EFD/CFD for MRJ Development

Integration 2012

2012/10/03

Mitsubishi Aircraft Corporation

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MRJ Mitsubishi Regional Jet

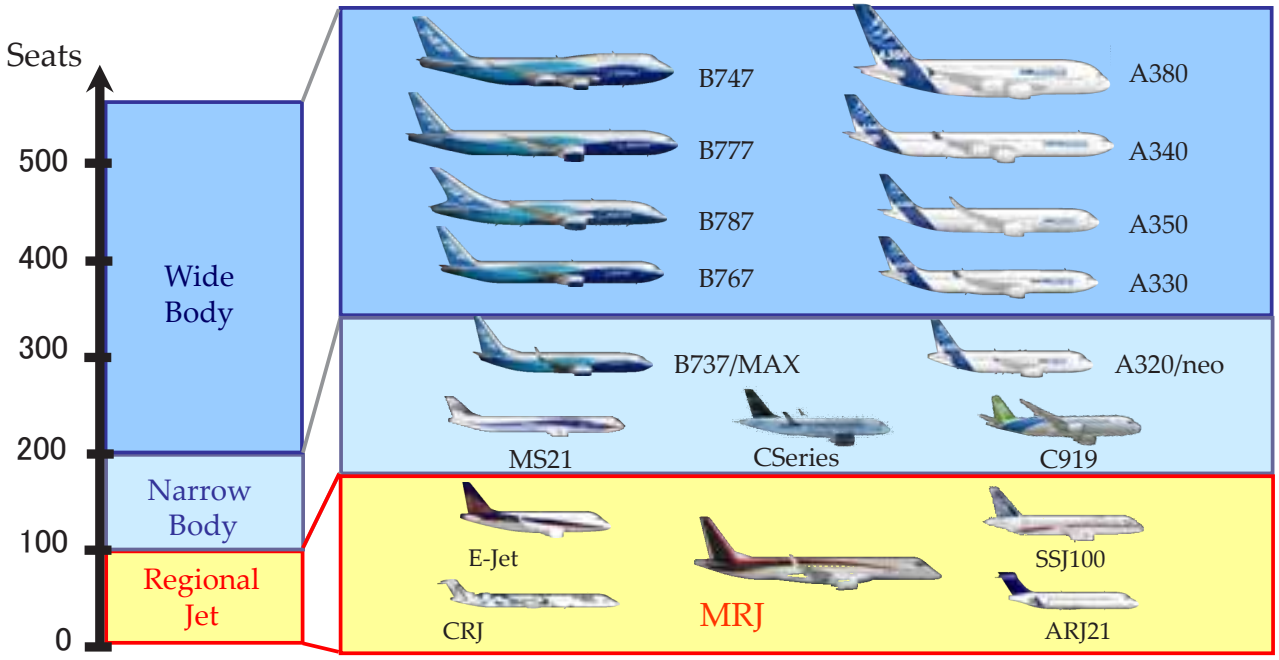
JAXA Japan Aerospace Exploration Agency

TOHOKU UNIVERSITY

1. Introduction of MRJ
2. EFD/CFD for MRJ Development
3. Future prospect on EFD and CFD

Commercial Jet Market

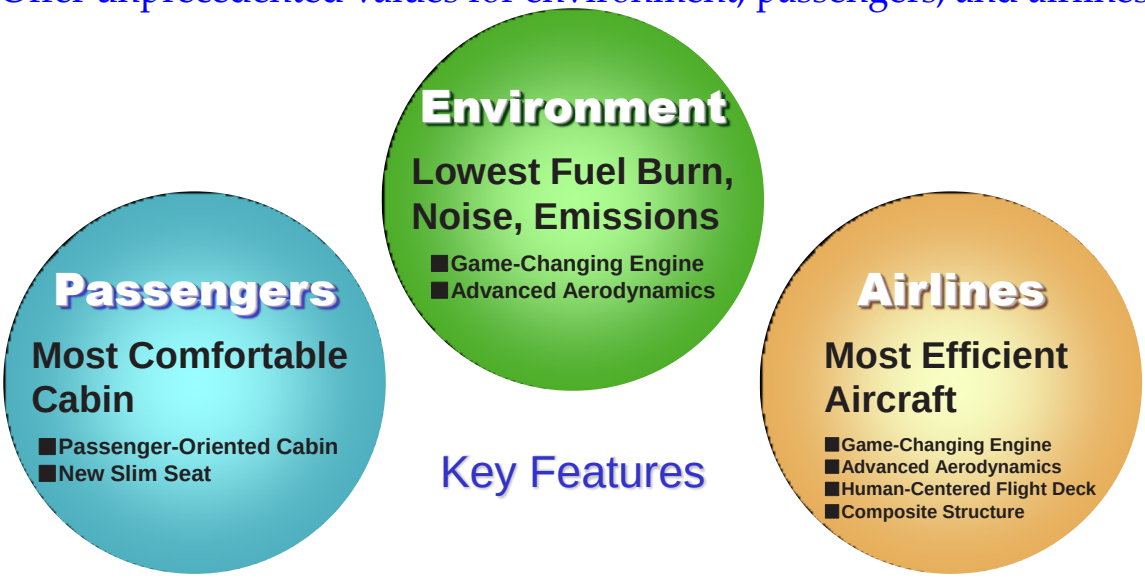
- More than 28,000 airplanes to be delivered in the next 20 years
- Fierce competition with five regional jet makers



