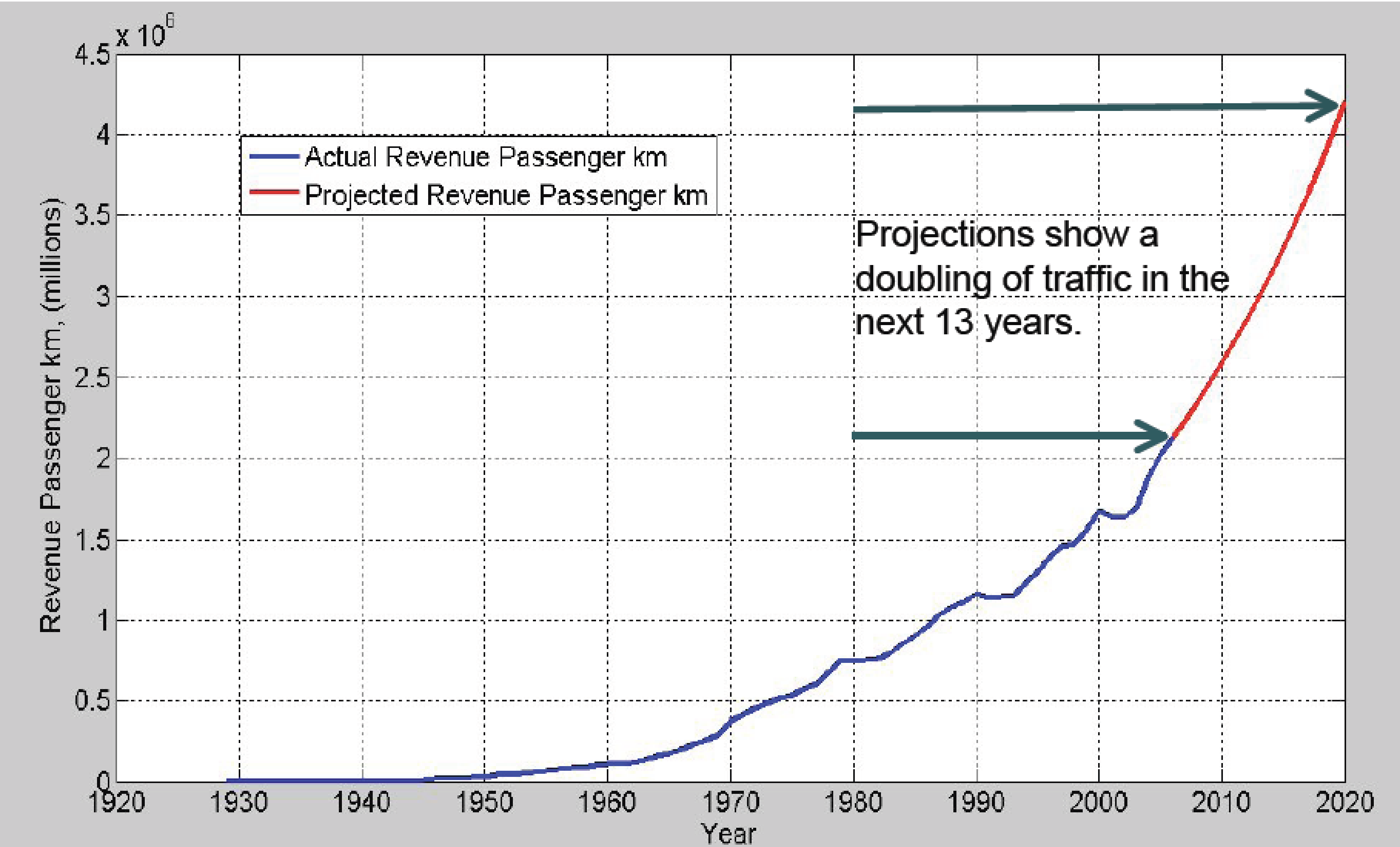
Next Gen Regional Transport Aircraft

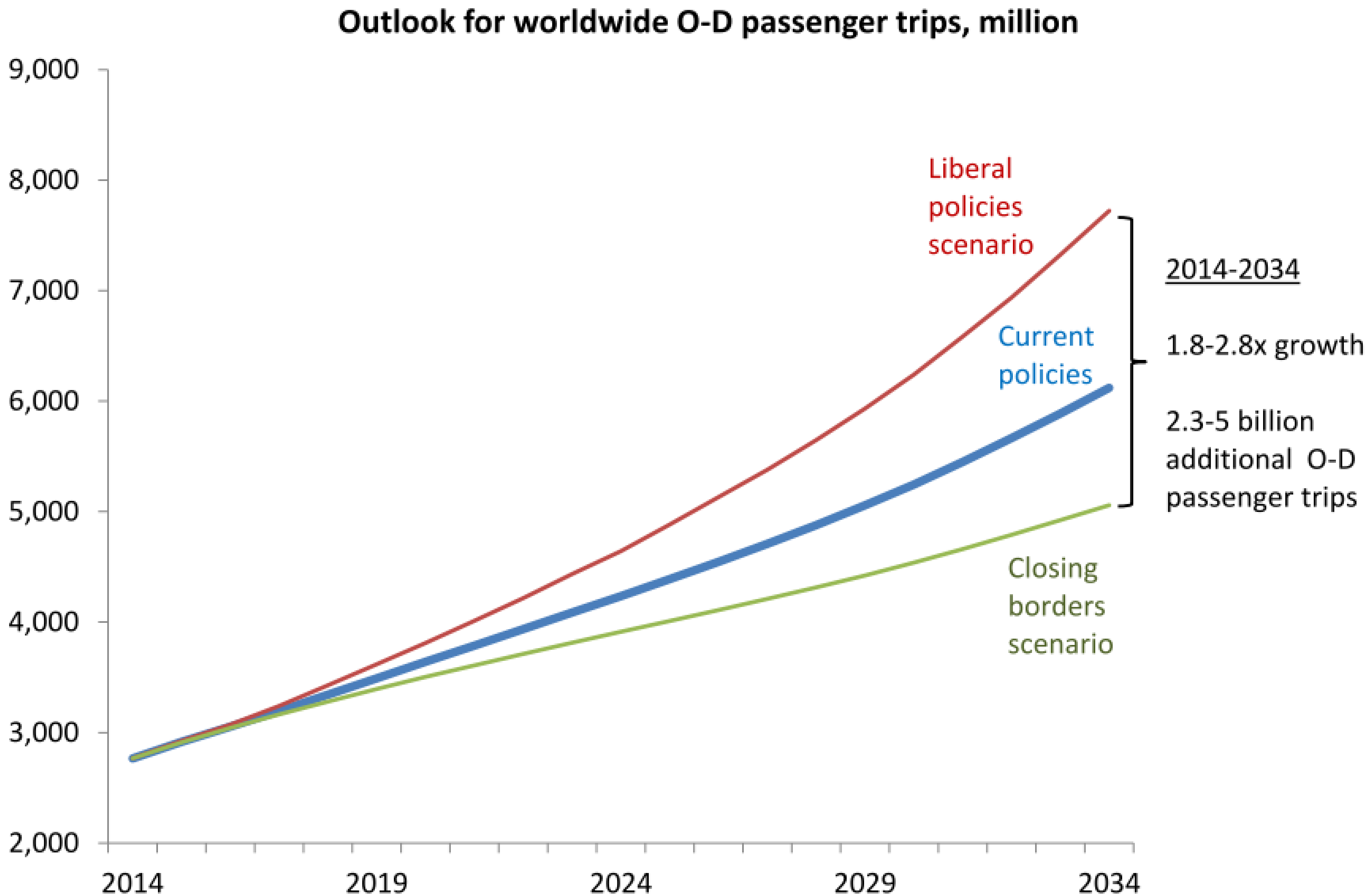
Kota Harinarayana

IITB,11-8-15

Annual Worldwide Air Traffic

