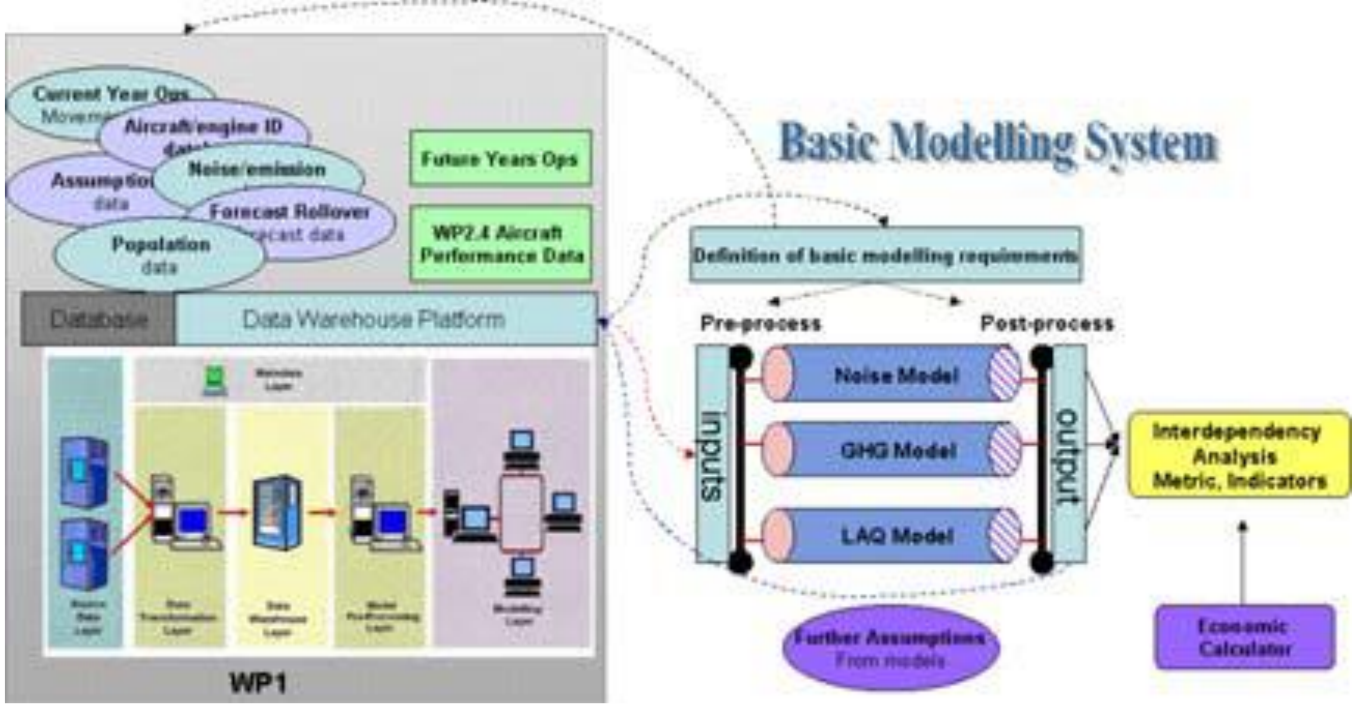
tools for eco-eco multicriteria assessment and optimization of

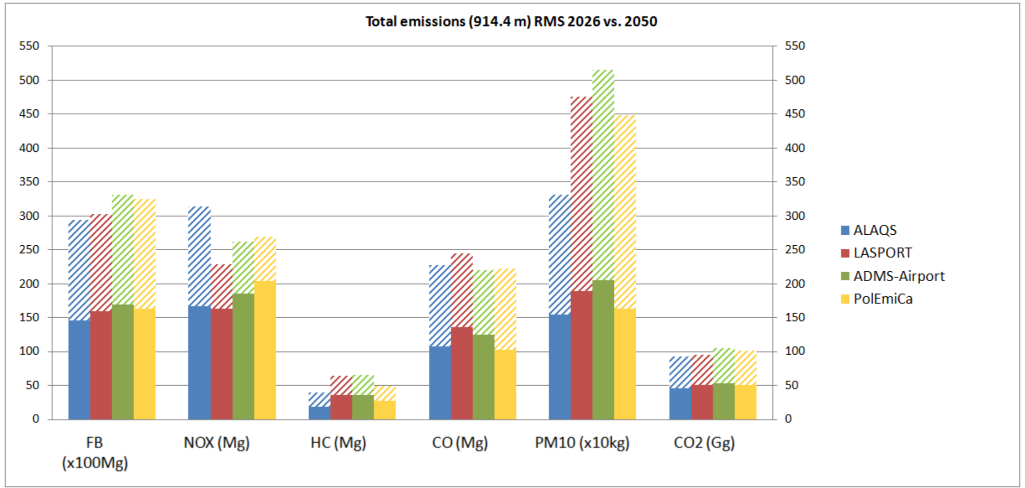
sustainable development of the aviation sector of Ukraine

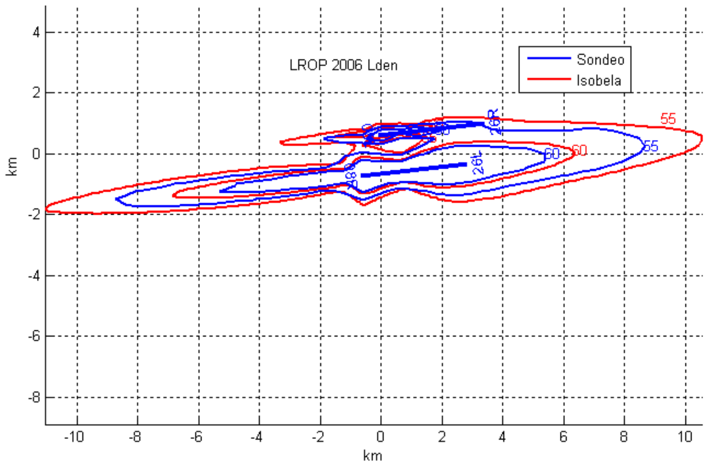
TEAM Play

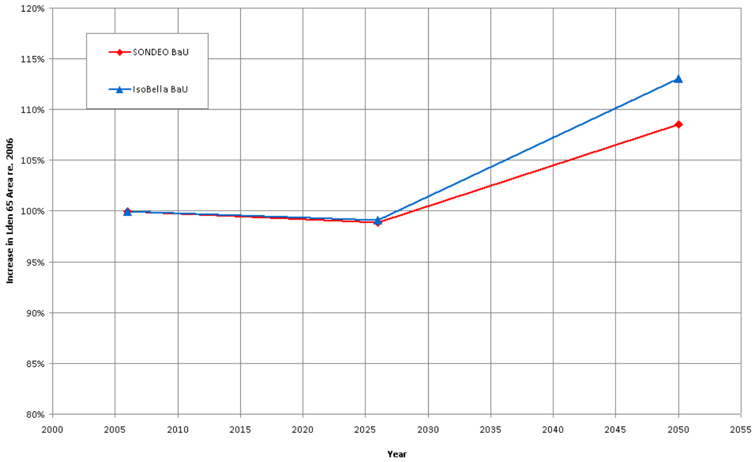
Tool Suite structure





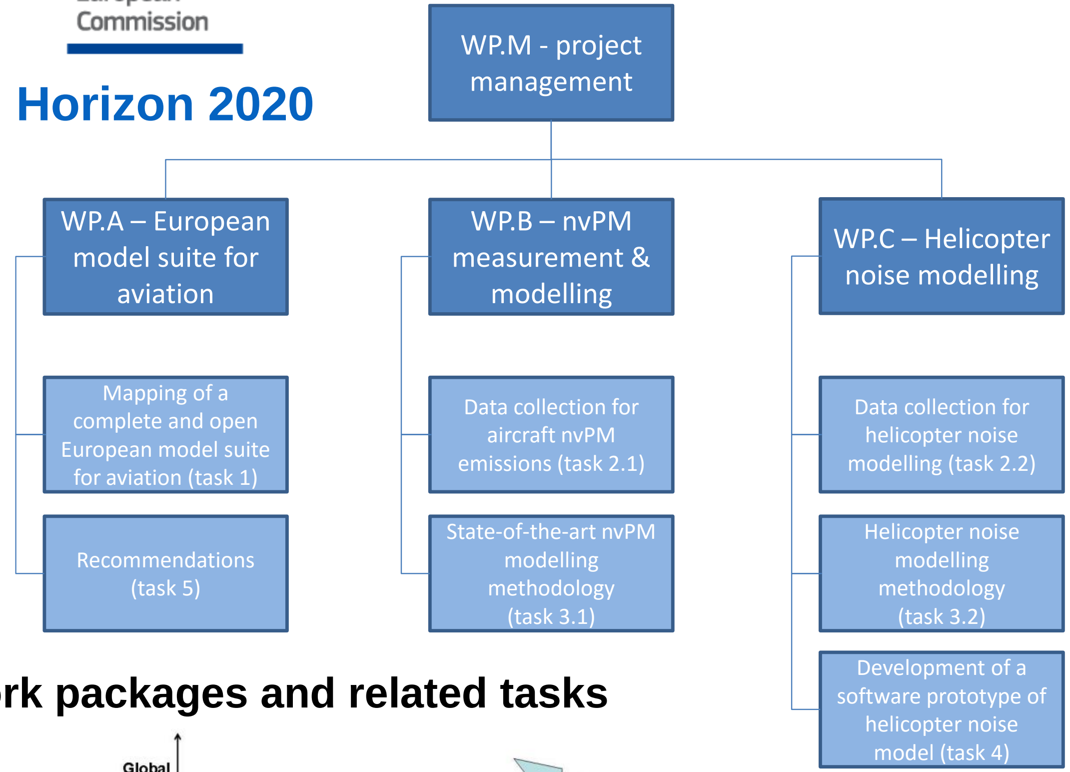




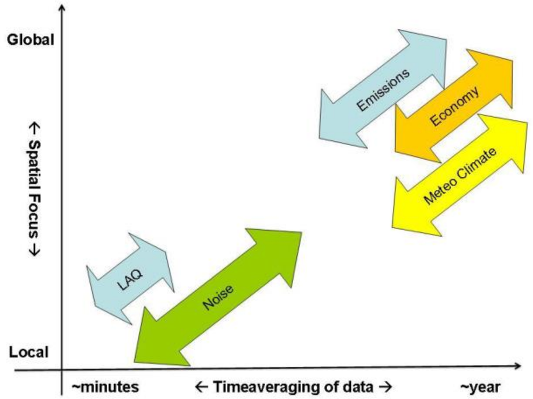


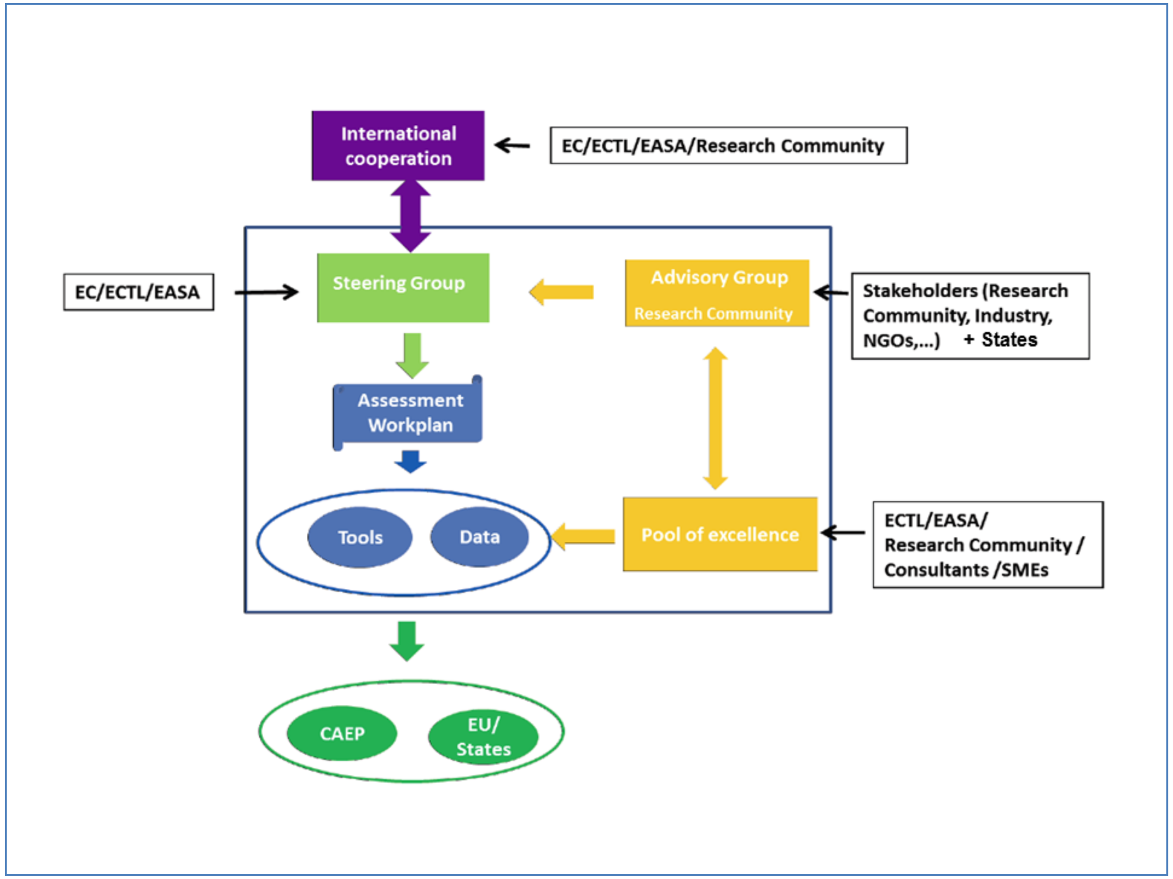
Report on the design of a publicly accessible aviation tool suite: ***Public European Model Suite for Aviation***

Horizon 2020



Work packages and related tasks





Steering Group, an Advisory Group (MITG) and a Pool of Excellence

- **European aviation environmental modelling strategy**

Author (Partner)	Ralf Berghof (DLR)			
Contributors (Partner)	Sven Maertens (DLR), Mark Jackson (CERC), David Carruthers (CERC), Chris Eyers (Limited Skies), Oleksandr Zaporozhets (NAU), Maria Tombrou (NKUA), Elissavet Bossioli (NKUA) and Paul Brok (NLR)			
Responsible Author (Partner leader of deliverable)	**Name**	Ralf Berghof	**E-mail**	Ralf.Berghof@dlr.de
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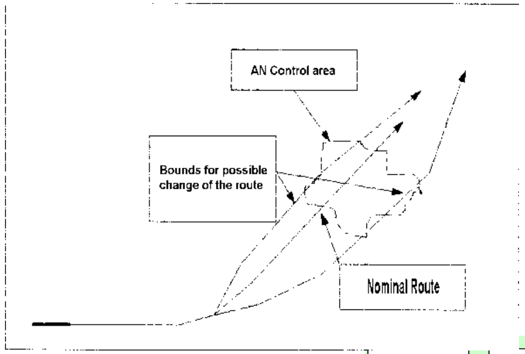
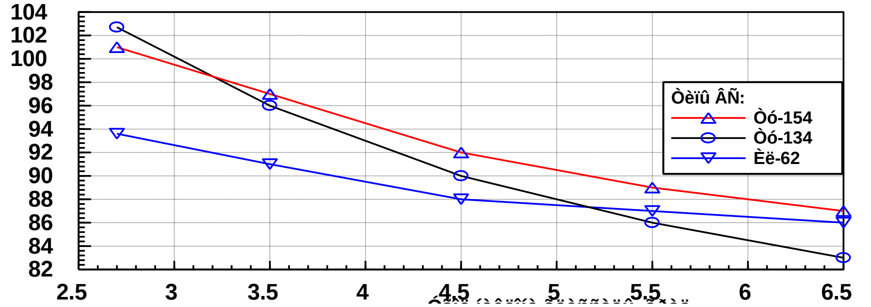
NOISE ABATEMENT OPERATIONAL PROCEDURES

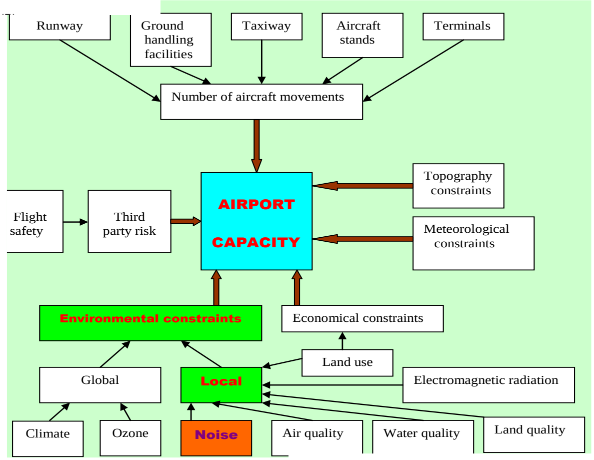
- ***Spatial management***
- preferential runway;
- noise abatement flight track or change of flight procedures of takeoff and landing;
- ***Ground management***
- ground run-up restriction of the engines;
- partial curfew (ban);
- displaced landing and take-off points;
- aircraft towing;
- reverse thrust restriction;
- ***Noise abatement flight procedures***
- noise abatement profiles;
- engine, flaps deployment and flight speed control;
- descent of aircraft in configuration of low drag...

Decomposition of the problem





1) Preferential runways and flight tracks (e.g. Noise Preferential Routes (NPR)) that require extra flying and taxi times;

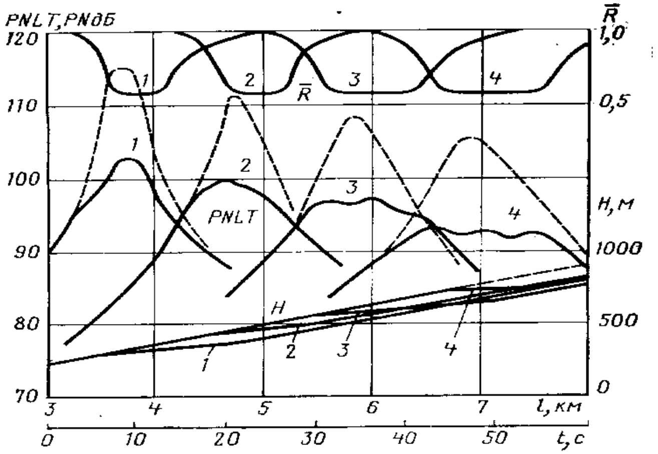


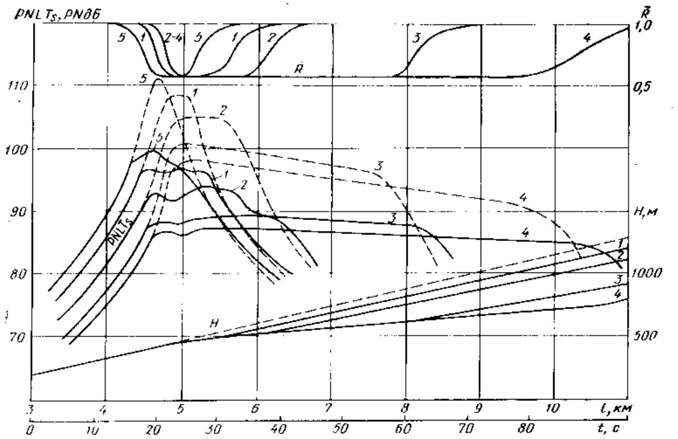
2) Flight route optimization in the airport vicinity;

3) Low-noise and low-emission take-off and approach flight procedures;

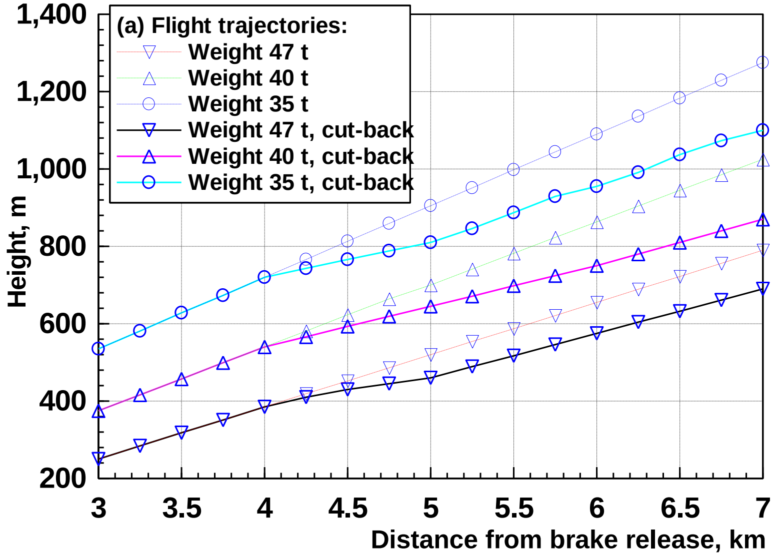
4) Optimal distribution of the aircraft among the routes;

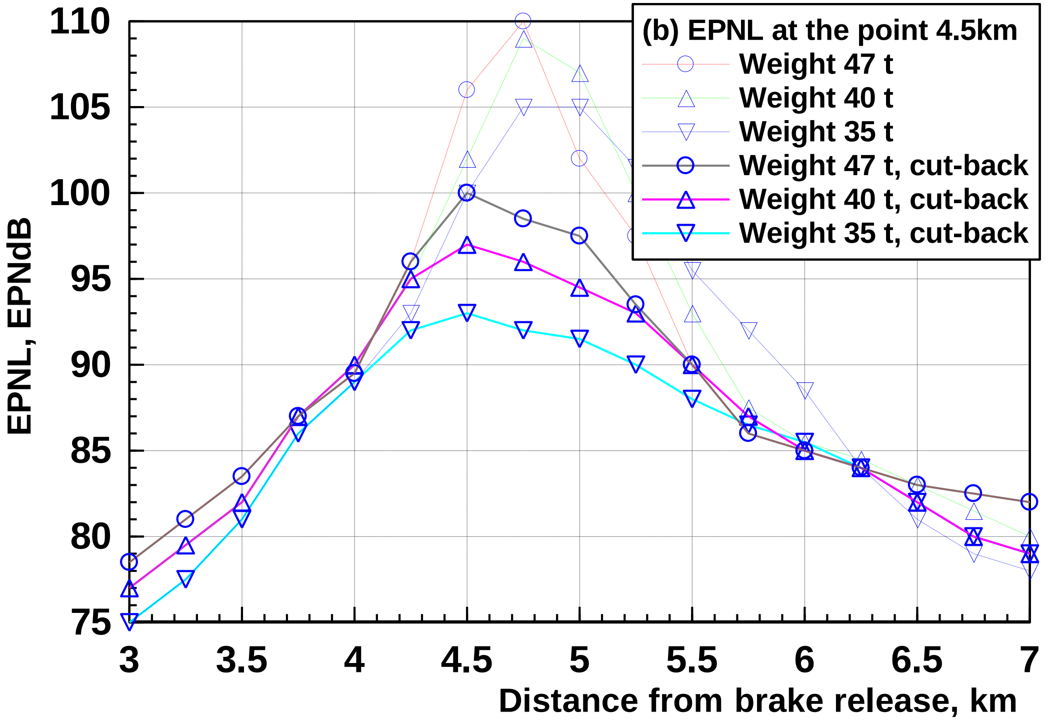
5) Optimal flight scenario



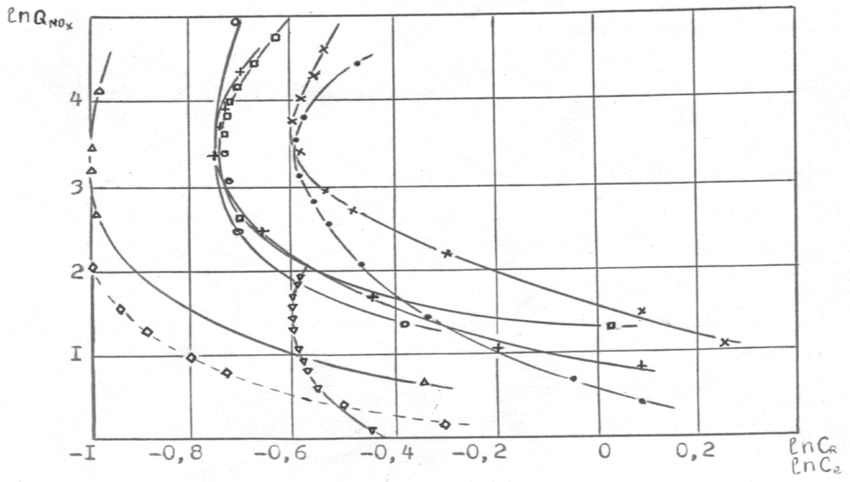


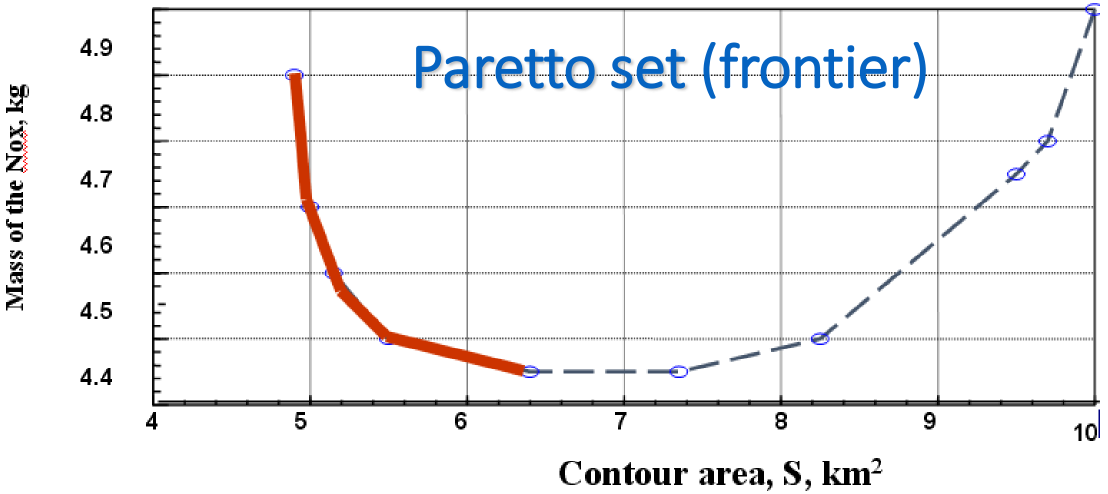
Low-noise flight procedures



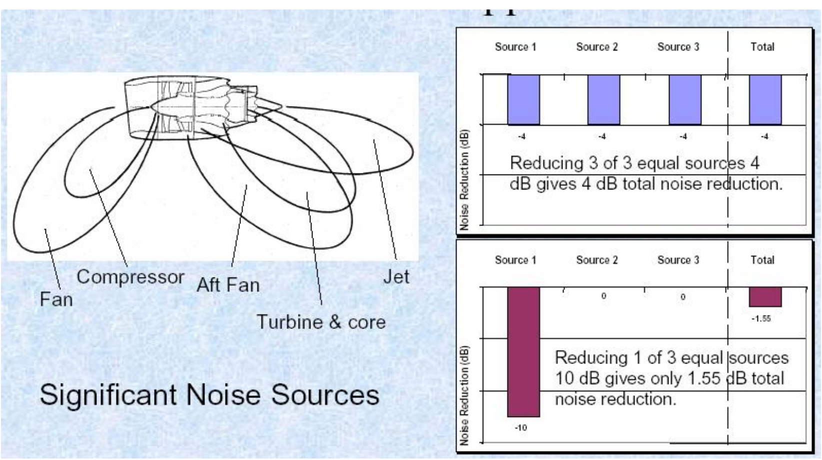


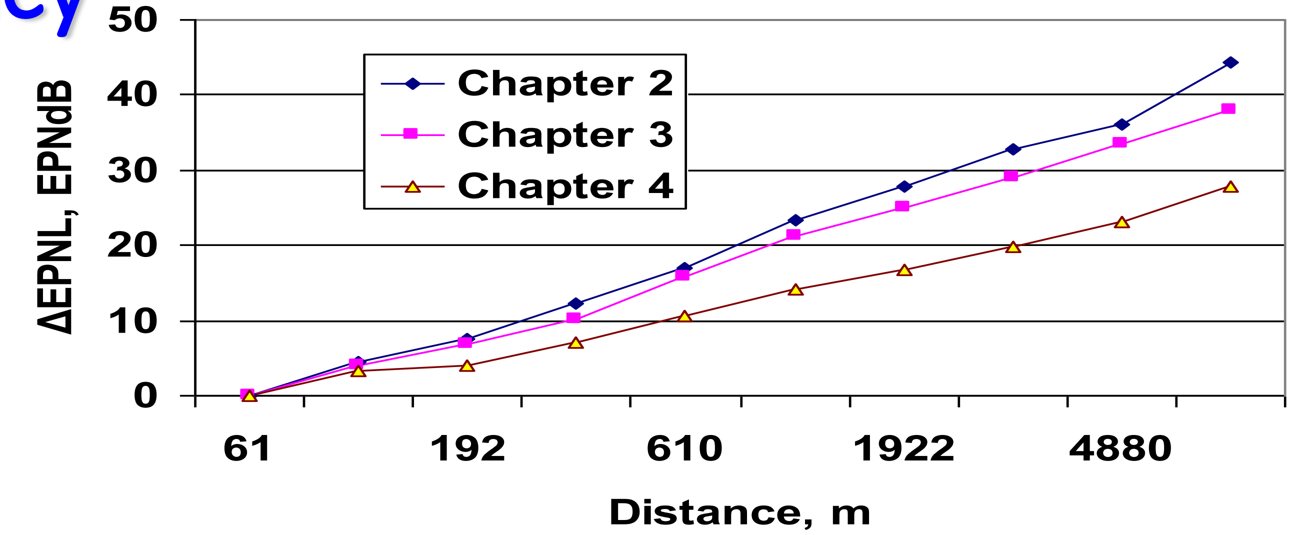
Low-emission flight procedures

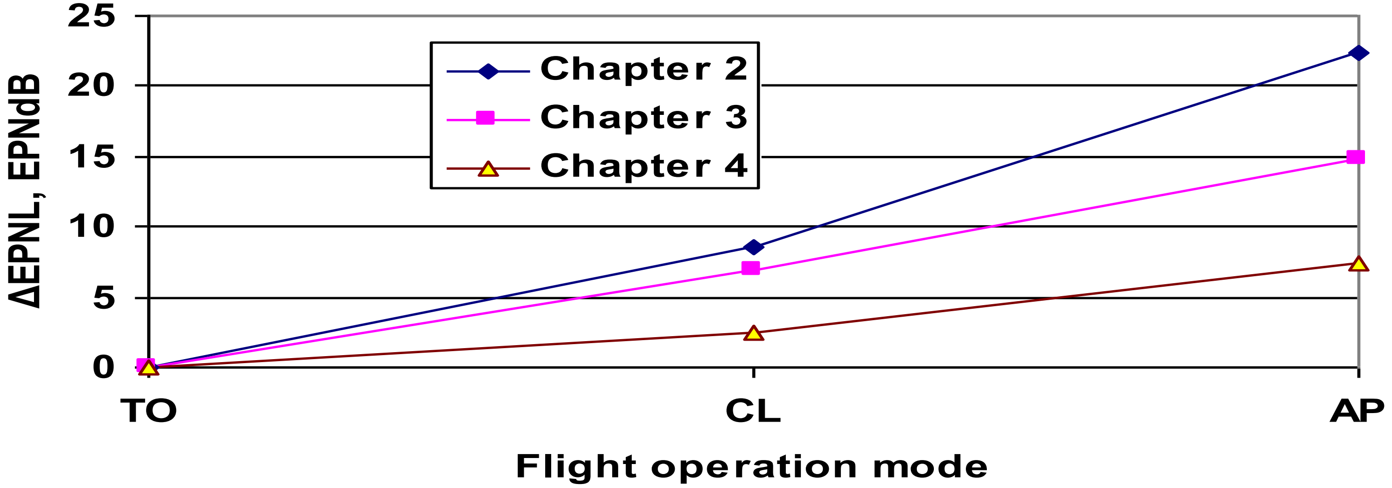




Annex 16 Chapter dependence of the NAOP performances and efficiency

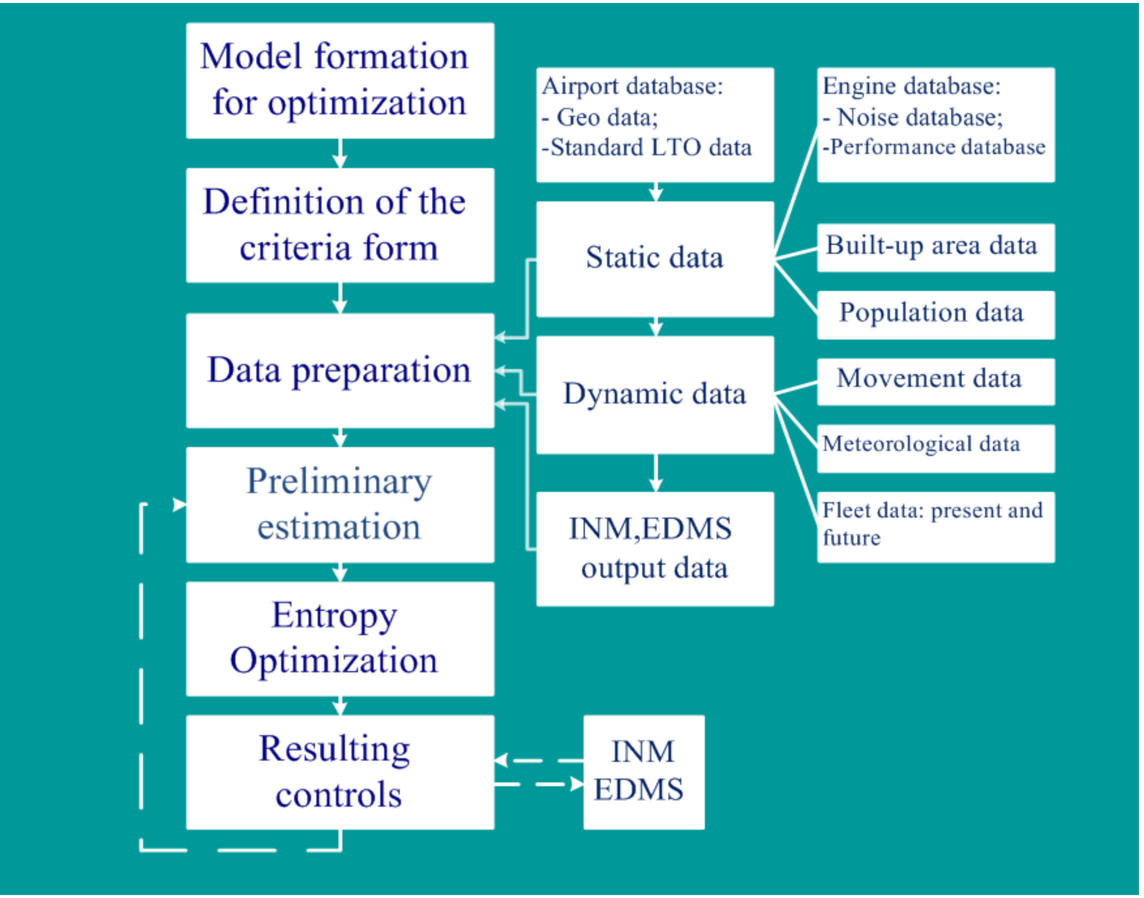


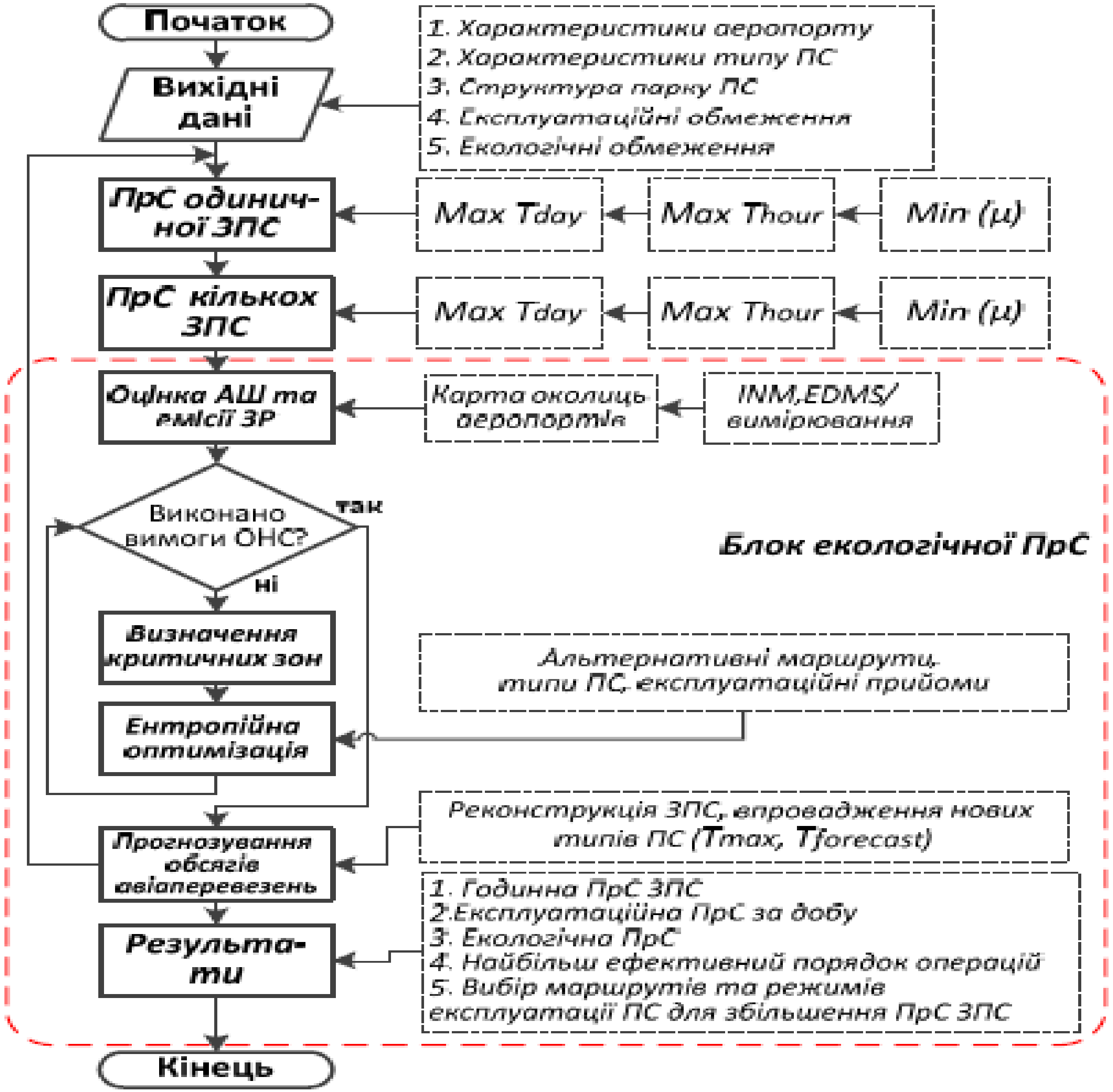




- More stringent noise standard => less noise/mode gradient => less efficient NAP