Vision and Key Features

【Vision】

- Apply advanced mainline jet technology to regional jet and create the standard for next-generation regional jet.
- Offer unprecedented values for environment, passengers, and airlines.



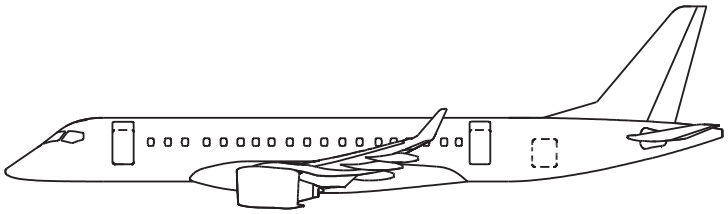
MRJ Family

- Three models to cover global market needs
- High commonality for airline economics
  pilot type rating, engines, maintenance program and spare parts

MRJ100X (Plan)
100 seats

MRJ90
92 seats

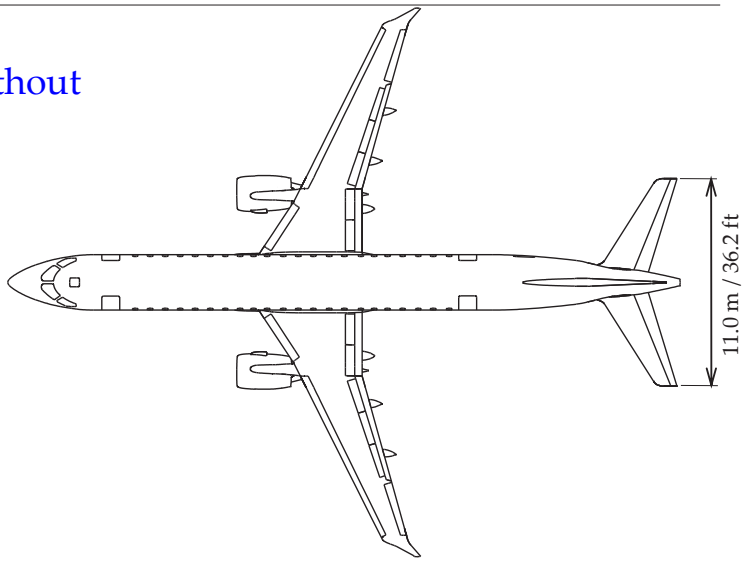
MRJ70
78 seats

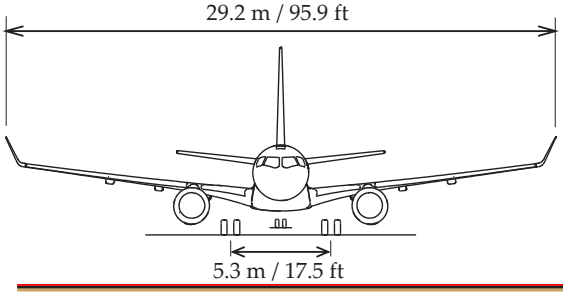


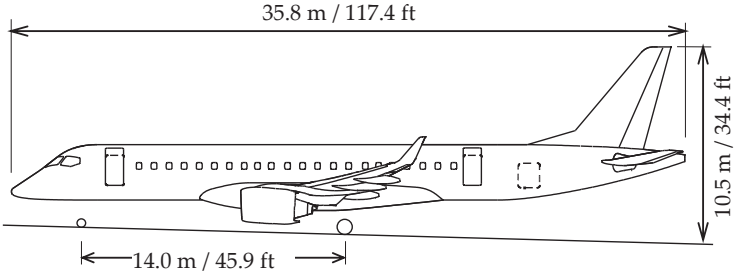
General Arrangement - MRJ90

- Designed for fuel efficiency without compromising cabin comfort
- High aspect ratio wing with winglets, small diameter fuselage, and innovative GTF engine