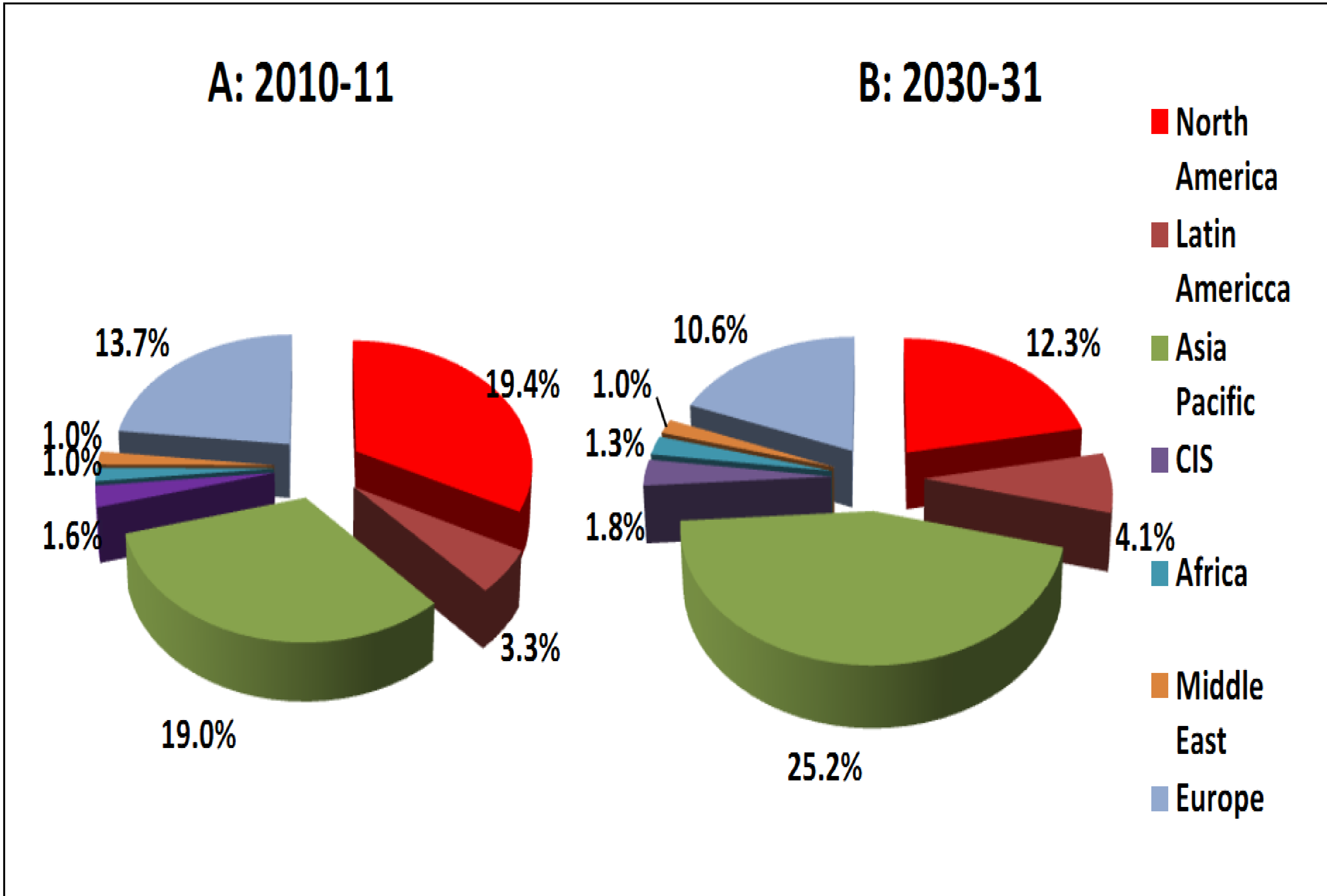


Air travel likely to double over next 20 years

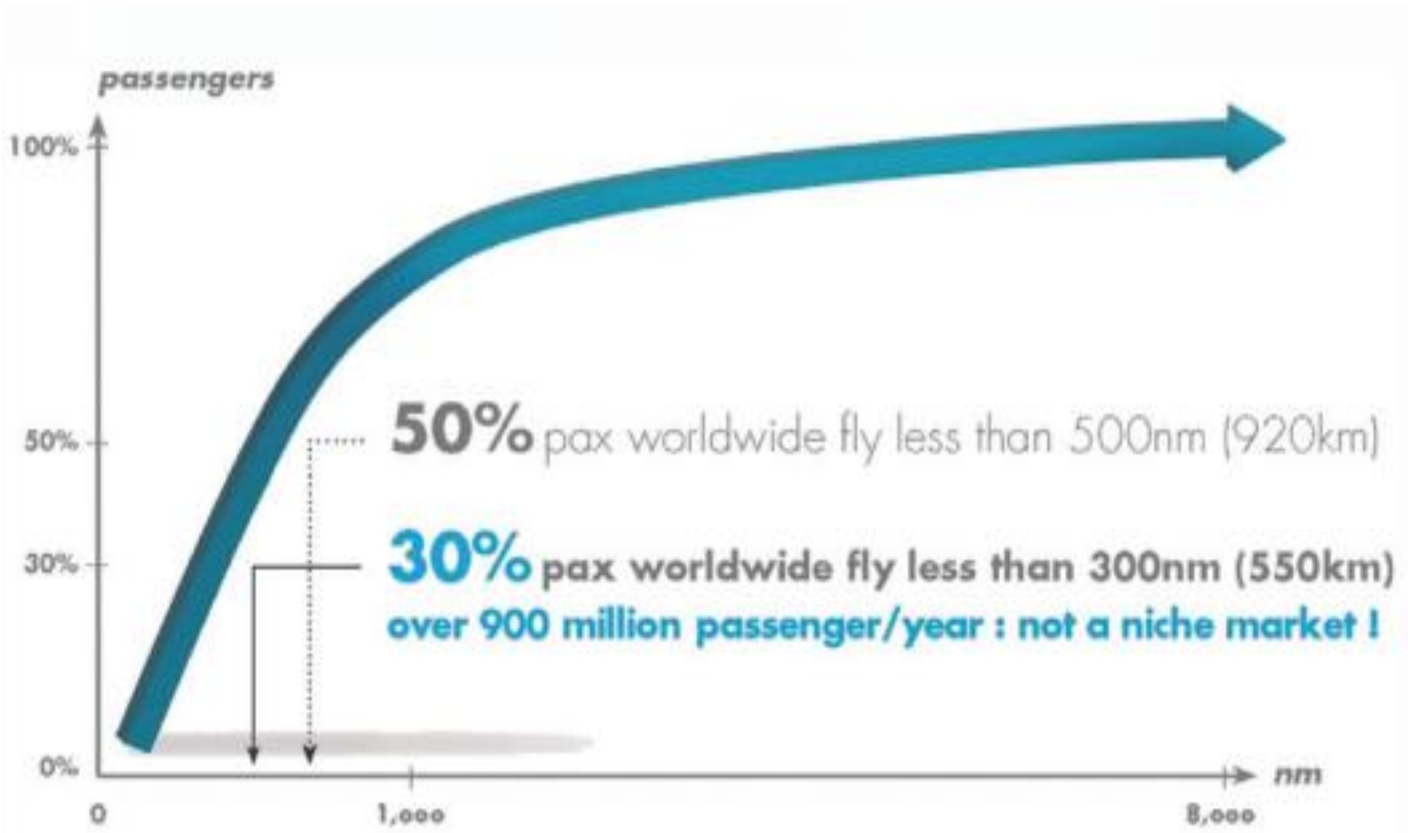


Source: IATA/Tourism Economics 'Air Passenger Forecasts'