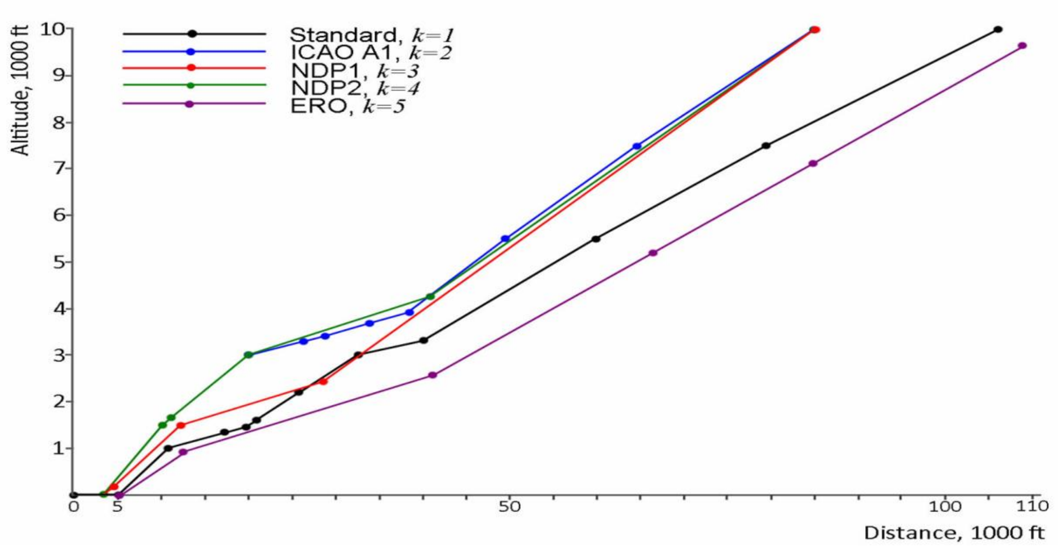
Algorithm of the Entropy Model

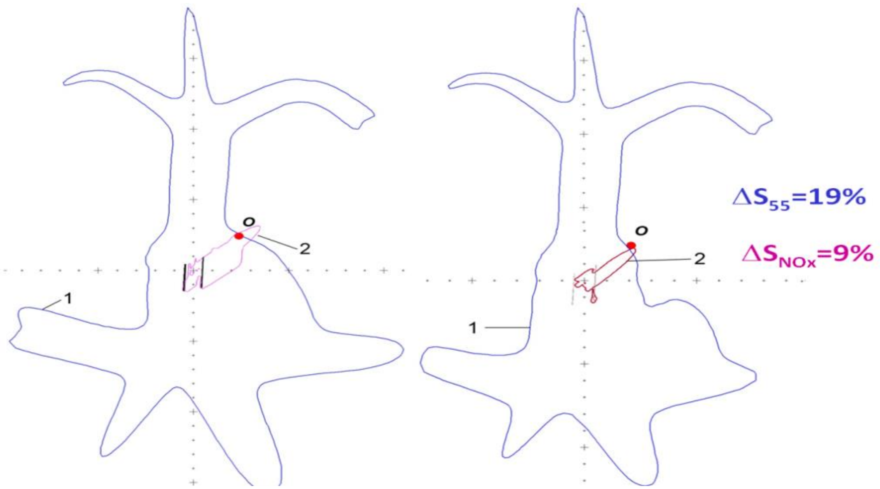


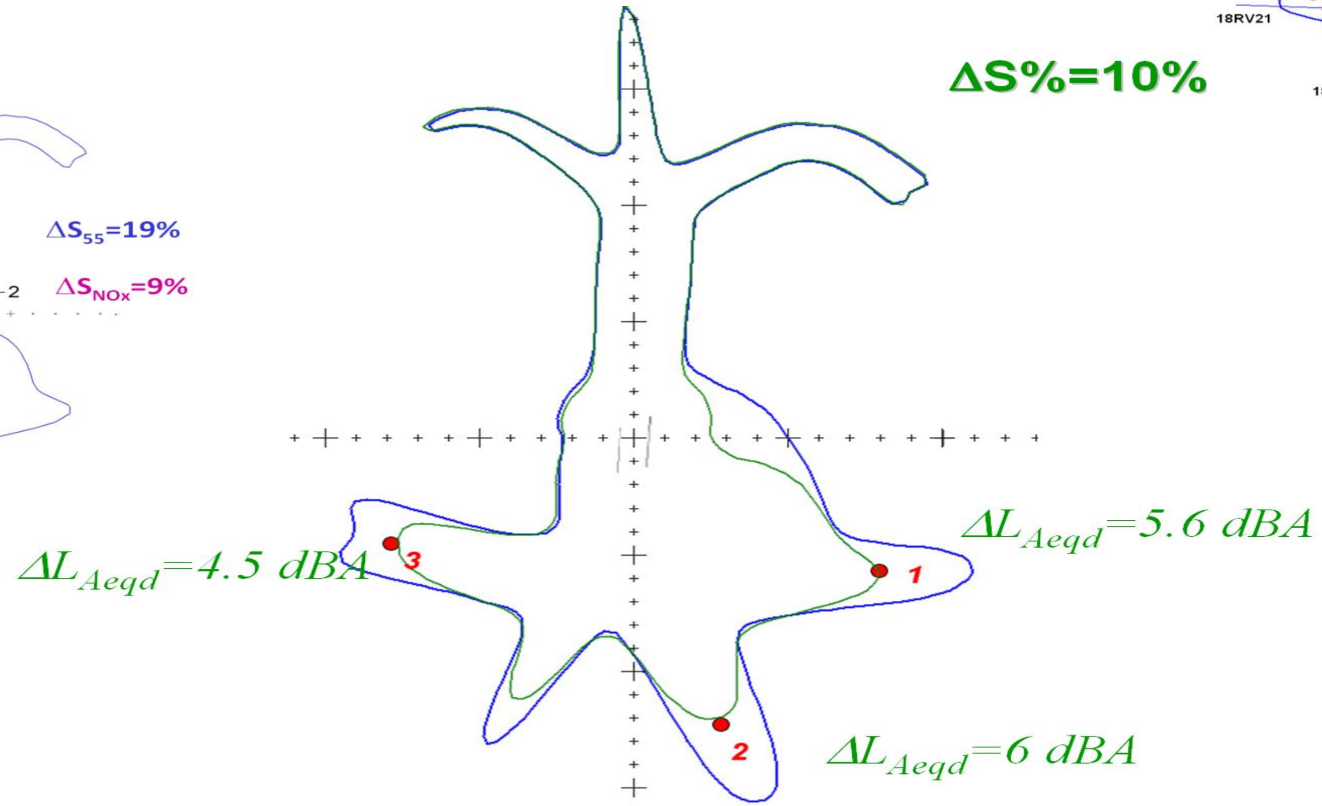


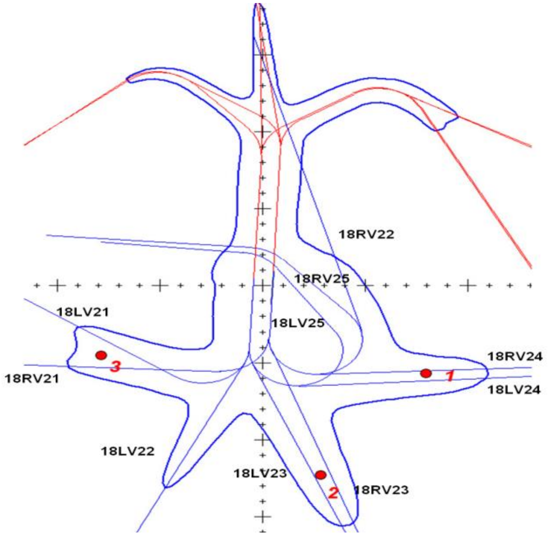
- From: CdSc Thesis Kateryna Kazhan

Solutions for Kyiv Borispol airport

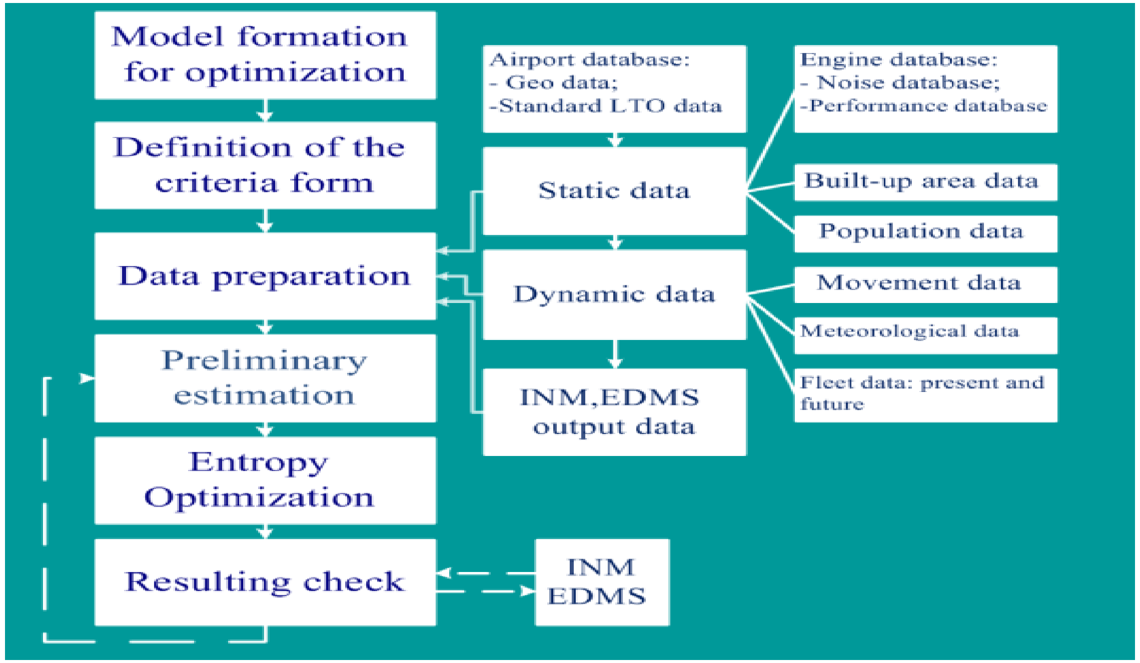








Principal scheme of the algorithm of the Entropy Model

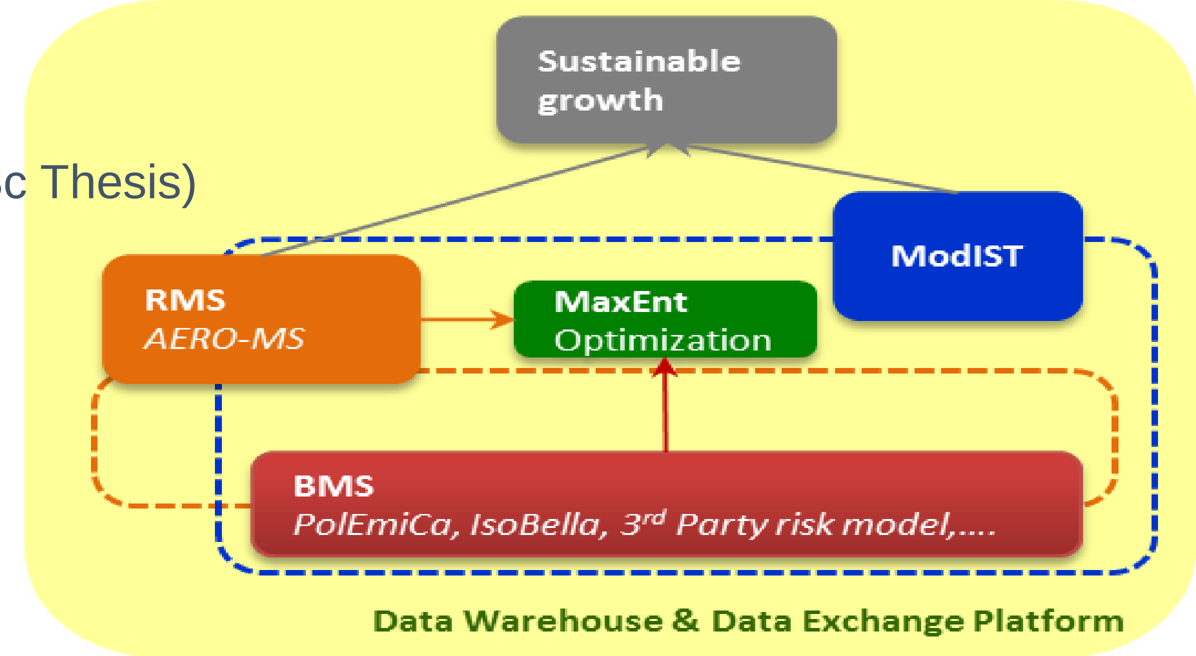


(from Kateryna Kazhan CdSc Thesis)

ModIST allows:

- to assess ability of effective using operational procedures,
- to determine optimal correlation among NAPs, air quality operations and environmental standards,
- to forecast schedule and aircraft fleet for installed capacity,
- and to rank environmental problems in the airport vicinity.

- **ALFA Platform**:
- **IsoBella**: for Aircraft Noise
- **PolEmiCa**: for Airport Emission & Pollution
- **3PRisk**: Third Party Risk around Airports
- **EMISource**: EM Radiation around Airports
- **MaxEnt**: Optimization Tool
- **ModIST**: Modellling Interactions and Synergies Tool

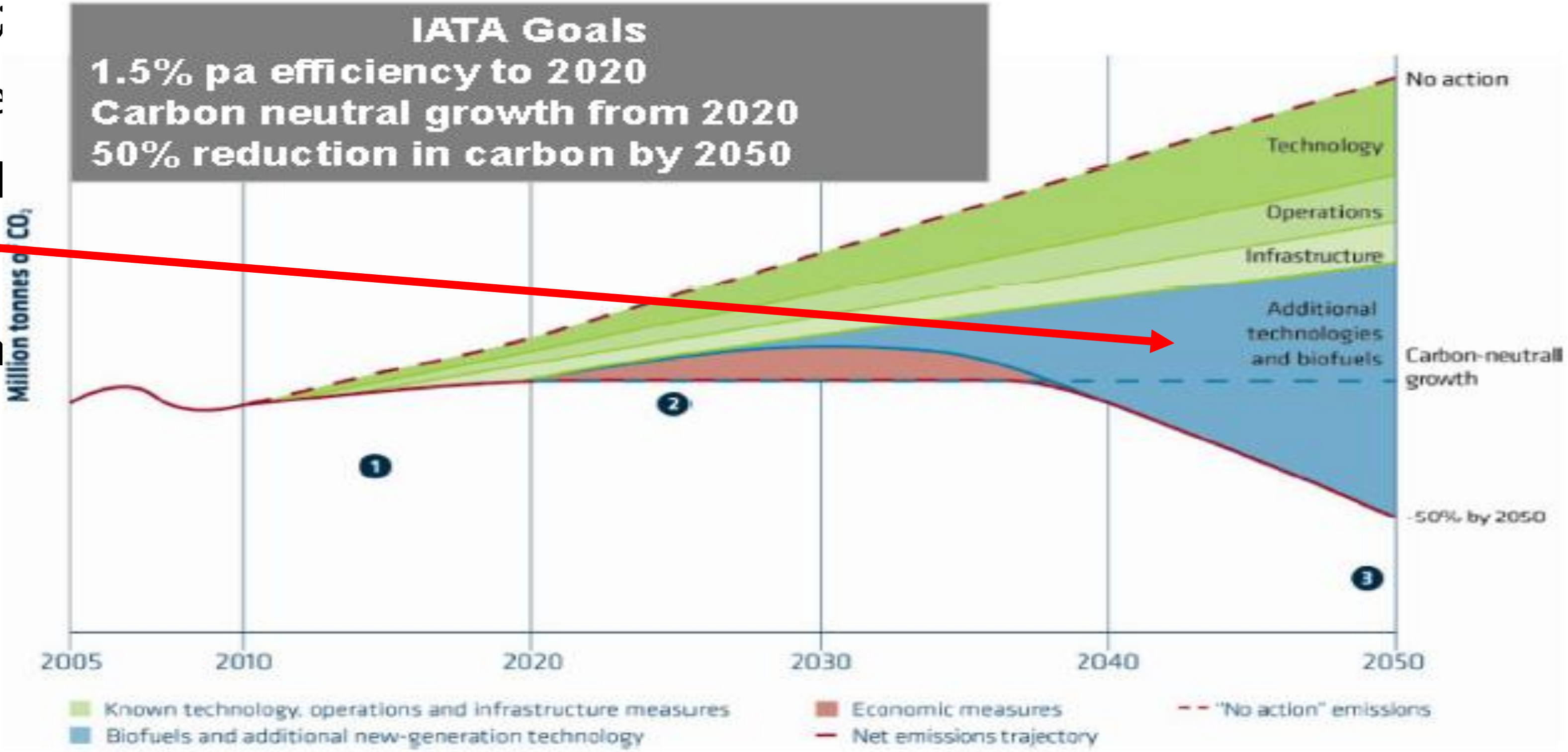


Sustainable Biofuels for Aviation

The purpose of the Center is to conduct scientific-researches and personnel training in sphere of chemmotology, certification, standardization and quality management, testing, permitting to production and use of fuels and lubricants, energy efficient innovations, in particular in aviation sector.

We study and test various fuels and lubricants:

- diesel fuels, gasoline;
- aviation gasoline, jet fuels;
- bioethanol, biodiese
- bio-jet; crude oil
- plant oils; greases;
- motor oils, bitumen
- technical liquids and additives;



Ukrainian Research & Educational Center of Chemmotology and Certification of Fuels, Lubricants and Technical Liquids

Sustainable Biofuels for Aviation

Our Center was first, who started activities in development/implementation of sustainable jet fuels in Ukraine.

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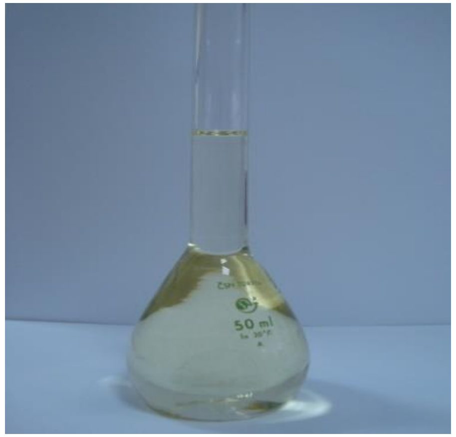

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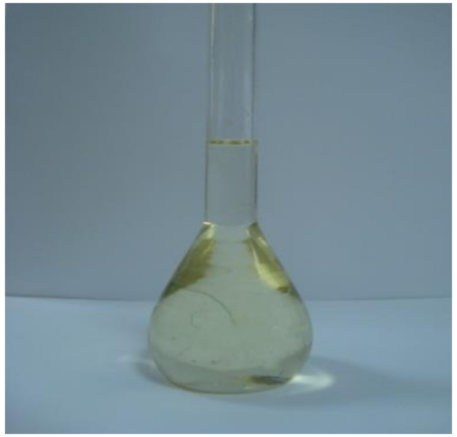
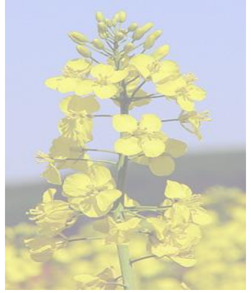
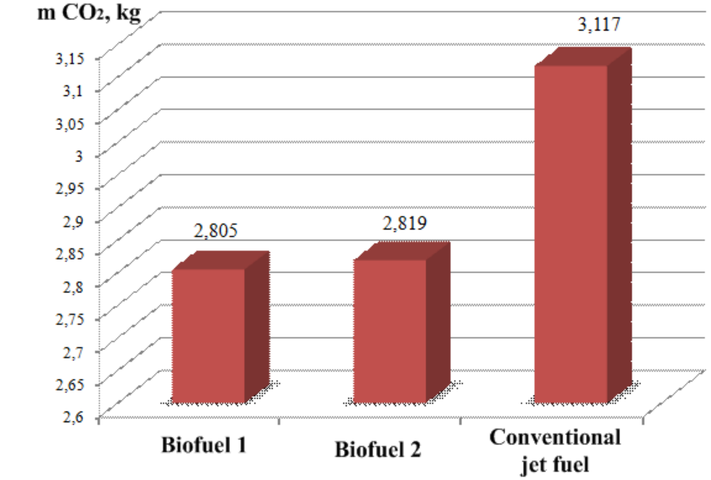


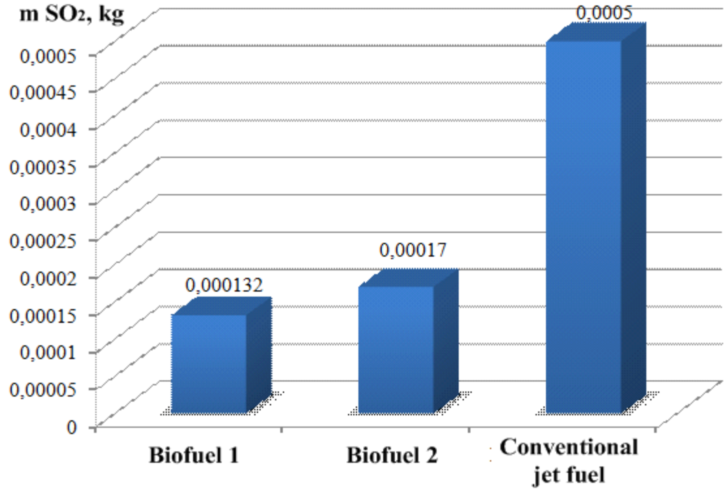
We develop **blended jet fuels** that contain **traditional oil-derived fuel** for jet engines and biofuel derived from plants (**rape and camellina**) oil.

Our Concept was used in Action Plan of Ukraine for reducing CO_2 emission in aviation sector (presented to ICAO by State Aviation Administration of Ukraine in 2012).





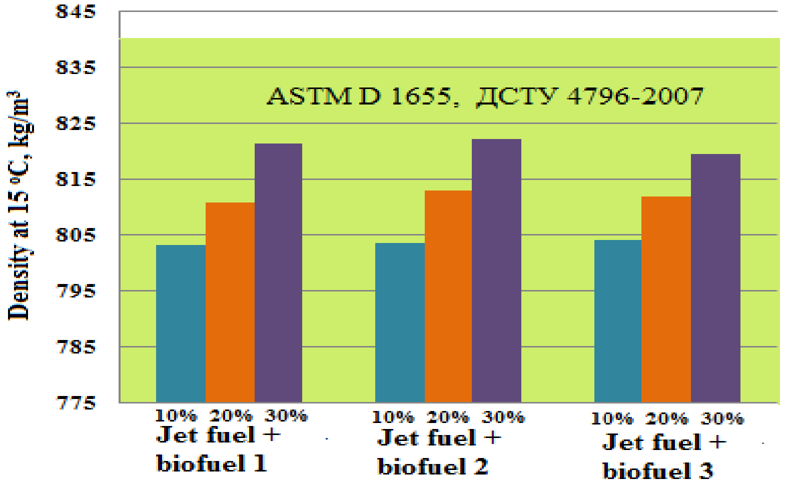
Conventional/Biofuels for Sustainable Aviation

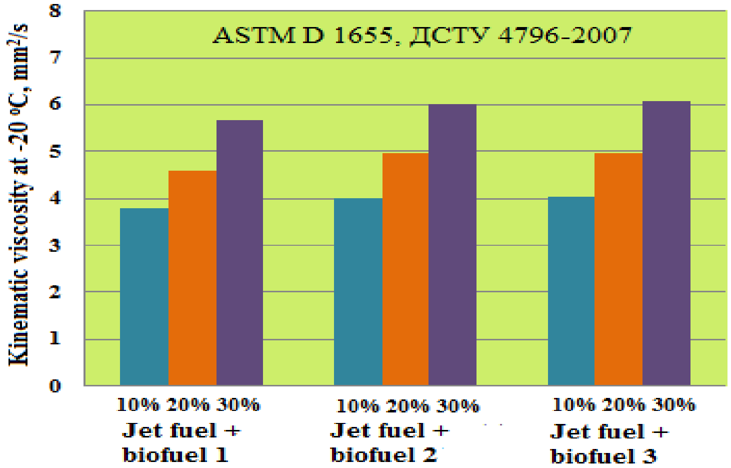


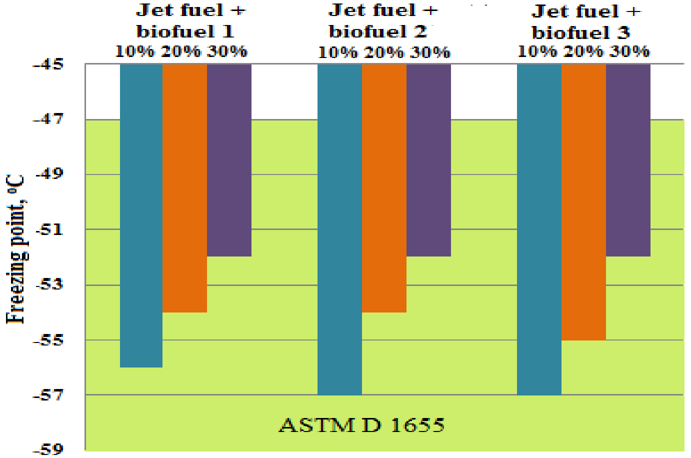
Bio-components differ from conventional jet fuels, however it is possible to blend up to 30% of bio-components in mixture with conventional jet fuel.

Quality parameters of conventional and synthetic jet fuels are determined with:

- 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.



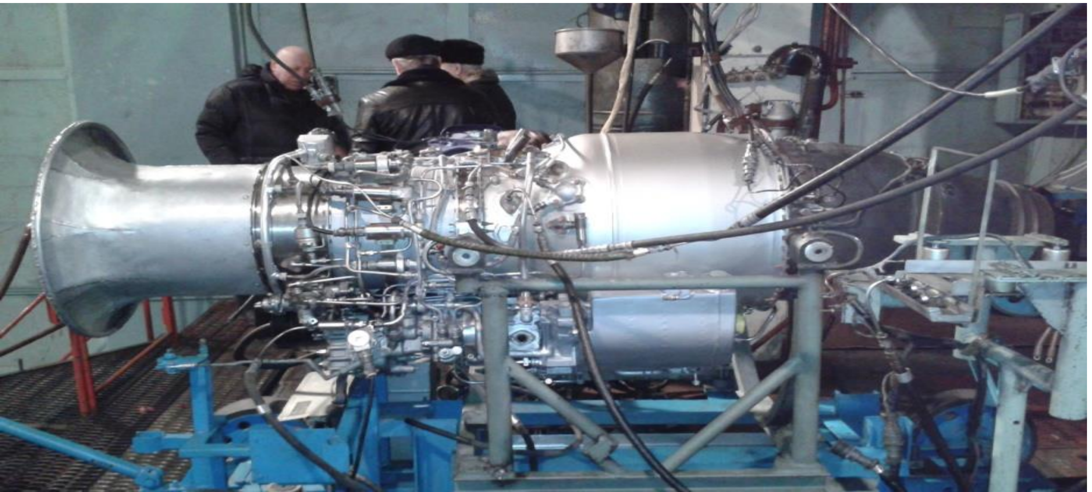




Aviation Biofuels: The future studies and proposals for cooperation

The next steps in our studies are:

- Production of trial batchs of new alternatives biofuels;
- Carrying out trial tests on aircraft jet engines powered by new alternative fuels;
- Test measurements and calculations of the emissions main exhaust gases from jet engines powered by new alternative jet fuels;
- Development of biocomponents from new kinds of plant oils like Camellina Sativa and others.



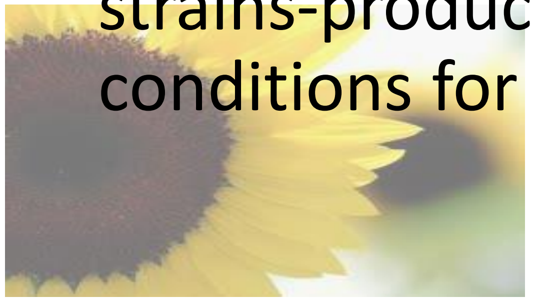
National Aviation University

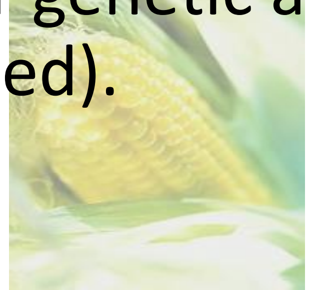
UkrREC of Chemmotology and Certification of Fuels, Lubricants and Technical Liquids

Biomass as a biofuel resources (“Biofuel”)

Target complex research program of the NAS of Ukraine **2010-2012**

- Subprogram "Sources of biofuels and biological means to enhance the raw materials for biofuels" formed the largest in Ukraine collection of power plants, which counts:
- 352 taxa (71 – sugarcontent, 139 - oil, 142 - commodity crops for the production of solid/liquid biofuels and biogas),
- a collection of strains with increased resistance to ethanol and acetaldehyde,
- and a collection of strains of algae (16 species, 32 of promising strains-producers lipids held their molecular genetic analysis, the conditions for effective cultivation are defined).

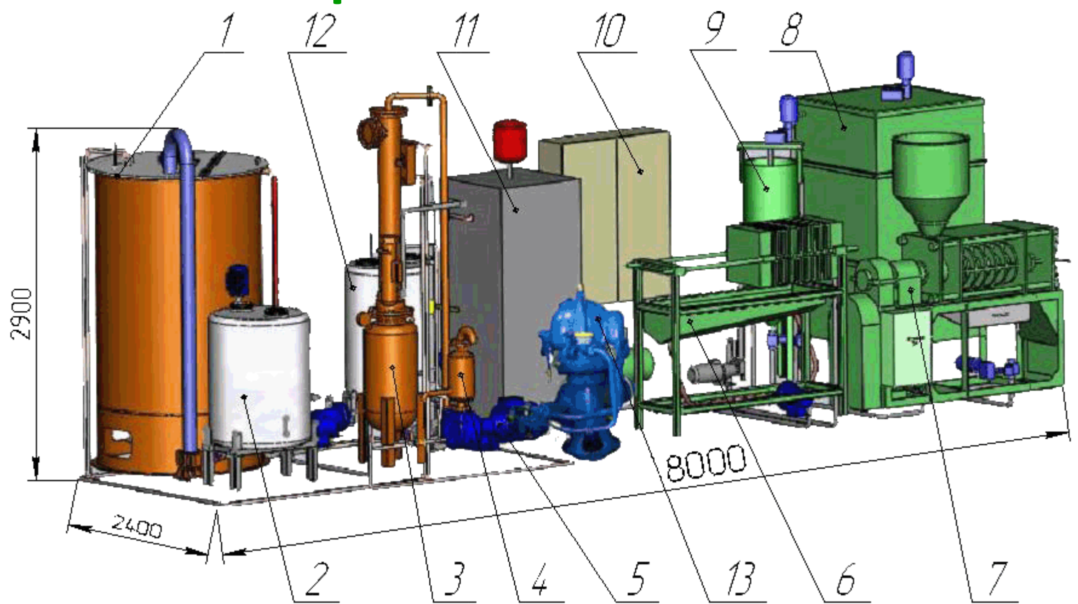



Biological resources and the latest technologies of the bio-energy-conversion **("Biofuel 2")**
Target complex program of research NAS Ukraine, 2013-2017

- increasing the efficiency of different types of biofuels by expanding the resource base with new (alternative) cultures and the improvement of crops that are used, by methods of breeding, genomics and molecular biotechnology

- inside "Technological and ecological basis of production and use of biofuels" effective technological scheme will be developed for **biodiesel production** with capacity from 8 to 128 ths. tons of fuel per year



National Academy of Science of Ukraine

Green Lubricants and Lubricant Additives

We have designed a number of technologies for chemical processing of non-edible vegetable oils, by-products from their production, and waste technical tallow. On the basis of elaborated techniques, we created:

- Multifunctional additives
- Thickeners
- Lubricating oils
- Plastic lubricants
- Machining fluids

All developed products are non-toxic, have high biodegradation degree and, at the same time, show excellent operating properties. According to the all parameters, described materials deserve the ‘Blue Angel’ grade.

Concluding remarks

- Previously the NAU (KIECA) was a leading scientific and educational centre in Civil Aviation sector of the USSR
- IES still in cooperation with leading scientific centers in Civil Aviation sector of the RF
- Today NAU/IES is widely participating in EU and bilateral programs
- Beginning from 2010 NAU/IES is involved in CAEP working groups
- Our vision: NAU/IES is ready for cooperation with US/FAA and to participate in US/FAA programs

ACKNOWLEDGEMENTS

- **FAA Office of Environment and Energy**

for inviting a team of Environmental Safety Institute of the NAU

to participate in ASCENT Advisory Committee Meeting

Cardiovascular Disease and Airport Noise Exposure

Project 03

Project manager: N. Sizov, FAA
Lead investigator: J. Peters, Boston University School of Public Health

April 26-27, 2016
Washington, DC

ASCENT
AVIATION SUSTAINABILITY CENTER

Linkage to AEE Roadmap

- Health Impacts of Aviation Noise
  – To investigate the risks of cardiovascular outcomes associated with noise-related exposures

Goal of the Project

- Aims to evaluate the relationship between aircraft noise exposure and cardiovascular health by linking with an existing national longitudinal health cohort (Women’s Health Initiative) for which detailed individual data and high geographical resolution are available.

Schedule and Status

- Fall 2014: Determine airports and time points for estimating noise exposure
  - Applications and forms for linking to WHI data completed
  - Noise data availability for airports and time points determined
- March 2015: Obtain noise estimates for 2000-2014 for 94 airports
  - Contract in place with Volpe and Wyle
  - Data Use Agreements with WHI and FAA in place
  - New projected date: April 2016
- May 2015: Develop methods to estimate pre-2000 noise exposure for WHI; Explore link with an additional cohort
  - Method development and discussion with the Nurses Health Study and Health Professional Follow-up Study in progress.
- August 2015: Link noise exposure with cohort data
  - New projected date: August 2016

Approach and Accomplishments

- Completed procedural steps related to accessing WHI data for linkage with noise data
  - Obtained approval from Boston University and University of North Carolina Human Subjects Review Boards
  - Entered into Data Use Agreement with WHI
- Coordinated with FAA regarding noise data
  - Determined data format for linking with geocoded residential addresses
  - Determined potentially available data for 2000-2015
  - Entered into a Data Use Agreement
  - Obtained and linked test noise data to determine potential issues with data linking in WHI

Approach and Accomplishments (cont)

- Worked with colleagues at Volpe and Wyle to determine optimal noise metrics from AEDT that could connect with WHI participant information
  - DNL
  - Leq
  - Time above threshold
  - Leq – Lamb
  - Possibly in future: SEL, LAmax

Approach and Accomplishments (cont)

- Obtained NIH funding (R01) to complete the multi-year study in WHI, including aircraft noise, traffic noise, and air pollution
  - ASCENT support for Project 3 provided pilot data and infrastructure necessary to successfully land large award
- New direction for Project 3 intended to provide insight about health effects of noise not available from WHI cohort
  - Evaluate the relationship among aircraft noise exposure, noise perception and stress response in the Nurses' Health Study (NHS) and the Health Professional Follow-up Study (HPFS)
  - Investigate whether there are gender differences in the relationship between noise and health in the NHS &HPFS

Summary

- Summary statement
  - We are obtaining noise data and will be assigning longitudinal aircraft noise exposures within the large cohort of WHI (N>160,000) with 1) participant-level exposures, 2) systematically ascertained, physician-reviewed outcomes, and 3) individual-level risk factors.
  - We are developing a collaboration to also conduct a noise-health study with the NHS/HPFS (another well-established cohort with individual data).

- Next steps
  - With NIH funding, we will evaluate the health effects of aircraft noise exposure in WHI.

- Key challenges/barriers
  - Historical modelling - spatially and temporally interpolating noise exposure particularly prior to 2000.
  - Procedures/applications involved in working with NHS & HPFS.

Publications

- N/A

Contributors

- BUSPH: Junenette Peters, Jonathan Levy
- UNC: Eric Whitsel (WHI Sponsor)
- Brown: Gregory Wellenius

References

- Babisch W, Kim R. Environmental Noise and Cardiovascular Disease. In: WHO European Centre for Environmental Health, ed. *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe*. Copenhagen: World Health Organization; 2011:15-44.
- Correia AW, Peters JL, Levy JI, Melly S, Dominici F. Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: multi-airport retrospective study. *BMJ.* 2013;347:f5561.
- Hansell AL, Blangiardo M, Fortunato L, et al. Aircraft noise and cardiovascular disease near Heathrow airport in London: small area study. BMJ 2013;347:f5432.
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Collaboration

- Between Noise PIs
  - Pennsylvania State University with NIH funding
- With Advisory Board
  - Wyle
- Other
  - Volpe Transportation Center

Noise Emission and Propagation Modeling

Project 5

Project manager: Hua (Bill) He, FAA
Lead investigators: Vic Sparrow [Penn State] and Kai Ming Li [Purdue]

April 26-27 2016
Alexandria, VA

ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

- There are gaps in current FAA tools to model en-route flights and include altitude-dependent atmospheric conditions
- Need to develop improved models and validate models for the emission of sound from aircraft and propagation from source to receiver
- Help enhance AEDT and its impact on aviation environmental management

Modeling needs

- For en-route, need to predict noise over broad area
  - current aircraft
  - future advanced propulsions, such as open rotor
- Need integrated databases for use by both noise and emissions models for all phases of flight
- Need to include source motion effects

Objectives

- Study effect of source motion and further develop numerical modeling methods
- Process field measurement data (e.g., EU's BANOERAC) and begin validating numerical models
- Continue linking AEDT weather databases for noise

Schedule and Status

- Ongoing for Year 3

  Penn State and Purdue
  - Assess usability and quality of data obtained from DiscoverAQ and Vancouver Airport Authority for future validation activities

  Penn State
  - Assess use of meteorological reanalysis datasets for inclusion in noise prediction tools

  Purdue
  - Develop a simplified model for the effect of ground impedance on enroute aircraft noise

- Summary for Years 1&2

  Penn State
  - Determine best practices for use of atmospheric absorption models
  - Include simplified atmospheric inputs to noise modeling

  Purdue
  - Provide a fast and reliable numerical model for predictions of sound field in a 3-dimensional space.

Outcomes and Practical Applications

- Outcomes
  - Penn State
    - New understanding of links between noise and emissions and relationship to altitude-dependent atmosphere
    - Validation of existing propagation models with experimental databases
    - Reports and codes
  - Purdue:
    - New understanding of source motion, time domain, 3-D prediction, and ground impedance influences
    - Validation of existing propagation models with experimental databases
    - Reports and codes
- Practical applications
  - Improvements to AEDT
  - Better prediction of noise in National Parks
  - Work useful for future use modeling noise from open rotor or other new propulsion systems

Approaches

- Penn State (began September 2014)
  - Evaluate alternative atmospheric profiles in comparison to current FAA/Volpe approaches
  - Assess model links between noise tools and AEDT weather databases
  - Prepare for and identify avenues for propagation model validation using 4-D (x,y,z,t) aircraft trajectory data using databases such as EU's BANOERAC database
- Purdue (began August 2014)
  - Study the combined effect of source motion, source directivity, atmospheric and terrain profiles on the propagation of en-route noise
  - Analyze and examine existing databases, DiscoverAQ for example, for validating the numerical models developed
  - Investigate the effect of terrain profile and microphone placement on noise measurements

Status of databases

- U.S. government acquired data
  - NASA/FAA Discover AQ (Data released in late 2015)
  - 8 complete sets of data conducted in September 2013
- Vancouver, Canada airport data
  - Owned by a non U.S. airport, but easily accessible
  - Extensive measurements of aircraft terminal-area noise with
    - Ground noise data
    - Radar tracking data (NAV Canada)
    - Local weather data
  - Agreements between Penn State, Purdue and Vancouver Airport Authority have been reached in April 2016
- BANOERAC database
  - Owned by EASA, distributed by ANOTEC
  - Negotiations restarted for agreements (May 2016)

Updated Schedule and Status

August 2015: The research team has been working on the project at its 3rd year

Sept. 2015: Continue liaisons with the Vancouver Airport Authority for the release of noise data

Oct. 2015: Fall 2015 ASCENT advisory committee meeting

Dec. 2015: Moving source prediction models have been completed

Jan. 2016: Discover AQ data became available. (Thank you, Volpe!)