GTF: Geared Turbo Fan

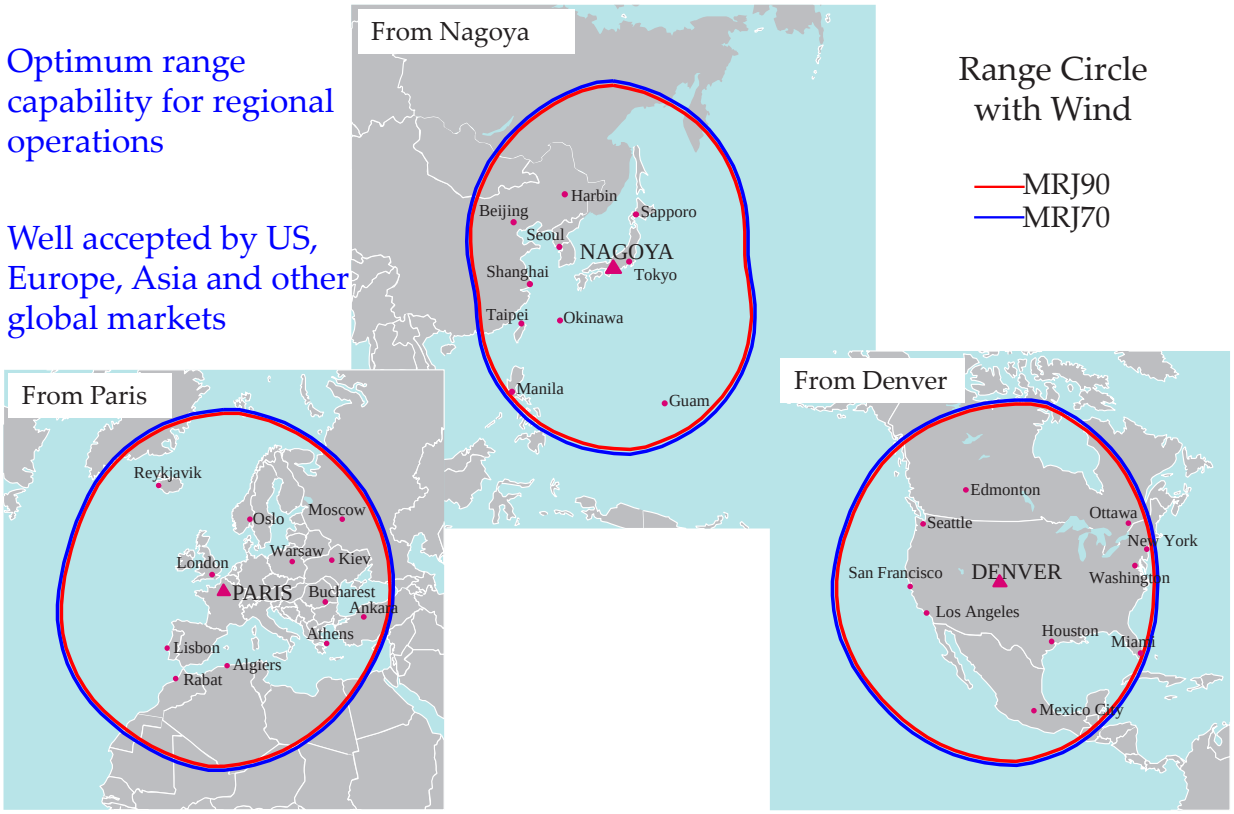




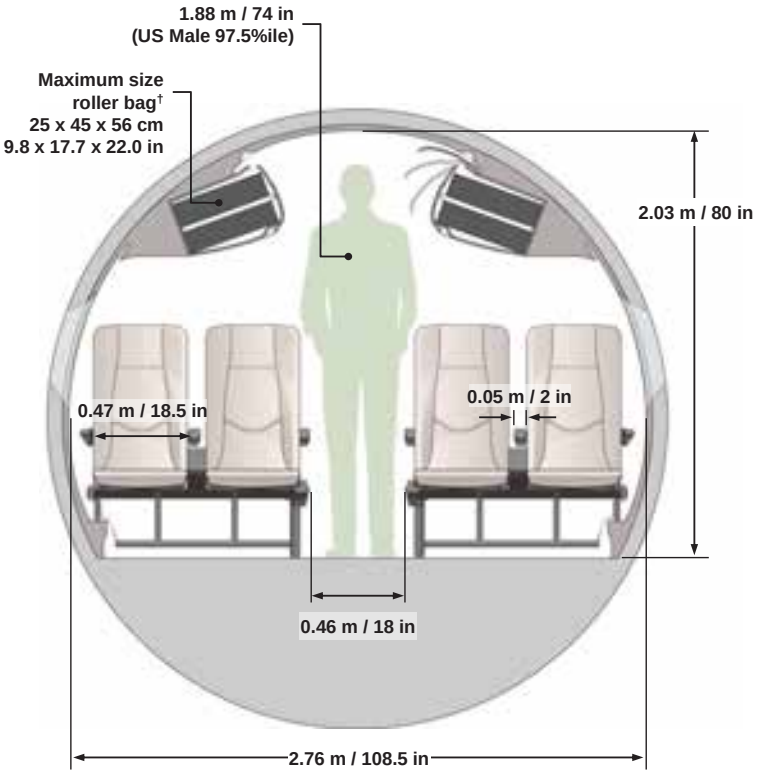


Range Capability

- Optimum range capability for regional operations
- Well accepted by US, Europe, Asia and other global markets