Continent wise share in Global RPK in 2010-11 and 2030-31

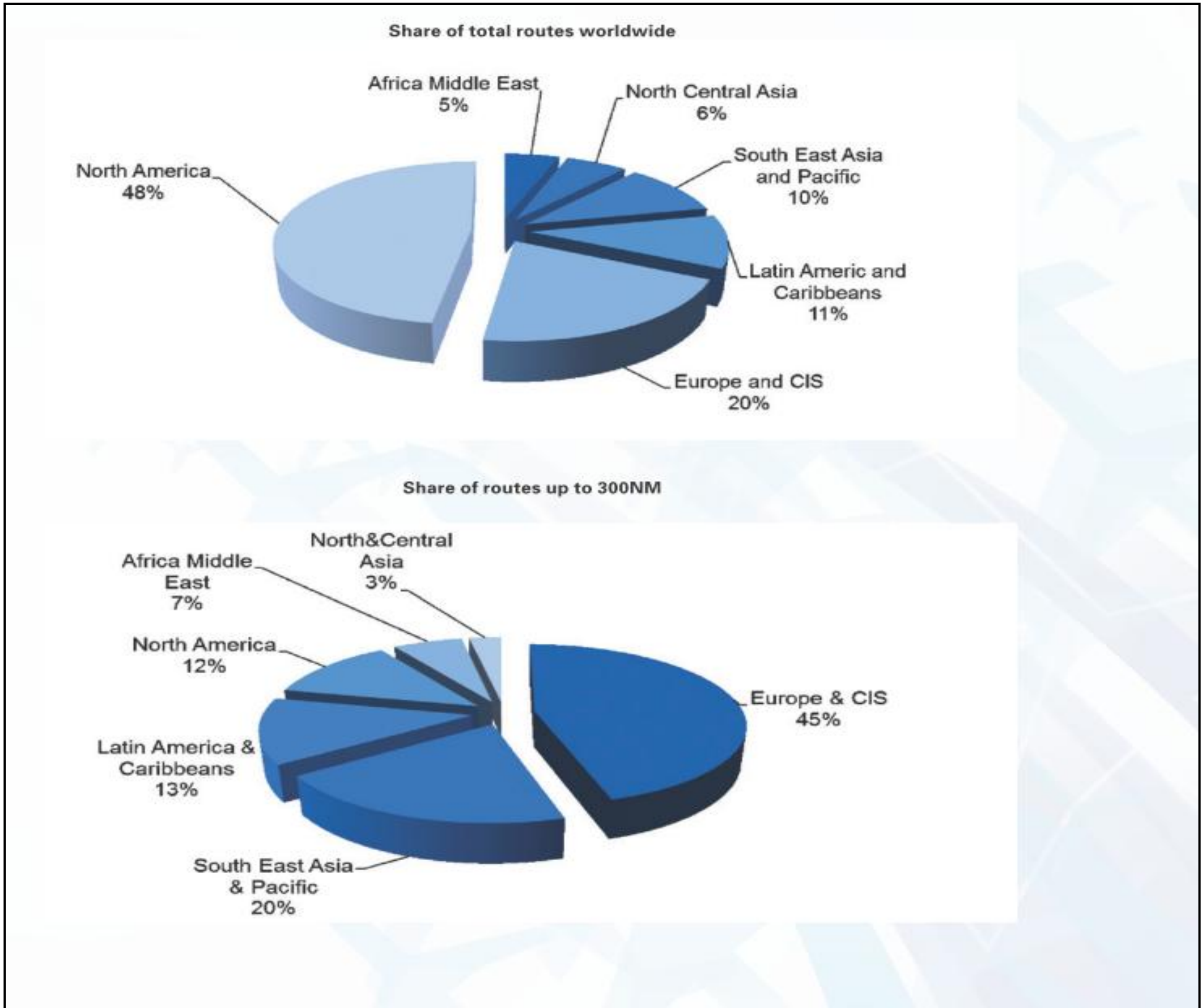


Source: MOCA, Working group on civil aviation, June, 2012



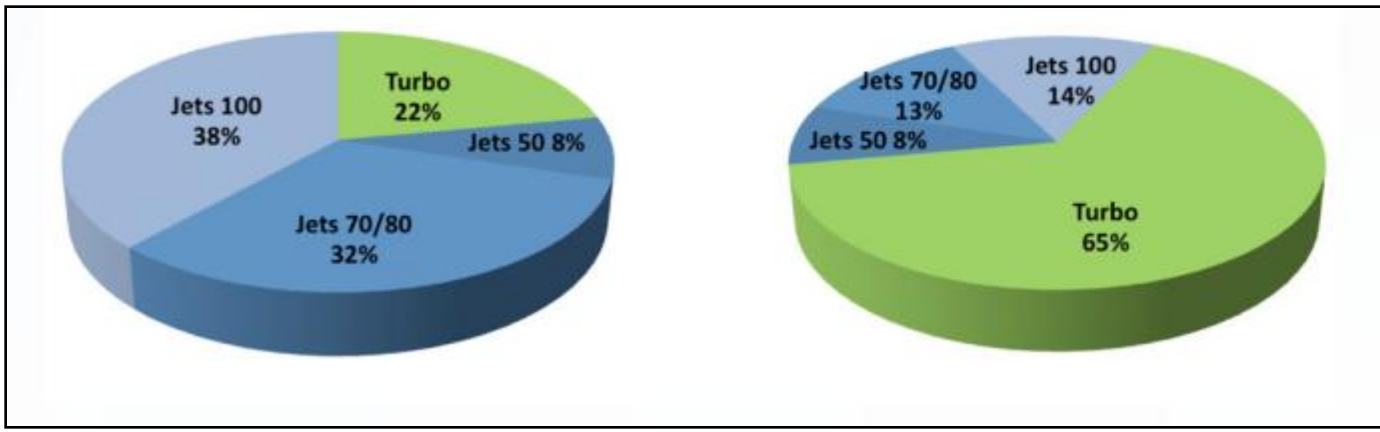
World wide passenger traffic by sector length