Feb. 2016: Underway: Analyze Discover AQ data, both Purdue and Penn State

March 2016: Initial agreements have been reached between Penn State, Purdue, and Vancouver Airport Authority

April 2016: Spring 2016 ASCENT advisory committee meeting

June 2016: Assessment of Vancouver Airport Authority datasets

June 2016: Second technical report is submitted

Validation of Source Motion Modeling (Purdue)

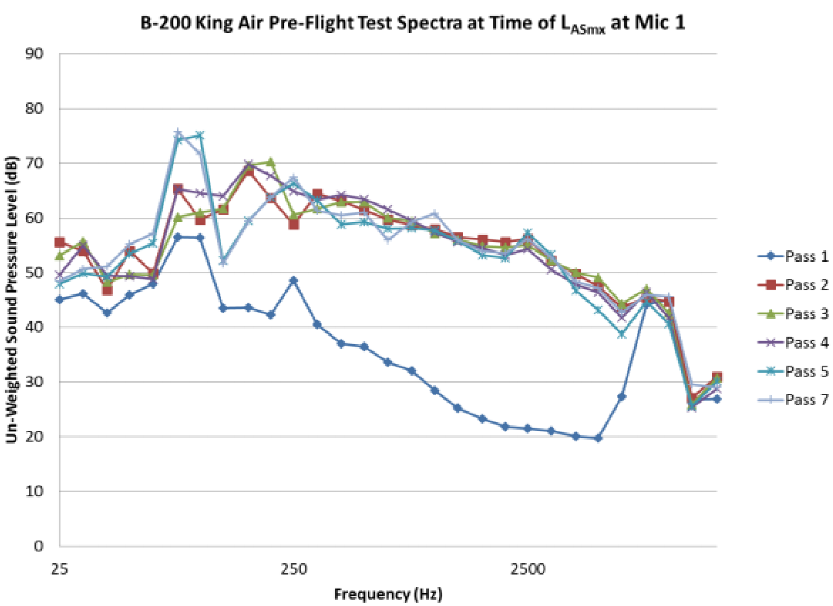
- **Validation of the predicted Doppler effect of en-route aircraft**

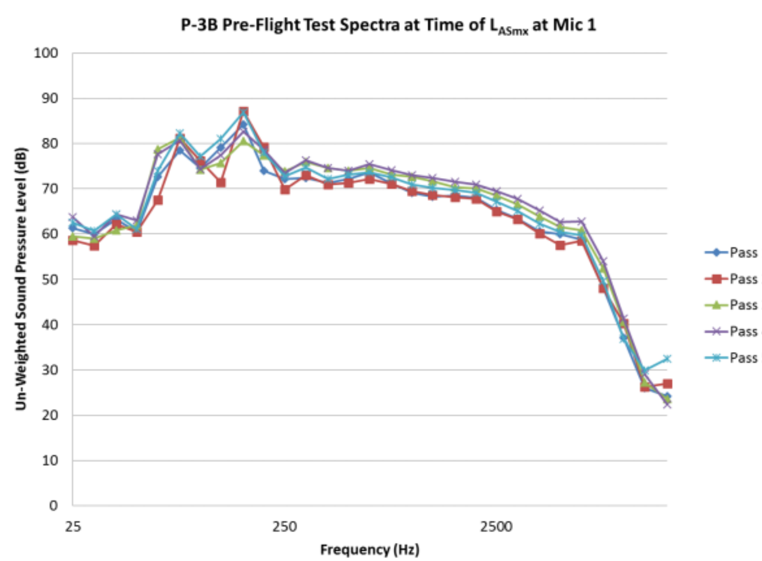
Photos and graphs taken from Discover – AQ Acoustics – Report prepared by VOLPE

Lockheed P-38 Orion

Discover-AQ Acoustics NASA/VOLPE

Beechcraft B-200 Super King Air

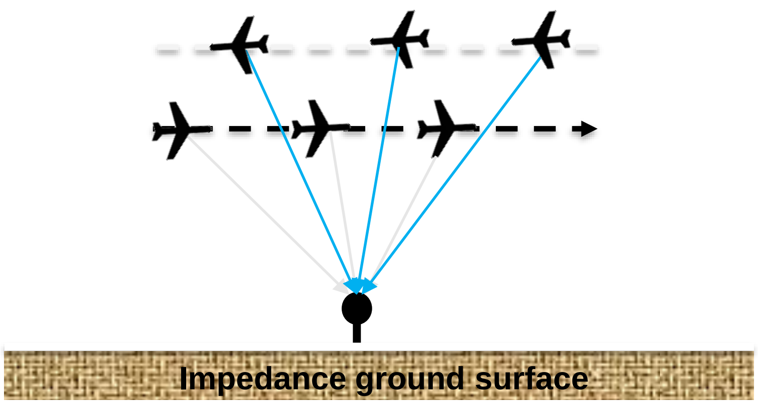




Research Summary (Purdue)

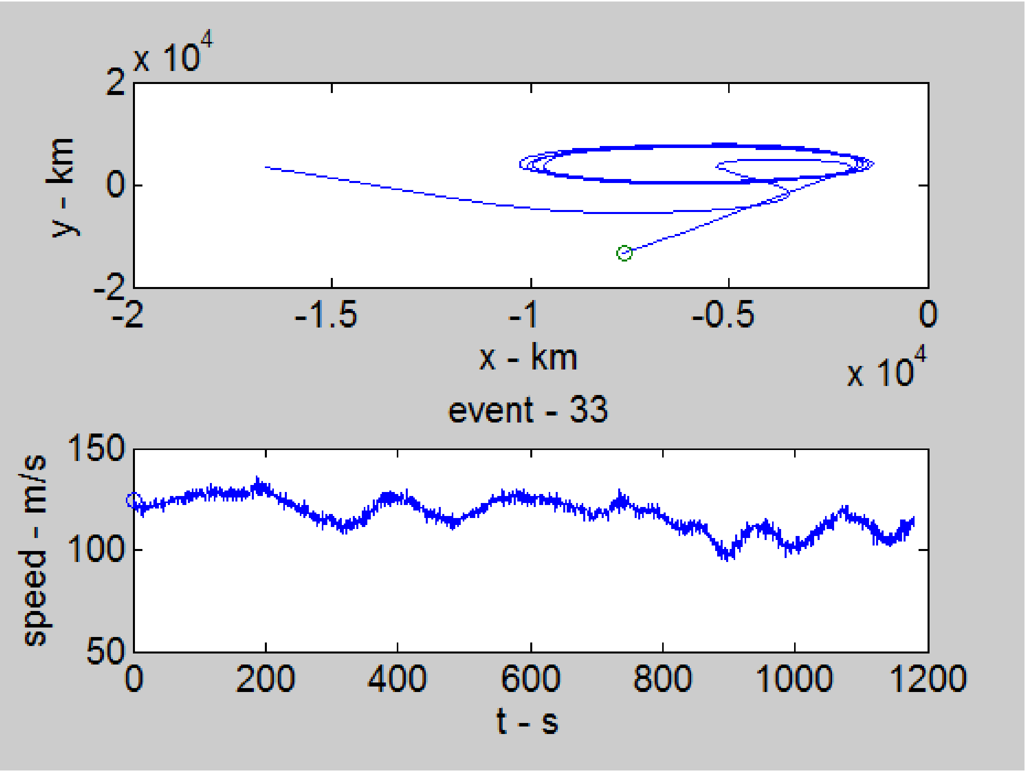
➢ **Prediction method**
  - The vertical speed is assumed to be negligible
  - In-coherent model is used

Arrival time at each sampling point of the aircraft is calculated



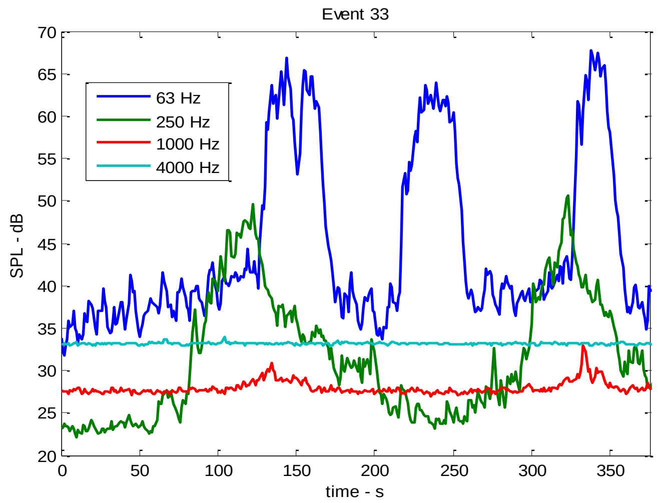
Doppler factor at each aircraft location are calculated from the current aircraft speed

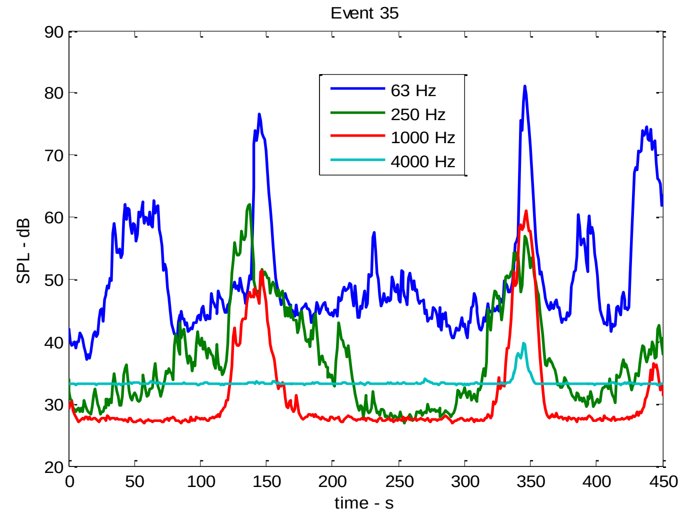
The path and the velocity of the aircraft

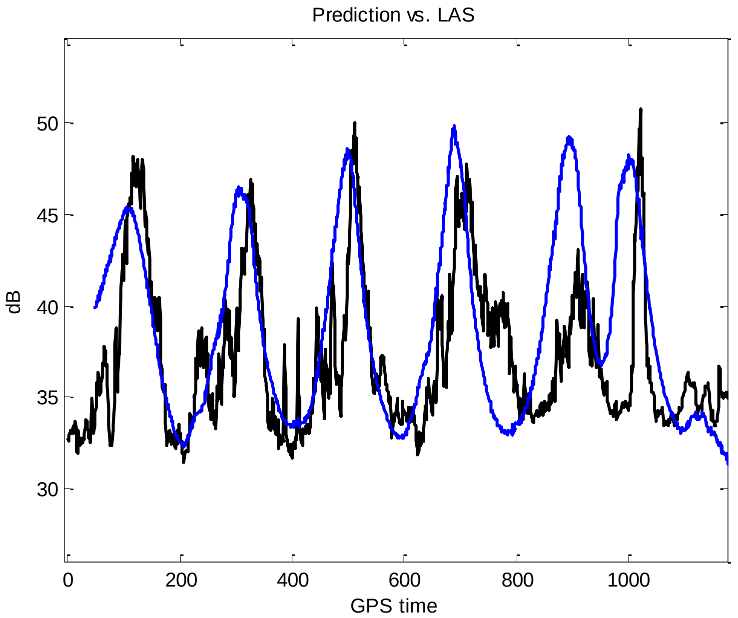


Preliminary Results (Purdue)

(I) Measured Noise Spectra of the pass-by aircraft





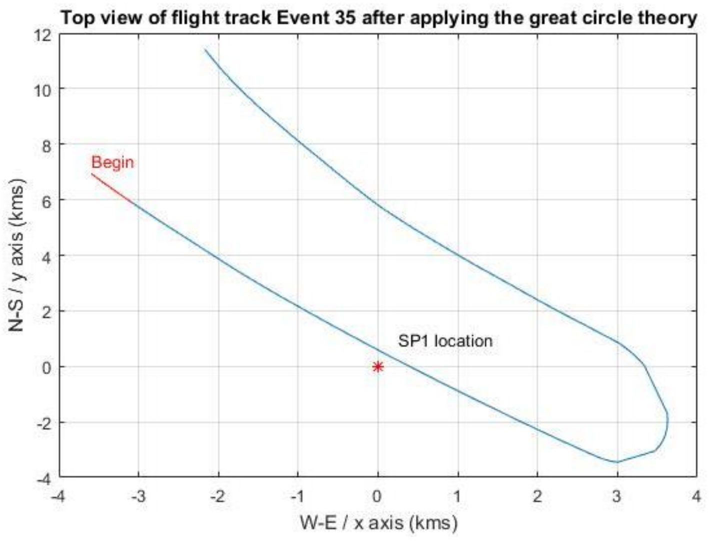


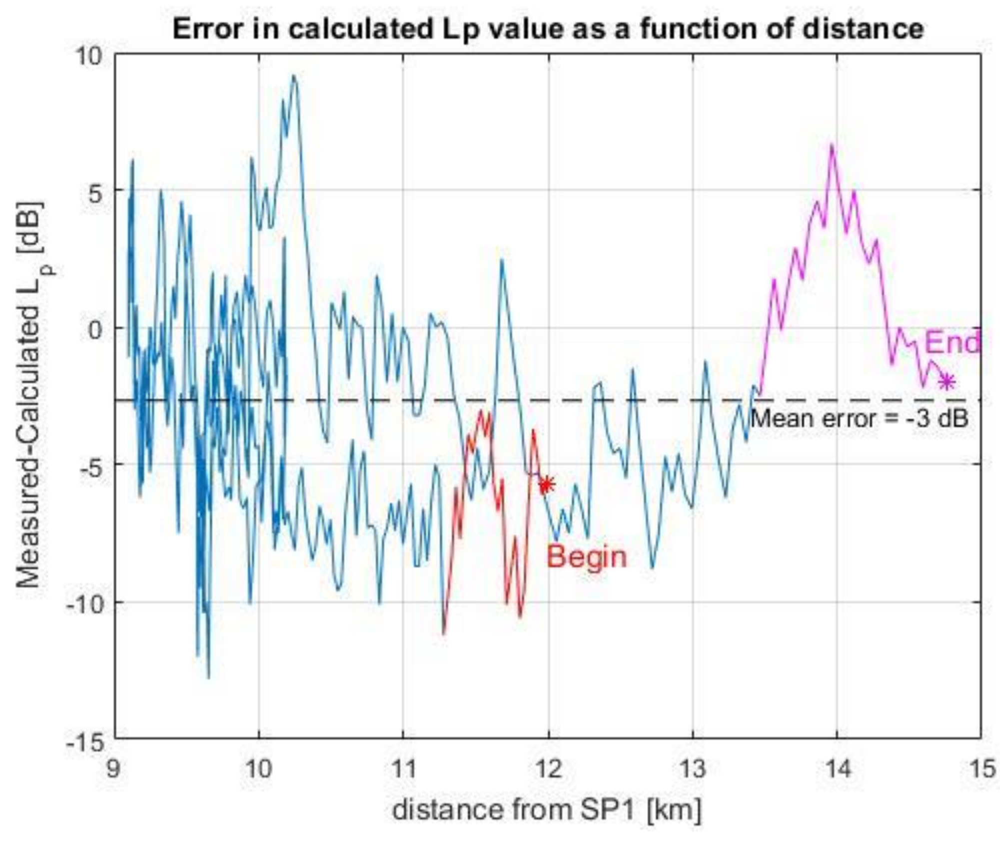
(II) Comparison of overall noise levels

- The peak location has been predicted well
- Currently assume simple atmosphere and omnidirectional source

Analysis Path for Event 35 (Penn State)

Assume spherical spreading → Use the value of L_p at point closest to SP1 → Find L_p at 10 m from aircraft → Find L_p at all points along the flight path

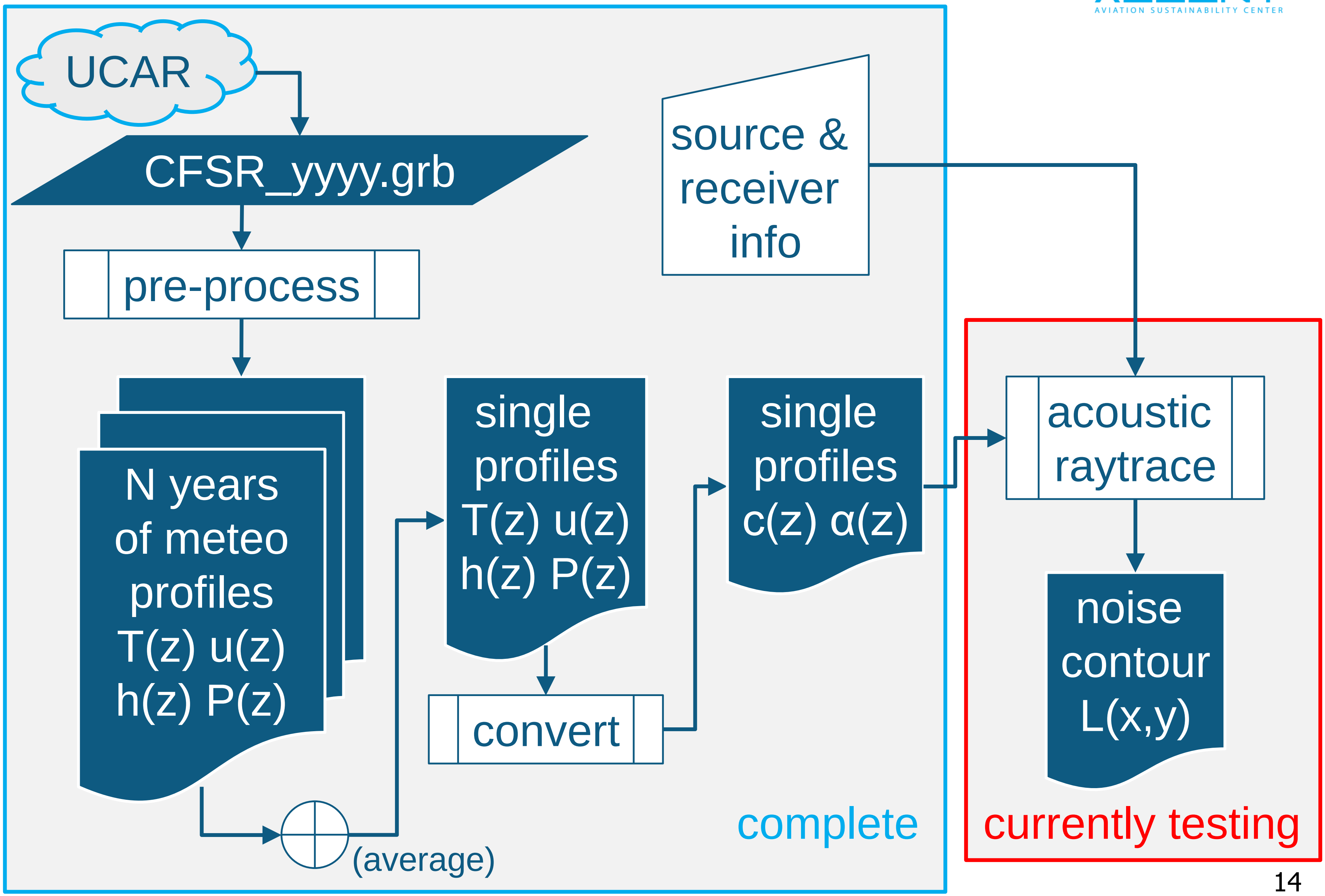




Use of Reanalysis Data for Noise Modeling (Penn State)

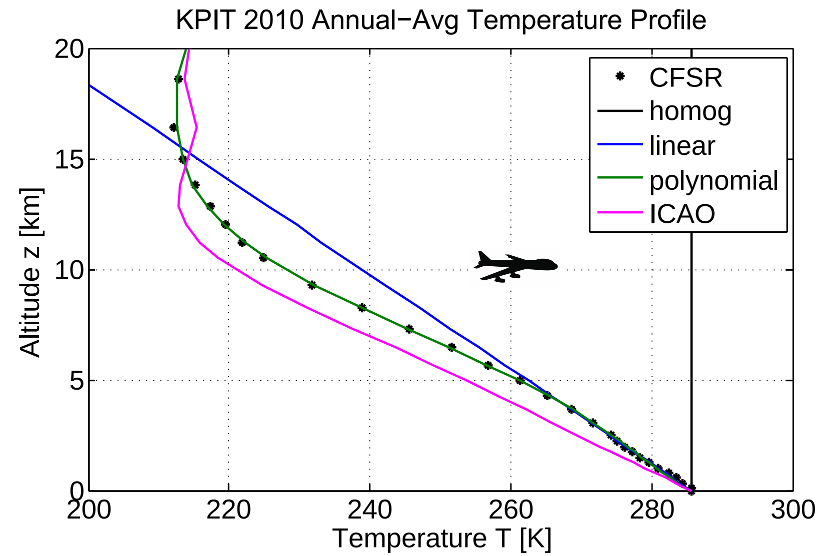
- Current Models: assume homogeneous atmosphere based on surface values
- Aircraft Noise Propagation: mostly far above surface layer
- Next Step: variable atmosphere with height (profiles)
- CFSR Reanalysis: consistent, QCed global sets of profiles
  - Temperature
  - Humidity
  - all vs. altitude
  - 0.5° horizontal resolution
  - vertical resolution depends on altitude
    - ~100 m near surface, ~1 km near cruise alt (10 km ≈ 33,000 ft)
  - Atmospheric Pressure
  - Wind Speed & Direction
  - every 6 hours, 1979 - present
- Now: insert into AERNOM raytracing propagation model
  - aircraft source sound power & spectrum
  - annual-average profiles (T,P,h,u vs. z)

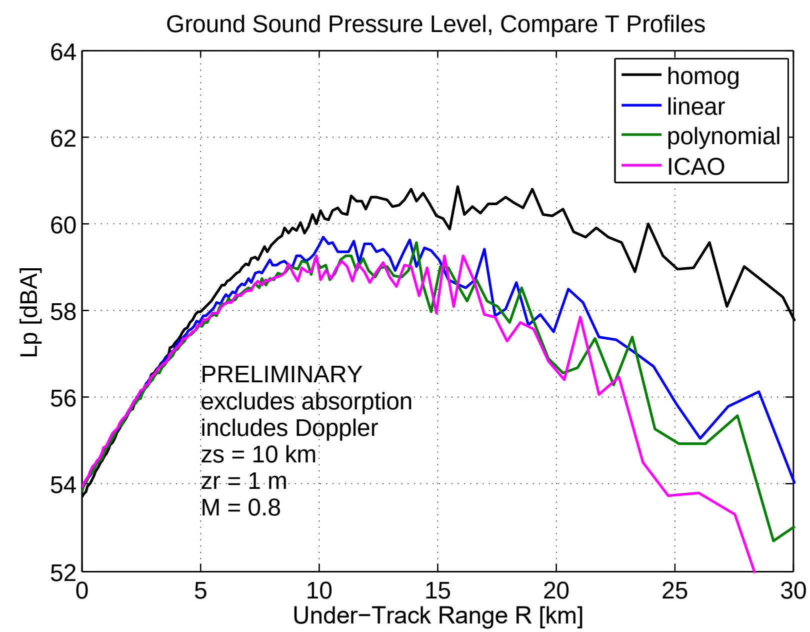
Reanalysis modeling (Penn State)



Reanalysis Approach and Results (Penn State)

- Extract & average 1 year of T profiles
- Assume for now
  - h(z) = 0 (dry air)
  - u(z) = 0 (no wind)
- Calculate fits of T
  - homog (as in AEDT)
  - linear fit
  - full polynomial fit
  - ICAO standard atmos
- Ground L_p is different for different fits of T





Interfaces and Communications

- External
  - B. N. Tong (Purdue) and E. Petersen (Penn State) presented papers at Internoise 2015, San Francisco, CA in August 2015.
  - Y Wang will present paper at Noise Con 2016, Providence, RI, in June 2016.
  - New participation in FAA/Volpe Modeling Tools teleconferences
- Within ASCENT
  - Congratulations to Graduate Research Assistants
    - Bao Tong for passing his Ph.D. defense in August 2015
    - Erik Petersen, receiving his M.S. in December 2015
  - New relationship with Vancouver Airport Authority
  - Continuing relationship with ANOTEC Engineering of Motril, Spain
  - Continuing interface with Volpe Center
  - Ongoing discussions with Penn State Dept. of Meteorology
    - Recommendations regarding atmospheric re-analysis data sets
  - Ongoing discussions with University of North Carolina (emissions)
  - Conversations with ASCENT Project 23

Summary

- Propagation modeling project is ongoing
  - New work on source motion affecting ground impedance (Purdue)
  - New work on atmospheric effects and noise modeling approaches (Penn State)
  - Assessment of DiscoverAQ dataset underway
  - Assessment of Vancouver Airport Authority dataset begins soon
    - Now have a data sharing agreement with Vancouver (YVR)
- Key challenges/barriers
  - Getting international data agreements in place can be challenging
    - Still working on gaining EASA approval for accessing BANOERAC database (en-route)
  - Would like to identify additional industrial partners who can provide supporting data or expertise

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- Y. Wang, B. N. Tong and K. M. Li, "Sound field generated by a 3-dimensional moving monopole point source above a locally reacting surface," Noise Con 2016, Providence, RI, June 13-15 (2016).

Contributors

- Penn State: Victor Sparrow, Rachel Romond, Manasi Biwalkar, Erik Petersen
- Purdue: Kai Ming Li, Yiming Wang
- Volpe: Eric Boeker
- Industry partners: Mark Cheng (Vancouver Airport Authority)
Nico van Oosten (ANOTEC)

Civil, supersonic over-flight, sonic boom (noise) standards development

Project 7

Civilian supersonics certification Task (7A)

Community impact standards Task (7B)

Project manager: Sandy Liu, FAA
Lead investigator 7A: Vic Sparrow, Penn State
Lead investigator 7B: Kathy Hodgdon, Penn State

5th Advisory Committee Meeting
April 26-27, 2016
Alexandria, VA

ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

Advance the understanding of low sonic boom noise by evaluating metrics for certification and supporting field tests to gather noise impact data critical for regulatory assessment of future civilian supersonic fight. This supports P1: Improved Scientific Knowledge and Integrated Modeling in the NextGen 5 Pillar Environmental Approach.

It addresses roadmap research question:
"What is needed from a standard to consider allowing supersonic flights over land?"
by implementing research that supports:

Civilian supersonics certification Task (7A)
Community impact testing & protocol Task (7B)

Objectives

- The Civilian supersonics certification Task 7A is evaluating:
  - Applicability of single event metrics for certification
  - Approaches to removing atmospheric turbulence effects from measurements
  - Strategic placement of microphones for certification ground measurements
- The community impact testing & protocol Task 7B is evaluating:
  - Noise monitors to optimize measurement requirements and minimize costs in future field tests.
  - Social media as a supplemental means to observe social dynamics in the community that provide insights into community perceptions.

Schedule and Status

Task 7A Milestone	Dates
Assess existing sonic boom datasets	Completed August 2015
Document variability in selected data	Completed October 2015; thesis writing underway
Investigate robustness of metrics	Began September 2015; April 2016 presentations
Developing “deturbing” approaches	Underway
Assessment of ground mic placement	Begin Summer 2016
Compile Report	July 2016

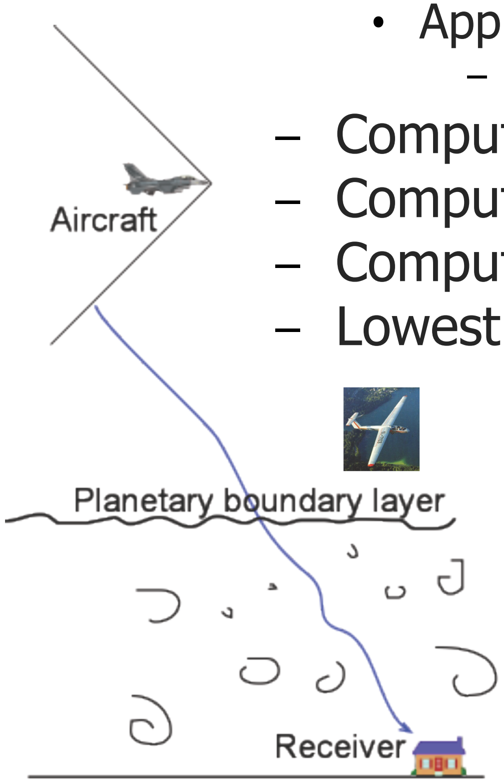
- Task 7A provides support to CAEP/WG1/SSTG.

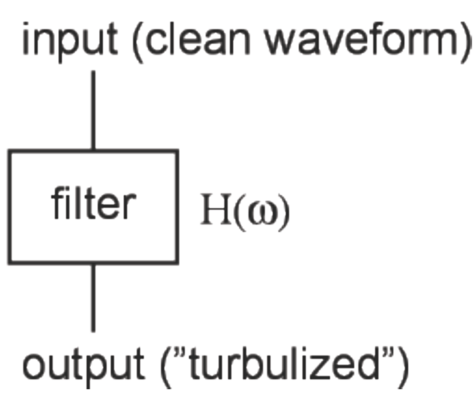
Task 7B Milestone	Dates
Investigate instrumentation options	ONGOING: Monitor type modified
Purchase and test instrumentation	March 2016 Extended to May 2016
Compare instrumentation performance	March 2016 Extended to May 2016
Summarize instrumentation comparisons	June 2016 Extended to July 2016
Identify data analytics methods	January 2016 ONGOING
Summarize social media approach	June 2016
Compile Report	July 2016

- The social media monitoring (SMM) task as an ongoing exploration of SMM as an element of proactive outreach.
- The ongoing instrumentation task will evaluate monitors and assess methods to capture the noise dose and monitor the community response outside of a formal survey research design.
- These findings will facilitate assessment of noise dose response measurements in support of future ~~NASA~~ plans for US National community response testing using an experimental low-boom flight demonstrator X-plane ~~(LBFD) aircraft~~ as part of the NASA Quiet SuperSonic Technology Program.

Task A: Approach

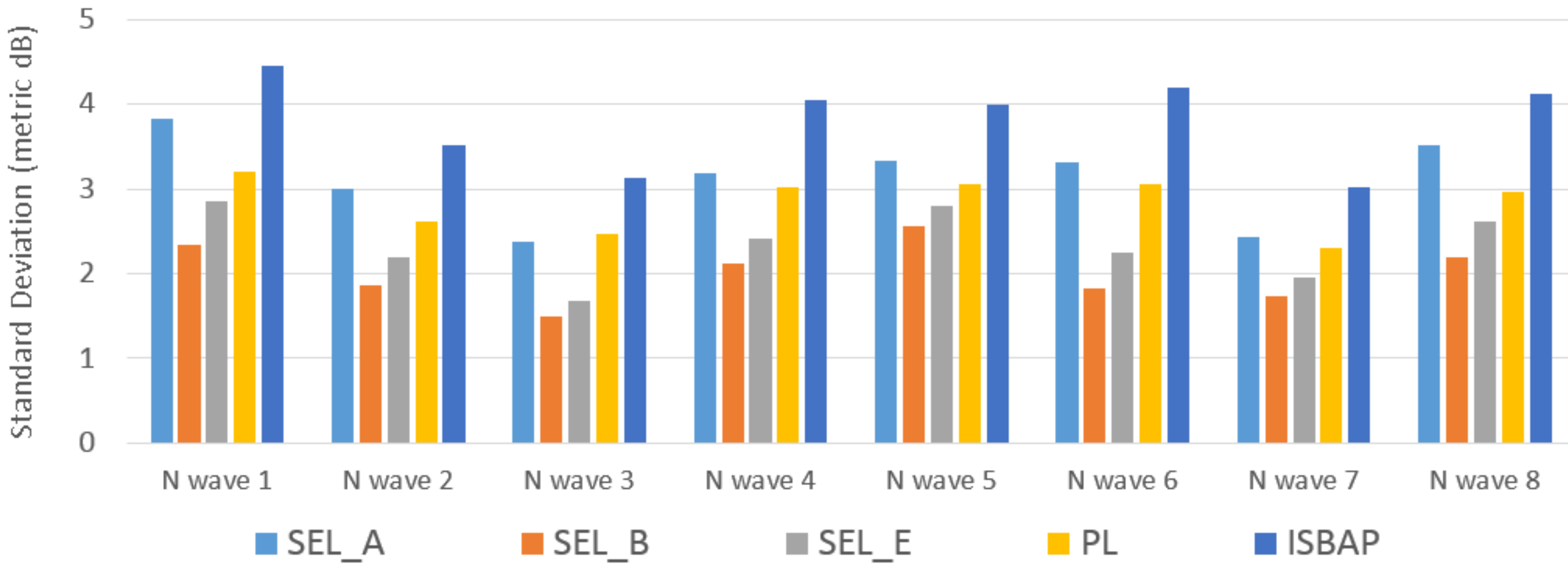
- Assess effects of turbulence on sonic boom metrics
- Method:
  - Treat atmosphere as finite impulse response filter (Locey & Sparrow, 2007)
    - Use atmospheric filters derived from NASA's 2006 and 2007 field test data
    - Apply filters to signatures without turbulence
      - Examine both N-wave and low-boom (industry partner) signatures
  - Compute metric values before and after turbulizing the signatures
  - Compute difference between before and after metric values
  - Compute standard deviation (SD) of these changes
  - Lowest standard deviation => most turbulence robust metric





Task A: Results

- Use key metrics suggested by (Loubeau, et al. 2015) on N-waves, processed by 10 filters to add turbulence:



- B-weighted sound exposure level had the lowest SD for 8 out of 8 traditional N wave signatures
- E-weighted SEL had the next lowest SD
- Similar results (not shown) for industry-supplied low-boom waves
- This work informs CAEP/WG1/SSTG activities.

Task B: Approach & Accomplishments

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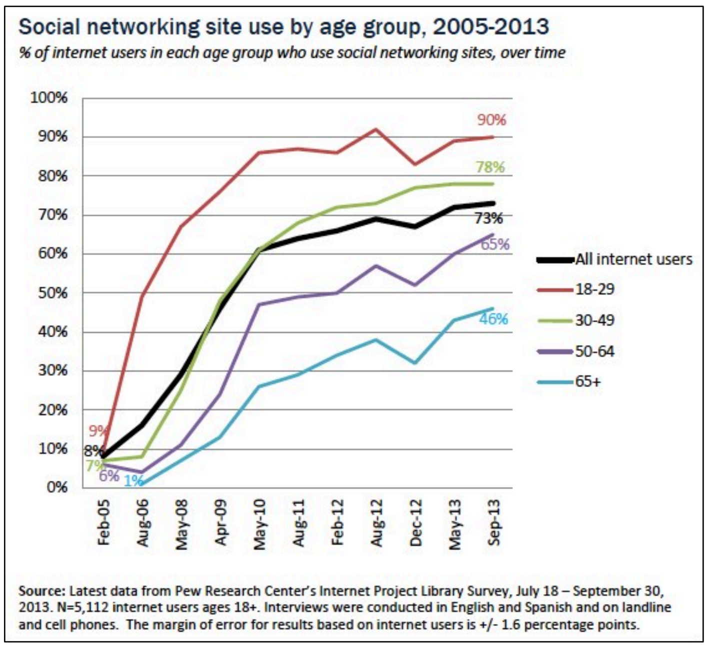
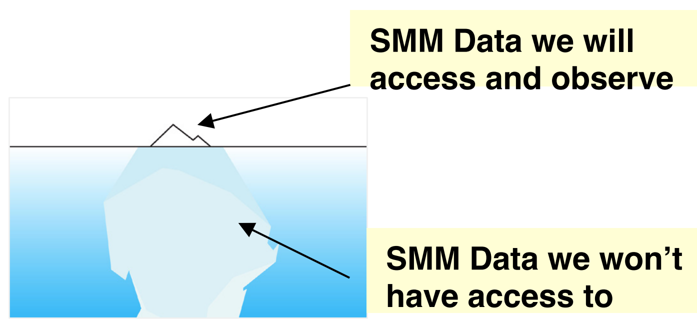
Social media monitoring as *proactive outreach* for new noise sources

- **Understand Social Media Monitoring (SMM) utility in the case of a viral media response.**
- **Observe on-line posts and community dynamics regarding noise**
- **Use Social media monitoring to observe community dynamics during test**
- **Intended for public domain information only and *not viewed as response data***



SMM is a *soft sensor* *to observe community dynamics*
Population-centric media: Facebook, Twitter, Instagram
Geographic based topic specific search of social media
Search dependent on users with location feature on
Used to ***identify viral negative media*** in community
Have press release draft templates ready for specific revisions
Press releases drafted to address negative media



Notional data access diagram

Trend Observation Only: Social media sites have population sampling biases
- Example: Instagram: Typically adults between the ages of 18 and 29 (age specific participation)
- Some "people" are: professional writers, PR for corporations, or can be bought

Task B: Approach & Accomplishments

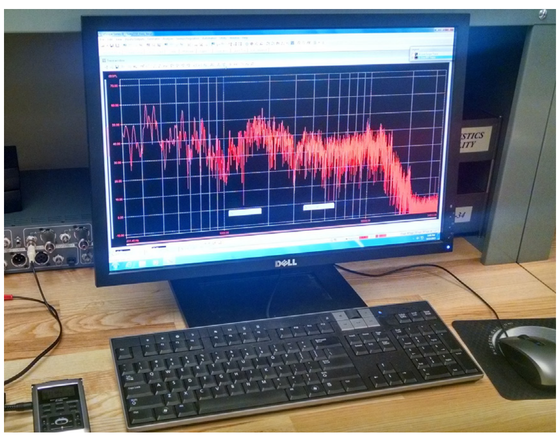
Snapshot of hits on boom comments

Using freeware (limited) version of Echosec (https://www.echosec.net/)

SMM in Action

SMM of sonic boom event in New Jersey 1/28/16 Snapshot on SMM for F-35 sonic boom "mistaken for earthquake" What did social media show?

Sample post



Assessment of noise monitors (ongoing effort)

- ➢ Lowest cost monitors may not be metric worthy monitors
- ➢ Ongoing effort to identify cost effective monitors that are metric worthy to augment existing field monitors
- ➢ Teaming with Volpe Labs to evaluate monitors

Interfaces and Communications

- External
  - Continued discussion with and feedback from NASA personnel and contractors involved in NASA's sonic boom modeling program
  - Sparrow continues work to support CAEP/WG1/SSTG:
    - Contributed to CAEP 10 Research Focal Point report
    - Many teleconferences
  - Proceedings of 2nd International Sonic Boom Forum, Lyon, France (2-3 July 2015) was published
    - http://scitation.aip.org/content/aip/proceeding/aipcp/1685
  - Mitch Gold is a Penn State student on the ASCENT Supersonics Social Medial Monitoring team. He is supported through the *Federal Cyber Corps Scholarship for Service (SFS)* program, offered and funded through the National Science Foundation and the Department of Homeland Security. The SFS program is administered by the Penn State College of Information Science and Technology and the Applied Research Lab.

- Within ASCENT
  - Industry partners being asked to contribute sample sounds for future tests

Summary

- The Supersonics research efforts include investigating certification standards, evaluating factors for community noise impact standards, and methods to monitor community dynamics during tests of community acceptability of low boom signatures.
- These topics are designed to support CAEP/WG1/SSTG and NASA activities on sonic boom research. As the research progresses, relevant research aspects may involve the support of: testing, data acquisition and analyses, of field demonstrations, laboratory experiments or theoretical studies.
- Next steps?
  - Continue work to remove turbulence from ground signatures and optimize placement of microphones as part of certification testing.
  - Ongoing effort to identify and test noise monitors
  - Ongoing effort to conduct tests of SMM software and methods
- Key challenges/barriers
  - None at this time.

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- J. Palmer and V. Sparrow, "Measured N-wave sonic boom events and sensitivity in sonic boom metrics," in *Recent Developments in Nonlinear Acoustics*, AIP Conf. Proc. **1685** 090012 (AIP, 2015), doi: 10.1063/1.4934478.