Passengers – Most Comfortable Cabin



Mainline jet comfort

- Same seat width as 787 with 8 abreast

MRJ	18.5 in
787 (8abreast)	18.5 in
787 (9abreast)	17.2 in
EMB170/190	18.25 in
CRJ	17.3 in

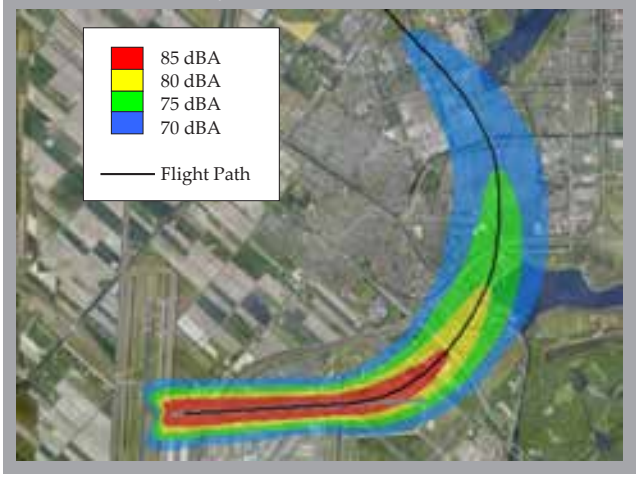
- Ample head & foot clearance at the seat
- Large overhead bin

† IATA-recommended maximum size bag

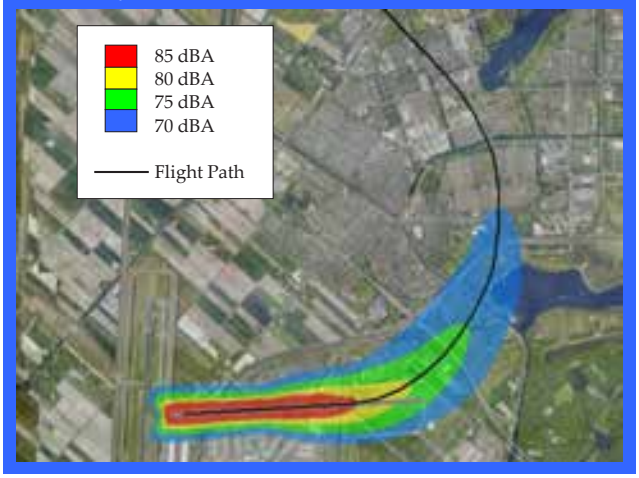
Environment – Lowest Noise

- Advanced aerodynamics and GTF engine for low noise
- MRJ90 noise area reduced by 40%