Source : report of ERAA,2014



Share of total routes Worldwide operated by Regional A/C

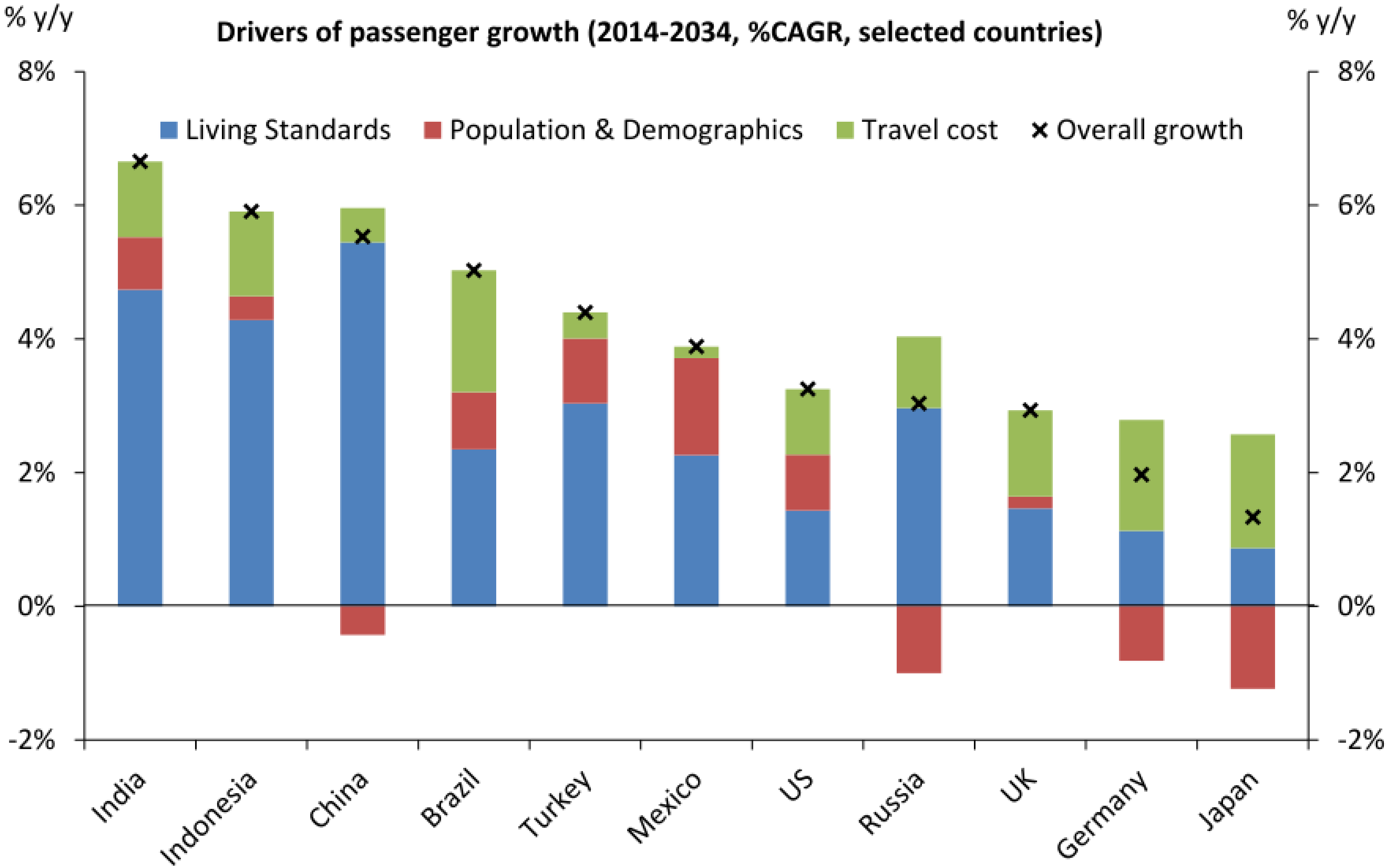
Source:ERAA,2014



Hub feed(left) & point to point(right) flights in Europe by category in 2012

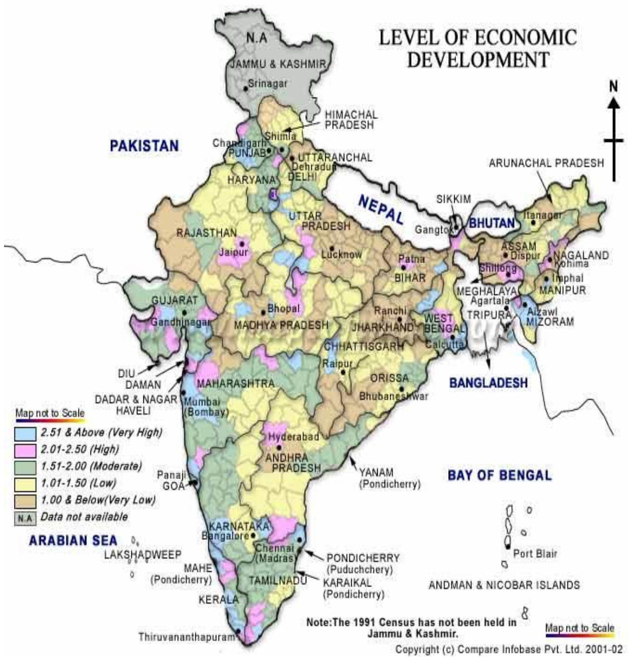
Source :ERAA, report,2014

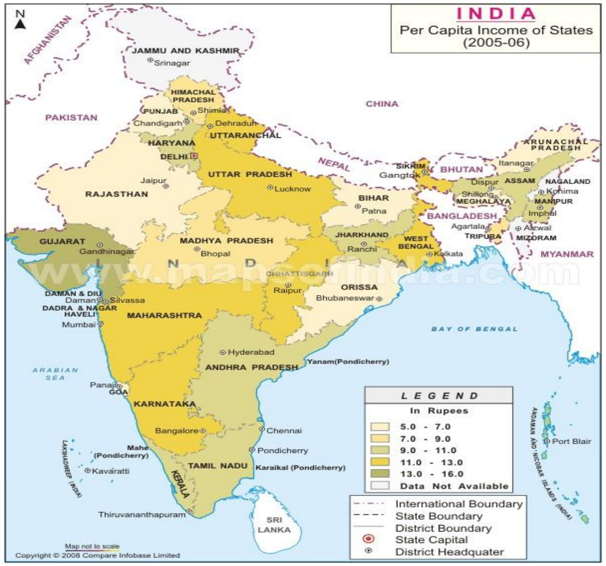
Developing economies show fastest growth



Source: IATA/Tourism Economics 'Air Passenger Forecasts'