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  - ARL Walker Graduate Assistants Josh Palmer and William Doebler
  - ARL co-administered PSU SFS undergraduate student Mitch Gold
- FAA: Sandy Liu, Project Manager
- Advisory Committee Partners and Colleagues:
  - -AERION: Jason Matisheck, Peter Strudza, *et al.*
  - -Boeing: Hao Shen, Bob Welge, *et al.*
  - -Cessna: Kelly Laflin, *et al.*
  - -Gulfstream: Robbie Cowart, Brian Cook, Joe Gavin, Matt Collmar, *et al.*
  - -Lockheed Martin: John Morgenstern, Tony Pilon, *et al.*
  - -NASA: Peter Coen, Kevin Shepherd, Alexandra Loubeau, Ed Haering, Larry Cliatt, et al.
  - -Volpe: Juliet Page, Bob Samiljan
  - -Wyle: Kevin Bradley, Chris Hobbs, *et al.*

Pilot Study on Aircraft Noise and Sleep

Project 17

Project manager: N. Sizov, FAA
Lead investigator: M. Basner, University of Pennsylvania

April 26-27, 2016
Washington, DC

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Motivation

- Field studies need to be conducted in the US to acquire current data on sleep disturbance relative to varying degrees of noise exposure to inform policy
- A methodology of using actigraphy and electrocardiography (ECG) has previously been found to provide a sensitive measure of awakenings
- ECG + Actigraphy is non-invasive, self-administration of electrodes is possible, with lower methodological cost than polysomnography
- Pilot field studies using this methodology are being conducted to evaluate the feasibility of its use and to inform the design of future studies

Objectives

- Long term
  - Develop models relating the indoor maximum noise level (L_{Amax}) to awakenings
  - Examine how individual variables (e.g. age, gender), situational variables (e.g. elapsed sleep time) and acoustical variables (e.g. spectral content, rise time) moderate the relationship between L_{Amax} and probability of awakening

- Near term
  - Complete data analysis for pilot study conducted around Philadelphia International Airport
  - Refine a study methodology for examining the effects of aircraft noise on sleep based on lessons learned from pilot field studies

Outcomes and Practical Applications

- Outcomes
  - An inexpensive yet sound study methodology for obtaining objective measures of sleep and noise

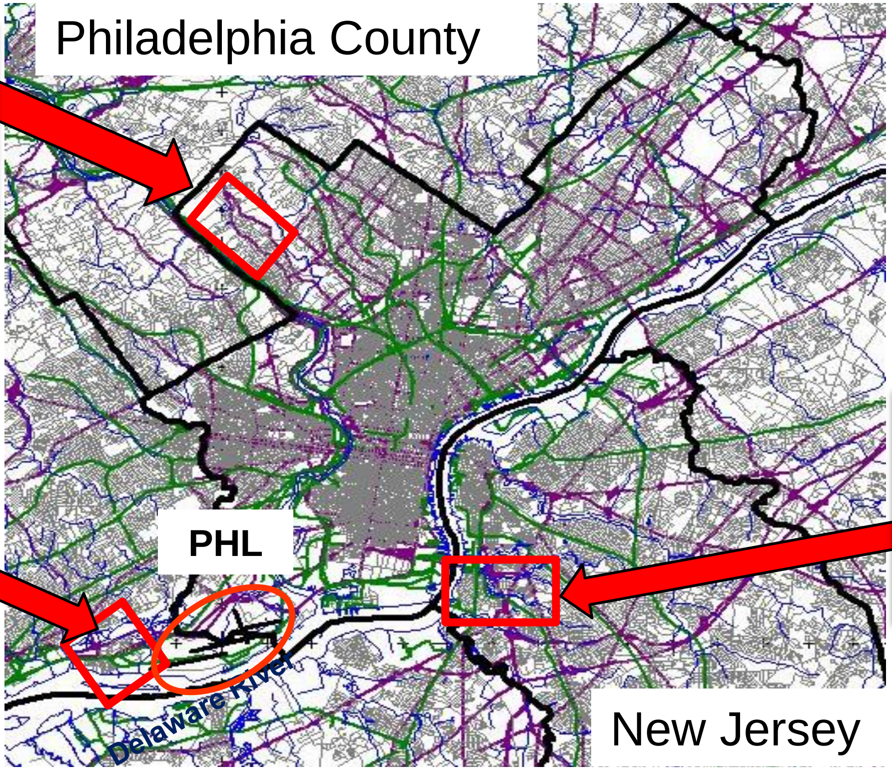
- Practical applications
  - Collaboration with the German Aerospace Center and other researchers could lead to the development of a common methodological approach which will allow comparisons between studies and data pooling

Schedule and Status: Philadelphia Airport Sleep Study

Period	Tasks	Status
Subject Recruitment and Data Collection		
7/2014-7/2015	• Data collection for 3 nights for each subject, for a total of 80 subjects	✓ **Measurements Completed 7/2/2015**
Data Analysis		
5/2015-9/2016	• Calculate single aircraft event noise metrics and cumulative nighttime noise levels	✓ **8/15: Obtained flight data from FAA to identify aircraft events** ✓ **11/15: Completed program to identify aircraft events in sound recordings based on airport flight operations data** ✓ **1/16: Identified aircraft events for all subjects**
	• Identify awakenings using ECG and actigraphy data	○ **In progress: Identifying and marking artifacts in heart rate measurements**
	• Compare sleep fragmentation and subjective results between control and aircraft noise exposed subjects	
	• Calculate models relating awakenings to single event aircraft noise metrics	
	• Compare results to the NORAH sleep study conducted around Frankfurt Airport	

Philadelphia Airport Sleep Study: Study Population Demographics

40 Participants
52% Female
Average Age: 32
(Age Range: 22-68)



23 Participants
70% Female
Average Age: 48
(Age Range: 23-77)

17 Participants
41% Female
Average Age: 42
(Age Range: 22- 62)

	Airport	Control
Education Level (had at least some college)	67%	90%
Duration of Residence (median)	8 years	2 years
Percent with Sound Proofing	30%	0%
Percent Highly Noise Sensitive	13%	10%

Philadelphia Airport Sleep Study: Acoustic Analysis Procedure

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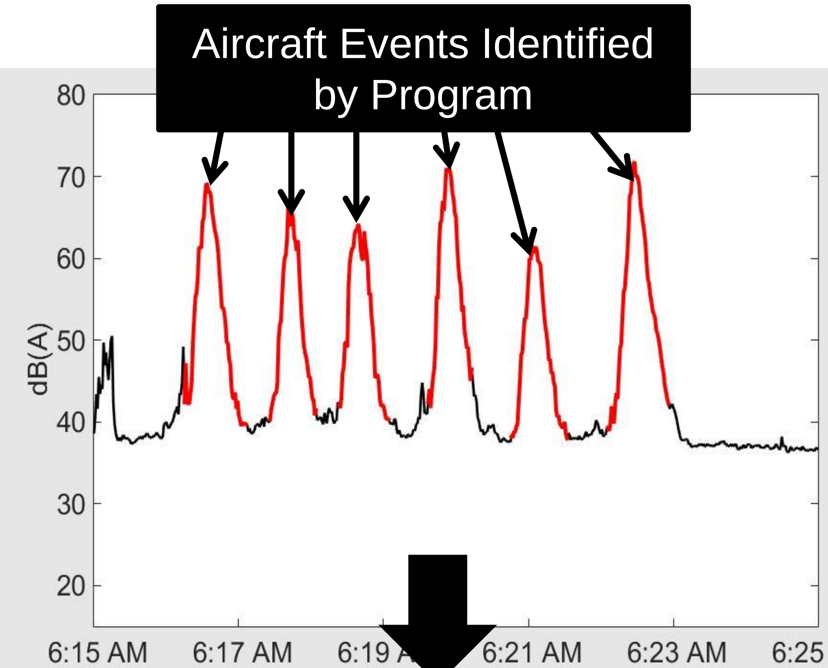
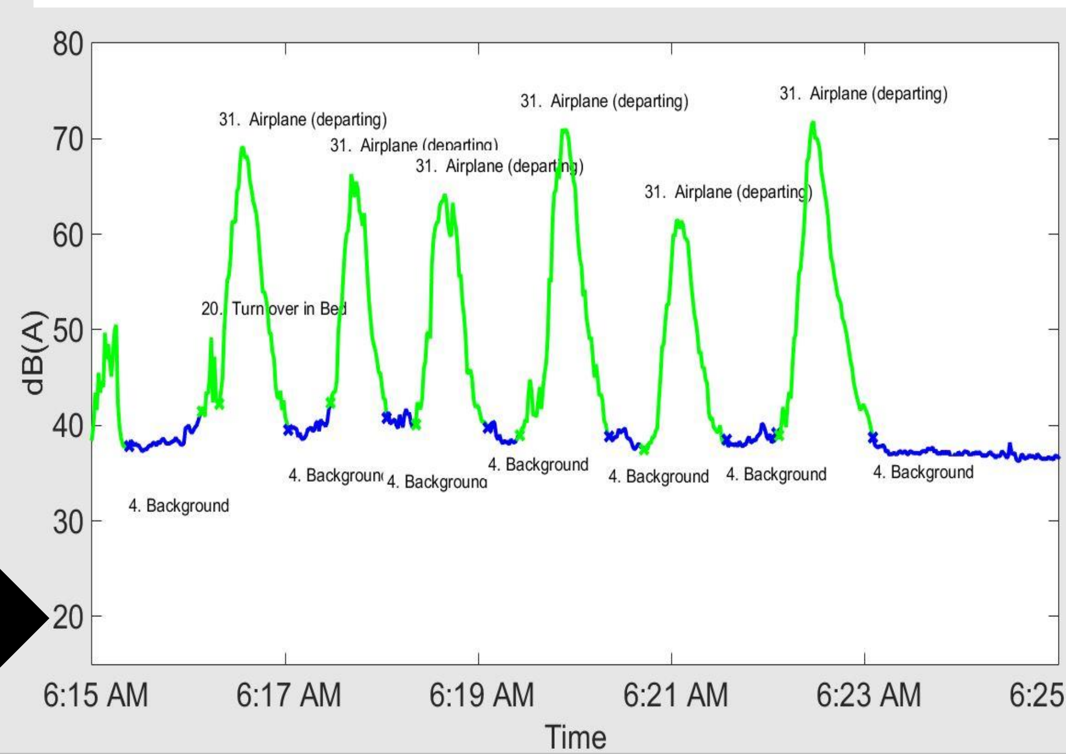
- Developed program for identifying aircraft events based on flight operations data (PDARS data obtained from FAA):
  - Geocoded participants' addresses
  - Calculated distance between aircraft flight path and geocoded address
  - Identified aircraft events in sound recordings based on level above background noise and calculated distance



- Identified aircraft were verified by listening to recordings
- 2 minutes before and after each aircraft event was also scored

- Program increases rate at which acoustic files can be scored

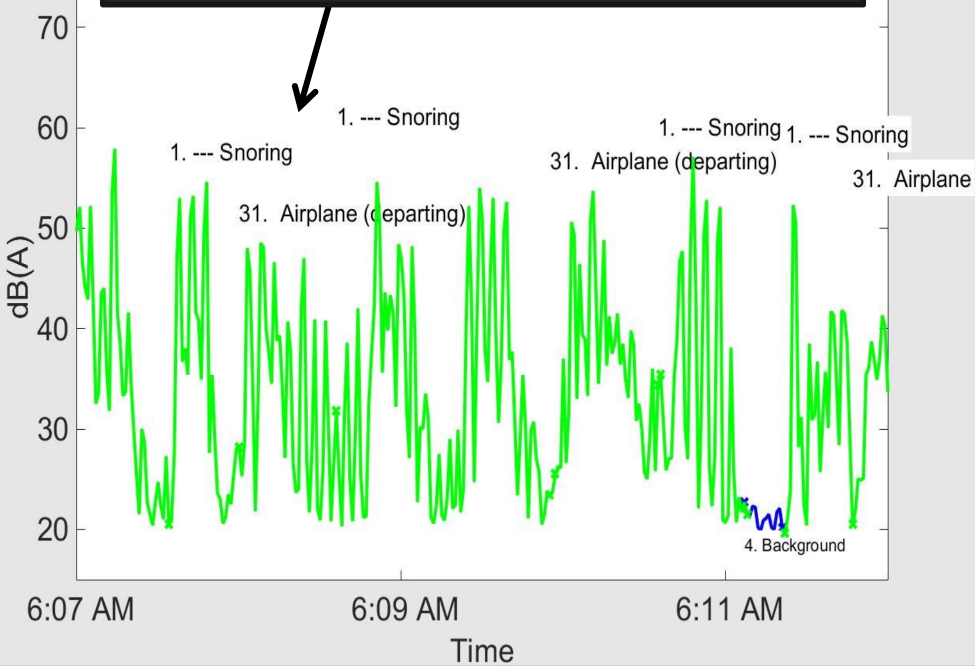


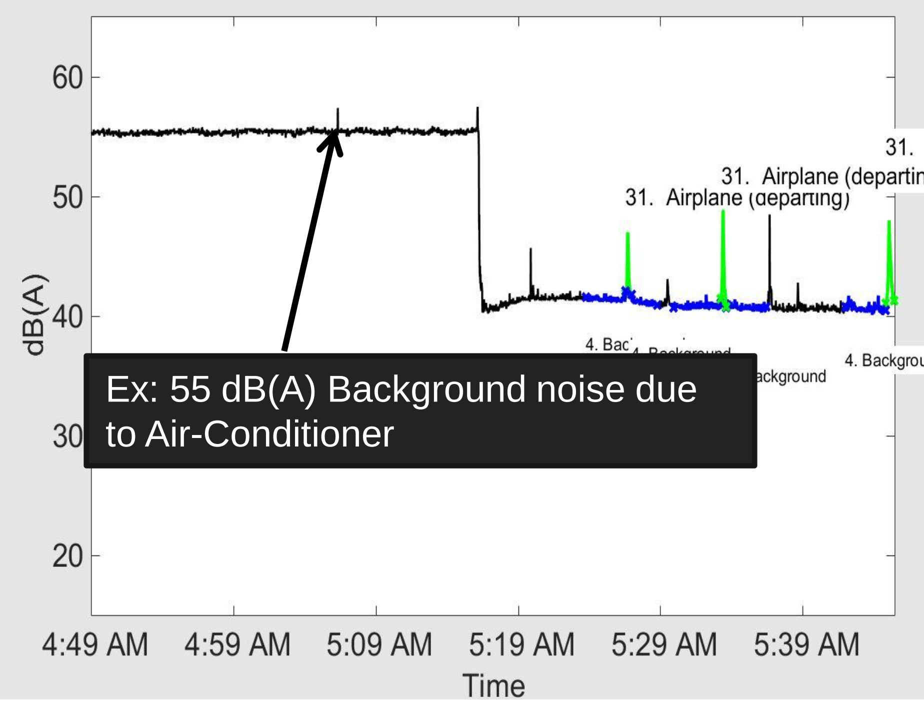
Philadelphia Airport Sleep Study: Acoustic Analysis (Challenges)

- Additional outdoor and indoor noise events can overlap with aircraft events
- Snoring for example can contaminate an event making it difficult to identify the noise level of overlapping aircraft events
- Methodology for including or excluding these disturbed aircraft events is being developed

- Participants were asked not to sleep with tvs, radios, or music on
- Participants could sleep with fans and air conditioners, pets could remain in room
- Periods of high indoor background levels > 40 dB(A) were observed for 46% of participants by the airport
- A method for handling these background levels in the data analysis is being determined

Ex: Aircraft Events disturbed by high snoring or other indoor sounds





Ex: 55 dB(A) Background noise due to Air-Conditioner

Philadelphia Airport Sleep Study: Lessons Learned

Recruitment Procedure	Going door to door to recruit participants resulted in only 10 participants • Individuals reluctant to answer door • Many individuals not home at time • Expensive due to time of staff in the field Mailing letters resulted in recruitment of remaining 70 participants however response rate was still low < 10%
Participant Retention	Individuals reluctant to allow unknown individuals in their home • A website with information on the study was created • A link to the website was on mailed flyers • Website allows participants to verify study and study team
Study Protocol	• Participants were able to follow the protocol unattended • We obtained full physiological and noise measurements for > 90% of the 230 nights of measurements
Study Equipment	• Surveys completed on tablets, allowed real-time monitoring of participant compliance • Heart rate devices were easy to use • Equipment should require minimal setup by participants • Space in many bedrooms was limited
Study Team	• Need to be available after normal work hours for enrolling subjects due to participants' work schedules • Need to be available 24 hours, by study cell-phone, to address questions at night or first thing in the morning

Approach: Year 2 Sleep Study

Further simplify the study methodology by eliminating staff in the field

- **Mail Survey**
  - Brief recruitment survey: Primary purpose is to determine eligibility for physiological measurements
  - Compensation for completing the survey will be an Amazon gift card with an amount of $2.00, $5.00 or $10.00
  - Target Enrollment Goal: 1000 Completed surveys
- **In-Home Study**
  - 5 nights of sleep and noise measurements
  - Equipment will be mailed to subjects' homes
  - Target Enrollment Goal: 200 Participants
- **Outcomes**
  - Determine response rates for both the mail and in-home study
  - Identify inexpensive and reliable equipment
  - Assess feasibility of mailing equipment
  - Evaluate quality of data obtained

Combined cost of equipment to be mailed out:

$1,130

Current Status
Year 2: Sleep Study

Period	Tasks	Status
Study Preparation:		
10/2015-4/2016	• Design recruitment questionnaire	✓ **Completed 10/15**
	• Developed study protocol and obtained IRB approval	✓ **Completed 11/15**
	• Identified and tested low cost sound recording equipment	✓ **Completed 2/16**
	• Created videos on how to use equipment, prepared information content for website	✓ **Completed 4/16**
	• Purchased study related materials	✓ **Completed 4/16**
	• Determine airport and obtain flight operations, predict L_{night} levels and number of overflights, identify sampling regions based on predictions	○ **Ongoing**
Data Acquisition:		
5/2016-9/2016	• Mail out recruitment questionnaires	○ **Start date: TBD**
	• Mail out equipment for in-depth field study	
	• Develop procedures for data analysis	

Interfaces and Communications

- External

  Collaborations: German Aerospace Center (DLR)
  - With DLR we developed and validated an algorithm for identifying awakenings based on ECG and actigraphy data using data from year 1 and 2 of the NORAH sleep study
  - Year 3 of the NORAH sleep study: Used similar methodology as PHL study
    - 3 nights of ECG and actigraphy and indoor sound level measurements
    - Similar ECG and actigraphy equipment used as PHL study
    - Equipment was dropped off on first night of the study and collected after the third night
  - Results from the PHL study and the second pilot study will be compared to results of the NORAH sleep study

- Within ASCENT

  Volpe National Transportation Systems Center: Provided the sound recording equipment used for the indoor measurements in the Philadelphia Sleep Study

Summary

- Summary statement:
  - Data analysis for the Philadelphia Airport study is ongoing
  - Preparations for the Year 2 study is almost complete with data collection anticipated to begin end of spring.

- Next steps

  Philadelphia Sleep Study
  - Calculate models relating awakenings, identified based on heart rate and actigraphy data, to indoor aircraft noise levels

  Year 2: Sleep Study
  - Complete nighttime noise predictions for airport
  - Select sampling regions
  - Obtain address list and mail recruitment surveys

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- Maryam Witte (Research Assistant), University of Pennsylvania

Rapid Fleet-wide Environmental Assessment using a Response Surface Modeling Approach

ASCENT Project 11A

Project Status
April 26, 2016

Project manager: Joe DiPardo, FAA

Principal investigators: Dr. John Hansman, MIT
Dr. Brian Yutko, MIT

Research Team: Luke Jensen, MIT
Jacquie Thomas, MIT
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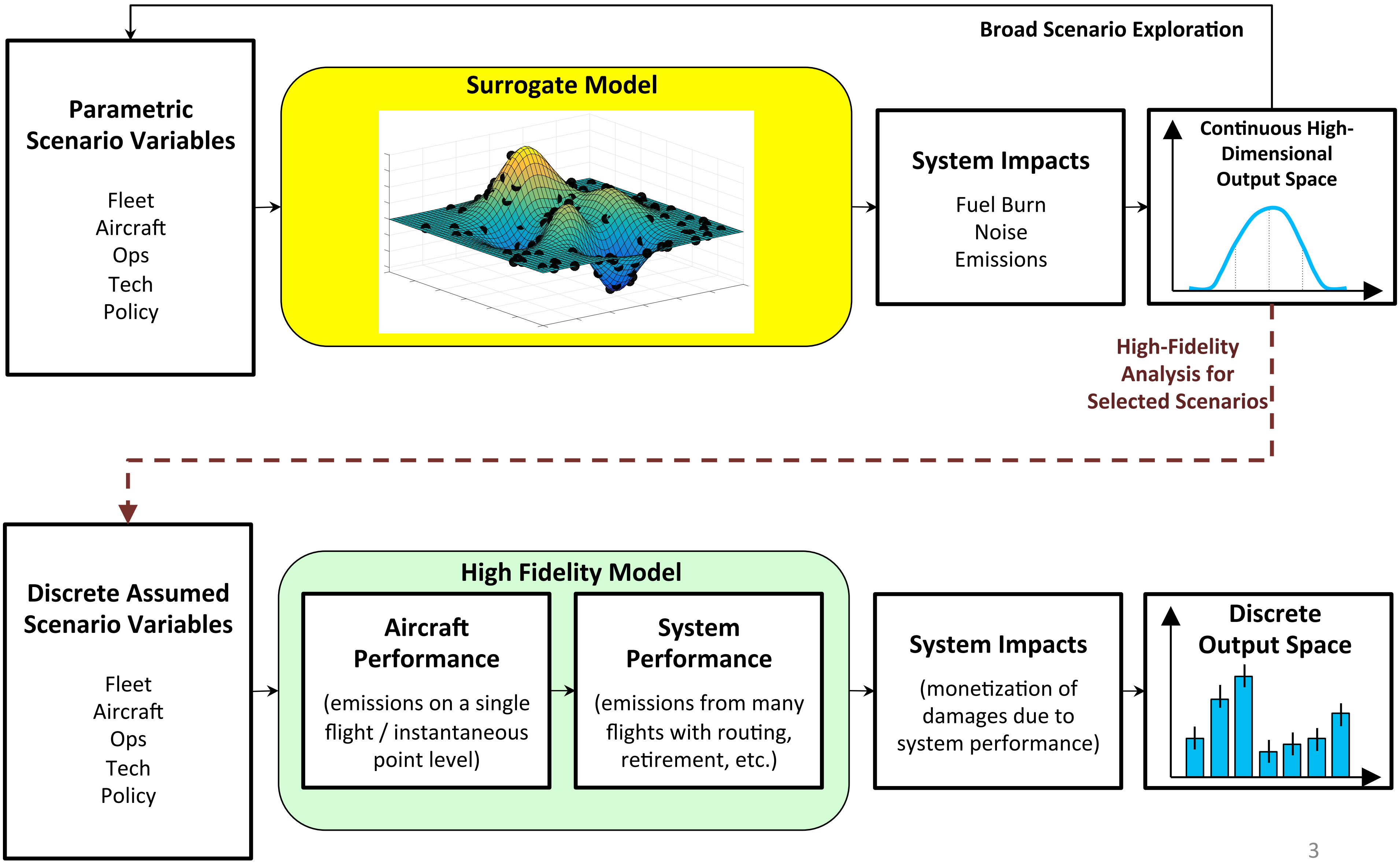
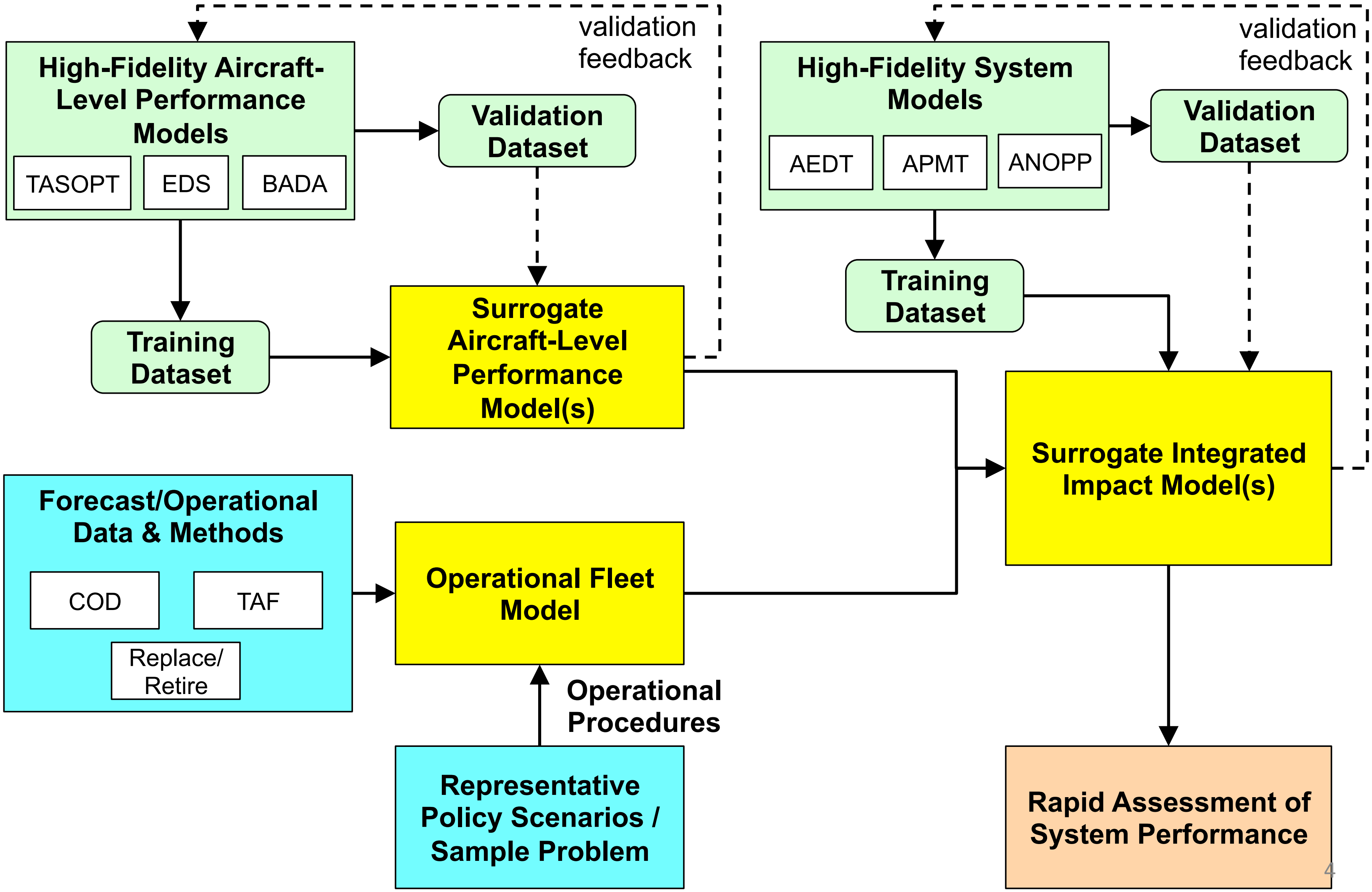
Objectives

- Develop surrogate models for environmental studies, enabling:
  - Broad scenario explorations
  - Fast parametric analyses
- Initial Phase: Noise Reference Problem
  - Develop response-surface modeling architecture
  - Explore inputs from, and interactions between, existing environmental analysis tools
    - Aircraft performance (TASOPT)
    - Aircraft Noise (AEDT, ANOPP)
    - High-fidelity system performance (AEDT)
    - Impact modeling (APMT)
  - Develop fast local noise modeling technique (interface with ASCENT Project 23)
- Second Phase
  - Apply response-surface modeling architecture to sample problem

Original Concept: Rapid Systemwide Environmental Analysis



Original Architecture Concept: Rapid Systemwide Analysis



Noise as a Component of Systemwide Analysis

- Several components of analysis translate quickly to system level
  - Fuel consumption, emissions
- Noise component of system analysis is highly location-dependent
  - Procedure design
  - Fleet mix
  - Traffic level
  - Population density
- Noise-specific concerns required a unique approach

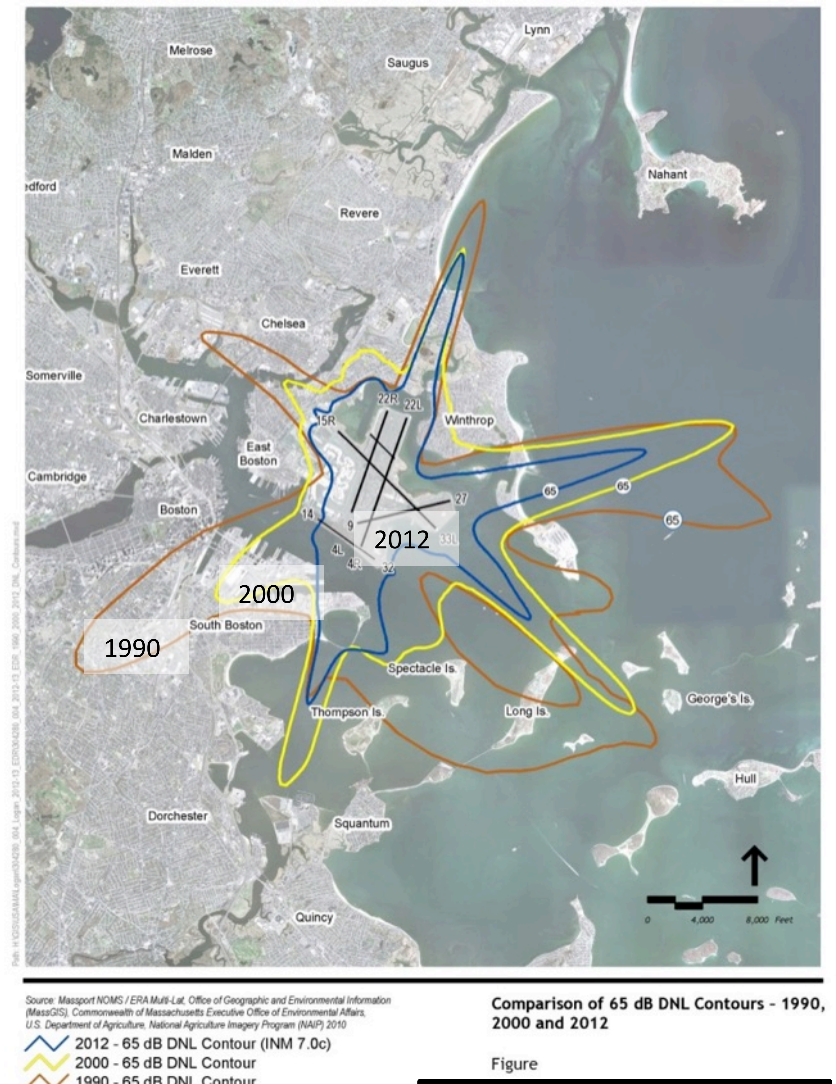


Figure Courtesy of Massport

Developing a Flexible Noise Analysis Framework

- Rapid noise evaluation model for use with existing and notional aircraft types and procedures
  - Cannot use existing NPD database for evaluation of future fleets and procedures, requires estimation tool
- Aircraft performance calculation requirements for noise modeling
  - Accurate drag calculation to determine thrust levels
  - Performance calculation to determine achievable climb, descent, and turn rates
- Noise model requirements for determining impact of new aircraft types or procedures
  - Physics-based calculation of projected noise levels based on performance capabilities and technology level of fleet

Noise Analysis Framework

Performance Model Inputs:

Operating/mission parameters

Aircraft sizing/performance parameters

Engine sizing/performance parameters

Flight Procedure Type:

Altitude

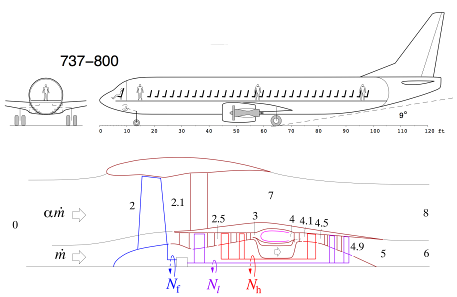
Velocity

Configuration

Performance Model

Flight Procedure Generator*

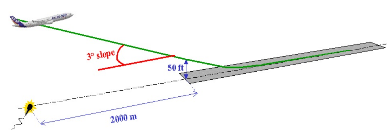
Performance Model Outputs:



Aircraft/engine performance & geometry

Flight Procedure:

Thrust, velocity, & position per time



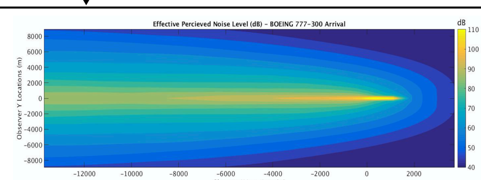
Noise Model Control Inputs:

Propagation settings

Observer locations

ANOPP or AEDT

Single-Event Noise Grids

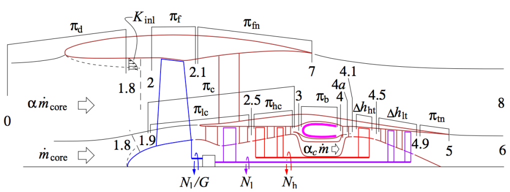


Output to Grid Rotation and Superposition

Aircraft Performance Models

New or Existing Aircraft

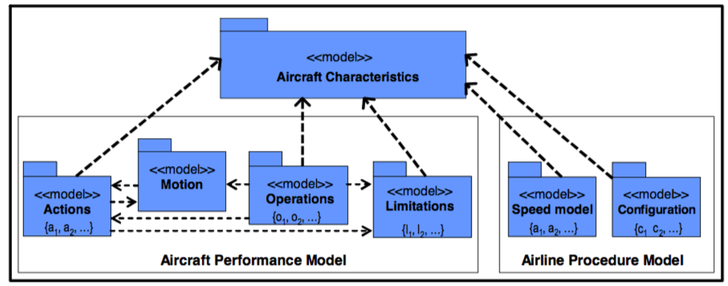
TASOPT: Transport Aircraft System OPTimization



- Software developed by Mark Drela at MIT
- Calculates optimal design parameters for an aircraft based on a specific mission (defined by payload and distance)
- Generates parameters necessary for calculating arrival and departure profiles
  - Engine Parameters
  - Airframe Geometry
  - Aerodynamic Coefficients

Existing Aircraft Only

BADA 4: Eurocontrol Base of Aircraft Data

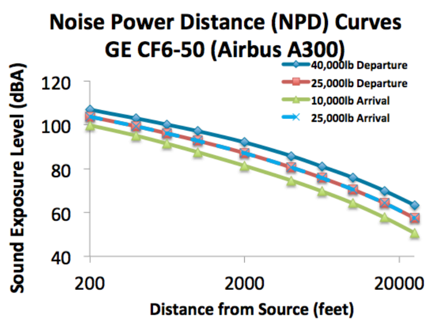


- Aircraft performance characteristics calculated using a mass-varying kinetic approach
- Performance coefficients derived from detailed information provided by aircraft manufacturers
- Particularly useful for predicting thrust requirements in high-lift or gear-down configurations

Noise Models

Noise-Power-Distance Approach

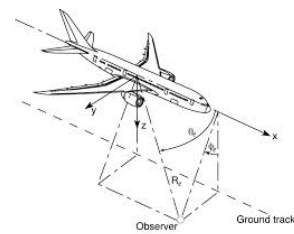
AEDT: Aircraft Environmental Design Tool



- Standard noise calculation tool for environmental evaluations
- Legal standard for generating DNL contours for AIP funding and impact statements
- Crude accounting for different flap and landing gear settings

Semi-Empirical Physics Approach

ANOPP: Aircraft Noise Prediction Program

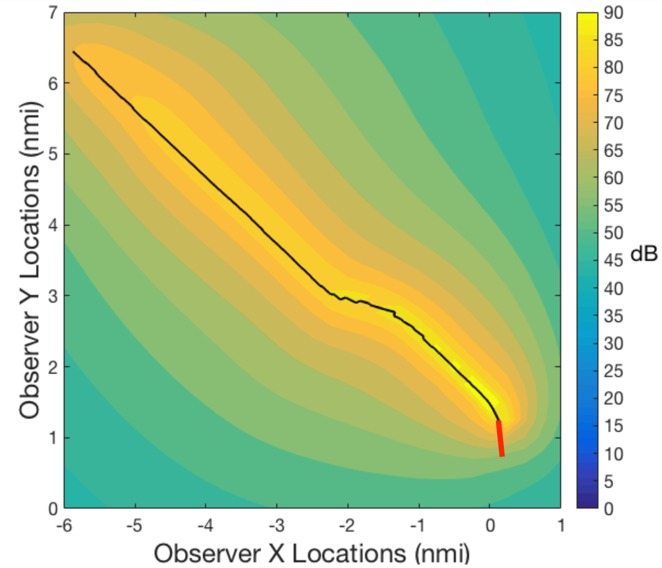


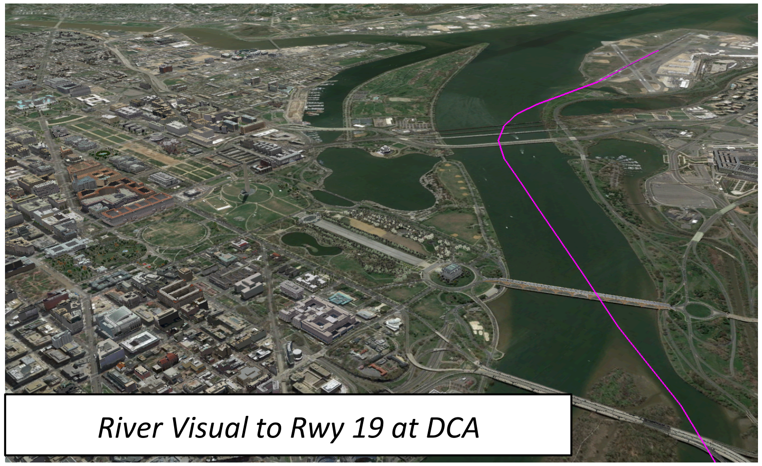
- Software developed by NASA for correlation-based noise estimation
- Calculates far-field aircraft noise from a range of different sources on an aircraft:
  - Airframe/aerodynamic
  - Engine
  - Fan, core, jet noise
  - Shielding, tonality, noise treatment, and other capabilities are included
- Currently using ANOPP Version 1, in process of implementing Version 2

Generating Single-Event Noise Grids

- ANOPP-TASOPT noise tool used to generate single-event noise grid for notional fleet
  - Baseline and upgauged fleet mixes
- Pre-calculated single-event noise grids for a variety of flight procedures, aircraft types, etc.
  - e.g. River Visual Rwy19, ILS Rwy01 at DCA, representative departure profiles
  - Runway allocation for procedural analysis based on historical runway configuration data (ASPM)
- Database of SEL grids can be combined quickly to form integrated noise contours

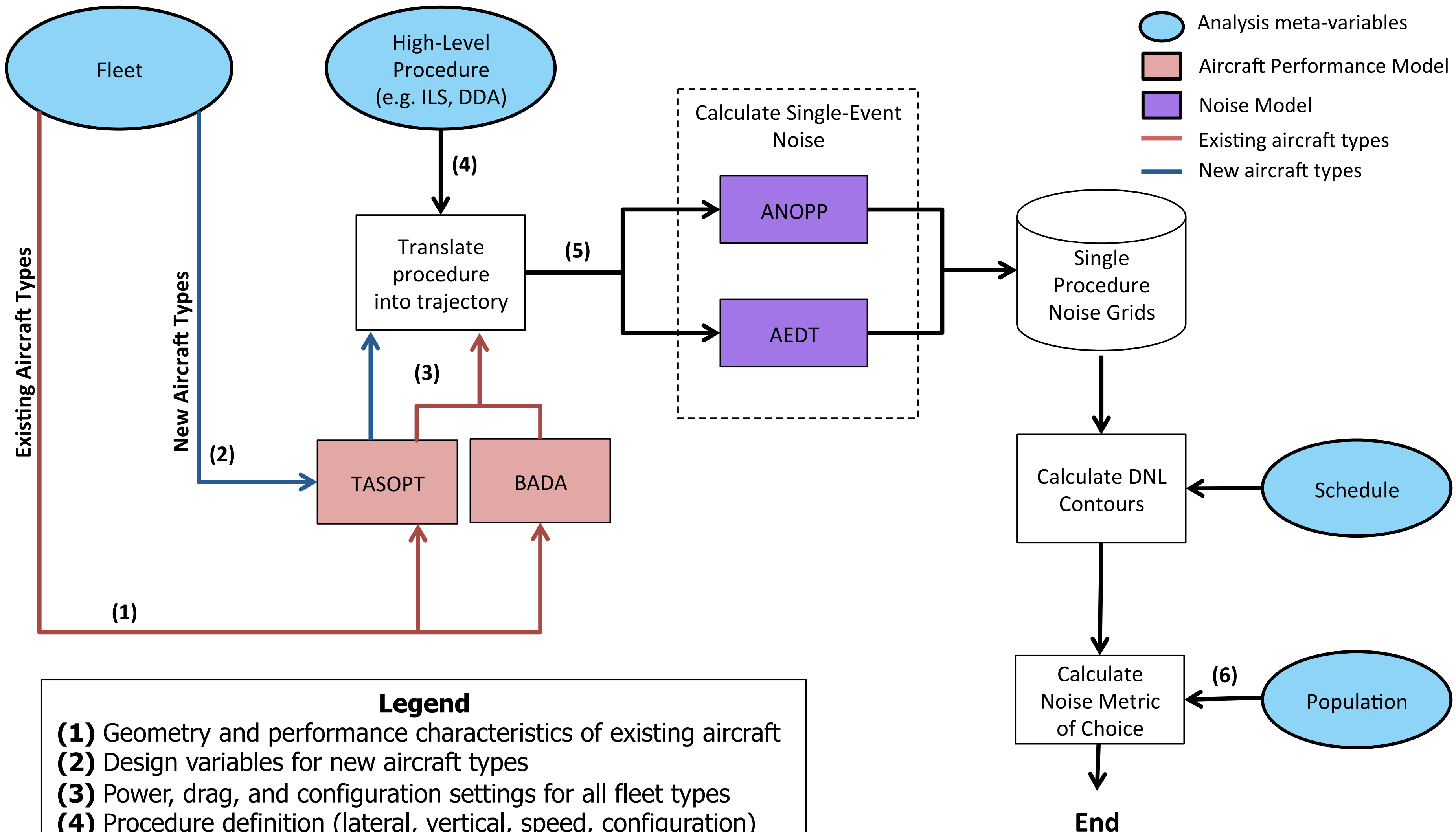
Example Single-Event Noise
Sound Exposure Level from 737-800 Rwy19 Arrival





River Visual to Rwy 19 at DCA

System Noise Analysis: Full Architecture

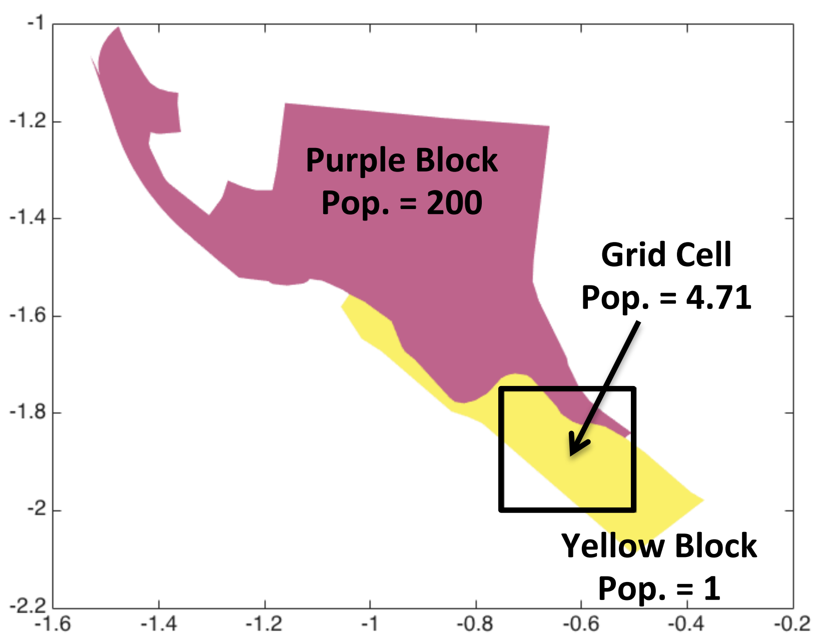


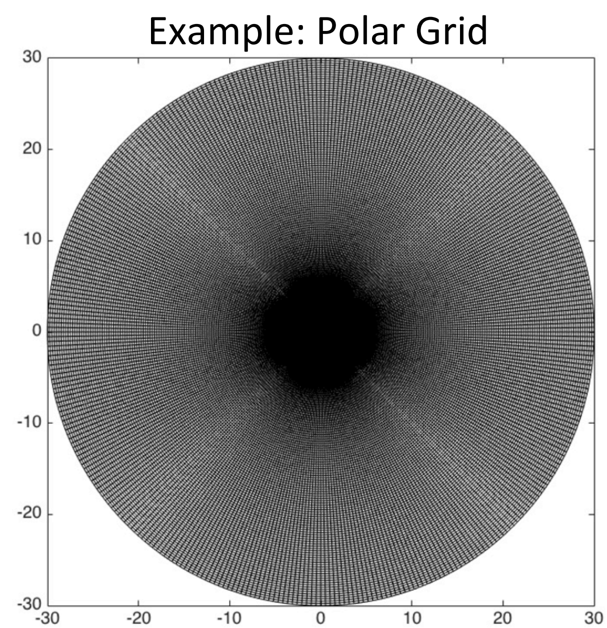
Legend

(1) Geometry and performance characteristics of existing aircraft
(2) Design variables for new aircraft types
(3) Power, drag, and configuration settings for all fleet types
(4) Procedure definition (lateral, vertical, speed, configuration)
(5) 4-D trajectory, thrust, and configuration
(6) Population density from census