Current RJ



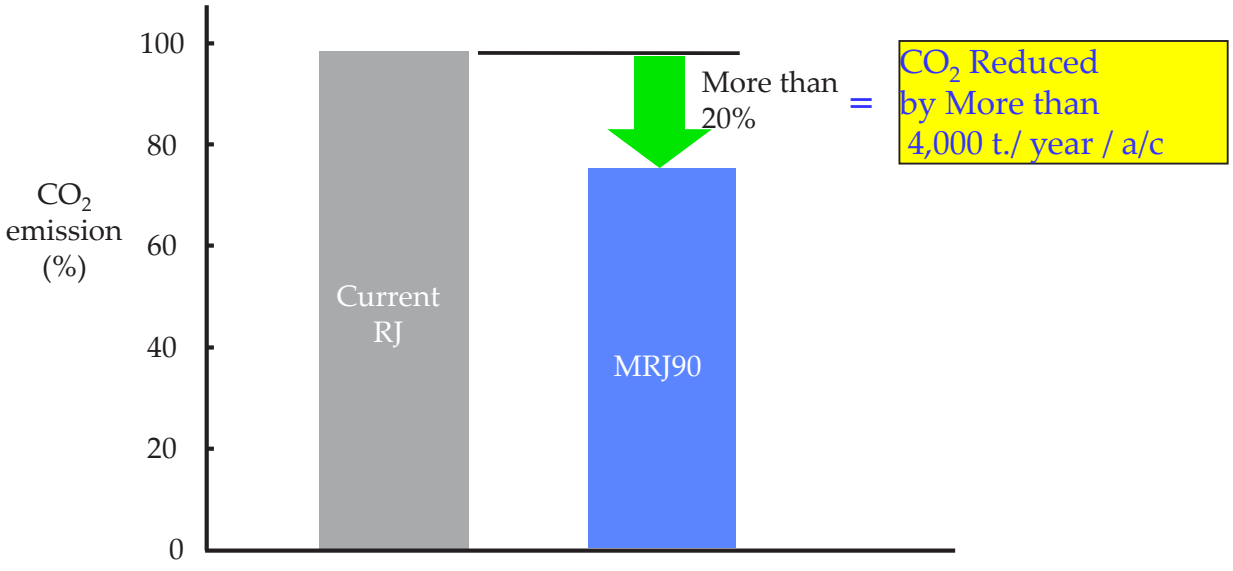
MRJ90



* Mitsubishi Aircraft Estimation at Schiphol Airport (AMS)

Environment – Lowest Emission

- Advanced aerodynamics and GTF engine for low fuel burn
- Significantly Lower Fuel Burn & CO_2 Emissions

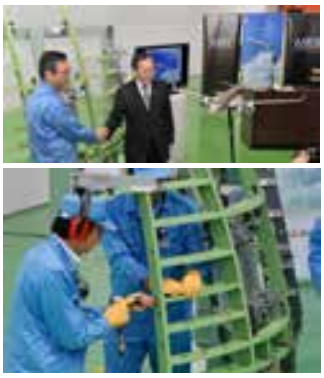


*Mitsubishi Aircraft estimation, 500nm Trip, 2,200 cycle/year, Fuel price 3$/USG

Milestones and Events

Metal Cut Ceremony
Sep./2010

Last Bolt Ceremony
Mar./2011



First Rivetting
April/2011

First Engine to Test
May/2011

Paris Airshow
June/2011

Iron Bird
Dec./2011

Farnborough Airshow
July/2012

EFD/CFD for MRJ Development : outline

Aerodynamic characteristics will be validated by flight test.

Aerodynamic design : designed by CFD and evaluated by EFD
Aerodynamic data : estimated by EFD interpolated or corrected with CFD
Noise prediction : investigated/estimated/evaluated by EFD and CFD

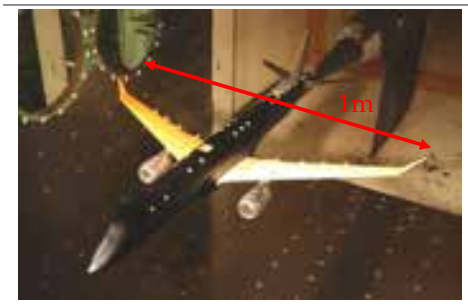
EFD application

- Wind tunnel tests (examples)
- Flow visualizations by advanced optical measurements
- Noise source survey at low speed wind tunnel

CFD application

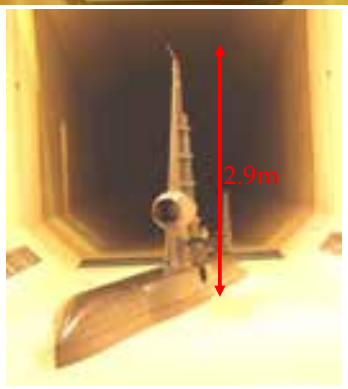
- CFD technology
- Simulation for all configurations
- Aerodynamic design based on MDO
- Equipment installation design for ADS and ECS
- Investigation for noise generation and propagation

EFD for MRJ Development : Wind Tunnel Tests

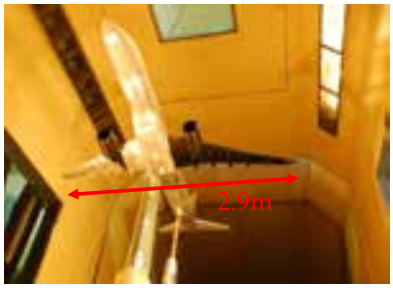


High speed wind tunnel test@
JAXA 2m × 2m TWT
JAXA/MHI collaborative work

Ground effect test@
MHI 2m LWT



20% half span model@
JAXA 6.5m × 5.5m LWT
JAXA/MHI collaborative work



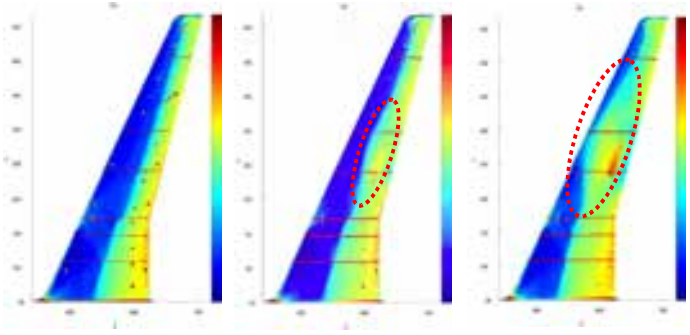
10% full span model@
JAXA 6.5m × 5.5m LWT
JAXA/MHI collaborative work