EVEN SPREAD OF AFFLUENCE ACROSS INDIA LEADING TO DEMAND FOR TRANPORTATION





Economic Growth

Higher disposable income

More modes of transport available

Improved Technology

More time on leisure and recreation

Increased urbanisation

Passenger Transport Demand

Amount spent on transport increases

Travel options increase

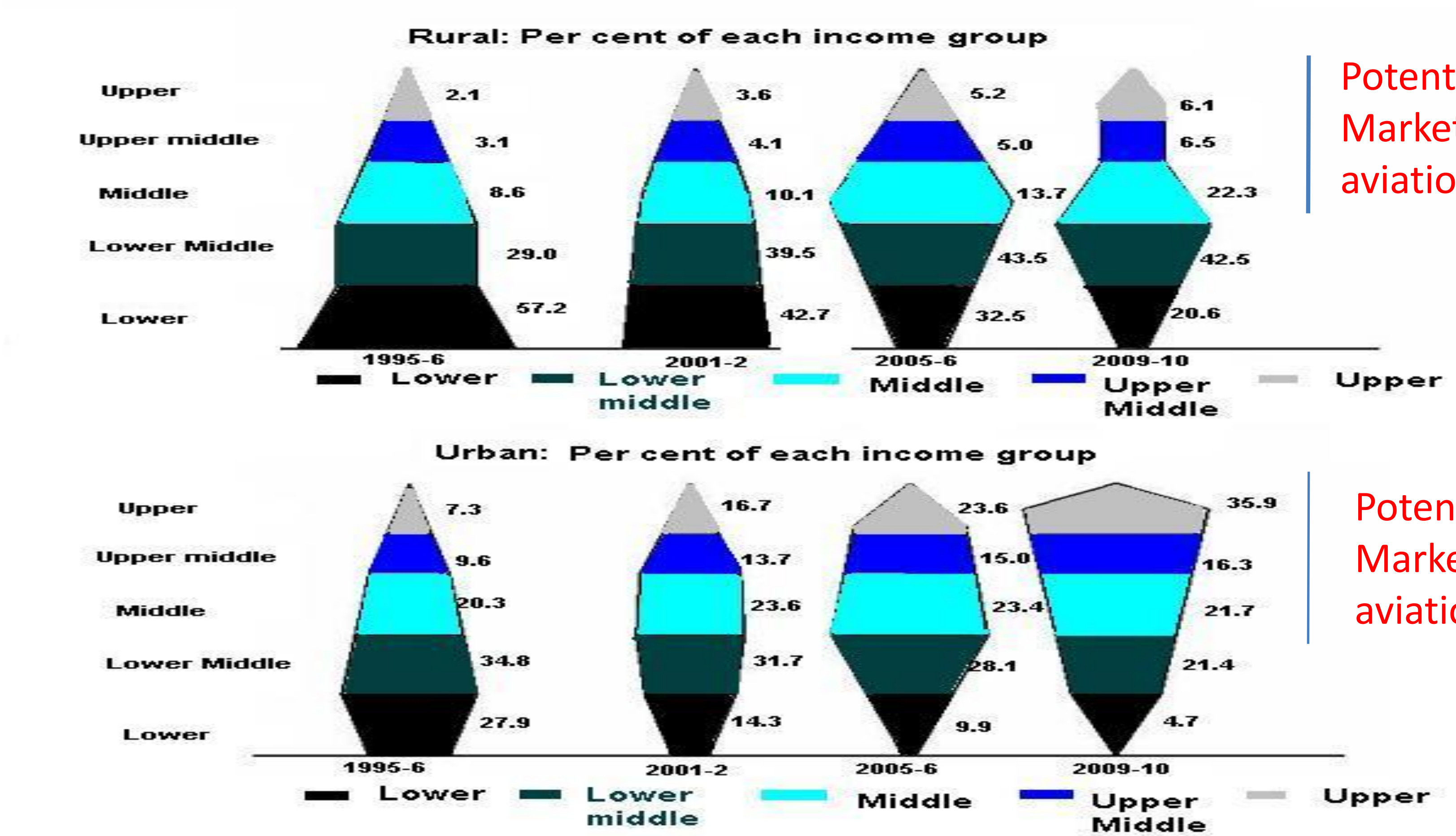
Longer distance of travel per unit time

Time spent on travel increases

Spur for travel

Urban population will rapidly increase In India by 87% by 2025 leading to higher demand for transportation