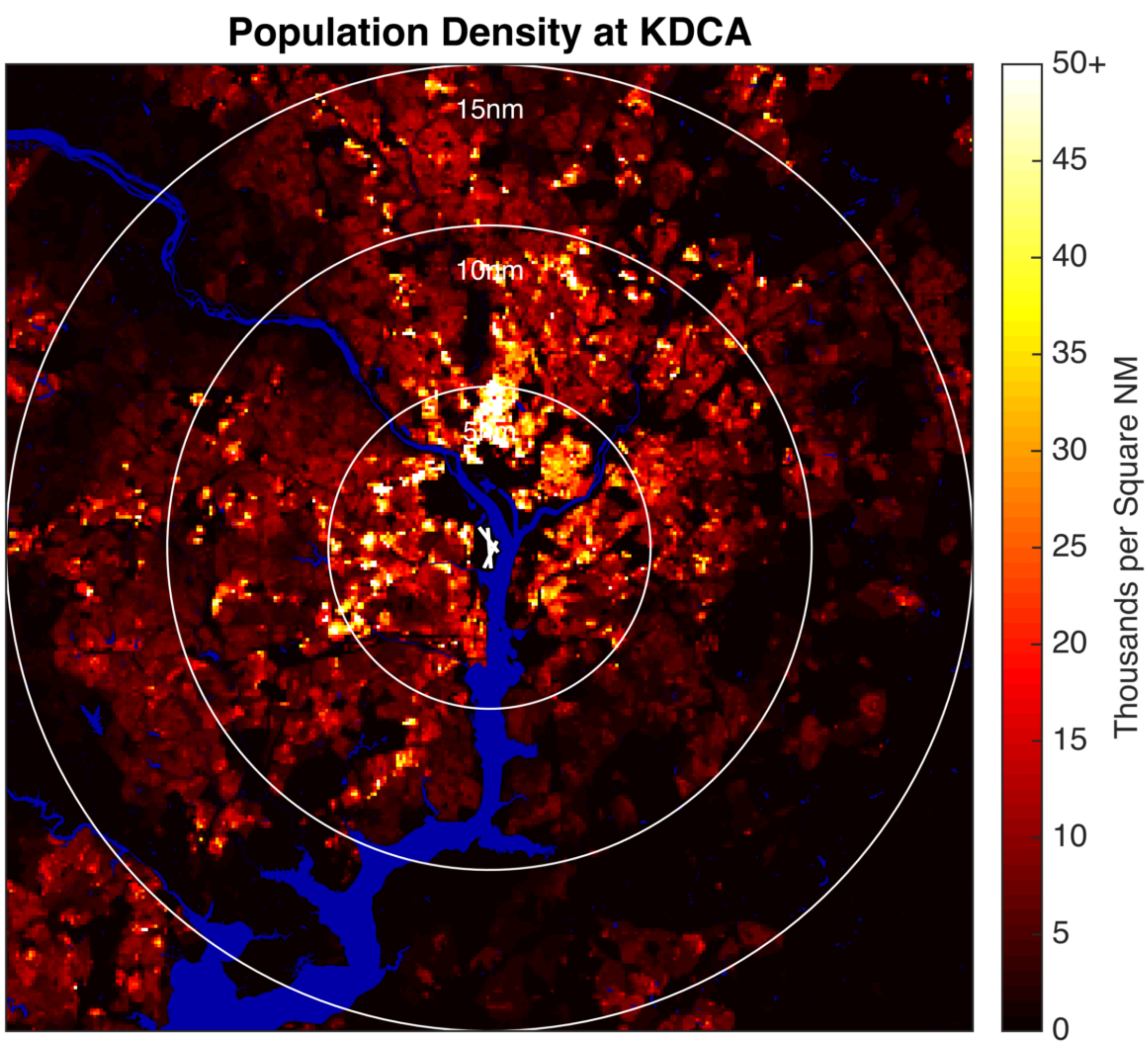
Gridded Population Data

- Population data provided by US Census Bureau in irregularly-shaped tracts and blocks
- Re-formatting population into regular grids allows for rapid summation of noise impacts
  - Rectangular or polar grids
- Repeated process for 49 busiest airports in the United States
  - Ranked by passenger movements
- Allows for rapid system-wide population noise exposure when combined with noise impact grids

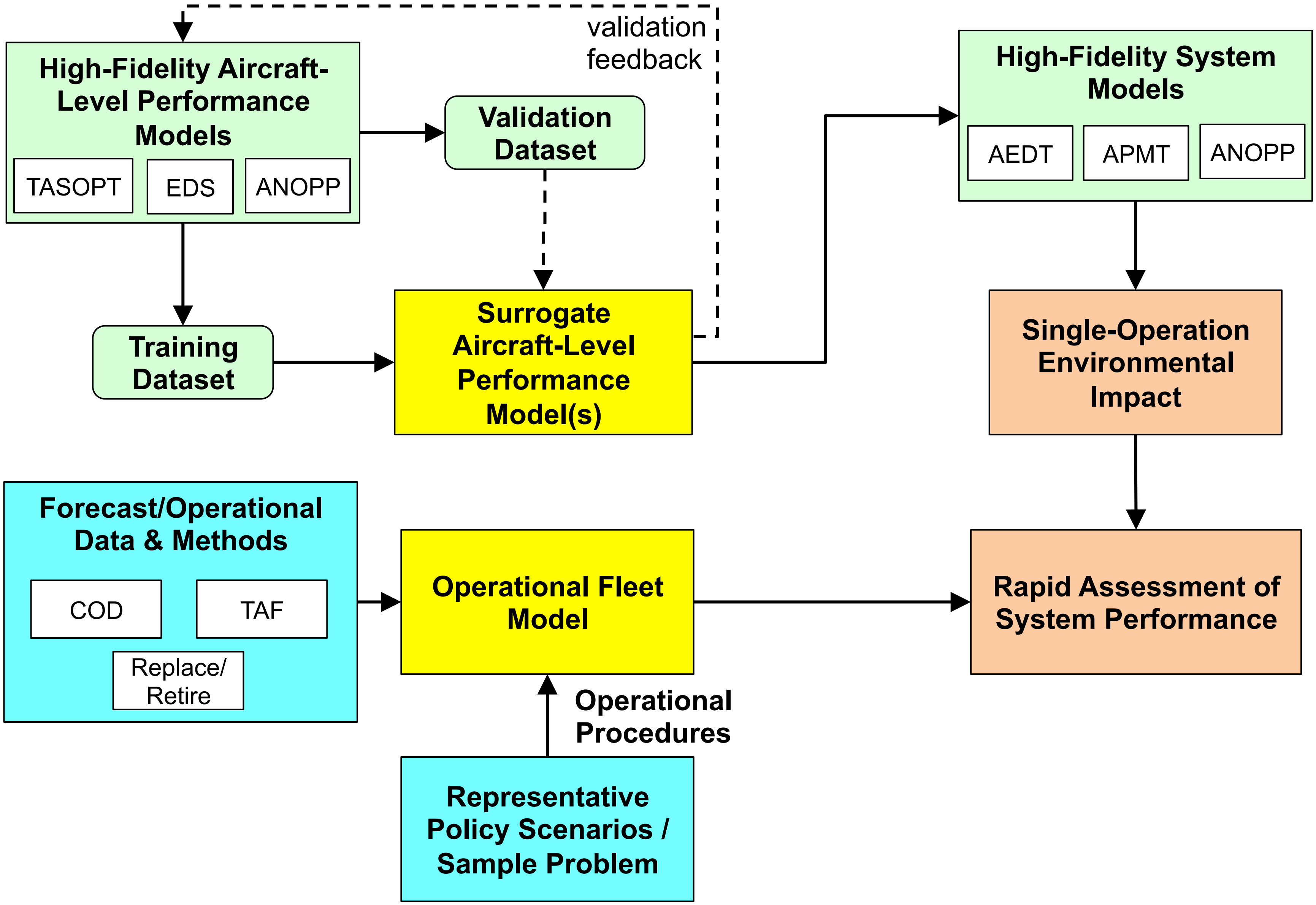




Gridded Population Data (Rectangular)



Updated Architecture Concept: Rapid Systemwide Analysis

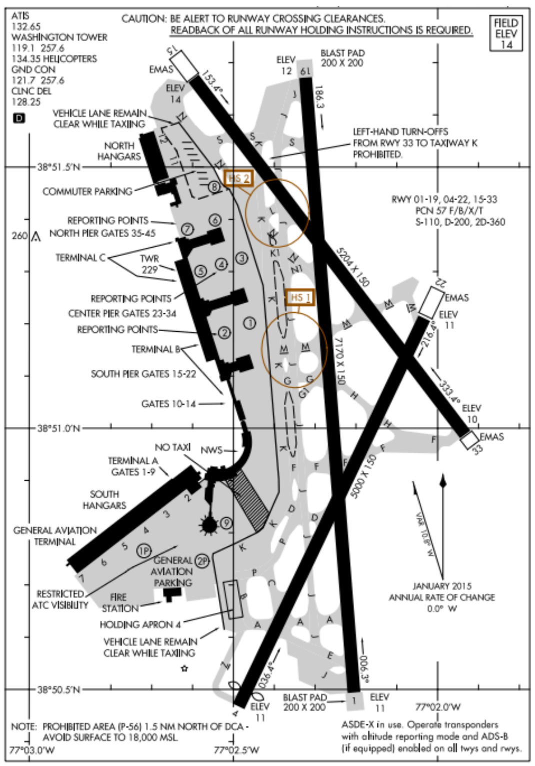


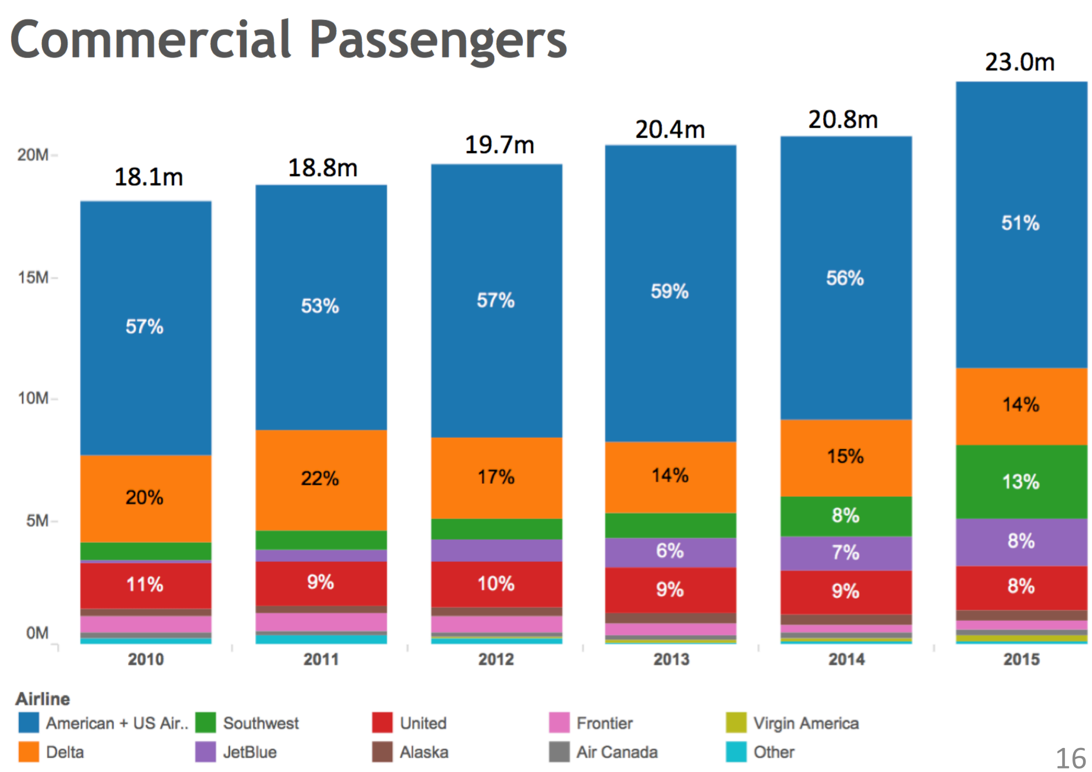
Initial Sample Problem: Impact of Aircraft Gauge on Environmental Footprint

- Current sample problem to demonstrate capability of response surface modeling approach including noise
- Challenge: evaluate impact of a hypothetical minimum aircraft gauge policy on environmental impact at an airport
  - Noise
  - Emissions
  - NO_X
- Demonstrate use of framework for evaluating multi-objective policy options
  - Generic airport layouts and operational mixes
  - Actual airports and operations (single airport)
  - Aggregate system noise analysis

Aircraft Gauge Policy Example: DCA Airport Analysis

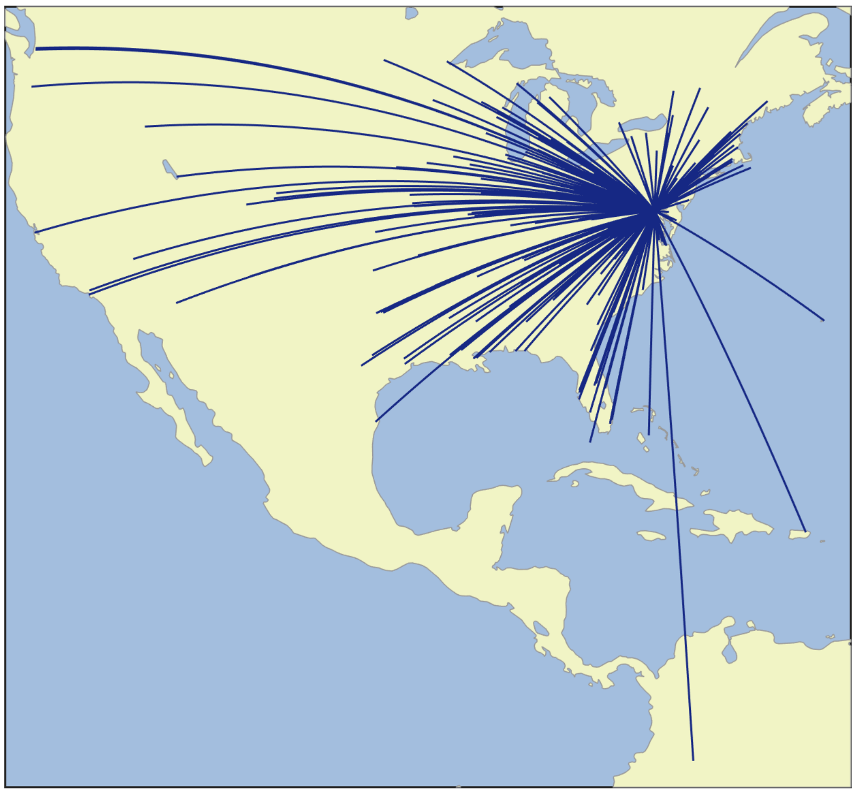
- Airport passenger throughput can be increased through aircraft gauge increase
  - At 2015 traffic levels, 10% gauge increase would increase passenger throughput at DCA by 2.30m
- Environmental impact lower than additional frequencies
  - How much lower?



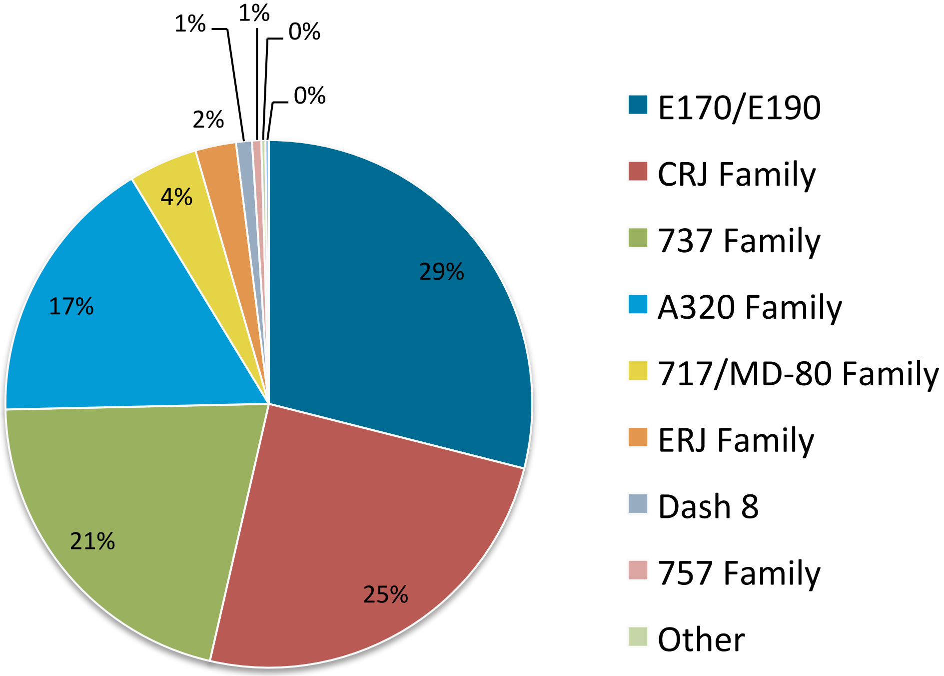


DCA Operational Baseline: 2015

Route Structure



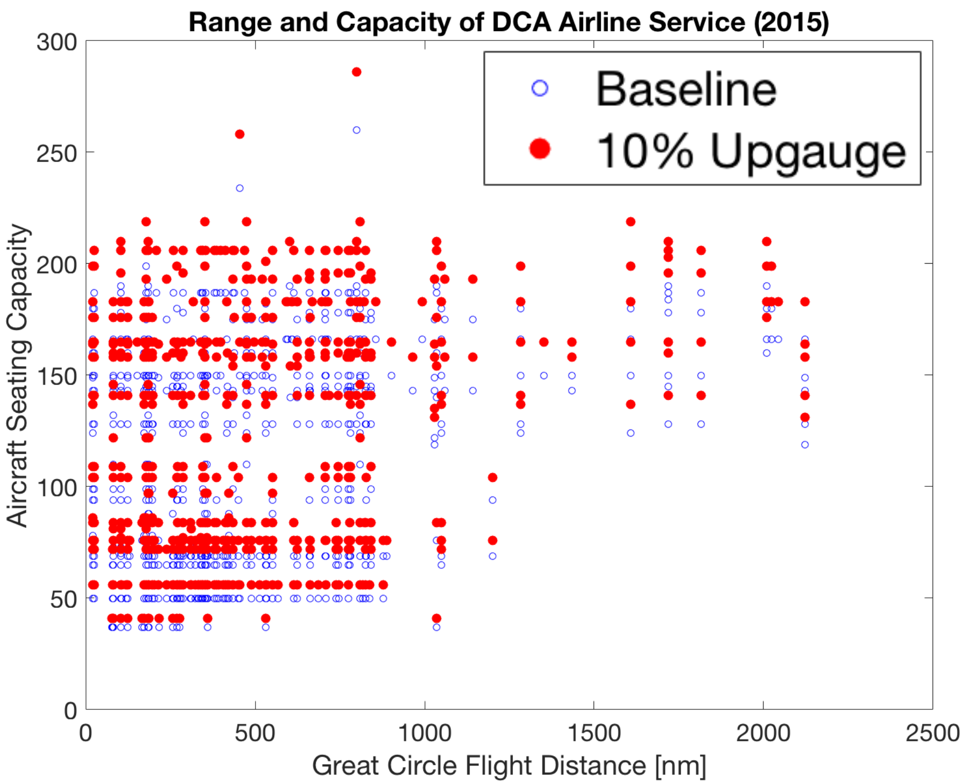
Fleet



Data Source:
FAA Aviation System Performance Metrics
Single-Flight Detail Records for 2015
(155,831 Total Flights)

Environmental Analysis Reference Problem: Aircraft Gauge Policy

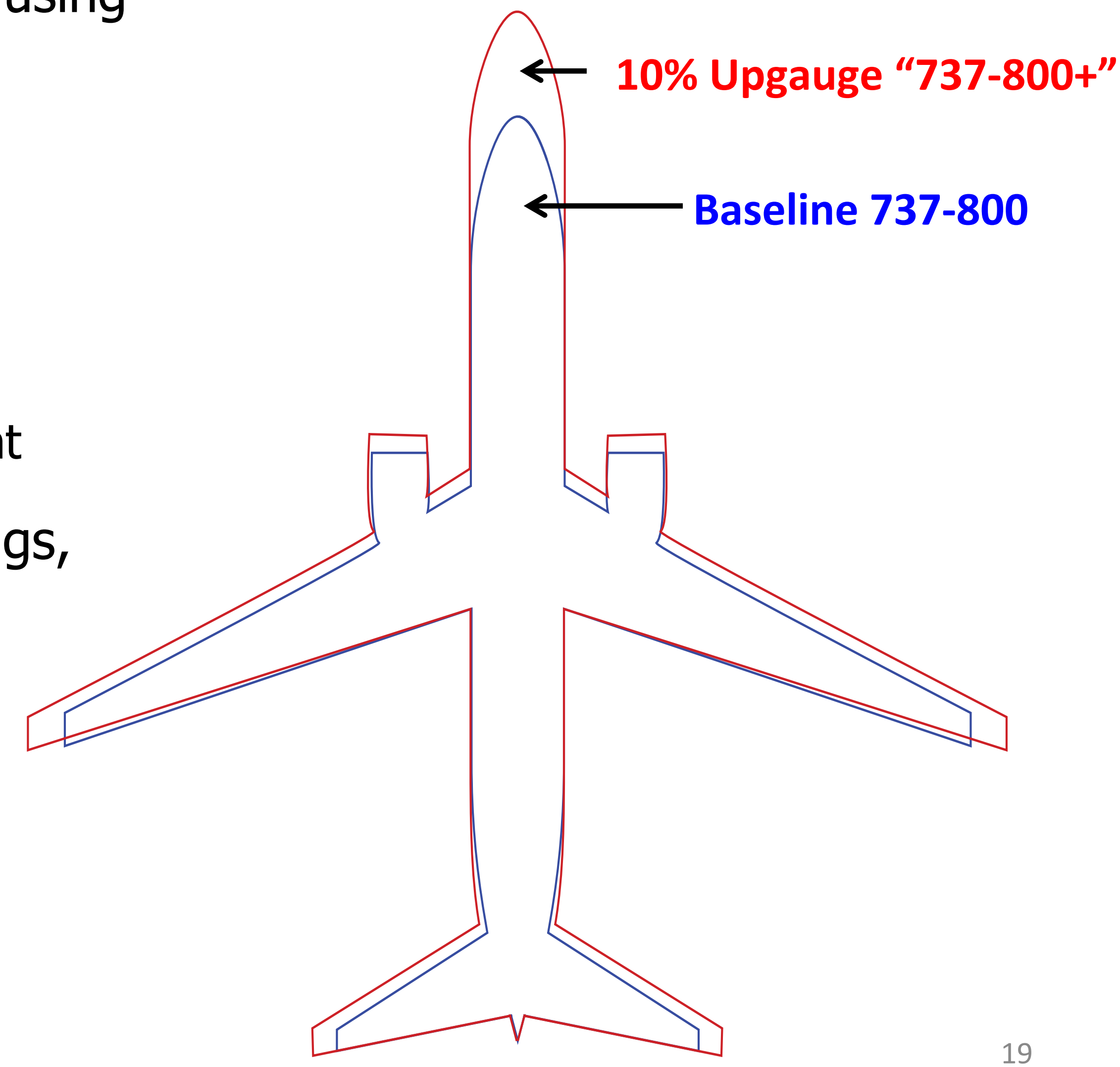
- Upgauging may be driven by several factors:
  - Existing industry trends and forces
  - Environmental policy goals and regulations
- Rapid environmental analysis tool will be used to evaluate gauge-change scenarios
  - Noise
  - Emissions (CO_2, NO_X)
  - Air quality
- Airport-level and system-level impact analysis of gauge change policies will be examined



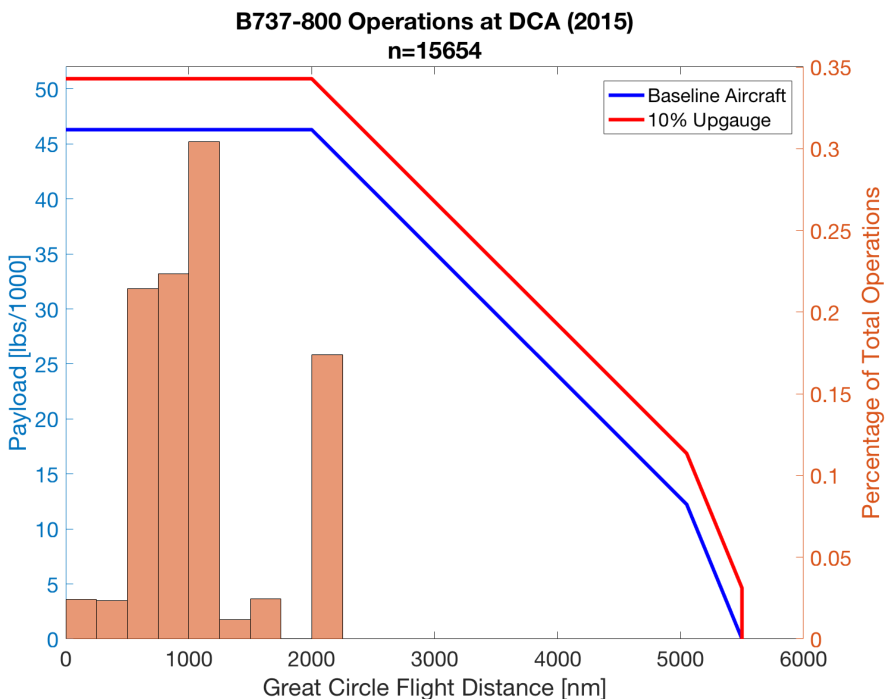
Aircraft Upgauge Process

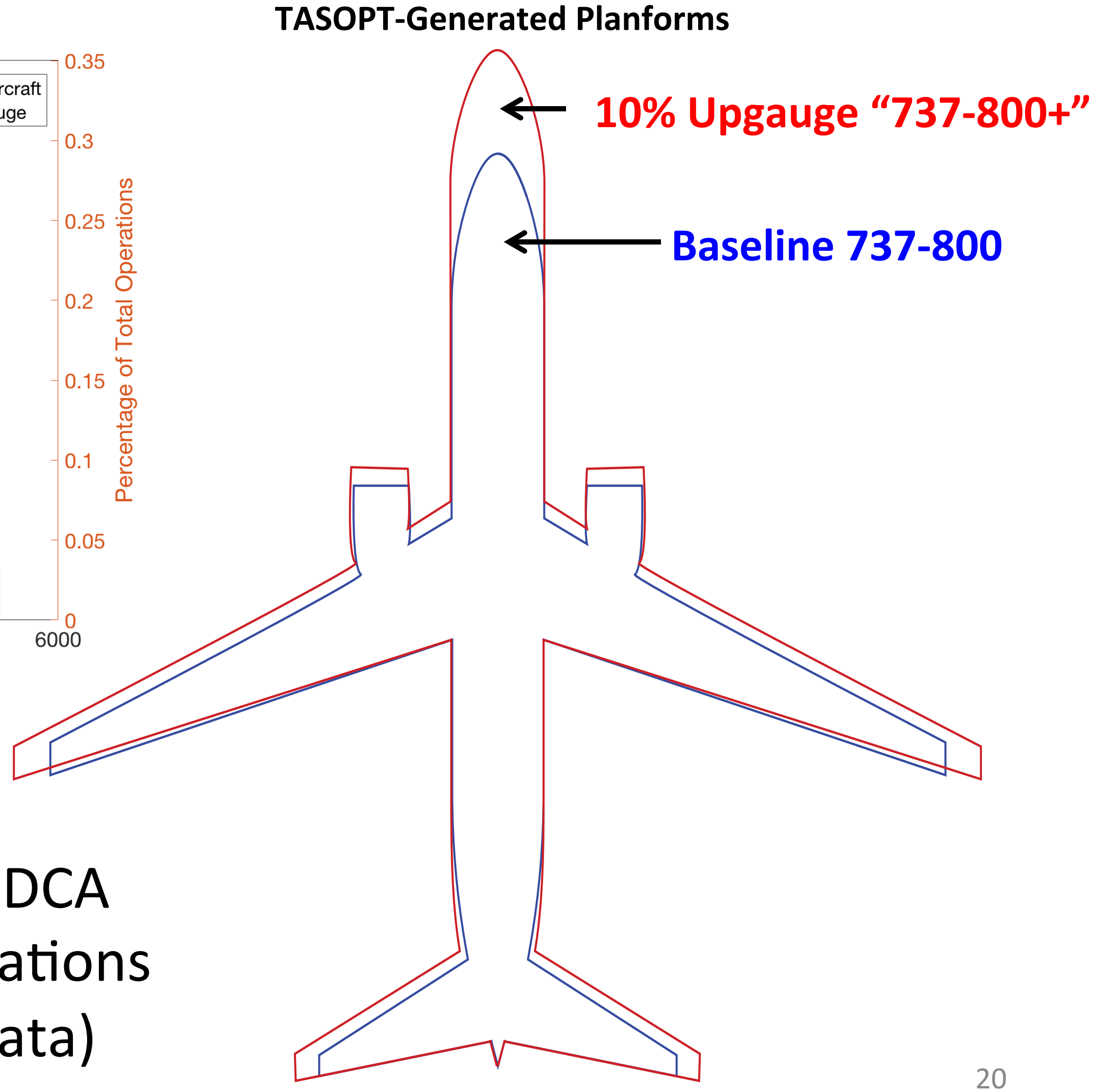
- Upgauged fleet generated using TASOPT constrained-optimization approach
  - Floor area and payload increased by 10%
  - Range held constant
  - Structural and engine technologies held constant
- TASOPT sizes engines, wings, and tail for new aircraft

TASOPT-Generated Planforms



Boeing 737-800 Upgauge Example





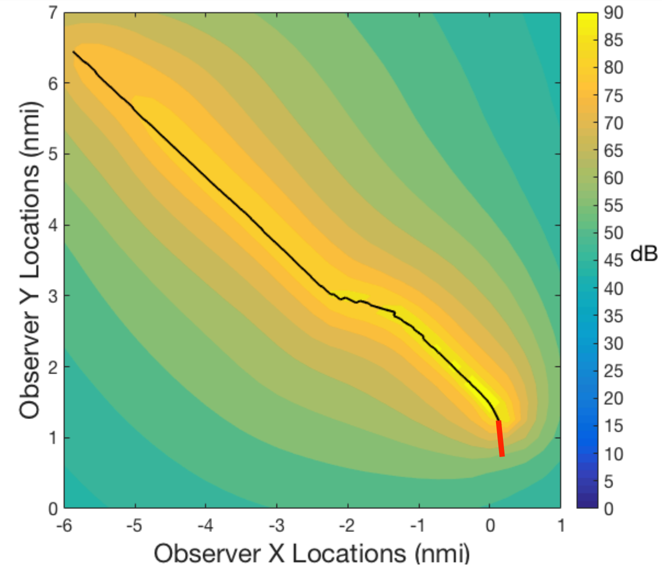
Upgauging the 737-800 at DCA would impact 15,654 operations annually (based on 2015 data)

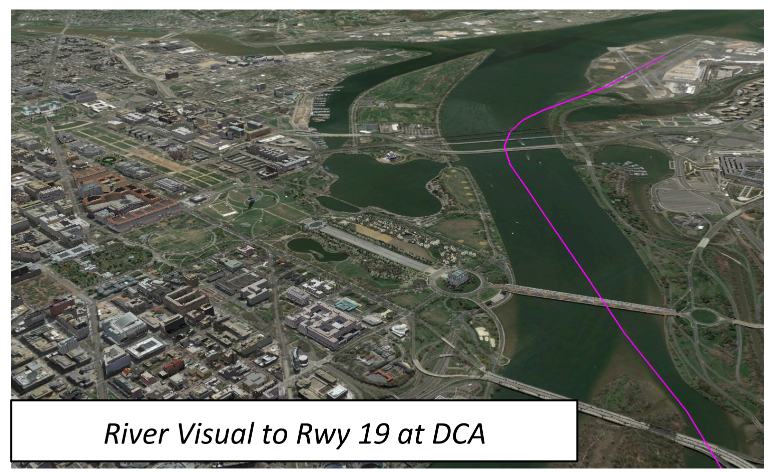
Generating Single-Event Noise Grids

- ANOPP-TASOPT noise tool used to generate single-event noise grid for notional fleet
  - Baseline and upgauged fleet mixes
- Pre-calculated single-event noise grids for a variety of flight procedures, aircraft types, etc.
  - e.g. River Visual Rwy19, ILS Rwy01 at DCA, representative departure profiles
  - Runway allocation for procedural analysis based on historical runway configuration data (ASPM)
- Database of SEL grids can be combined quickly to form integrated noise contours

Example Single-Event Noise

Sound Exposure Level from 737-800 Rwy19 Arrival





River Visual to Rwy 19 at DCA

Summary

- Surrogate modeling techniques, such as the surface modeling approach, allow rapid environmental analysis for aviation systems
- Next steps
  - Continue development of noise sample problem to demonstrate capability of approach
  - Complete integration of TASOPT and ANOPP for use in noise reference problem training dataset
- Key challenges
  - Addressing dimensionality of aviation environmental analysis
    - Identifying classes of problems that can be analyzed using surface modeling approach
    - Selecting appropriate high-fidelity input models and variables for desired problem classes

Rapid Fleet-wide Environmental Assessment Capability

Project 11B

Project manager: Joe DiPardo, FAA

Lead investigator: Michelle Kirby, Georgia Institute of Technology

April 26-27, 2016
Alexandria, VA

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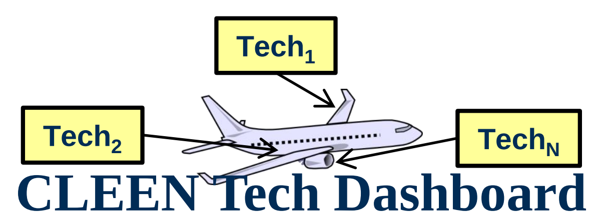
Motivation for ASCENT Project 11B

- To complement AEDT with a lower fidelity **screening** tool capability that allows for consideration of a **large number** of **technology scenarios** that could be quickly analyzed and reduced to a manageable set of scenarios for more focused, high fidelity analysis in the environmental tools suite
  - Provide quick means of quantifying impact of new technologies applied at the aircraft level to assess fleet-wide **interdependencies** on fuel burn, emissions, and noise
- Requires linking/leveraging several necessary components from previous PARTNER efforts
  - PARTNER P-14:
    - Global Regional Environmental Aviation Tradeoff (GREAT) tool
    - Airport Noise Grid Interpolation Method (ANGIM)
    - Generic airport models
    - Generic vehicle models
  - PARTNER P-36
    - CLEEN technology dashboard
- These tools require further development and connectivity to provide rapid scenario analysis capabilities to complement AEDT



Objectives

- Develop an interactive environmental decision making tool to complement AEDT with a screening capability for quicker analysis of a large number of policy scenarios
- Extend and link capabilities of previously developed tools: Global and Regional Environmental Aviation Tradeoff (GREAT) Tool and the Airport Noise Grid Integration Method (ANGIM)
- Add Census data to include population and housing unit exposure counts to current noise capabilities
- Enhance user experience
- Validate GREAT against AEDT scenarios, specifically the recent 2015 GATBA noise analysis

Outcomes and Practical Applications

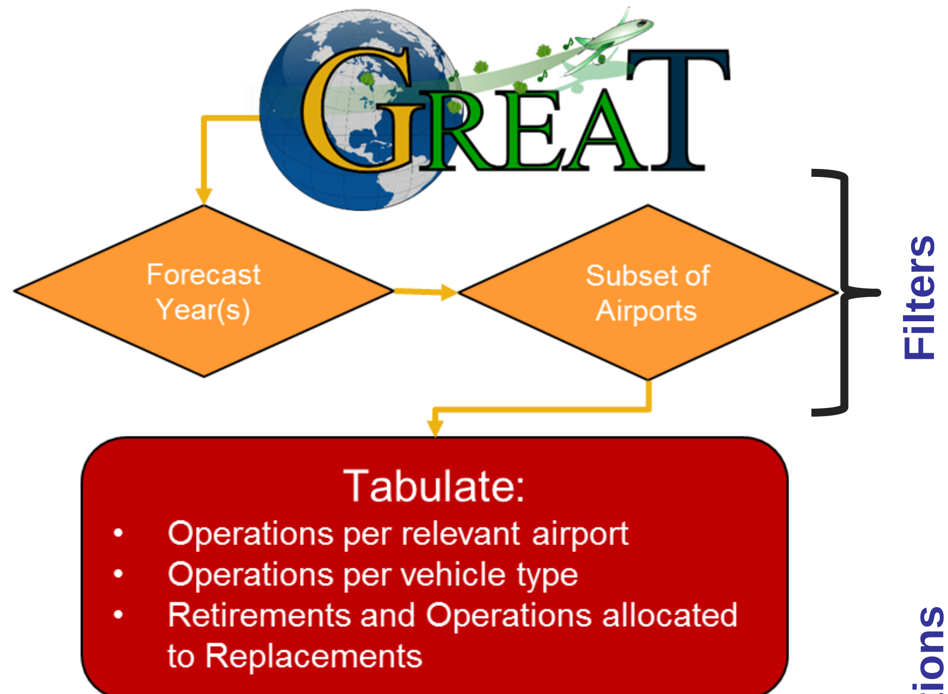
- Outcomes
  - Monthly progress reports
  - GREAT Enhancement list includes but not limited to:
    - Customizable retirement curves
    - Options to run noise with Actual or Generic airports
    - Comparison tab for overlaying results from different scenarios
    - Inclusion of out-of-production vehicles in noise analysis
    - Normative forecasting techniques for top-down assessment
  - Updated GREAT and ANGIM user's manual
  - Validation of GREAT against noise Goals and Targets Benefit Assessment (GaTBA)
- Practical applications
  - Screening-level analysis of:
    - Technology insertion (e.g. CLEEN)
    - Goal setting
    - Trends scenarios for AEE

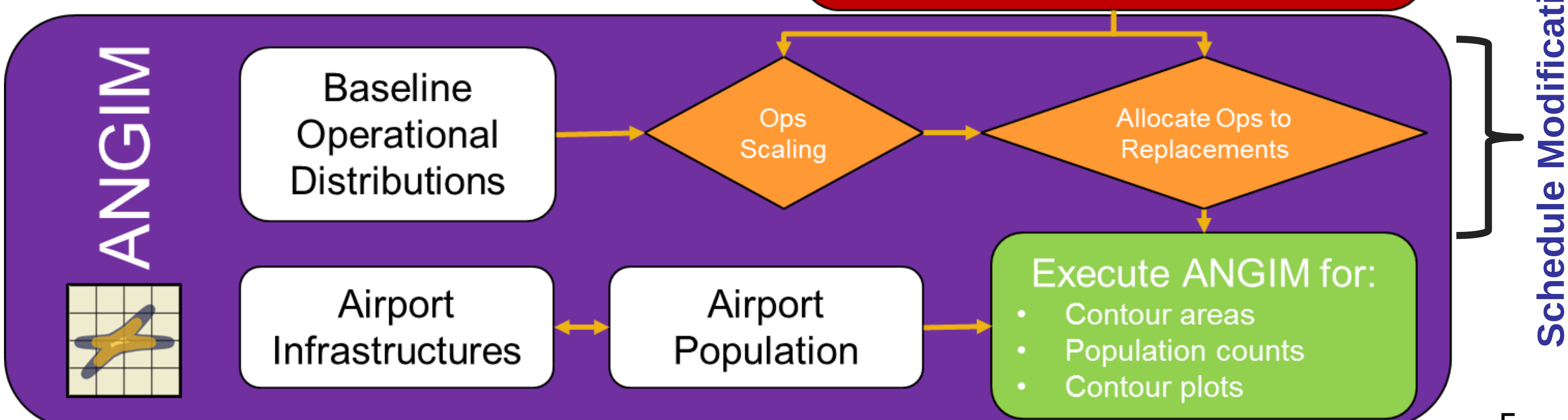
Approach

- GREAT is the primary engine for fuel burn and NOx based on a user specified forecast

- ANGIM created specifically to model noise

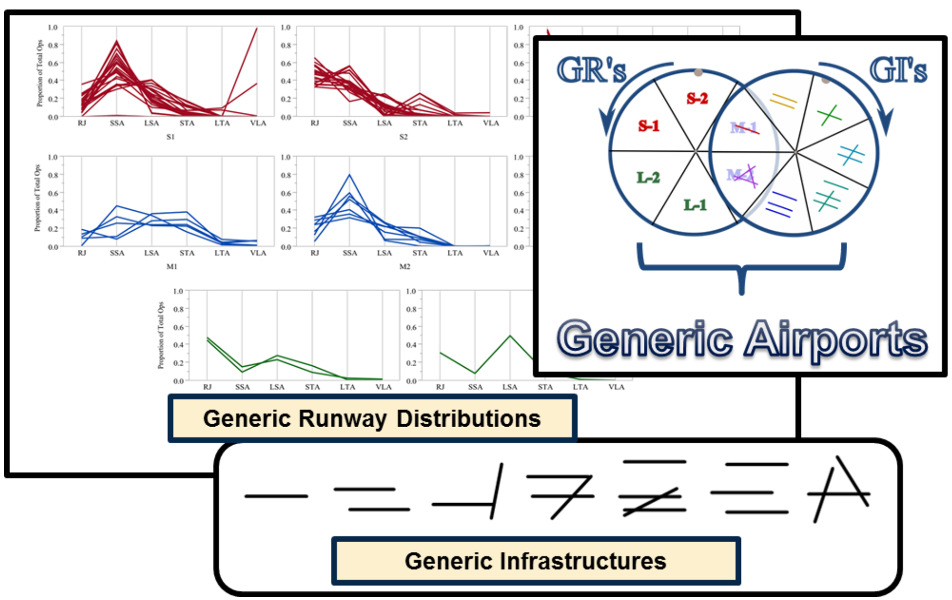
- User can run both together or separately