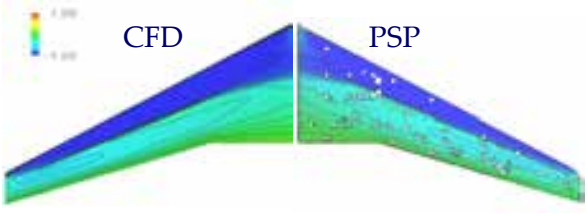
EFD for MRJ Development : Flow Visualization

Advanced optical measurement technologies (JAXA/MHI collaborative work)

・PSP (Pressure Sensitive Paint) : aerodynamic load estimation.
・PIV (Particle Image Velocimetry) : evaluation of chine design.

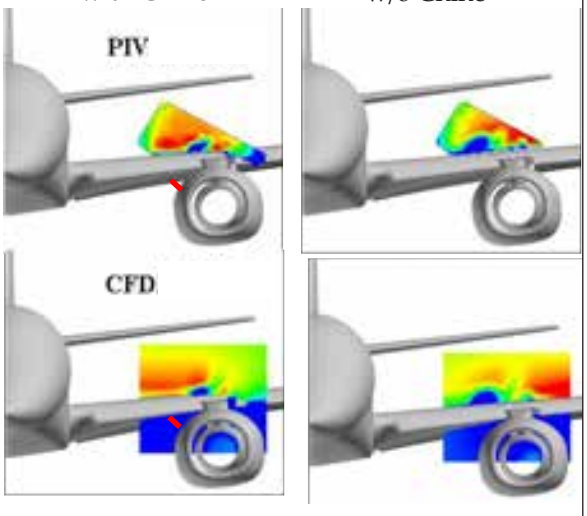
δ_{sp}= 0deg δ_{sp}= 20deg δ_{sp}= 60deg





Wing Pressure Distribution at Cruise condition

with Chine w/o Chine



Velocity distribution around the wing-pylon junction (PIV)@High AoA of HLD cfg.

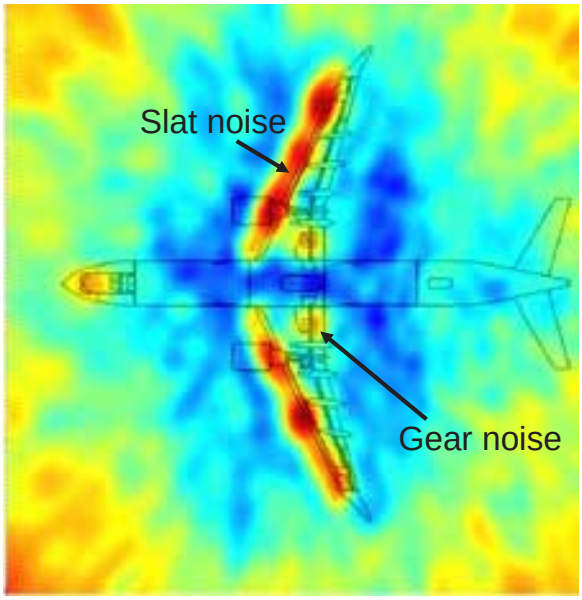
EFD for MRJ Development : Noise prediction

Noise source survey (JAXA/MHI collaborative work)

・Evaluate aerodynamic properties and noise level simultaneously.

・Understand where the noise comes from.

JAXA 6.5m x 5.5m LWT



Noise visualization for HLD cfg.

CFD for MRJ Development : CFD Technology

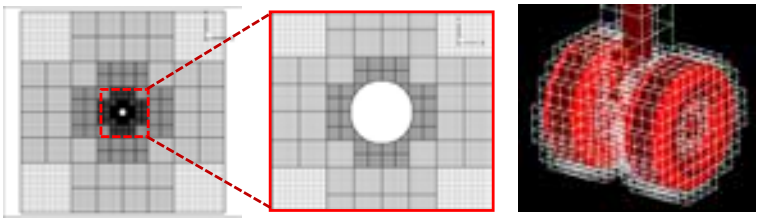
Apply CFD technology developed by collaborative work with Tohoku Univ. and JAXA

⇒ Over 100,000 CPU hours calculation!