The case for inclusive growth



Potential Market for aviation

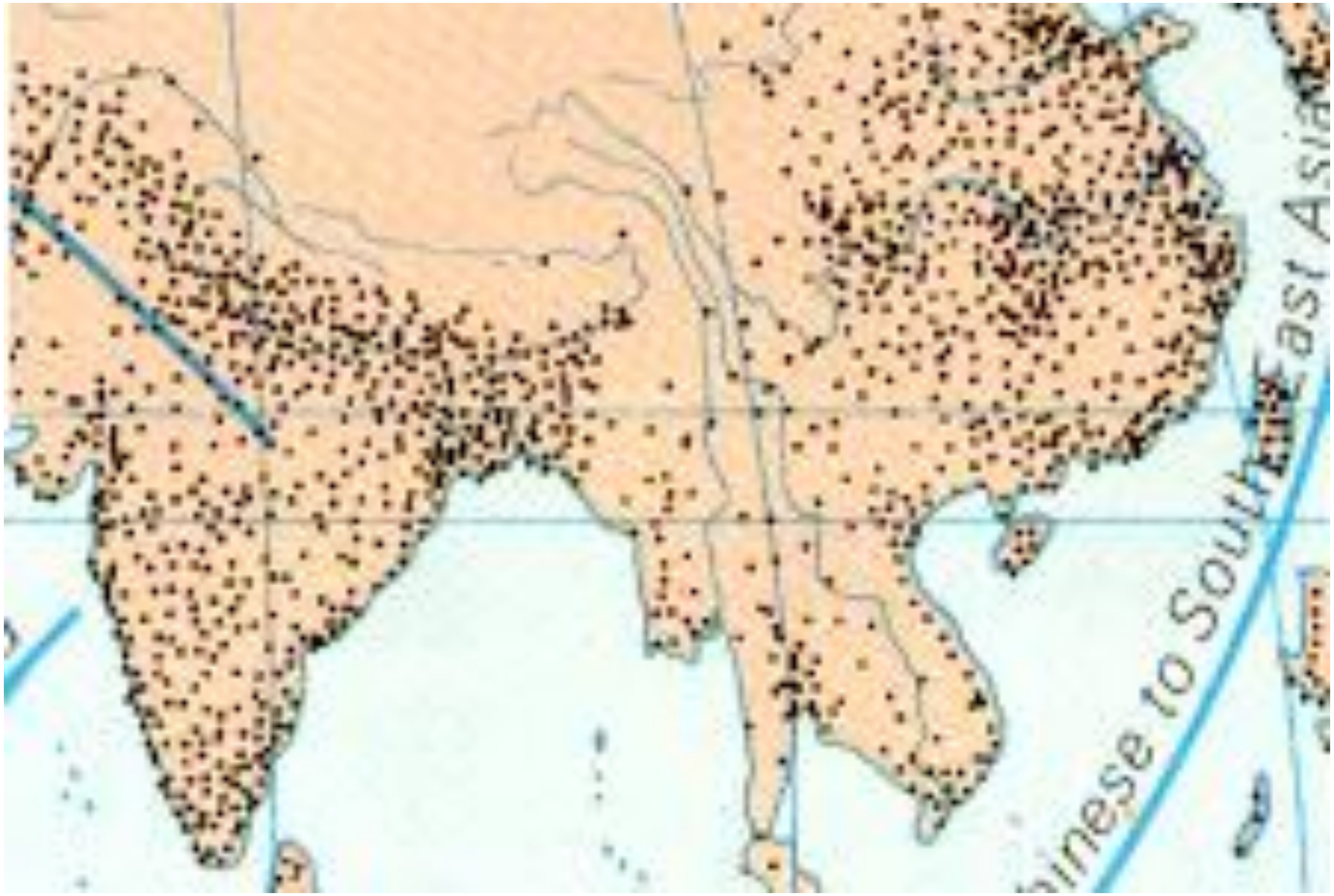
Potential Market for aviation

Changing Shapes of Income Distribution --India

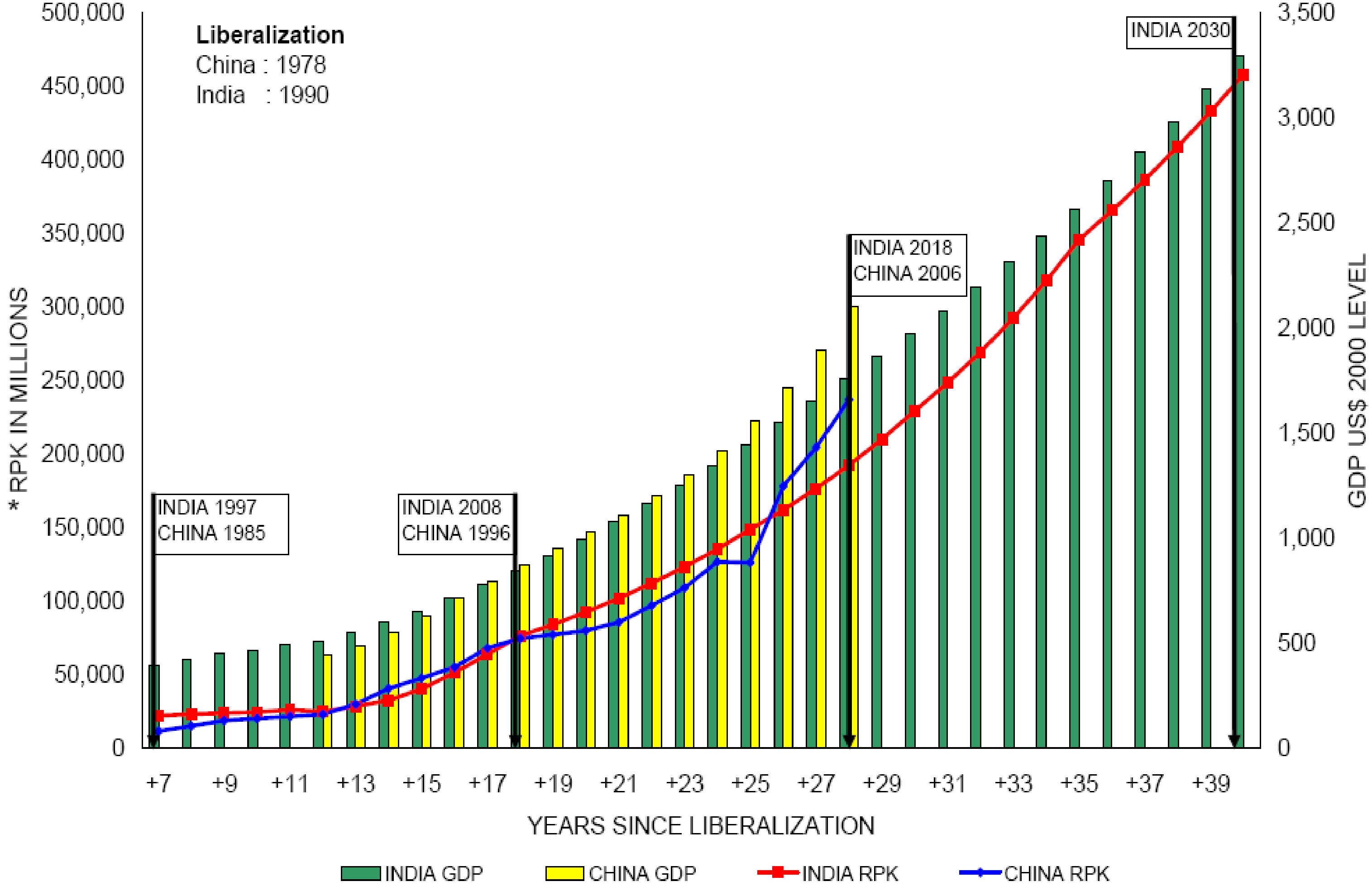
source: Rama Bijapurkar

Economic geography

Even distribution of population unlike China



INDIA RPK GROWTH POTENTIAL

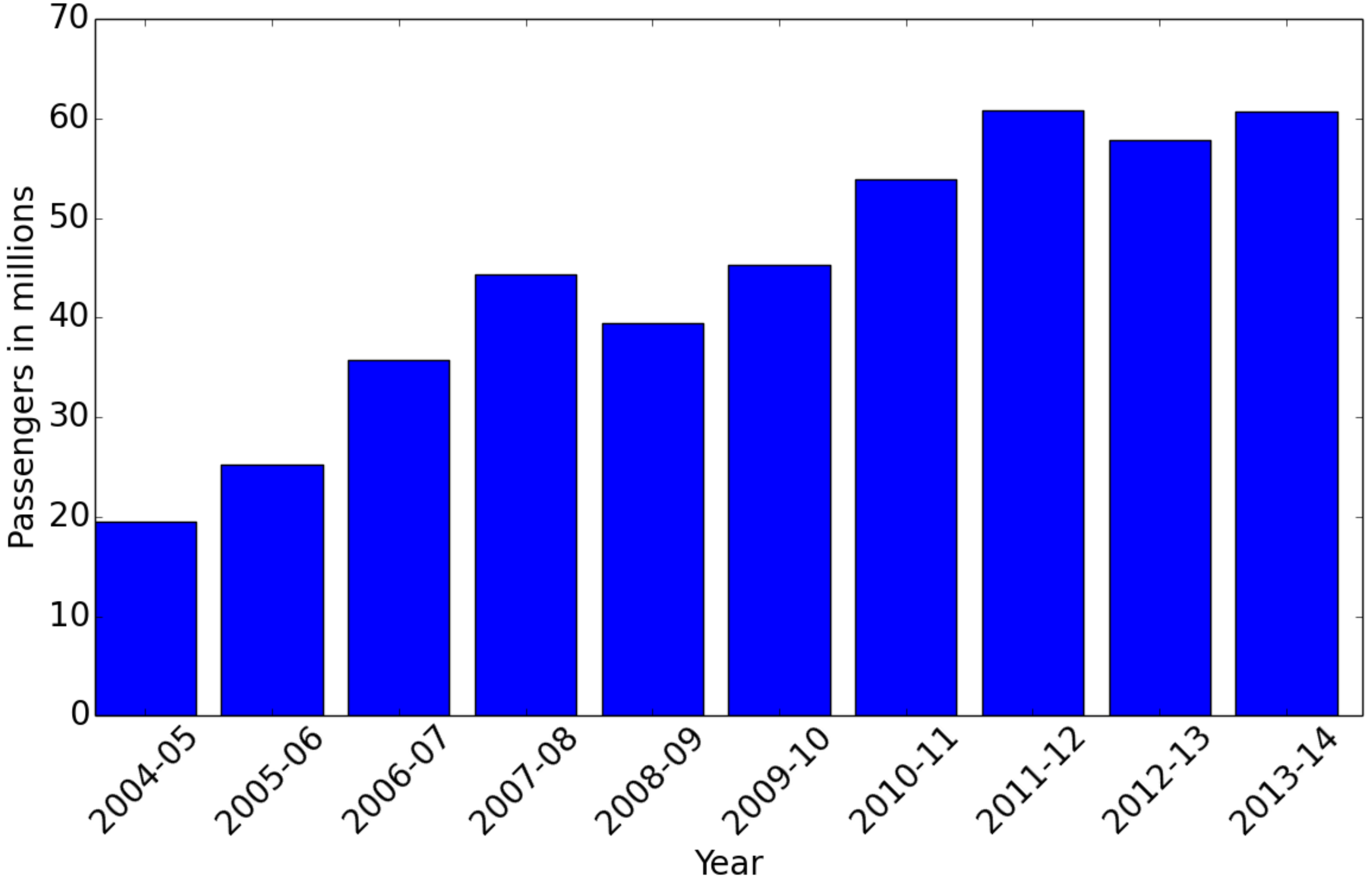


Indian RPK expected to grow ~ 3 times in 10 years, similar to China

Source : Director General of Civil Aviation (India), Global Insight, National Bureau of Statistics of China