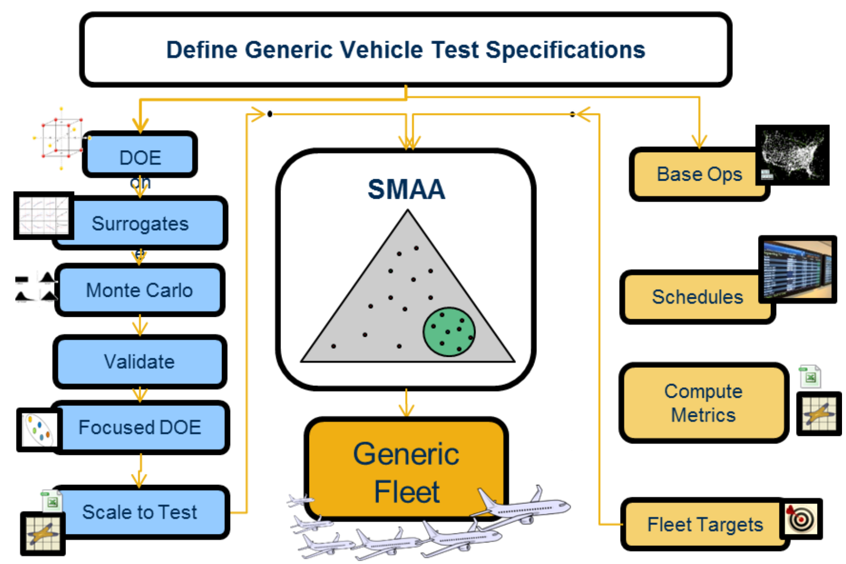




Approach - Generic Methods

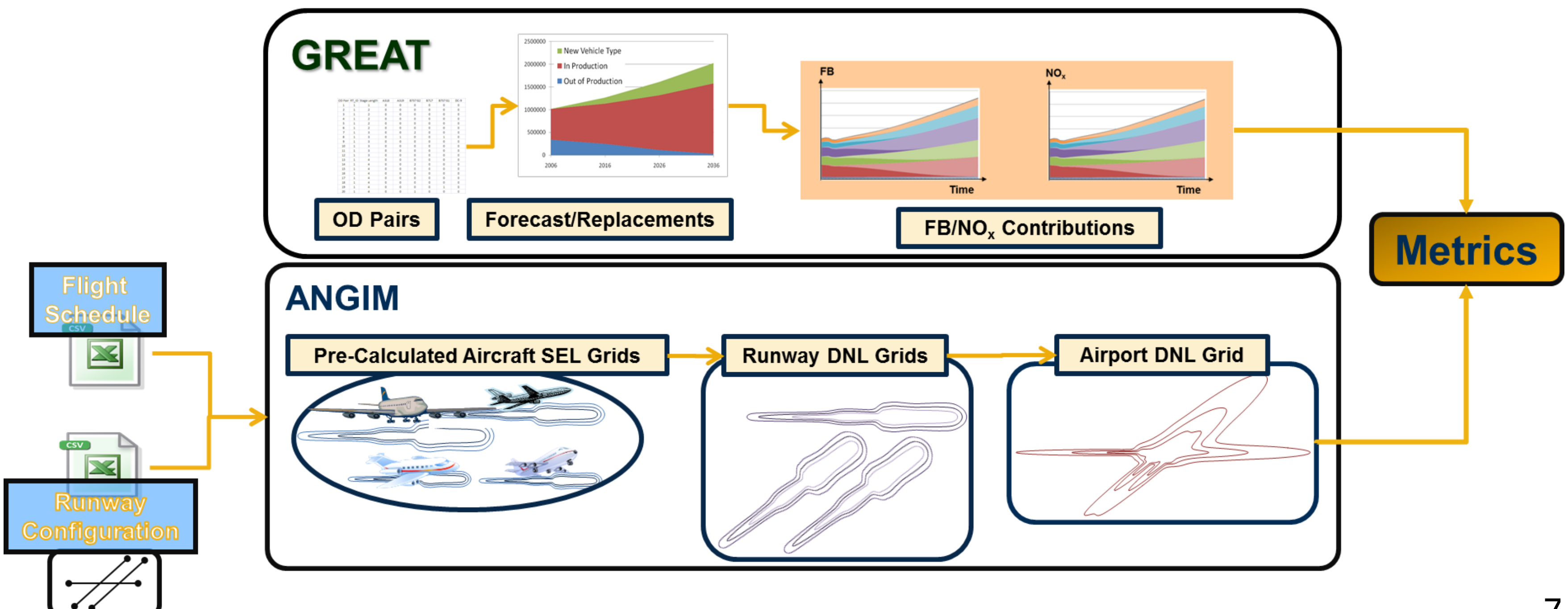
- Methods developed to enable *increased flexibility* for analyzing *technology infusion scenarios* by exchanging fidelity for reduced runtimes
  - **Generic Airports (Jose Bernardo's PhD thesis)**
    - Reduced major airports to a subset of airports that represent average operational schedules and runway geometry/configurations
  - **Generic Vehicles (Keith Becker and Matthew Levine theses)**
    - Reduced fleet to a few vehicles matching average vehicle-level metrics per vehicle class ➔ Improved fleet-level accuracy relative to typical representative vehicles
    - Generic vehicles serve as virtual testbed for technology modeling for use in bottom-up exploratory fleet-level analysis





Approach - Previous Tools

- Methods developed to enable *rapid analysis* of fleet-level environmental impacts
  - **G**lobal and **R**egional **E**nvironmental **A**viation **T**radeoff (**GREAT**)
    - Metrics: Fuel-Burn, NO_x
  - **A**irport **N**oise **G**rid **I**nterpolation **M**ethod (**ANGIM**)
    - Metrics: Grids of DNL values, DNL contours (measures areas & shape metrics)
    - In the past year added 2010 Census block data at 94 airports



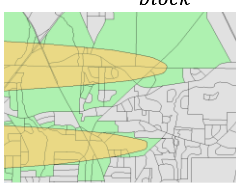
Schedule and Status

- GREAT forecast/assumptions/options update: Dec. 2014 (Complete)
- GREAT-ANGIM Connectivity: Feb. 2015 (Complete)
- Beta version of GREAT-ANGIM environment: June 2015 (Complete)
- GREAT-ANGIM Connection for Actual Airports: July 2015 (Complete)
- Scenario Comparison Tab: August 2015 (Complete)
- Inclusion of out-of-production vehicles for noise analysis: October 2015 (60%)
- Incorporation of Normative Forecasting: Spring 2016 (15%)
- GREAT comparison against GATBA: Late Spring 2016 (15%)

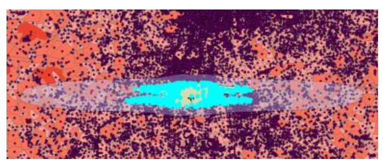
Recent Accomplishments: Tradeoffs for Various Population Methods*

- Learned pros and cons for various population methods
  - Prefer quasi-continuous methods to connect contour area improvement with population exposure improvement
  - At fine resolution (Census blocks), uniform population distribution is a reasonable assumption
- Settled on Thiessen polygon grid approach and **created step-by-step pictorial manual** for exporting population grids from ArcGIS

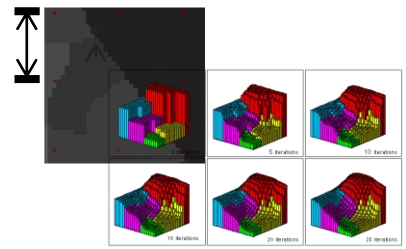
$$Pop_{Exposed} = \frac{Area_{intersect}}{Area_{block}} \times Pop_{block}$$



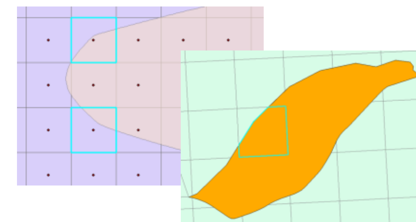
ArcGIS Contour Overlay



Centroid Method



Rasters with Pycnophylactic Interpolation



Thiessen Polygon Grids

PopType	PopMethod	Population Exposed DNL-65dB	Housing Units Exposed DNL-65dB	Population Exposed DNL-55dB	Housing Units Exposed DNL-55dB
CENSUS BLOCKS	ArcGIS Contour-Overlay (Area-Ratio)	Reference	Reference	Reference	Reference
CENTROID	Centroids within ANGIM Contour	6.65%	5.16%	-1.71%	-1.69%
GRID	1x Resolution Raster	-6.39%	-6.44%	-6.52%	-7.59%
GRID	15x Resolution Raster	1.76%	1.94%	-0.17%	-0.23%
GRID	15x Resolution Raster with Pycnophylactic Interpolation	2.01%	2.44%	-0.54%	-0.36%
THIESSEN POLYGON GRID	Overlay Thiessen polygons from ANGIM grid points with Census Blocks and use Area-Ratio	1.73%	1.91%	-0.17%	-0.24%

Relative Difference

* Matthew Levine's thesis goes into more detail on this process. Available upon request)

Recent Accomplishments: Population Exposure Comparisons

- Generated Thiessen Polygon grids of population and housing units from 2010 Census Blocks for **all** MAGENTA 95 airports
- Ran 2010 operational schedules for following:
  1. Actual in-production Vehicles (~2.5 hours)
     - No out-of-production vehicles, but conserve total operations per airport
     - Subject to ANGIM assumptions (Standard day sea-level atmo, straight ground tracks)
  2. Generic Vehicles (~4.5 min)
     - One "average" vehicle per class (RJ, SSA, LSA, STA, LTA, VLA) – 6 vehicles, typical approach for technology forecasting
     - Subject to ANGIM assumptions
  3. Representative Vehicles as a point of reference for Generic Vehicles (~4.5 min)
     1. Chose one AEDT database vehicle with most operations per class – 6 vehicles
     2. Subject to ANGIM assumptions
- Generic vehicles provide **significantly better estimates** of contour areas and exposure counts than the representative vehicles at comparable runtimes
- Grid trimming has **reduced disk space required** and significantly **shortened runtimes**

		Actual Vehicles	Generic Vehicles		Representative Vehicles	
		Cumulative Totals	*Cumulative Totals*	*Relative Error*	*Cumulative Totals*	*Relative Error*
DNL 65-dB Contours and Exposure	*Contour Area [nmi]*	180.63	183.90	1.81%	204.49	13.21%
	Population	254351.79	250146.15	-1.65%	318036.63	25.04%
	Housing Units	93406.45	92212.39	-1.28%	118279.71	26.63%
DNL 55-dB Contours and Exposure	*Contour Area [nmi]*	1183.38	1168.82	-1.23%	1377.62	16.41%
	Population	4551725.30	4395745.92	-3.43%	5421434.79	19.11%
	Housing Units	1776190.35	1714786.82	-3.46%	2127172.12	19.76%

Applications of GREAT

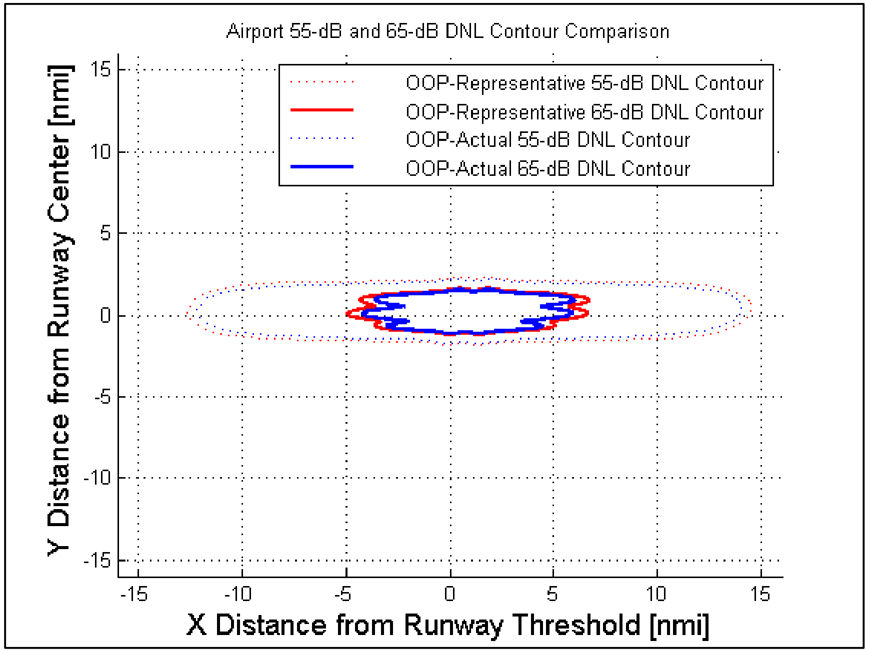
- Two potential applications of GREAT are:
  - Inclusion of out of production aircraft noise
  - GATBA comparison
- Each application requires some development before the application can be started
  - A methodology is needed to assess the noise implications of varying out of production (OoP) vehicles retirement rates without sacrificing run-time or accuracy
  - GATBA requires consistency in the assumptions of the fleet evolution, operations baseline, and technology improvement

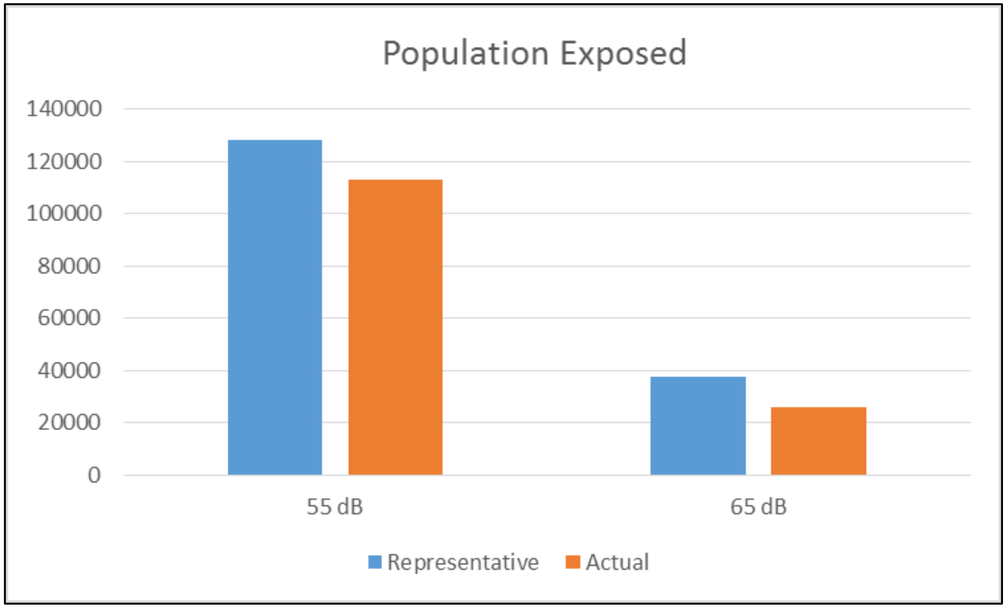
Out-of-Production Vehicle Noise

- For In-production vehicles, the use of Generic Vehicles greatly reduces runtime
- The GV approach is challenging to apply to the OoP aircraft types, without going through the GV generation process
- Including all Out-of-Production vehicles in noise may counteract the runtime benefits gained from reducing the number of grids required for ANGIM Approach
- Two-pronged approach take:
  - "Representative Out-of-Production vehicles"
    - Classified the OOP AC Families by seat class and chose one representative vehicle per class based on the frequency of flights – **COMPLETED**
  - Out of Production families
    - Classify similar noise signature aircraft together to develop a small set of "families" to represent the OoP fleet – **IN PROGRESS**
- Examined 2010 schedules at 4 airports (only 2 shown here for brevity) and compared this approach to the results with the use of the actual OOP vehicles
- **NOTE**: the contours shown are **NOT** the actual flight tracks of the aircraft. Contours are based on the assumptions of ANGIM of straight in-out tracks and standard day atmosphere

Large Hub Airport: Representative OoP Comparison

Preliminary results. NOT to be cited or quoted



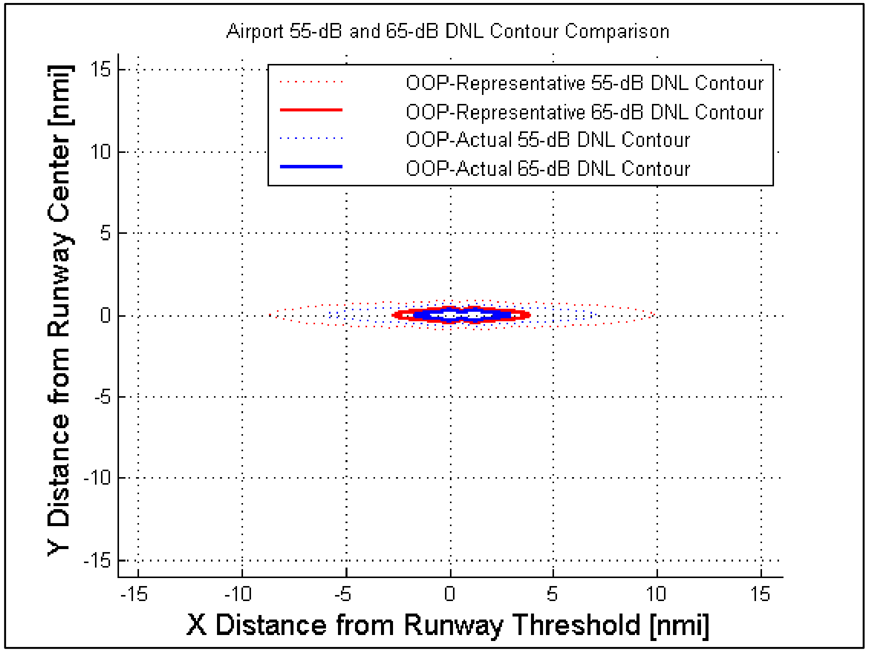


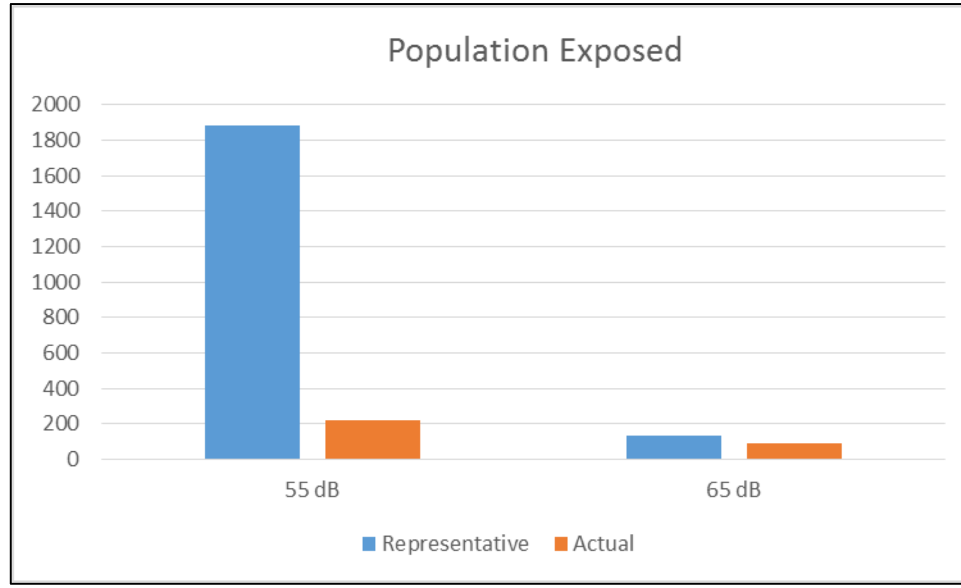
- Representative approach leads to over-prediction of contours, primarily observed at closure points for this large hub with a large surrounding population

- Population exposure is also over predicted at the DNL 65-dB by ~45%

Small Regional Airport: Representative OoP Comparison

Preliminary results. NOT to be cited or quoted





- Representative approach leads to over-prediction of contours, primarily observed at closure points
  - More pronounced than at the other airports, but contours and population exposure counts are much smaller at this airport
  - Airport dominated by B717 operations, more ops by Out-of-Production aircraft than In-production; very typical of small airports

- Population over-prediction is more significant for DNL 55-dB than for DNL 65-dB, although the actual number of people exposed is small in comparison to the Large Hub on the prior slide

Summary of Status of OoP Noise Capturing

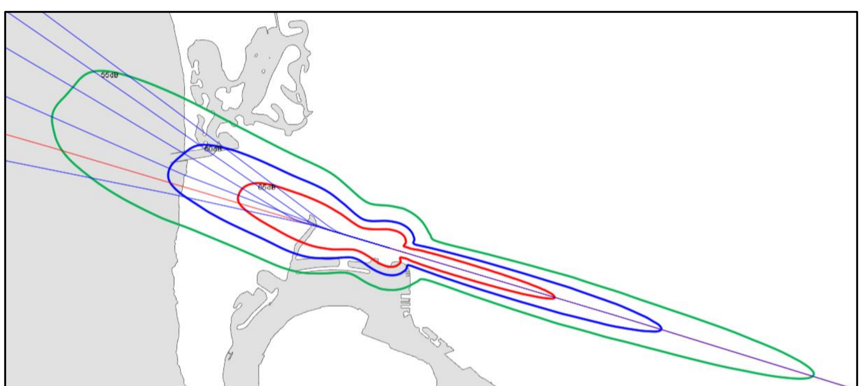
- Representative approach does not do well at capturing noise for 2010 schedules
  - Ideally would like to have Average Generic Out of Production aircraft, but it is not worth the resources to develop
  - When investigating varying retirement rates of OoP aircraft, this approach would over inflate the savings due to over estimates of noise exposure in the test cases
- However, most of these vehicles are no longer in the schedule after 2030 and for runtime savings, they representative approach could be used after 2030
- Alternative method being researched is a family approach based on similar noise signatures and operational frequencies – **IN PROGRESS**

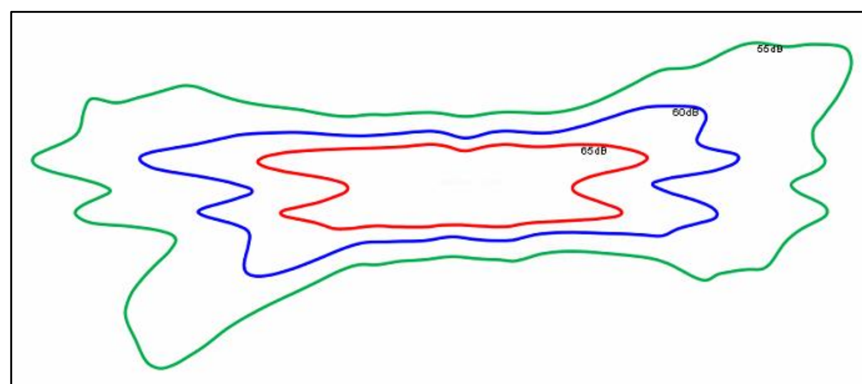
2016 Tasks and Goals Through June

- Updated Tool Release
  - Release along with training (June 2016)
  - Provide updated User's Manual and training materials including use cases
  - Incorporate additional library entries of future vehicles to explore a multitude of technology scenarios
- Current Focus on Tool Development
  - Streamline the forecast/assumptions/data
  - New functionalities
  - Improve user friendliness
  - Incorporation of all major OoP aircraft noise
  - Incorporating normative techniques including equivalencies for noise analysis
- Validation of GREAT against Goals and Targets Benefit Assessment (GaTBA)

FAA Goals and Targets 2015

- Motivation:
  - Conduct a side by side comparison of GREAT to AEDT 2b for the GATBA noise study results
- Assessed fleet-wide impacts noise from airframe and engine improvements in the 2030 timeframe
- Scope
  - Used TAF-M
  - Analysis conducted for 2012 and 2030
  - Metrics for Shell I airports:
    - 65, 60, and 55 dB DNL area
    - Population exposure to 65dB DNL
    - Population exposure/payload capacity
- Two example airports that were modeled are provided below





GATBA Analysis Status

- GT received GATBA AEDT data from Volpe and restored the DBs in the server in March 2016
- Development efforts are focused on syncing the assumptions to actually run the analysis → Matched AEDT and GREAT aircraft and airports
- Reproducing GATBA results without military and GA operations for apples to apples comparisons
- Initial comparisons at KSAN and KATL show reasonable match in contour areas for year 2012
- GT will expand the analysis to other airports and the analysis year 2030
- Completion of the comparison expected in June

Interfaces and Communications

- External
  - NASA ERA project
  - Talks
  - Publications
  - Other groups you are working with
  - Etc.
- Within ASCENT
  - P10
  - P37
  - Volpe and FAA
- Publications
  - José E. Bernardo, Matthew J. LeVine, Michelle Kirby, and Dimitri Mavris, “Analysis of Aircraft Vehicle Class Contributions to Airport Noise Exposure”, Journal of Aerospace Operations, Accepted, Awaiting Publication. (doi: not yet available)
  - José E. Bernardo, Michelle Kirby, and Dimitri Mavris, “Probabilistic Assessment of Fleet-Level Noise Impacts of Projected Technology Improvements”, Journal of Air Transport Management, Under Review, (doi: not yet available)
  - Amelia J. Wilson, Matthew J. LeVine, Jose Enrique Bernardo, Michelle Kirby, and Dimitri N. Mavris. “Development of Generic Ground Tracks of Performance Based Navigation Operations for Fleet-Level Airport Noise Analysis”, 15th AIAA Aviation Technology, Integration, and Operations Conference, AIAA Aviation, (AIAA 2015-3029), doi:10.2514/6.2015-3029
  - Matthew J. Levine, “A framework for technology exploration of aviation environmental mitigation strategies,” PhD Thesis, Georgia Institute of Technology, Dec 2015

Summary

- Working to improve capabilities and user-interface of previously delivered version of GREAT with ANGIM
  - Expanding tool capabilities derived from PARTNER P-14
  - Linking capabilities together to provide one-stop source for fleet-level analysis with interdependencies between metrics
- Next steps include:
  - Evaluating best approach for incorporation of noise signatures of Out-of-Production vehicles without sacrificing runtime or accuracy
  - Incorporating normative techniques including equivalencies for noise analysis
  - Populating a library of technology vehicles to explore a multitude of technology scenarios
  - Comparing integrated GREAT/ANGIM capabilities to AEDT scenarios from GATBA analysis
- Key challenges include:
  - Adding more modularity without sacrificing computational speed
  - Debugging multiple integrated codes in different languages (C#, VBA, etc.)
  - Ensuring a complete understanding of the GATBA analysis so as to identify differences in results

References

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- Generic Airports
  - Bernardo, Kirby, & Mavris, "Development of Generic Airport Categories for Rapid Fleet-Level Noise Modeling," Journal of Aerospace Operations, TU Delft, Accepted Jan. 2015
- Generic Vehicles
  - LeVine, Wilson, Kirby, & Mavris, "Development of Generic Vehicles for Fleet-Level Analysis of Noise and Emissions Tradeoffs," AIAA Aviation 2014, Atlanta, GA AIAA 2014-2731 (preparing for submission to AIAA Journal of Aircraft)

Contributors

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Aircraft Technology Modeling and Assessment

Project 10

Project manager: Arthur Orton, FAA
Georgia Tech (Lead University): Dimitri Mavris (PI), Jimmy Tai (Co-PI)
Purdue: Daniel DeLaurentis, William Crossley (PI's)
Stanford: Juan J. Alonso (PI)

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Overview

Objective: : Define range of scenarios that bound the demand for future aviation activity and assess the effects of different fleet composition and aircraft technology on fuel burn, emissions, and noise from aviation

- Evaluate broad set of future scenarios out to 2050, showing potential benefits of technology on fuel burn, emissions, and noise
- Provide modeling and assessment mechanism for aircraft technology
- Support NextGen Goals Analysis, other analyses

Approach:

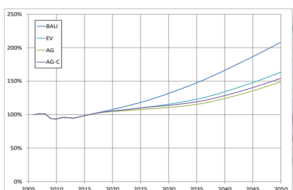
1. Develop a set of harmonized fleet assumptions for use in future fleet assessments;
   - Workshops/consensus building among academia, government, industry
2. Model advanced aircraft technologies and advanced vehicles expected to enter the fleet through 2050; while
   - Leveraging, heavily, previous modeling work in CLEEN, NASA programs – and filling gaps as necessary for scenarios developed in (1)
3. Perform vehicle and fleet level assessments based on input from the FAA and the results of (1) and (2).

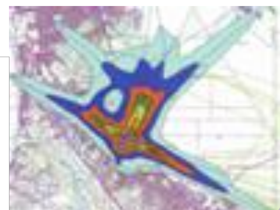
Studies will be performed by each university team using in-house expertise and tools in complementary areas.

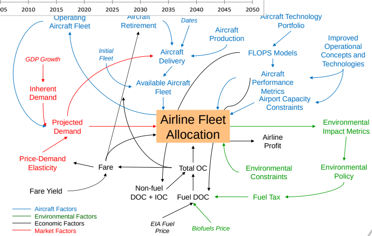
ASCENT-10 Project Focus Areas

Fleet Benefits Assessment

- Use each university's analysis tools to understand fleet level implications of advanced technology on
  - Fuel Burn
  - Emissions
  - Noise







Ascent 10 Team

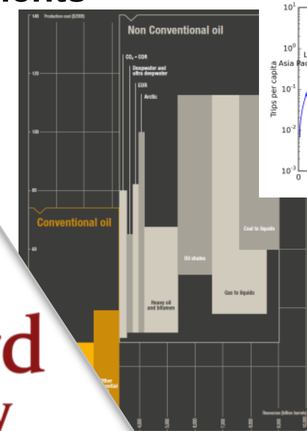
Georgia Institute of Technology

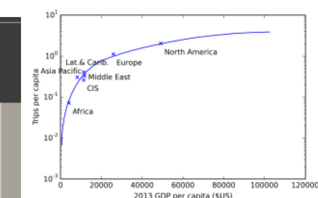
Purdue University

Stanford University

Technology Assessment Assumptions Setting

- Work with broader community to define a standardized set of technology and fleet modeling assumptions for future benefits assessments





FAA CLEEN System Level Assessments

- Work with CLEEN industry contractors to perform vehicle and fleet benefits assessment to show impact of CLEEN technologies

Subsystem Technology Impacts → Technology Effects on Vehicle → Fleet Level Implications

Team Approach to Tasks

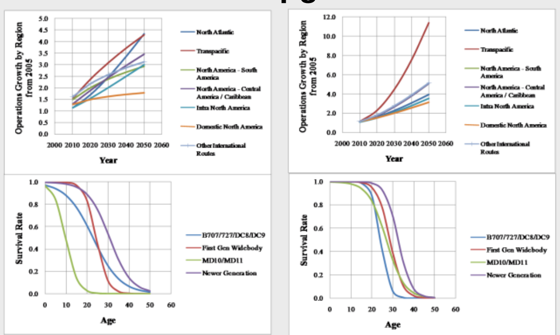
Objectives		Georgia Tech	Stanford	Purdue
1	**Harmonize Fleet Assumptions**	Lead process, coordinate industry, government participation, provide basis for discussion	Support assumptions definition, provide expert knowledge	Support assumptions definition, provide expert knowledge
2	**Advanced Vehicle and Technology Modeling**	CLEEN GE proprietary technology modeling, additional public domain technology modeling, Provide tech models to Stanford and Purdue	Input into public domain technology modeling	N/A
3	**Vehicle and Fleet Assessments**	Perform vehicle and fleet level assessments for CLEEN and public domain technologies	Provide trade factors for mission specification changes. Provide tech factors for some tech modeled in (2)	Sample problem demonstrating capabilities of FLEET (Fleet-Level Environmental Evaluation Tool)

DEVELOPMENT OF FLEET & TECHNOLOGY MODELING ASSUMPTIONS

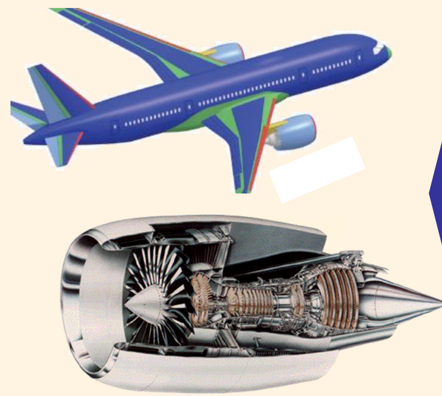
Fundamental Assumptions & Approach

Operations

- Demand Forecast
- Aircraft Retirements
- Replacements Schedule
- New Product / Upgrade

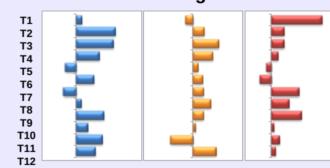


Vehicle Analysis



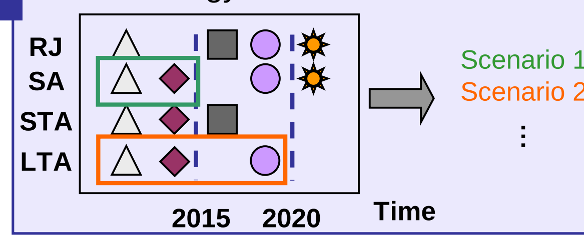
Technologies

- Benefit
- Applicability
- Availability



Technology Evolution

Scenarios



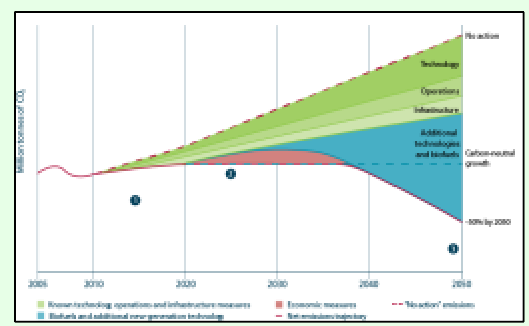
Vehicle Performance Characteristics

FLEET or GREAT

Fleet Analysis

- FB/Operation
- Total Ops
- Total FB

Fleet Impact



Task 1

- A series of workshops to help define fleet assumptions and scenarios that will serve as the basis for future fleet environmental assessments
  - Engaging experts in industry, academia, and government to bound the future with a range of scenarios
- Scope:
  - Commercial passenger aviation, today through 2050
  - *Demand* – what factors affect passenger demand for air travel and thereby the operations forecast?
  - *Fleet evolution* – when will there be new products when technologies can be applied?
  - *Technology* - Aircraft technologies, new aircraft configurations, mission specification changes **(PUBLIC)**
- Outcome will be a public-domain document to capture different fleet evolution scenarios
  - Will be used as basis for analysis in this project, as well as leveraged by other projects (e.g. Goals and Targets Benefits Assessment)

Workshop Strategy

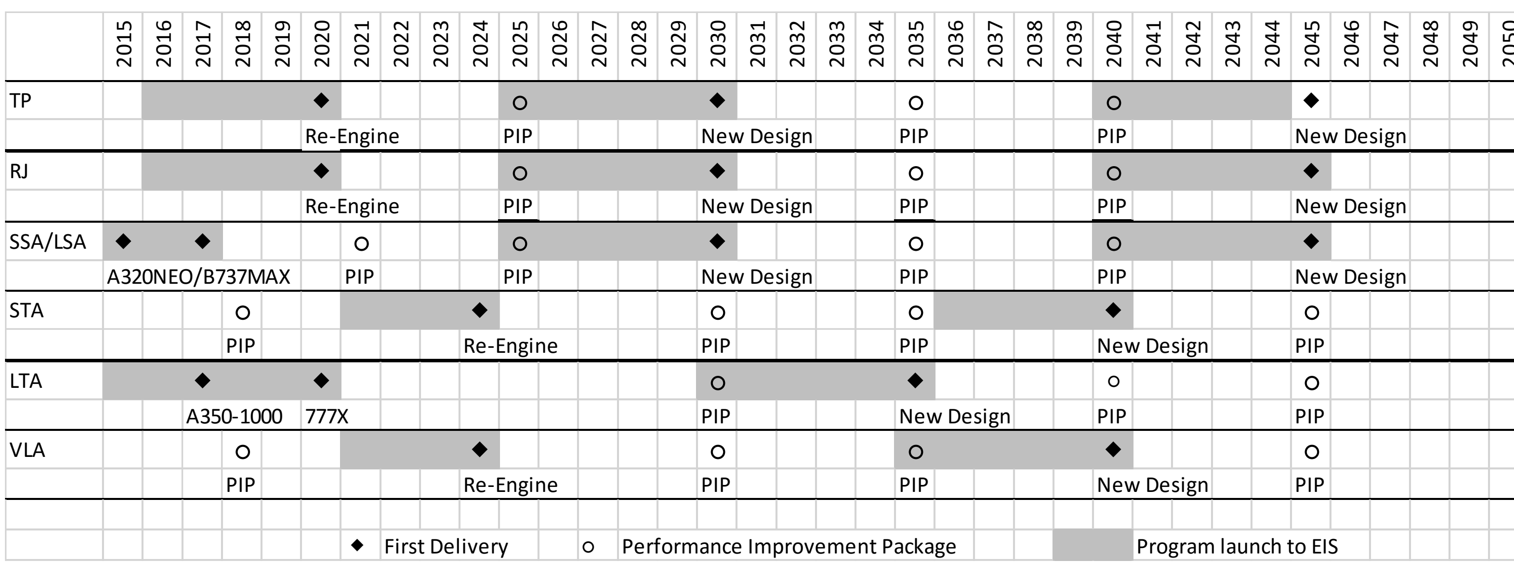
- **Fleet Workshop 1 – *May 14, 2015***
  - Goal: Determine what defines a world view or scenario
  - Feedback on descriptors (variables, ranges, and importance)
  - Bring forward initial worldviews for comment
- **Fleet Workshop 2 – *August 27, 2015***
  - Goal: Gather information to select specific worldviews/scenarios of interest
  - Feedback on technology insertion opportunities and their timing, aircraft life, production rates
  - Feedback on proposed worldviews and scenarios
- **Technology Workshop(s) 1 – *June 10-11, 2015***
  - Goal: Identify technology maturation and availability for a broad range of technology areas (e.g. wing design, engine core noise)
  - Feedback on examples of 1st/2nd/3rd generation technologies
  - Provide specific examples of technologies for feedback
  - One session on airframe + operational technologies
  - Another on engine + operational technologies
- **Technology Workshop 2 – *February 16, 2016***
  - Goal: Consensus on technology evolution scenarios
  - Feedback on specific technology impacts and maturation rates

Participants thus far: The U.S. Air Force, Airports Council International – North America, Booz Allen Hamilton, Boeing, Department of Transportation Volpe Center, Embraer, FAA Office of Environment and Energy, FAA Office of Aviation Policy & Plans, Georgia Tech, Honeywell, Lufthansa, Mitre, NASA, Pratt & Whitney, Purdue, Rolls-Royce, Stanford, Textron Aviation and Virginia Tech, General Electric

Workshop 2 - Fleet Evolution

- Formulate structure for aircraft introduction, retirement, replacement
- Questions to participants centered on:
  - Aircraft life in future
  - Development program duration
  - Development program timing
  - Future production rates, backlogs
- Results combine with technology availability to "build" future aircraft and introduce into fleet

Example:



Workshop 2 - Scenarios

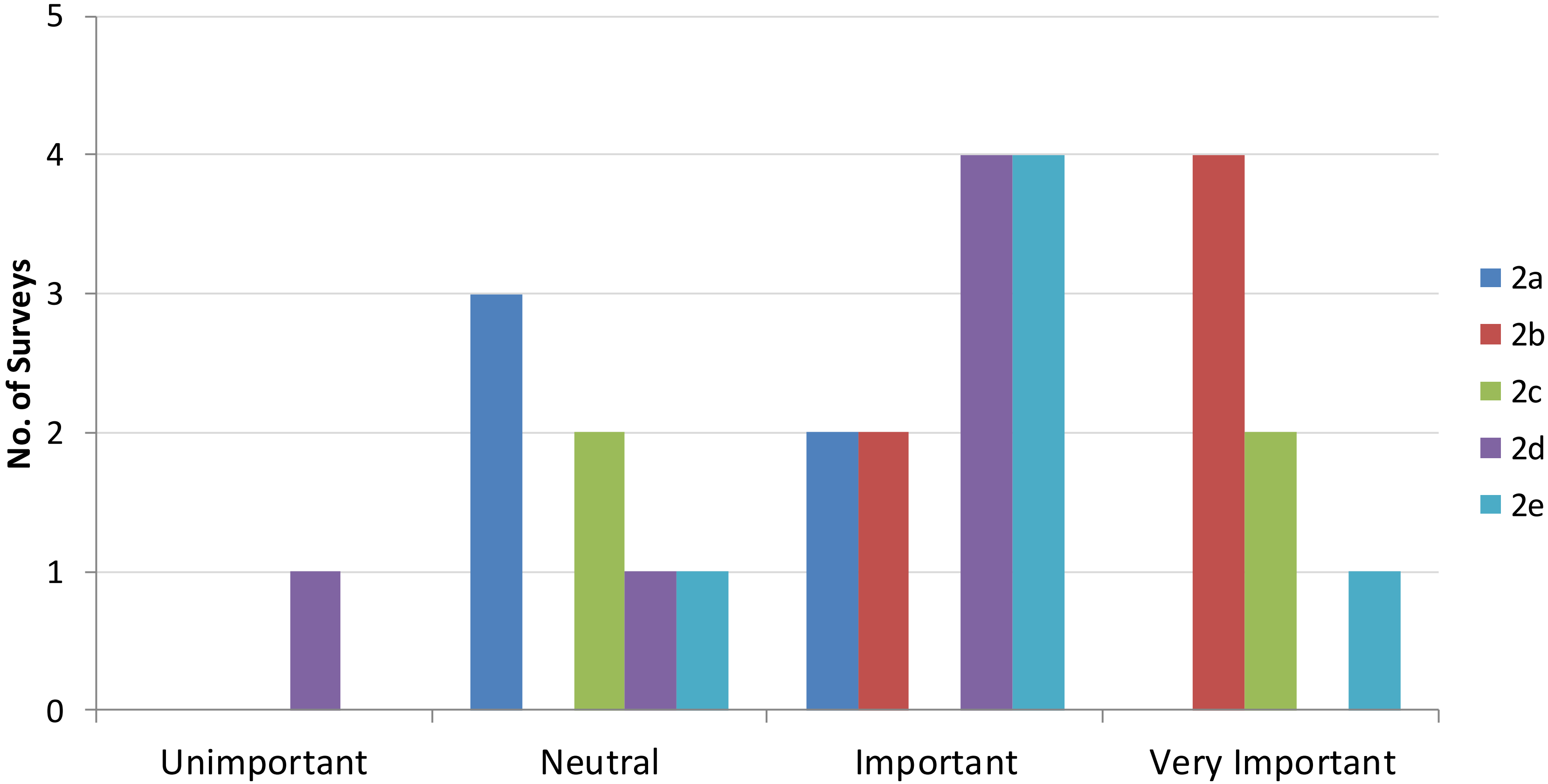
- Proposed a large range of potential scenarios
- Current Trends/High Demand/Low Demand
- Environmentally Constrained
  - Various scenarios with combinations of emissions costs, noise capacity limits, energy price
- Environmental "Bounds"
  - True bounding of futures with extreme descriptor values