- CFD Tool for Complex Geometry (Collaborative work with Tohoku Univ.)
  - Unstructured Mesh : TAS (Tohoku Univ. Aerodynamics Simulation)
  - Cartesian Mesh : BCM (Building-Cube Method)
- Parallel Computing with Supercomputers (JSS, Cyber Science Center)

  Collaborative work with JAXA and Tohoku Univ.
  - Standard Steady Calculations : Aerodynamic Design etc.
  - Large Scale Unsteady Calculations : Noise and Flutter Analysis

TAS

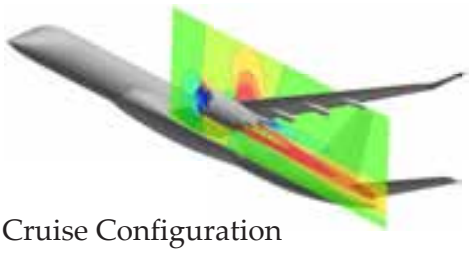


BCM

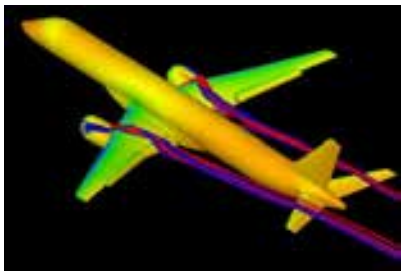
CFD for MRJ Development : All Configurations

Data productivity criteria for practical aircraft design : more than 1 case/day.

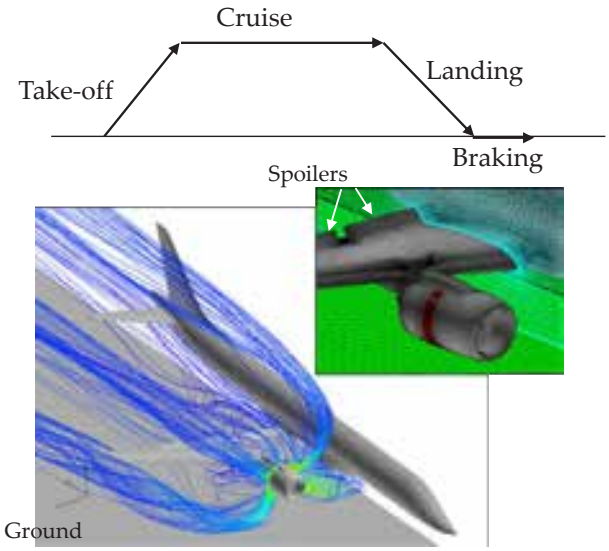
- Simulate all configurations of aircraft operation in a practical time.
- Apply to thrust reverser design to improve design efficiency and reduce risks before flight test.



Cruise Configuration
7.5 million mesh points 10 cases/day



Take-off/Landing Configurations
10 million mesh points, 3 cases/day

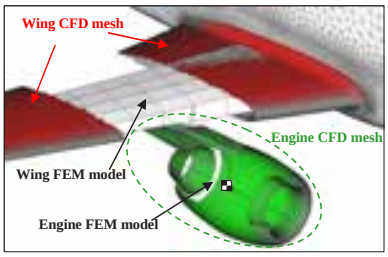


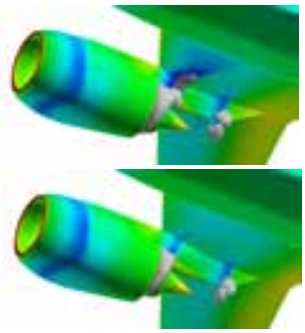
Braking with Thrust Reverser
15 million mesh points, 1 case/day

CFD for MRJ Development : Aerodynamic Design

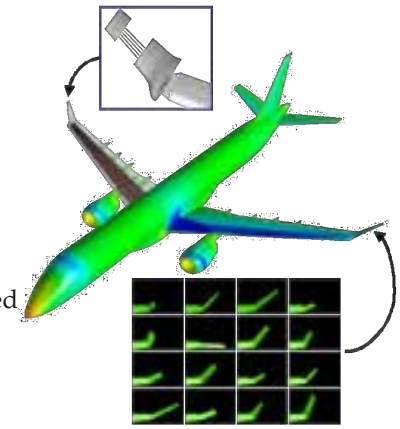
MDO (Multidisciplinary Design Optimization) developed by Tohoku Univ.

- Apply to aerodynamic designs of wing/engine configuration and winglet
- Optimize aerodynamics (drag, lift) and structure (size, weight) simultaneously under constraints from design requirements.