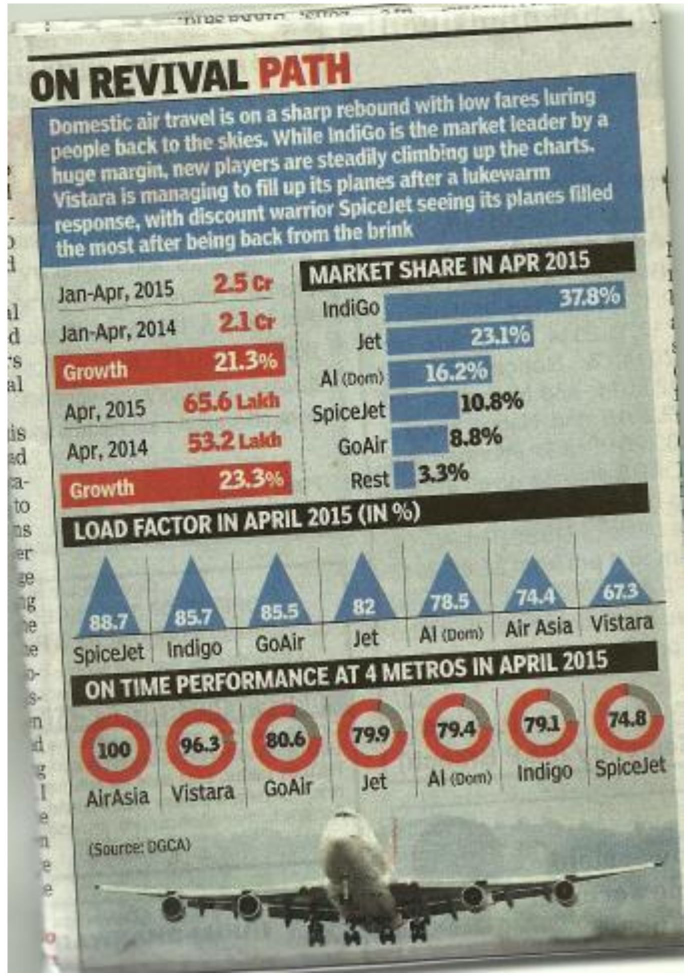
* Total Market, domestic + International