All include various technology R&D rates

Requested feedback on descriptor values selected, priority and "usefulness" of each sub-scenario

Workshop 2 - Scenarios

Example

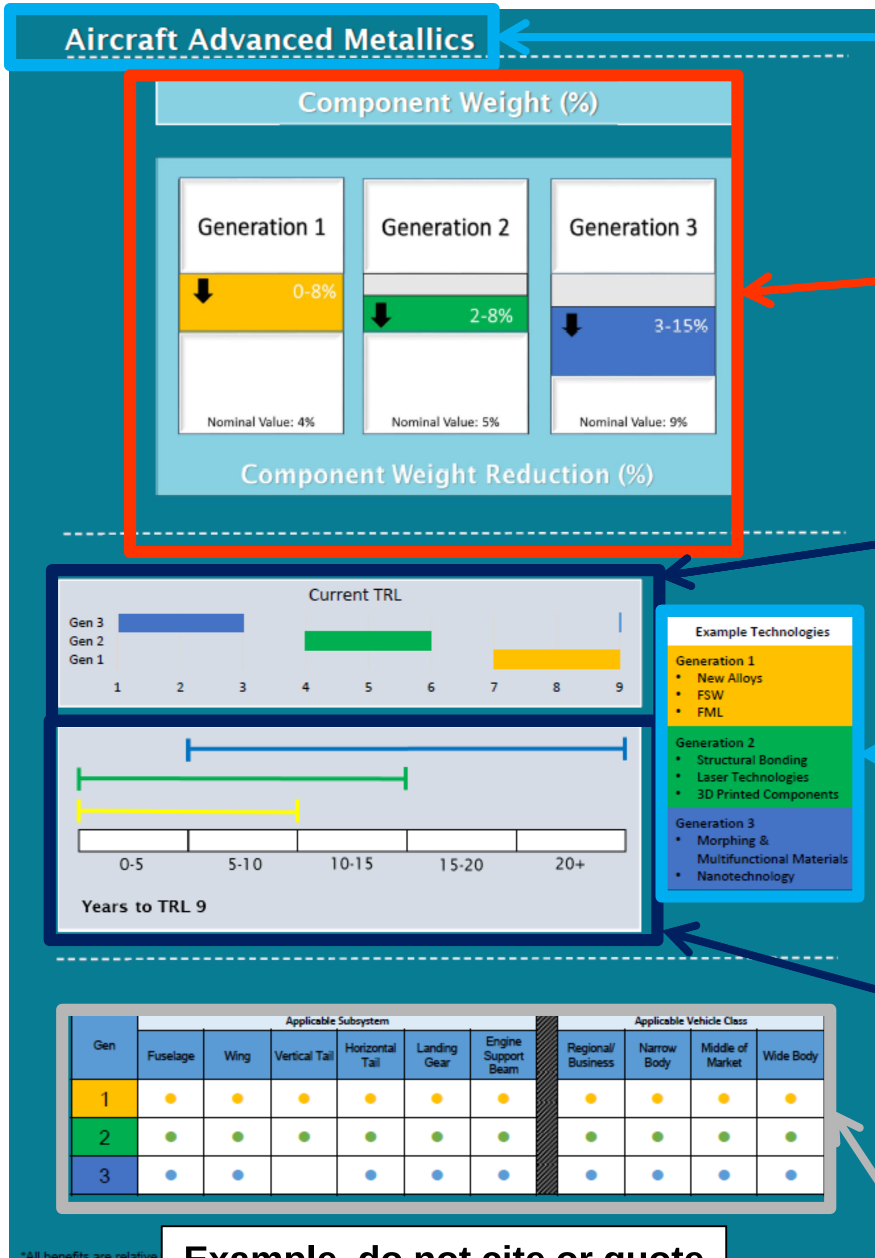


2a: High Demand Domestic Focus
2b: High Demand Global Focus
2c: High Demand Airport Capacity Limits
2d: High Demand Low R&D Investment
2e: High Demand Fast Technology Adoption

Scenarios

- Workshop feedback being used to formulate recommended scenarios
- Scenarios currently under consideration
  - Current Trends
  - Variations
    - Environmental “Bounds” – Low/High
    - Demand – Low/High
    - Aircraft Technology – Low/High R&D
  - Downselected to no more than a dozen interesting scenarios with meaningful descriptor settings and combinations
- Working on producing final scenario descriptions including specific time series data

Format of Technology Scenario Presentation



Example, do not cite or quote

Technology Area

Technology Impact Area & Impact Ranges

- Top lists technology impact area
- Applicable vehicle class and subsystems
- Generation 1, 2, and 3 impact ranges (three point estimate)

Current TRL

- Lists current TRL for each technology generation

Example Technologies

- Lists potential examples of applicable technologies by generation

Time to TRL 9

- Shows high and low estimates on time from present to bring each generation of a technology from the current generation to maturity

Applicable Vehicle Classes & Subsystems

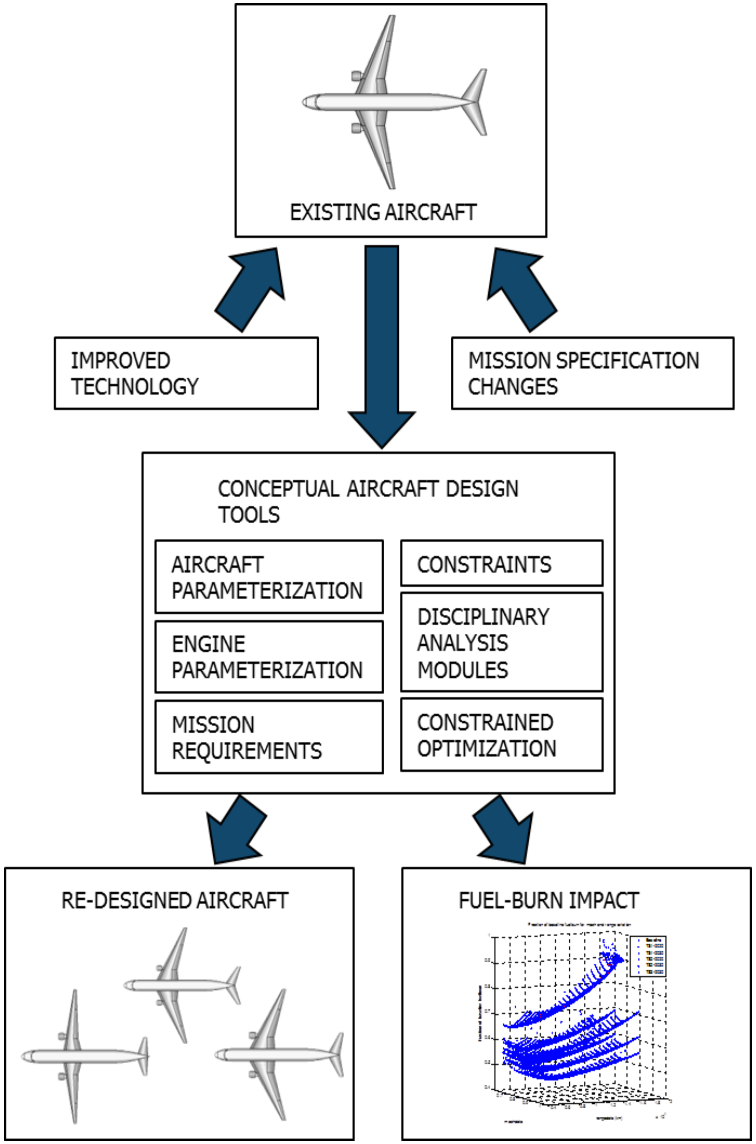
Next Steps

- Analyze data and develop set of scenarios
- Present finalized scenarios in report
- Run quantitative assessment of selected scenarios

MISSION SPECIFICATION CHANGES

ASCENT Task 2 overview

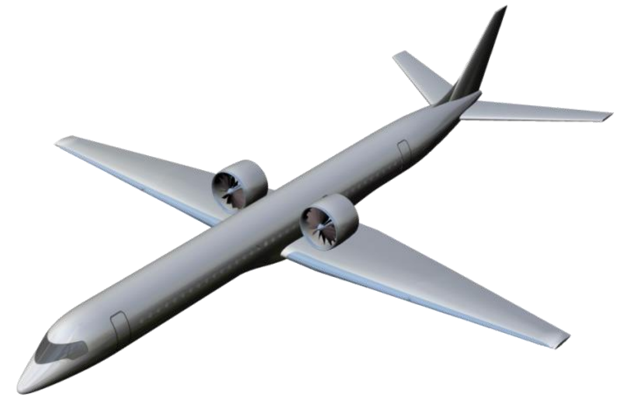
- Some of the emerging world views and scenarios resulting from the ASCENT 10 fleet and technology workshops (particularly the “High R&D” and “Environmental Bounds” worldviews) call for innovative solutions
- **Mission specification changes are operational improvements**, including aircraft and engine redesign, that can lead to significant fuel savings
  - **Cruise Mach number reductions**
  - Changes to Payload/Range capabilities
  - Maximum allowable span
- PARTNER Project 43, investigated system-level implications using our best tools at the time. Improved tools and system-level analyses are now available during ASCENT Project 10 to refine the quality of the results

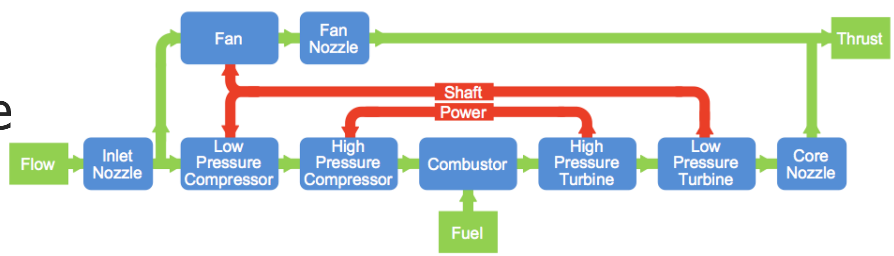


SUAVE Conceptual Analysis and Design Framework

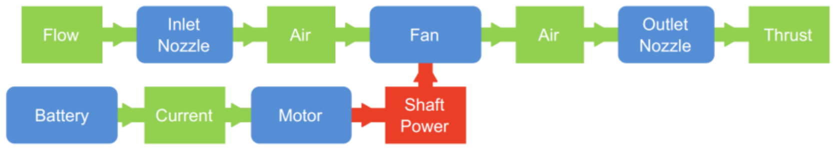
- **SUAVE** has been created from the ground up with improved accuracy (through multi-fidelity approaches) and versatility in mind
- **Reach credible design conclusions for future aircraft** with advanced technologies at the conceptual level
- **Manage innovative energy networks** including traditional and carbon-free propulsion systems in one analysis tool
- **Highest fidelity conceptual** design tool we have developed thus far. Many improvements in analyses
- **Optimization-based** solutions with appropriate objectives, parameters, and constraints

Electric Regional Aircraft Hybrid Design



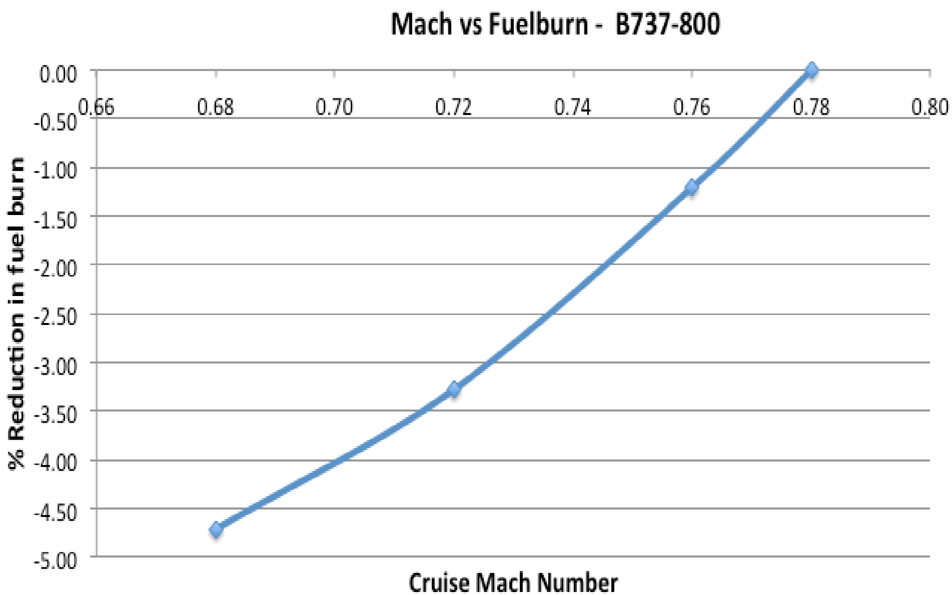


Turbofan Energy network



Li-Air Battery-Electric Energy Network

Cruise Mach Reduction Examples

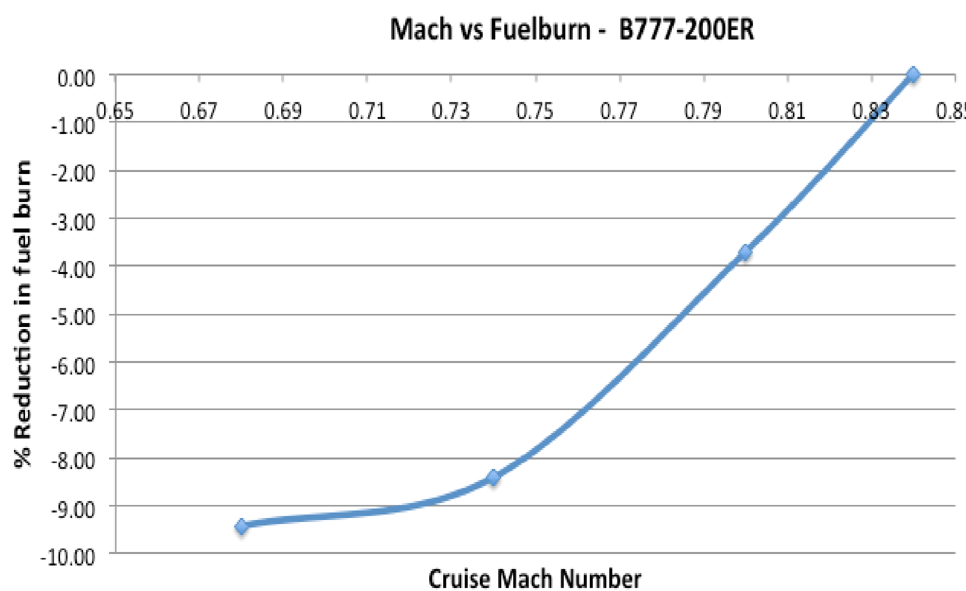


B777-200ER

- ~ 10% reduction in fuel burn possible
- Earlier P43 results indicated similar results
- Compromise in Mach reduction required for system-level / economic benefits
- Majority of benefits can be obtained with M 0.75 reduction

B737-800

- ~ 5% reduction in fuel burn possible
- Earlier P43 results indicated ~7%
- Constraints on propulsion system installation prevent further engine performance improvements
- Compromise in Mach reduction required for system-level / economic benefits



Summary of Design Trends – CSR

How are improvements achieved?

- For the **B737-800 + CFM56 at existing technology levels** a fuel burn reduction of 4.7% is obtained by reducing the cruise Mach to 0.68
- The **wing reference area decreases** for lower Mach numbers (except for the baseline case) resulting in lower wing drag. TOFL is the active constraint in selecting wing area
- The **wing sweep decreases significantly** accompanied by an **increase in the t/c ratio**, helping to reduce the wing weight. Wing weight reduced by approximately 8%
- The **LPC pressure ratio increases** and the FPR and the bypass ratio hits their upper bounds. Given the OPR is held constant, the HPC pressure ratio decreases as cruise Mach is reduced
- **Fan diameter** (for installation), **OPR, TOFL are all active constraints**. Additional improvements possible (up to 7-9%) for novel engine installation and improvements in engine technology
- For the **B777-200ER + GE-90 at existing technology levels** a fuel burn reduction of 9.4% is obtained by reducing the cruise Mach to 0.68. The **trends are similar to the B737-800**

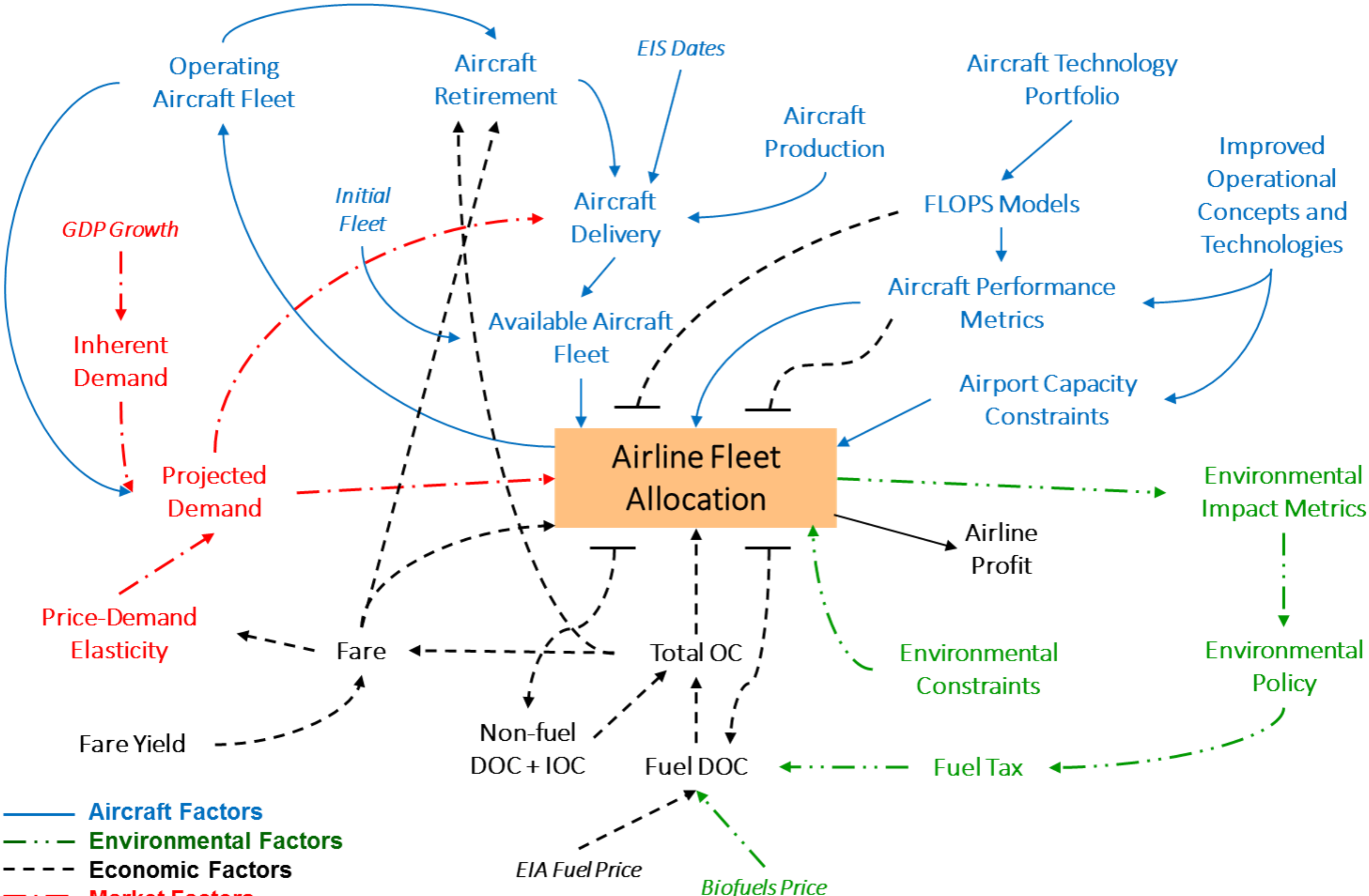
Ongoing Efforts

- Similar studies are being conducted for **all five aircraft classes**:
  - RJ: Embraer 190, CRJ900
  - SA: B737-800
  - STA: B767-300
  - LTA: B777-200ER
  - VLA: B747-400
- **Factors** over the baseline vehicle fuel burn can be included in fleet-level simulations including **all aircraft types** and **different payload/range combinations**
- **Similar trends observed in other aircraft classes** (smaller wing area, engine parameters against bounds, de-sweeping / increased t/c).
- **Decreased fuel burn due to CSR varies by aircraft class** with long range vehicles showing larger benefits
- **Validation and verification** (of engine and airframe results) continues with partners

TASK 3 FLEET ANALYSIS: GT'S GREAT AND PURDUE'S FLEET

Assess fleet-wide impacts under Scenarios generated in Task 1

- "FLEET": Fleet-Level Environmental Evaluation Tool
  - Measures the fleet-wide environmental impact from new aircraft concepts and technologies under various carbon policy scenarios, based on an approach that mimics airline behavior
  - Focus on "US-touching" operations – all routes have at least origin or destination in United States
  - Considers scenarios that vary technological, policy, and economic factors
  - Model-Based; Uses a 'system dynamics-like' approach to allow demand, fleet size/composition, and fares to evolve over time
  - Uses a core algorithm that optimally allocates aircraft to best meet fleet-level objectives of an airline
  - Runs reasonably fast (a few hours to analyze 45 year-long simulation period)



Operating Aircraft Fleet
Aircraft Retirement
EIS Dates
Aircraft Technology Portfolio
Aircraft Production
Improved Operational Concepts and Technologies
Initial Fleet
Aircraft Delivery
FLOPS Models
GDP Growth
Aircraft Performance Metrics
Inherent Demand
Available Aircraft Fleet
Airport Capacity Constraints
Projected Demand
Airline Fleet Allocation
Environmental Impact Metrics
Airline Profit
Price-Demand Elasticity
Fare
Total OC
Environmental Constraints
Environmental Policy
Non-fuel DOC + IOC
Fare Yield
Fuel DOC
Fuel Tax
Aircraft Factors
Environmental Factors
Economic Factors
Market Factors
EIA Fuel Price
Biofuels Price

FLEET distinguishing features

Modeling features	Effect on results
Use of a resource allocation problem to reflect how an airline would assign aircraft to routes	• Outputs metrics (aircraft utilization, emissions, etc.) at route-level resolution • Describes impacts of different operational and economic constraints on airline profitability
Leverage of the system dynamics stock-and-flow concept in a discrete-event implementation	• Effect of new technologies on fleet-level noise and emissions can be assessed
Use of carefully calibrated aircraft performance and cost models where available	• Show impact of an aircraft's economic performance on airline profitability and its utilization • FLEET fuel burn trend consistent with BTS reported fuel consumed
Use of a value-based model for aircraft replacement decisions	• Incorporates aircrafts' (existing vs. new) profit potential in fleet upgrade decision-making • Uses previous year's optimal fleet allocation in fleet turnover

ASCENT10 Scenario- FLEET Parameter Mapping- Run 1

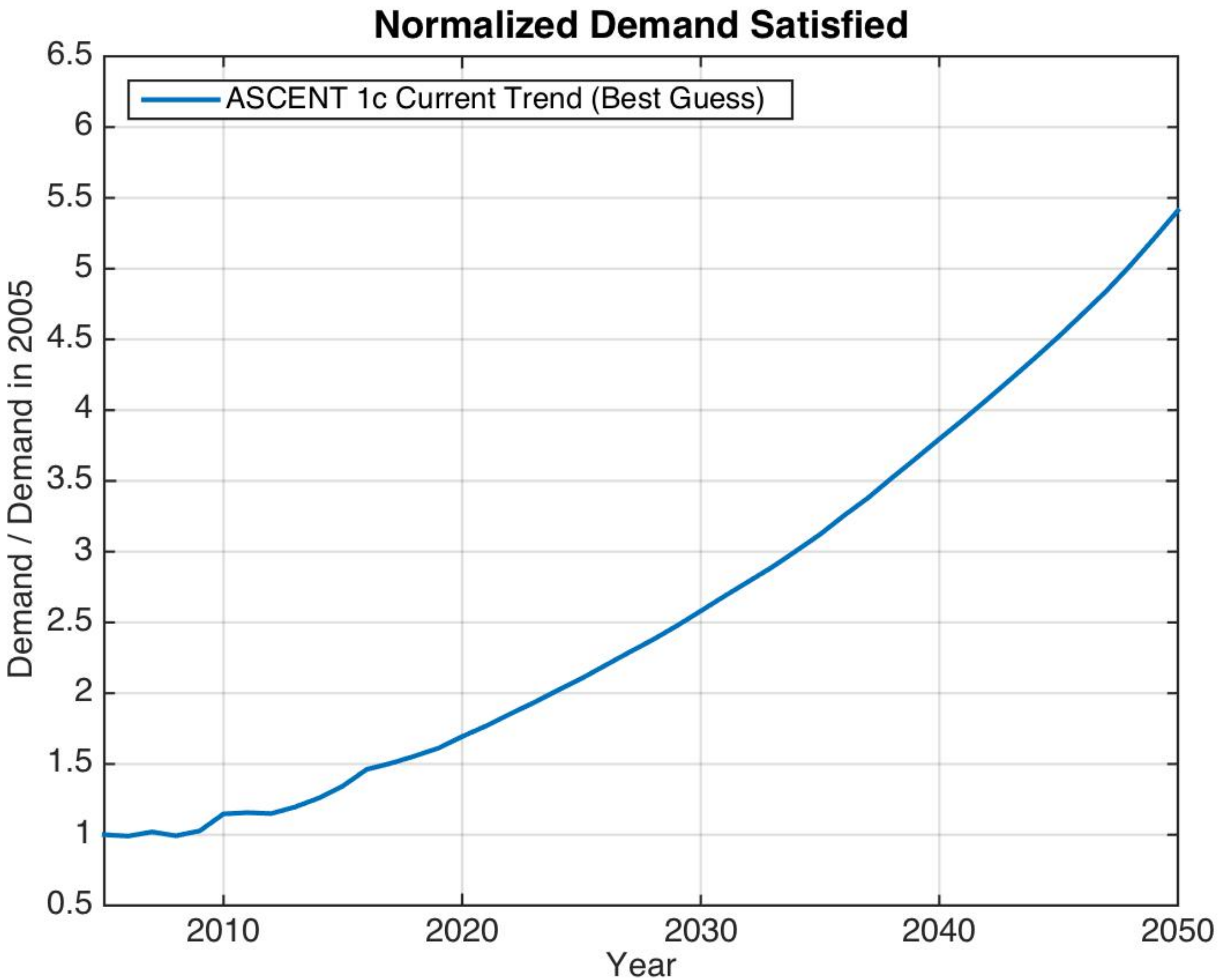
ASCENT 10 Scenario 1c Parameter	FLEET Parameter	Comment
GDP Growth (2.8%/year)	GDP Growth Rate (%/year)	Inherent Demand Growth = GDP Growth Rate * 1.4.
Energy Price ($77/bbl) in 2013 dollars	Fuel Price ($/gal) convert to Jet A price in 2005 dollars	Modified EIA reference fuel price scenario
Cost of CO_2 Emission ($21/MT)	Additional Fuel Price	Can add this cost to fuel price
Population Growth (0.58%/year)	Not used separately from GDP in FLEET	Demand Growth = GDP Growth * Factor. Factor can be adjusted if desired.
International Trade (4.3%/year Asia)	Not implemented	FLEET can adjust the demand growth factor for routes connecting US to Asia
Airport Noise Limitations (25% airports noise limited in future)	Noise Area Constraint imposed for each US airport	1. For FLEET, % of airport limited by noise would be an output 2. Refer to subsequent slides “Noise Area”
Industry Competitiveness (12cents/ASM)	Market Share Function in two-airline model OR Price Elasticity Model	1. If competitiveness between airlines, FLEET models via market share function. 2. If competitiveness between different modes of transportation, FLEET models with price elasticity.
Amount and Speed of Technology R&D Investment (relative) – 1.02	1. EIS dates of each new aircraft 2. Aircraft coefficients to represent new aircraft performance	Require inputs from ASCENT team

Red font in FLEET column indicates not yet implemented in Scenario Run 1

FLEET Parameters Setup- Scenario 1c- Run 1

- Economic Environment:
  - Constant 2.8% GDP growth rate
  - Modified reference EIA fuel price scenario
- Aircraft:
  - Aircraft fleet split across 6 aircraft classes
  - “Aggressive minus CLEEN” scenario aircraft models and EIS dates
  - The amount of aircraft delivered to the United States set at 23% of global aircraft production
- Scenario simulation from 2005 to 2050

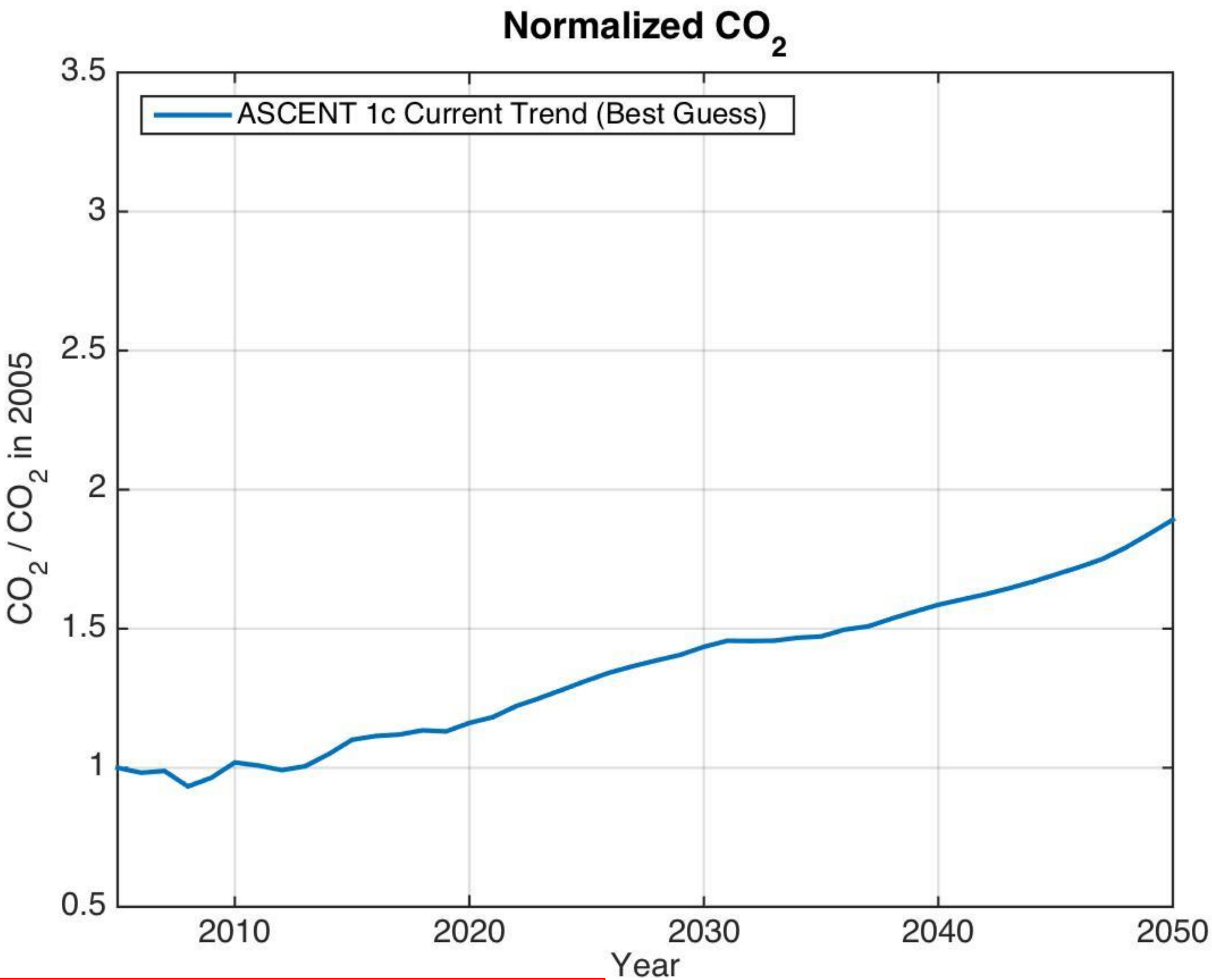
Normalized Demand Satisfied



Demand served grows, driven both by inherent demand growth and increasingly attractive offering by the airline with enhanced technology fleet.

***Preliminary Results, do not cite or quote**

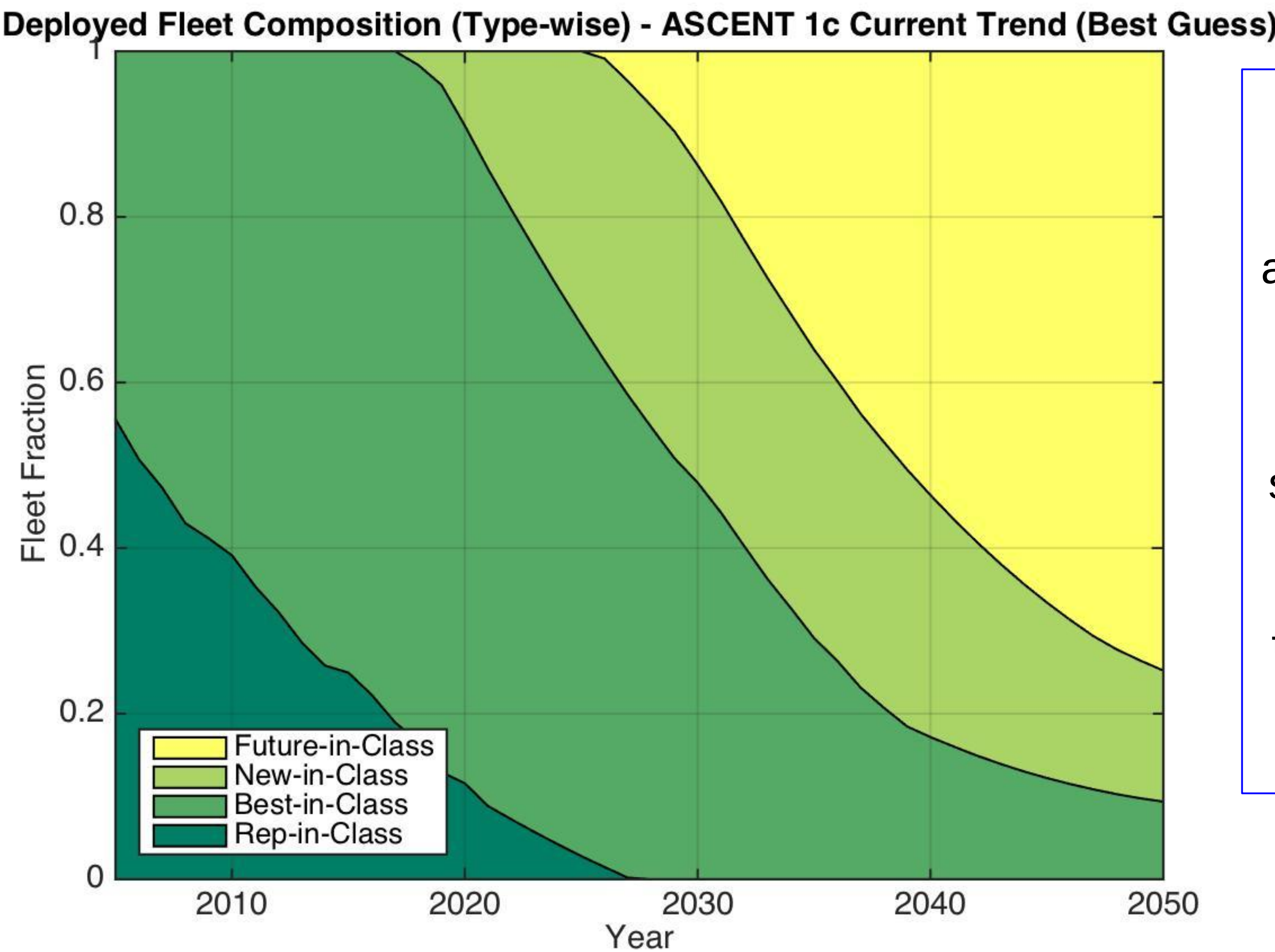
Normalized CO_2 Emission



*Preliminary Results, do not cite or quote

CO_2 grows as well, but at lower rate than demand given technology improvements and efficient resource allocation.

Deployed Fleet Composition (Type-Wise)

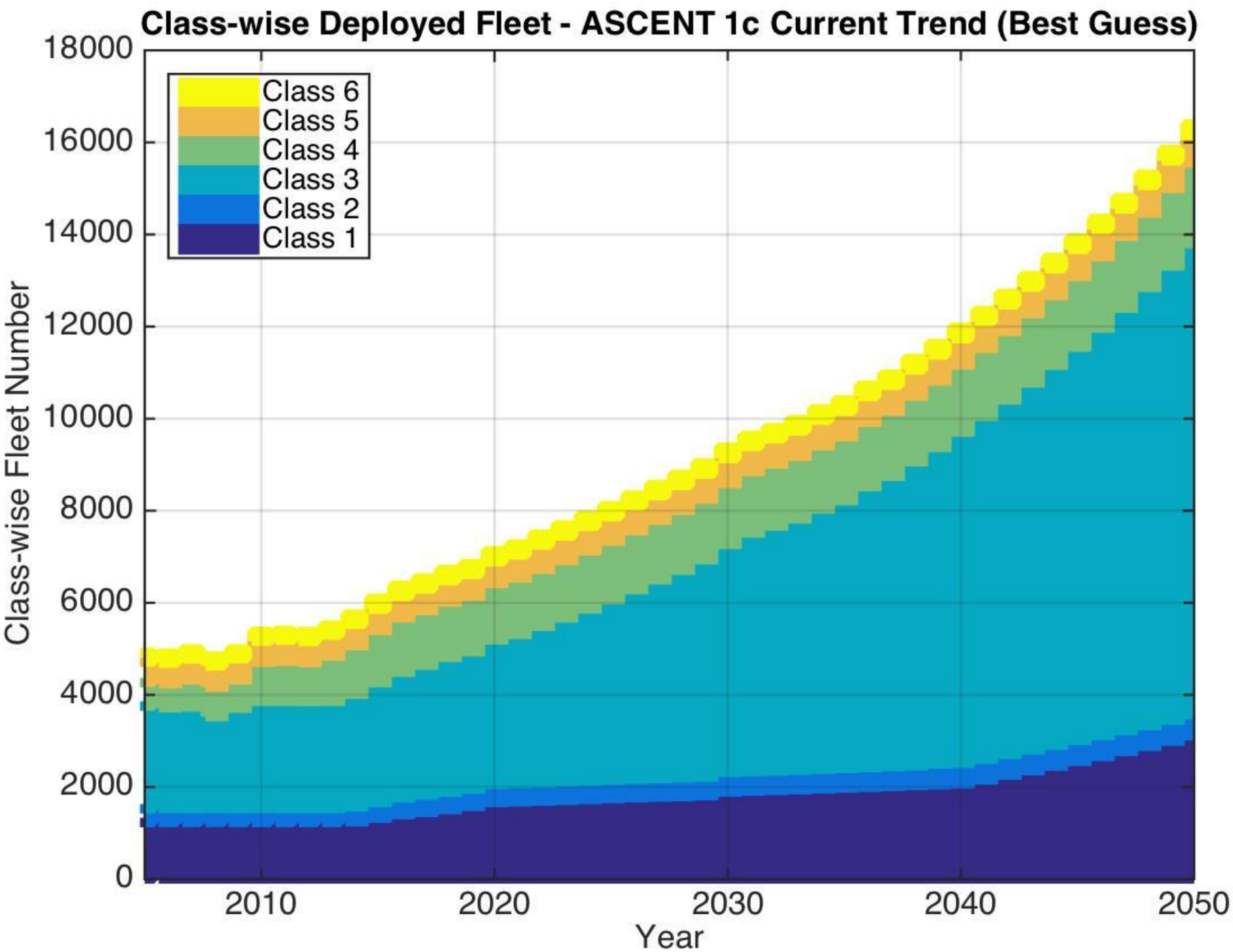


As “new” and “future” in class aircraft become available, turnover is fairly quick.