Design of Wing/Engine Configuration



Winglet Design

CFD : Aerodynamic characteristics and aerodynamic load
FEM : Internal forces and displacement of structure

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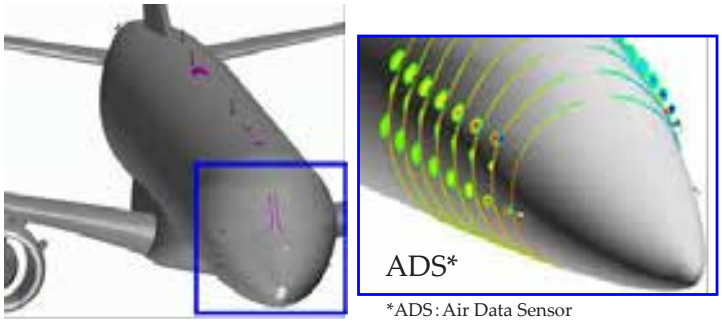
CFD for MRJ Development : High fidelity simulation

Toward CFD for "Actual aircraft ", instead of aero "Aircraft model"

- Protuberance drag, conventionally estimated with hand-book method.
- Location of ADS, conventionally defined at WT and FT.
- Performance of air inlet/outlet for ECS, APU, ventilation etc.

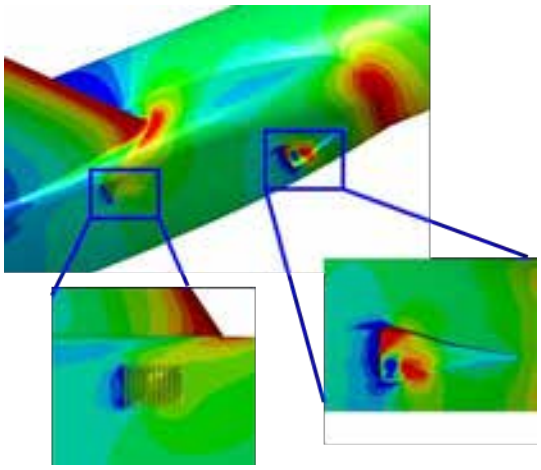
CD	=0.0300	:Total Drag of Airplane (about 1/10 of Car)
ΔCD	$=10^{-4}$(1count)	:Low-Drag Design
ΔCD	$=10^{-6}$	:Drag of a Sensor

Miscellaneous drag = 5% of CD!!!



*ADS : Air Data Sensor

Evaluation of Small-size Equipments



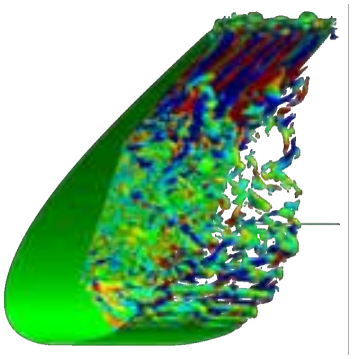
Performance Evaluation of Inlet/Outlet of ECS* ram air flow

*ECS : Environment Control System

CFD for MRJ Development : Noise prediction

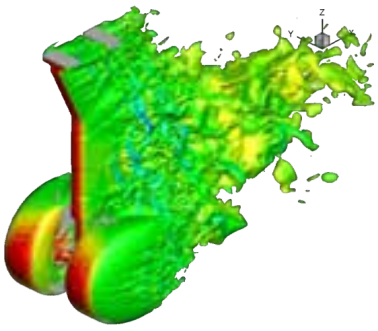
Noise prediction and Low-noise design by collaborative work with JAXA and Tohoku Univ.

- Investigation of noise source and prediction of airframe noise with acoustic analysis for community noise
- Prediction of engine noise propagation into cabin for passenger noise



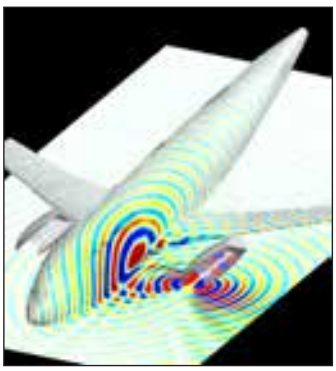
LES* for Slat Noise
(Courtesy of JAXA)

*LES : Large Eddy Simulation



BCM*/LES for Landing Gear Noise
(Collaboration with Tohoku Univ.)

*BCM : Building-Cube Method



LEE* for Fan Noise Propagation to Cabin
(Courtesy of JAXA)

*LEE : Linearized Euler Equation

Future prospect on EFD and CFD

Issues to be improved :

EFD

- Lead time for test model preparation : design/manufacturing
- Data productivity : per day/per test run
- Accuracy of measurement : drag
- Compensation for the effects due to flow condition differences : Re/facility etc.

CFD

- Lead time for calculation model preparation : geometry/grid generation
- Data productivity : hardware, algorithm

Further application :

EFD

- Extension to flight test : optical measurement/noise source survey
- Unsteady measurement : PSP for buffet

CFD

- Integration of multi-flow field : internal/external flow of equipment
- Unsteady simulation : dynamic stability/noise prediction