Results also suggest need for an additional “technology age or type” of aircraft with EIS around 2035 or 2040

***Preliminary Results, do not cite or quote**

Deployed Fleet (Class-Wise)



Airline in FLEET increases number of aircraft from about 5,000 in 2005 to over 16,000 in 2050

***Preliminary Results, do not cite or quote**

ASCENT10 Scenario- FLEET Parameter Mapping- Run 2

ASCENT 10 Scenario 1c Parameter	FLEET Parameter	Comment
GDP Growth (2.8%/year)	GDP Growth Rate (%/year)	Inherent Demand Growth = GDP Growth Rate * 1.4.
Energy Price ($77/bbl) in 2013 dollars	Fuel Price ($/gal) convert to Jet A price in 2005 dollars	Modified EIA reference fuel price scenario
Cost of CO_2 Emission ($21/MT)	Additional Fuel Price	Added Fuel Tax due cost of CO2 emission to Fuel Price parameter
Population Growth (0.58%/year)	Not used separately from GDP in FLEET	Demand Growth = GDP Growth * Factor. Factor can be adjusted if desired.
International Trade (4.3%/year Asia)	Regional GDP Growth Rate (4.3%/year)	Applied 4.3% GDP growth rate to routes connecting US to Asia
Airport Noise Limitations (25% airports noise limited in future)	Noise Area Constraint imposed for each US airport	1. For FLEET, % of airport limited by noise would be an output 2. Refer to subsequent slides “Noise Area”
Industry Competitiveness (12cents/ASM)	Market Share Function in two-airline model OR Price Elasticity Model	1. If competitiveness between airlines, FLEET models via market share function. 2. If competitiveness between different modes of transportation, FLEET models with price elasticity.
Amount and Speed of Technology R&D Investment (relative) – 1.02	1. EIS dates of each new aircraft 2. Aircraft coefficients to represent new aircraft performance	Require inputs from ASCENT team

Red font in FLEET column indicates not yet implemented in Scenario Run 2

Airline Flight Data Examination to Improve flight Performance Modeling

Project 35

Project manager: Hua (Bill) He, FAA
Lead investigators: Dr. John-Paul Clarke and Jim Brooks,
Georgia Institute of Technology

March 26, 2016

ASCENT
AVIATION SUSTAINABILITY CENTER

Research Objectives

- Improve the aircraft weight versus stage length (trip distance) relationship, thereby improving the accuracy of the weight values used in the prediction of departure trajectories.
- Develop correlations to compute the departure thrust as a function of aircraft type, weight, and operating conditions, thereby improving the accuracy of the departure trajectories and their associated performance.
- Update AEDT to enable accurate modeling of reduced thrust departures, which are used in more than 90% of all commercial aircraft departures.

Operational Database

- A substantial Aircraft Communication Addressing and Reporting System (ACARS) database has been acquired that contains aircraft specific departure data for a wide range of commercial aircraft. The data includes a number of performance parameters along with the takeoff weight, percent of reduced power/thrust used to conduct the departure, the origin and destination airports, and current temperature.

Planned Action – Weight Estimation

- Aircraft Weight Estimation
  - AEDT now uses a “Stage Length Table” to estimate the aircraft departure weight. This table was last updated in 2003 and assumed a specific load factor, passenger weights, fuel loading requirements and no cargo. The operational database now provides and opportunity to generate an algorithm relating actual aircraft weights to the distance flown. The user input would remain a distance flown.
  - Currently the research has been regressing Great Circle Distances between the known airports to develop an algorithm. In addition, a Flight Planning database has recently been acquired that will provide an opportunity to support a regression of “Planned Trip Miles” versus aircraft weight which is expected to have an improved correlation.

B767- 400ER Weight vs GCD

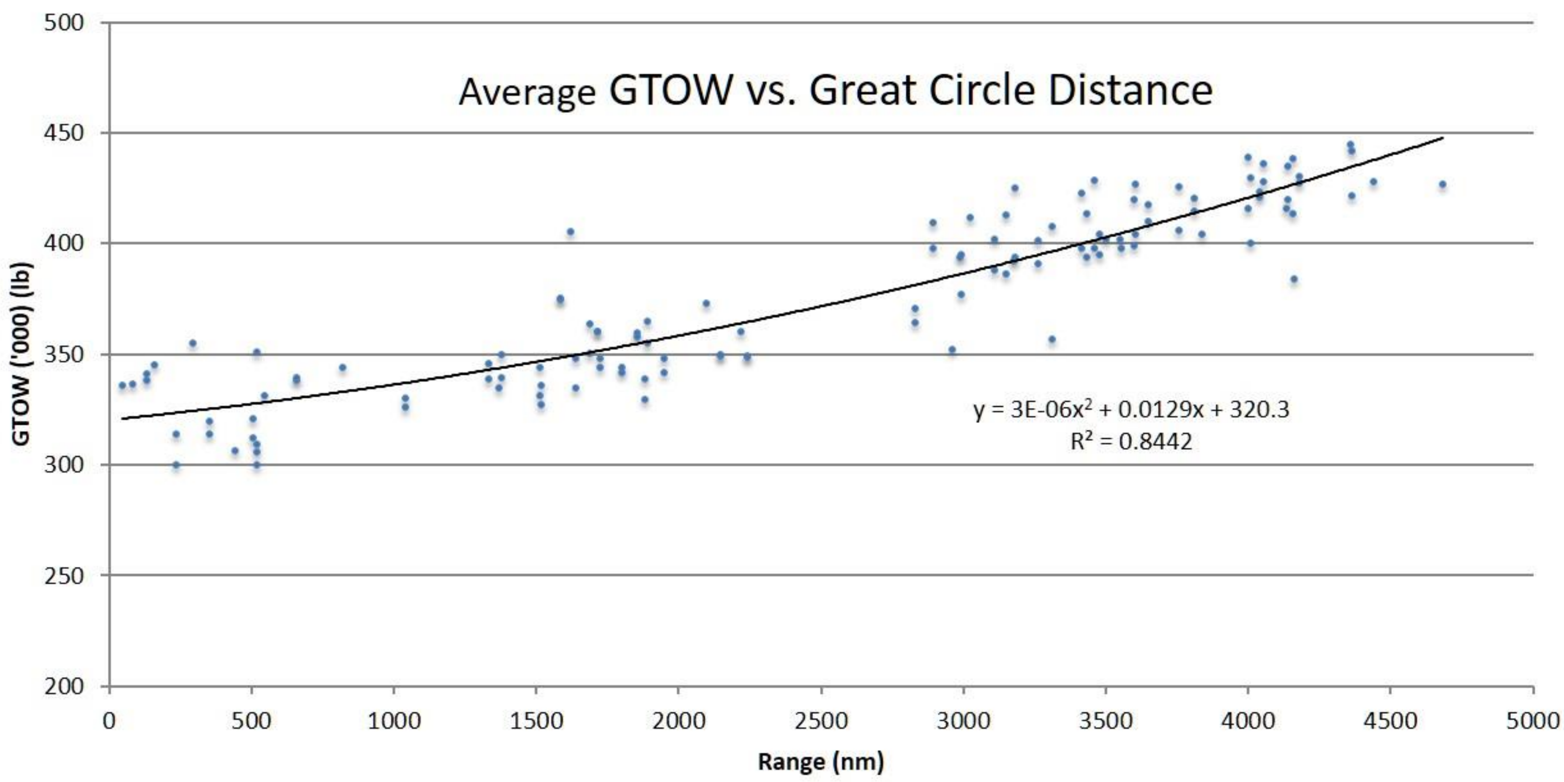


Figure 1

B767- 300ER Weight vs GCD

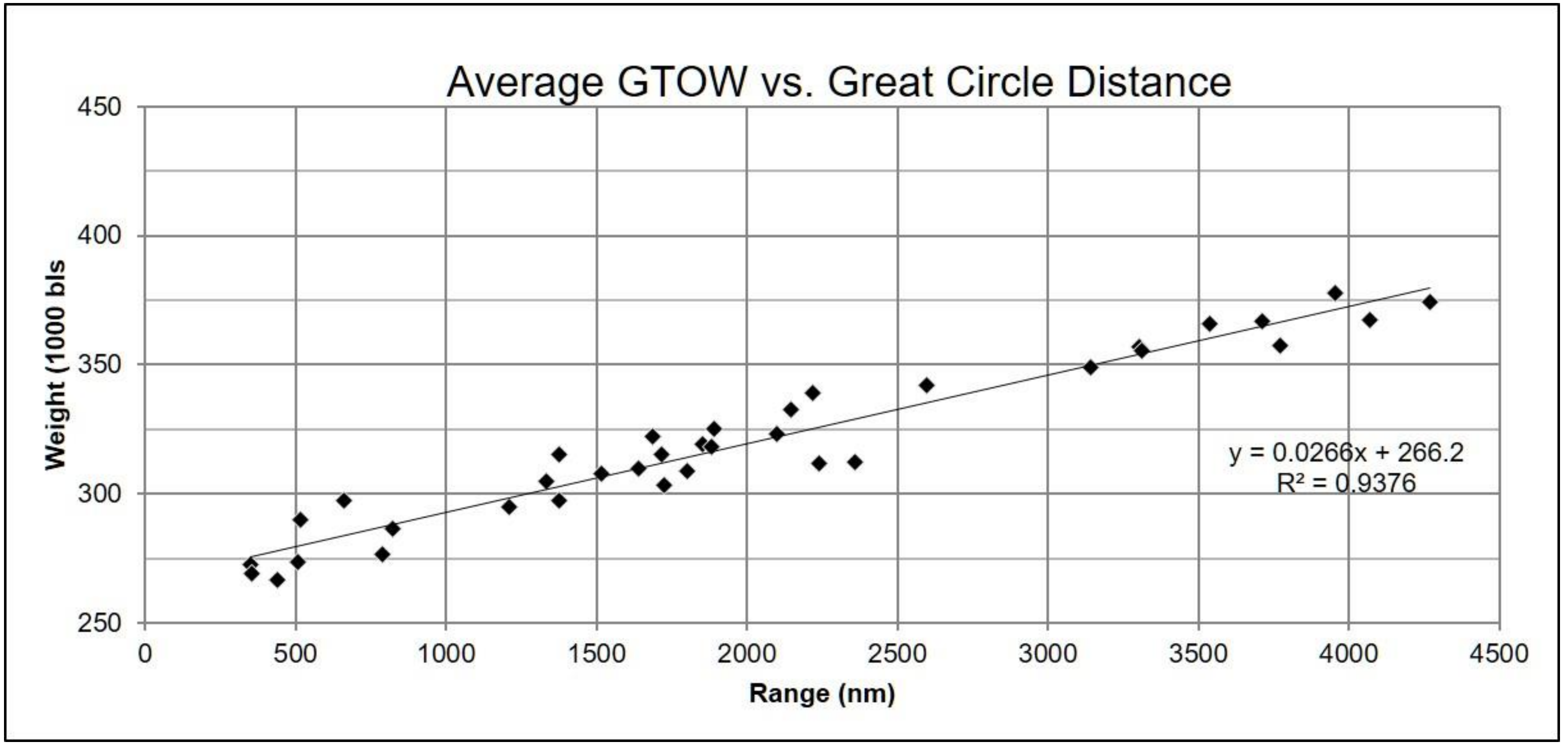


Figure 2

B737- 800 Weight vs GCD

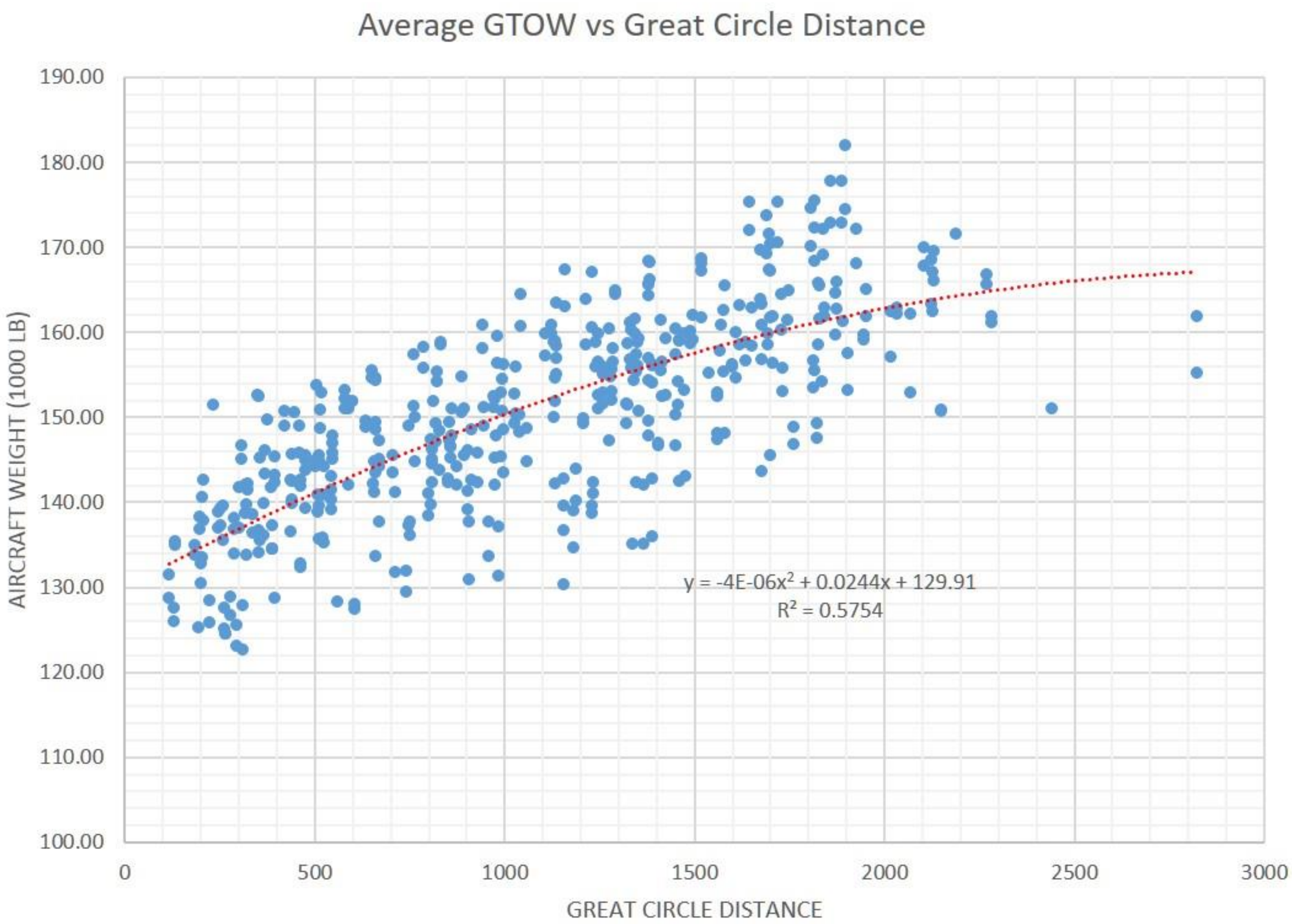


Figure 3

Planned Action – Reduced Thrust Determination

- The use of reduced thrust for a specific departure is determined by a regulatory certified performance analysis typically referred to as “assumed temperature”. It is typically employed to departures when the actual aircraft weight is well below the weight that would require the use of full rated takeoff power/thrust.
- While the use of reduced and derated power takeoffs has been utilized by air carriers for many years, until now, there has been no definitive database to substantiate it’s rate of use or the level of reduced thrust typically used.
- The operational database contains the actual reduced thrust used and reveals a wide spread of data for a given aircraft weight (Figure 7). While the aircraft weight, airport elevation, and temperature all effect the determination of reduced thrust use, it is the implementation of reduced thrust that contributes significantly to the variation. While the cause of the variation in the data is understood, the reduction of the data into an acceptable prediction will be the task for the researchers in conjunction with an SAE A-21 Project Working Team.

Assumed Temperature Example

TMPF	SSWT	ATMPC	TMPF	FLWT	ATMPC
85	461050	30	85	462053	30
86	457068	31	86	459975	31
88	453823	32	88	457883	32
90	449721	33	90	455662	33
92	445546	34	92	453317	34
94	441055	35	94	450440	35
95	436837	36	95	447261	36
97	433333	37	97	443289	37
99	429727	38	99	439886	38
101	425943	39	101	437484	39
103	422154	40	103	435071	40

TMPF	SSWT	ATMPC	TMPF	FLWT	ATMPC
104	418360	41	104	432643	41
106	414505	42	106	430185	42
108	410596	43	108	427699	43
110	406746	44	110	425255	44
112	402931	45	112	422837	45
113	399117	46	113	420415	46
115	395303	47	115	417990	47
117	391387	48	117	415500	48
119	387444	49	119	412992	49
121	383103	50	121	410257	50
122	378707	51	122	407491	51

Example: Aircraft Actual Weight of 415,000 lbs. with ambient temperature of 85F

The maximum takeoff weight is the lesser of the Field Length Limit Weight (FLWT) and Second Segment Climb Limit Weight (SSWT). From the performance data above, the maximum weight is 461050 pounds using full rated takeoff power. The Actual weight of 415000 lbs. is well below the limit weight for full rated takeoff power.

Step 1: Determine the maximum assumed temperature associated with a FLWT just greater than the actual weight
415500 at AT48

Step 2: Determine the maximum assumed temperature associated with a SSWT just greater than the actual weight
418360 at AT41

Therefore the maximum assumed temperature takeoff power for an aircraft weighing 415000 lbs. is AT41
Note that the 415000 lb. aircraft can also use any assumed temperature below AT41 down to AT30.

% Reduced Thrust vs Aircraft Weight

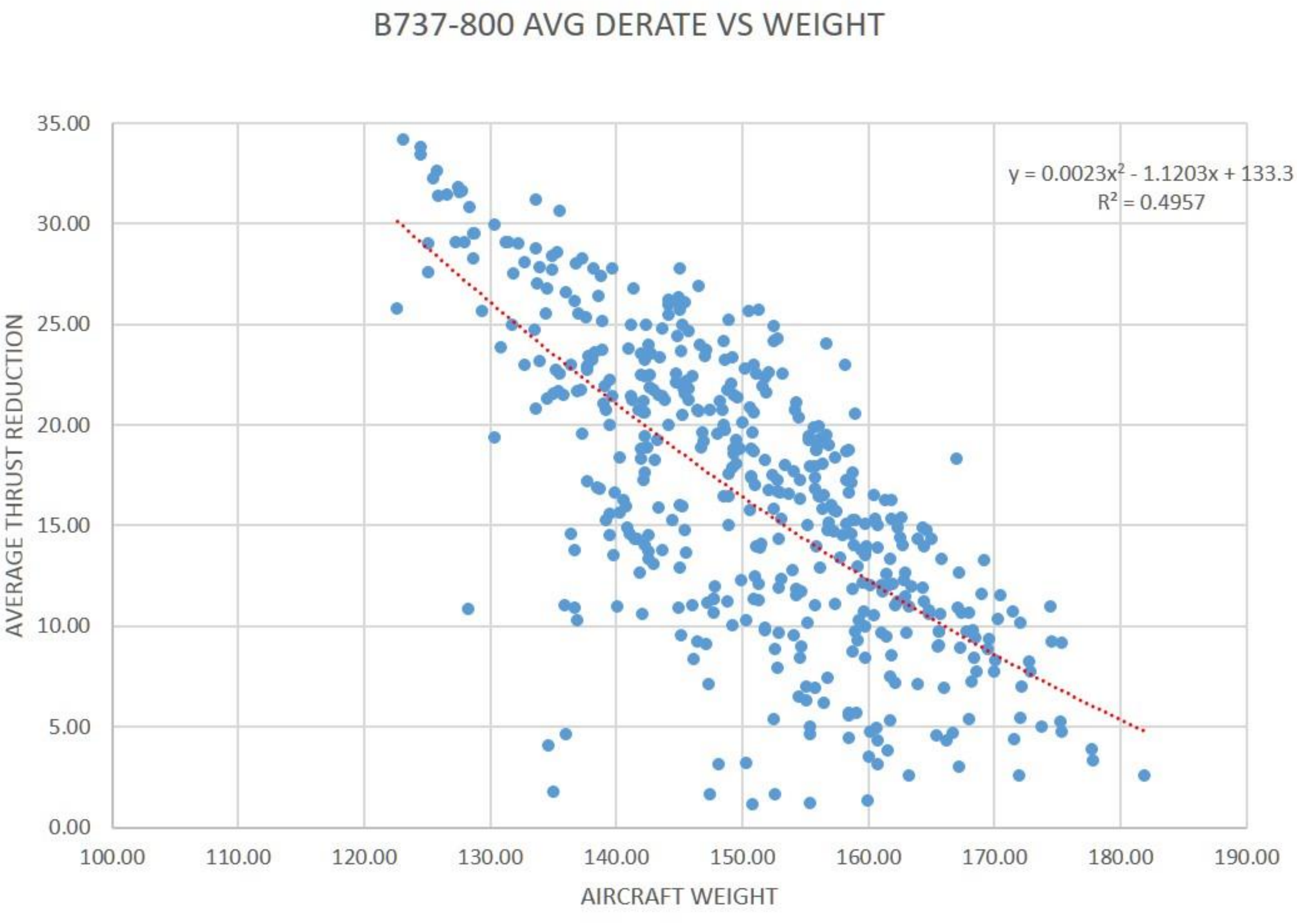


Figure 7

Reduced Thrust to Weight Variance

The following are known causes of the variance in the percentage of reduced thrust to weight data or in the weight to distance data:

- Temperature and airport elevation
- Some airports with characteristics preventing use of reduced thrust (short runways, severe obstacles).
- Charter flights
- Positioning flights
- Contaminated runways (water, snow/ice)
- ATC request to expedite climb
- Variation in pilot takeoff power selection
- Simple data recording errors
- Fuel “tankering” (opting to carry fuel for return trip if destination market pricing is high)
- Data Recording Errors

Objectives

- Provide aircraft specific algorithms to accurately estimate the actual weight of the aircraft based on stage length.

- Enable the AEDT to model aircraft specific reduced thrust departures using thrust coefficients in the same manner as is currently done for full-rated thrust departures.

- Provide aircraft specific percentage of departures using reduced thrust and the percentage of reduced thrust used.

Accomplishments:

- Data has been reduced for the following aircraft:
  - B767-300ER - 49,000 departures
  - B767-400ER - 10,600 departures
  - B737-800 - 99,000 departures

Objectives (cont'd)

Accomplishments:

- A preliminary Weight to Distance algorithm has been developed for all three aircraft.

- The B737-800 data is ready to be forwarded to Boeing for coefficient development.

FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Investigation and Support of Integration of Departure Metering Concepts into Surface Capabilities

Project 16

Project managers: Stephen Merlin and Chris Dorbian, FAA
Lead investigators: Hamsa Balakrishnan (MIT) and Tom Reynolds (MIT LL)

April 26-27, 2016
Alexandria, VA

ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

- Airport surface congestion leads to increased taxi times, fuel burn and emissions

- Potential to mitigate adverse impacts through surface congestion management
  - Departure metering is critical element of any surface traffic management tool suite
  - Departure metering also needs to be more effectively integrated into broader “full flight” traffic management programs, e.g. Traffic Flow Management System (TFMS), Time-Based Flow Management (TBFM), etc.

Objectives

- Integration of systematic control techniques for departure metering into surface management capabilities
  - Identify opportunities for relatively "light-weight" solutions
  - Identify and evaluate implementation challenges

- Demonstrate potential benefits (in terms of taxi-out time, fuel consumption and emissions reduction) through validated fast-time simulations

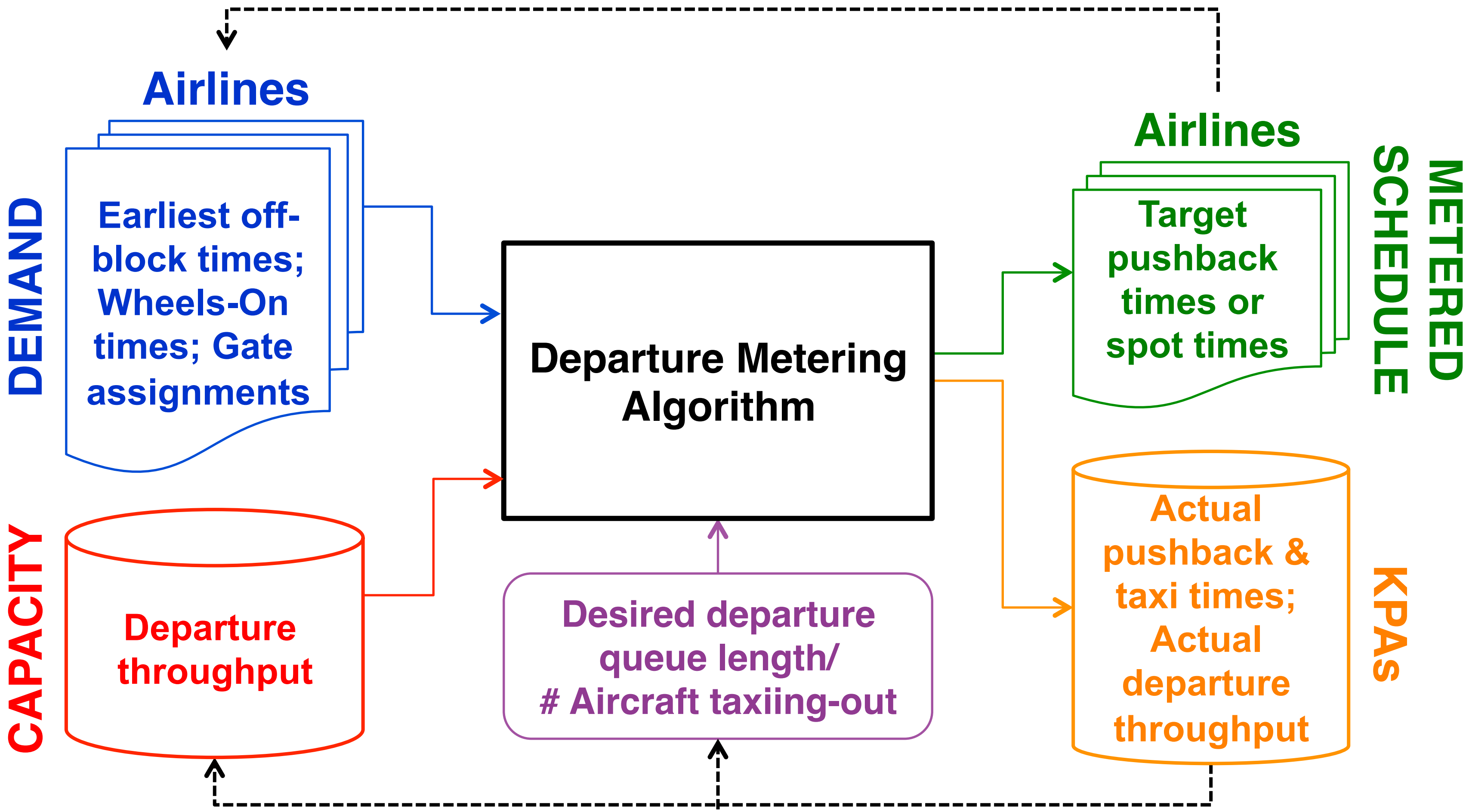
- Investigate integration/synergies with Surface Collaborative Decision Making (S-CDM), advanced surface automation (e.g., TFDM, NASA ATD-2) concepts and alignment with RTCA NextGen Integrated Working Group goals

Outcomes and Practical Applications

- Outcomes
  - Guidance on operationally-realistic departure metering approaches to inform FAA and other stakeholders
  - Estimates of potential benefits
  - Insights into implementation barriers and opportunities

- Practical applications
  - Support of departure metering in S-CDM, TFDM, ATD-2, RTCA
    - Evaluate impact of uncertainty in availability and accuracy of various data elements (e.g., EOBTs, arrival demand, gate assignments, etc.)
    - Impact of increasing planning horizon
  - Site adaptation of departure metering algorithms
    - Evaluate benefits/challenges for different airports/operating environments
    - Handling ramp operations (and mapping spot times to pushback times)

Approach: Interpretation of Surface-CDM Concept

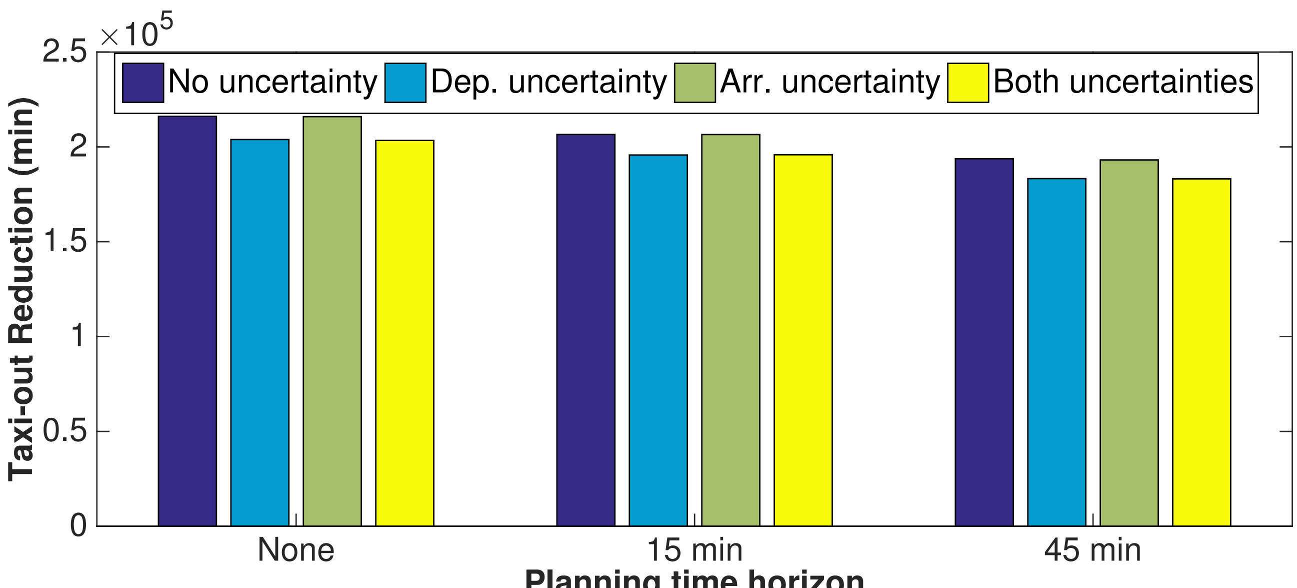


Schedule and Status

- Development of framework to simulate departure metering within S-CDM
- LGA data analysis and proof-of-concept of framework
  - Modeling and simulation of N-Control impacts at LGA
  - Gate conflict/impact analysis by airline
  - Fairness of gate-holds and taxi-out time savings; pushback/takeoff sequences
  - Design of protocols
    - N-Control and dynamic programming
    - Evaluation of the impacts of uncertainty/choice of planning horizon
- Adaptation of framework to CLT operations (ongoing)
  - Alignment with NASA's ATD-2 demo, RTCA NIWG Surface goals
  - Spot and Runway Departure Advisor (SARDA)
- Investigation of integration and synergies with S-CDM and TFDM (ongoing)

Recent Accomplishments (1)

- **Simulations of LGA operations**, Jul-Aug 2013
  - Departure metering (N-Control/Dynamic Programming)
    - Choice of advance planning horizon (0, 15-min, 45-min)
    - Arrival rate uncertainty
    - Departure demand uncertainty
      - Accuracy of EOBT (±3.5 min)
  - What-if simulations
    - Increasing gate capacity, limiting gate-hold times
    - Eliminating alleyway conflicts



Recent Accomplishments (2)

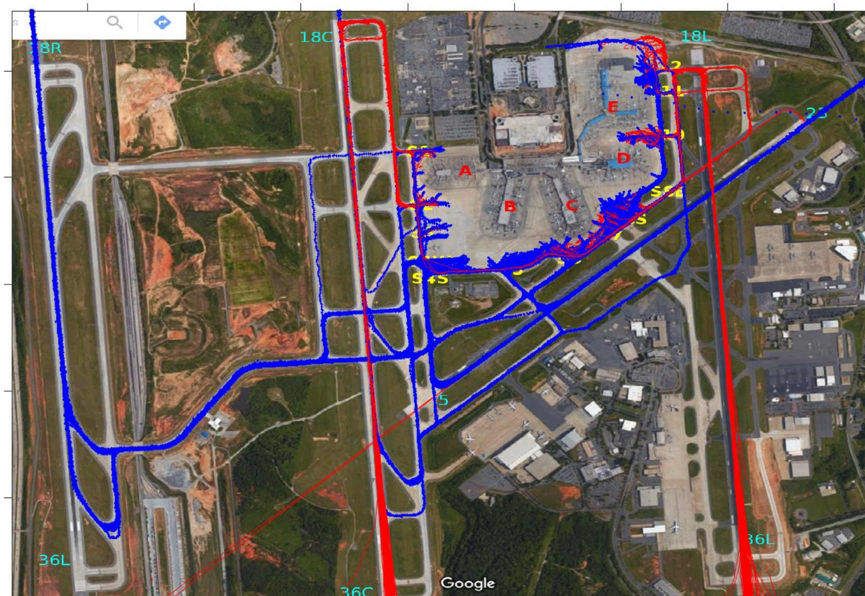
- **Modeling and analysis of CLT operations**
  - Consider gate-to-spot and spot-to-runway movements

North flow configuration:

- 36L,36C,36R|36C,36R
- Avg. taxi-out time = 21.2 min
- Avg. gate-to-spot time = 10.2 min
- Avg. taxi-in time = 10.2 min

South flow configuration:

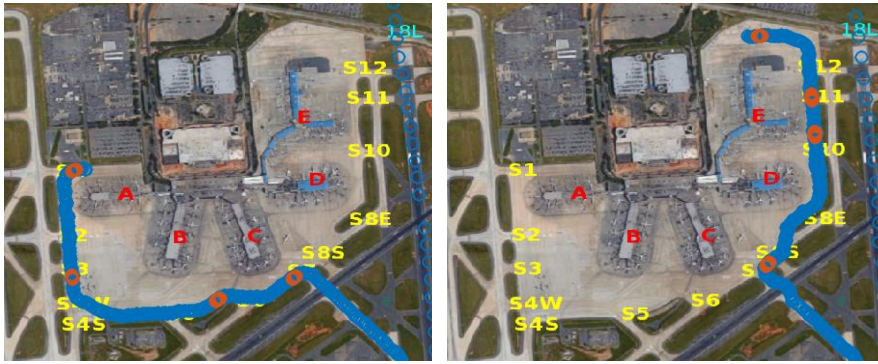
- 18R,18C,23|18C,18R
- Avg. taxi-out time = 19.9 min
- Avg. gate-to-spot time = 11.9 min
- Avg. taxi-in time = 11.4 min



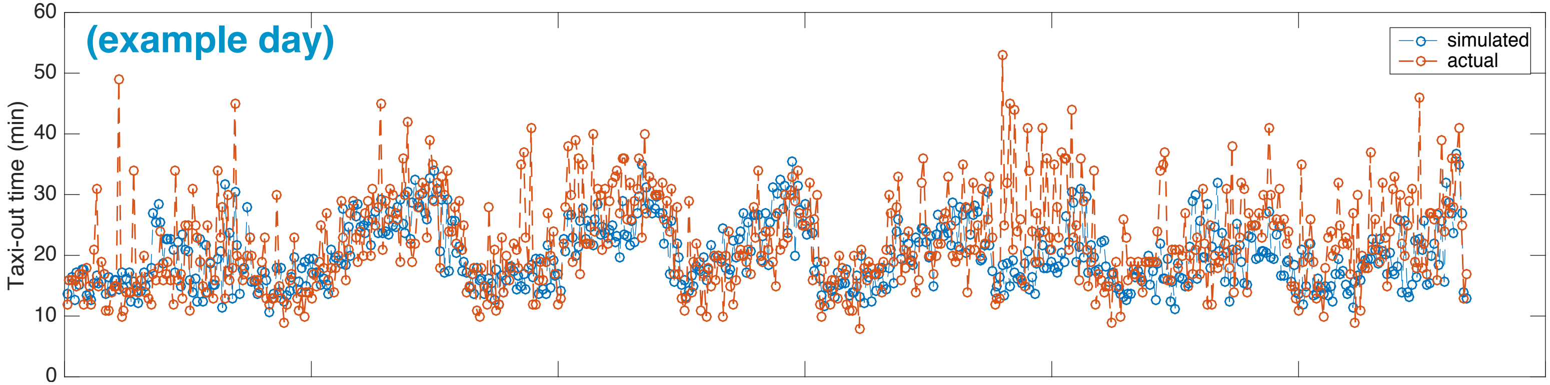
Arrivals Departures

Recent Accomplishments (3)

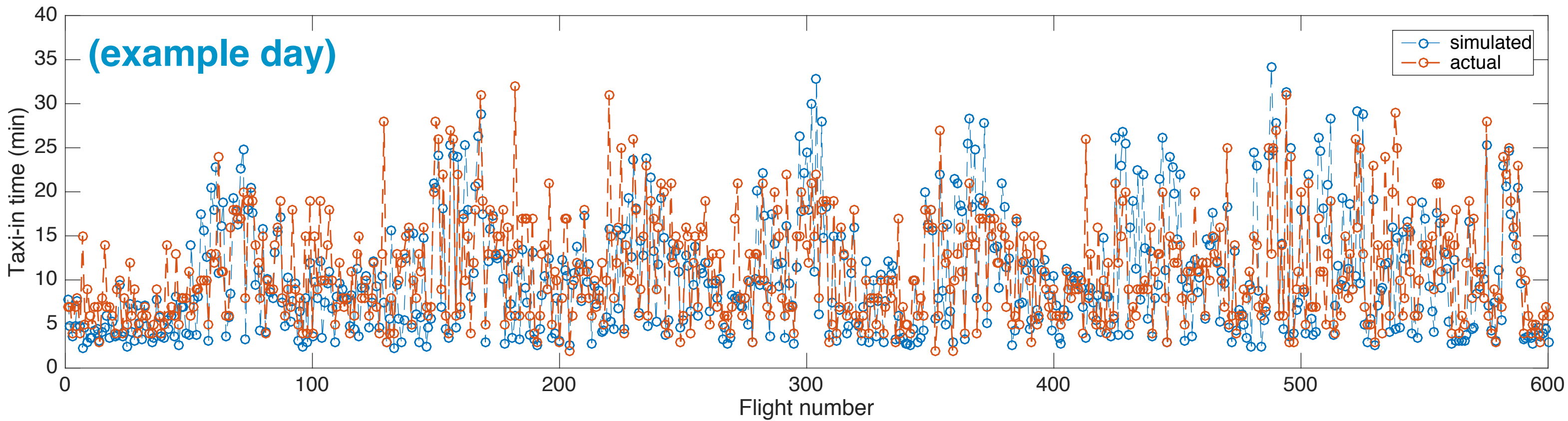
- **CLT ramp operations**
  - 5 terminals, 13 spots
  - Holds near spots (interactions)
  - Weak ASDE-X coverage in ramp



(min)	Sim	Act
Gate-spot	10.9	11.1
Spot-OFF	9.1	11.1
Taxi-out	20.0	22.2



(min)	Sim	Act
Rwy-spot	4.3	4.6
Spot-gate	6.0	6.6
Taxi-in	10.2	11.2



Interfaces and Communications

- External
  - P. McFarlane and H. Balakrishnan. "Optimal Control of Airport Pushbacks in the Presence of Uncertainties," American Control Conference, Boston, MA, June 2016.
  - Ongoing/regular discussions with
    - TFDM Investment Analysis Team
    - FAA Surface Office (regarding S-CDM)
    - NASA (regarding the ATD-2 demo at CLT)
    - RTCA NextGen Integrated Working Group surface team

Summary

- Development of airport characterization methodology and simulation framework for the integration of departure metering with advanced surface management capabilities
  - Proof-of-concept illustration using LGA case study
  - Focus on impacts of uncertainty and information-sharing on the benefits of departure metering
  - Extension of framework to CLT operations, for alignment with planned ATD-2 demo (Q4 of CY 2017)

- Analysis of ramp operations, to develop mapping between target spot times and target pushback times
  - Support spot metering algorithms (as opposed to pushback control)
  - Continue to evaluate impacts of uncertainty and information-sharing on the benefits of departure metering

References

- M. Sandberg, T. G. Reynolds, H. Khadilkar and H. Balakrishnan. "Airport Characterization for the Adaptation of Surface Congestion Management Approaches," ATM R&D Seminar, June 2013
- P. McFarlane and H. Balakrishnan. "Optimal Control of Airport Pushbacks in the Presence of Uncertainties," American Control Conference, June 2016

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- MIT Lincoln Laboratory: Melanie Sandberg, Ngaire Underhill and Emily Clemons (RAPT and ASDE-X data)
- MIT Students: Patrick McFarlane, Sandeep Badrinath