Passenger traffic in India last 10 years

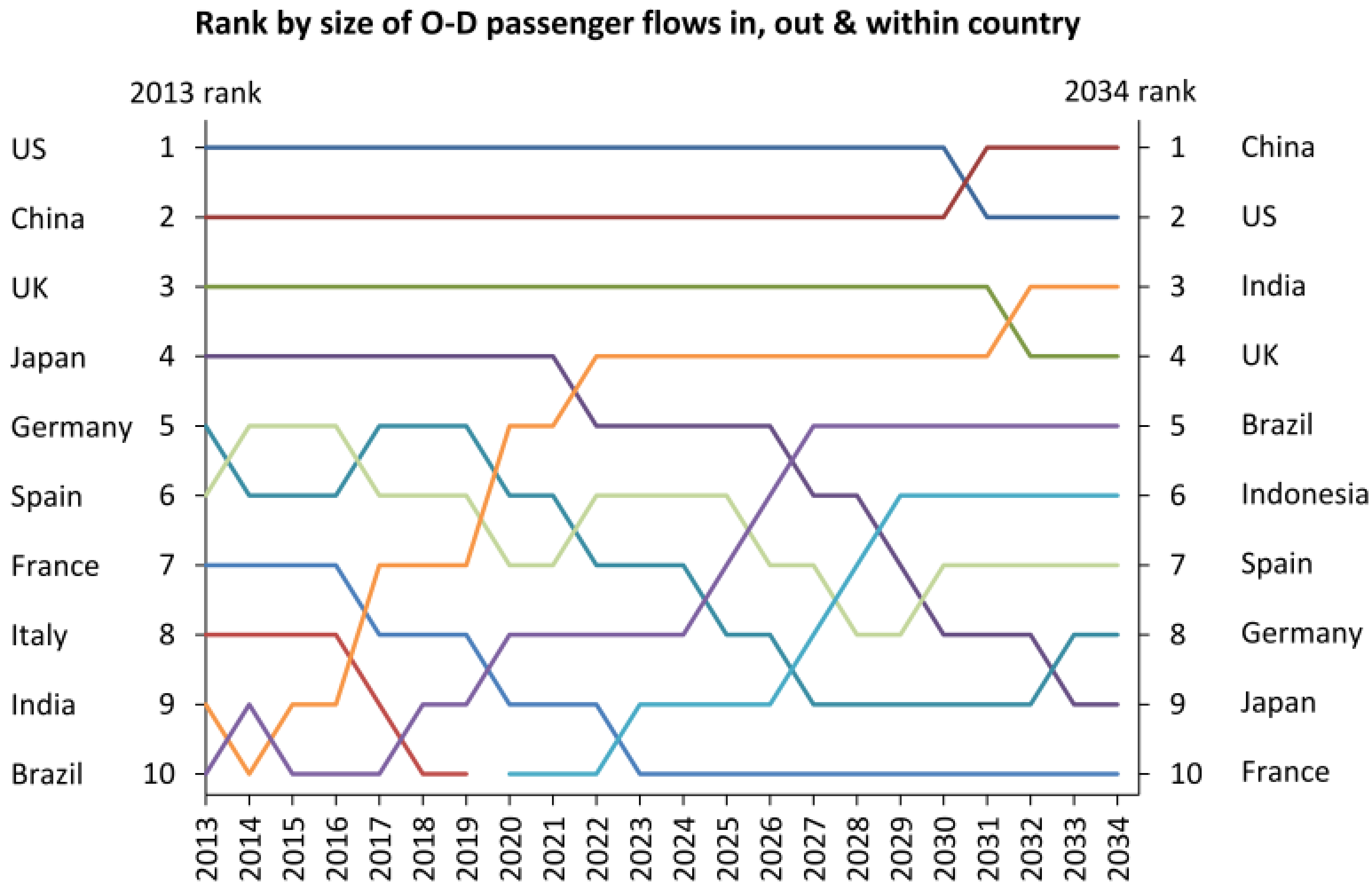


Source : DGCA

Growing Domestic Air Traffic In India



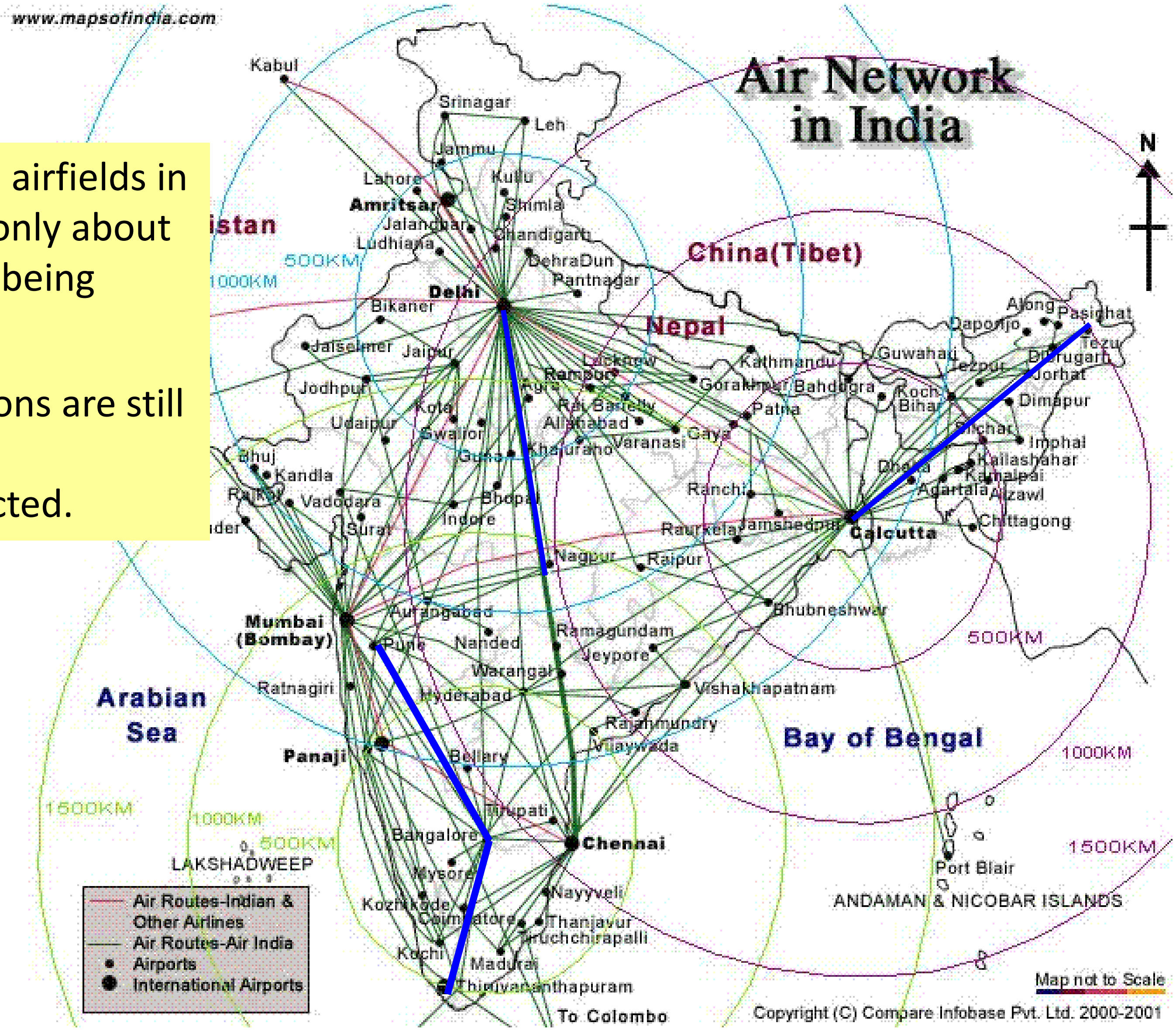
TOI,23rd May,2015



Source: IATA/Tourism Economics 'Air Passenger Forecasts'

Of the 449 airfields in India, only about 86 are being used.

Many regions are still poorly connected.



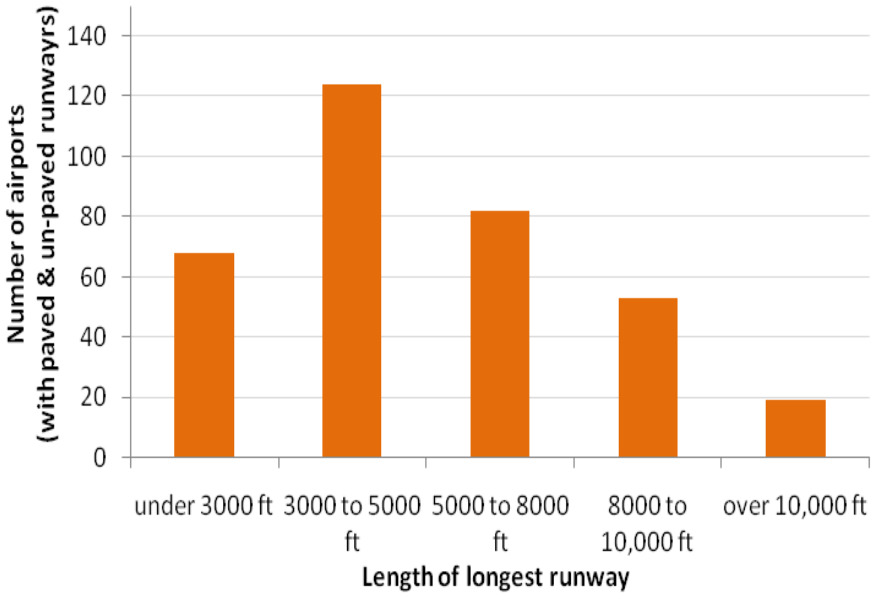
Airport Infrastructure … expanding

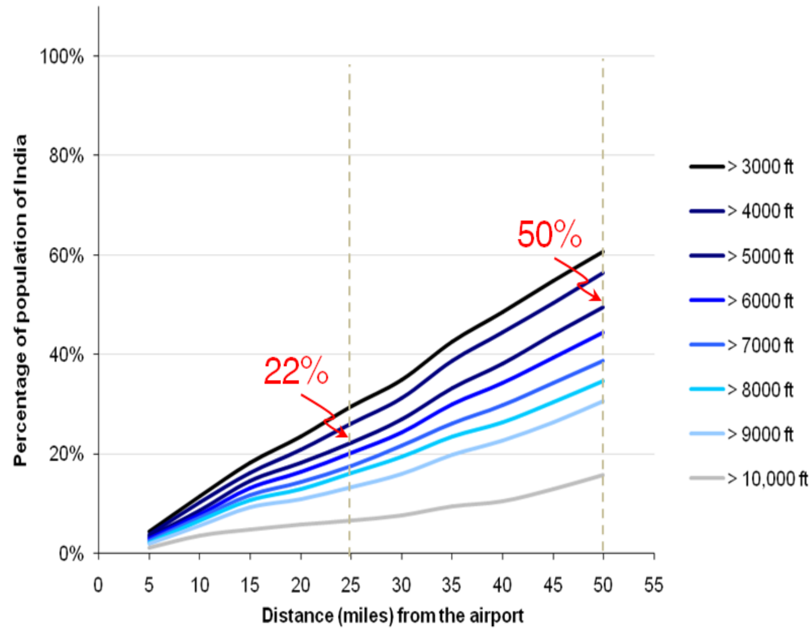
Expansion

- 61 airports, 50% of traffic thru Delhi & Mumbai
- $9B Investment Plan thru 2010
- Greenfield: HYD ('08), BLR ('08)..opened
- Upgrades: Delhi ('08 runway/'10), Mumbai ('10)
- 35 Non-metro modernization: $1.2B Inv, ('10)

Opportunities

- Broad distribution of existing airports aligned with population centers >1M
- Centrally located between Europe & Asia
- Int'l point-to-point … WBs, Cargo
- Hub bypass – target underserved markets
- Merchant airports





Characteristics of Airports and Access to Air Transportation in India

Source: Bonneyfoy , Indo-US workshop(2008)

Mosaic of Low Cost Aerodromes

- No frills, passenger friendly, functional non-air conditioned Terminal Building.
- No capital intensive facilities like PBBs, escalators, elevators, baggage carousels.
- Modular concept for future expansions.
- Usage of low-cost, energy efficient, sustainable technology
- Total Land (400 - 600 acres) to be provided by State Government free of cost.
- Runway length of 1200m to max. 2000m, compatible for ATR 72, CRJ 700/Q400 operations.

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Cost Optimization

- Airport Rescue & Fire Service through local sourcing
- Explore remote ATS concept
- State Government supports:
  - Security through Local Police
  - Defray Aero charges i.e. Handling/Parking/RNFC
  - Exemption of Property tax and VAT on ATF
  - Support Airlines by underwriting riding seats (identified routes with < 50% load factor)
  - Provide viability gap funding to Airport Operator
  - Creation of Essential Air Services Fund (EASF)

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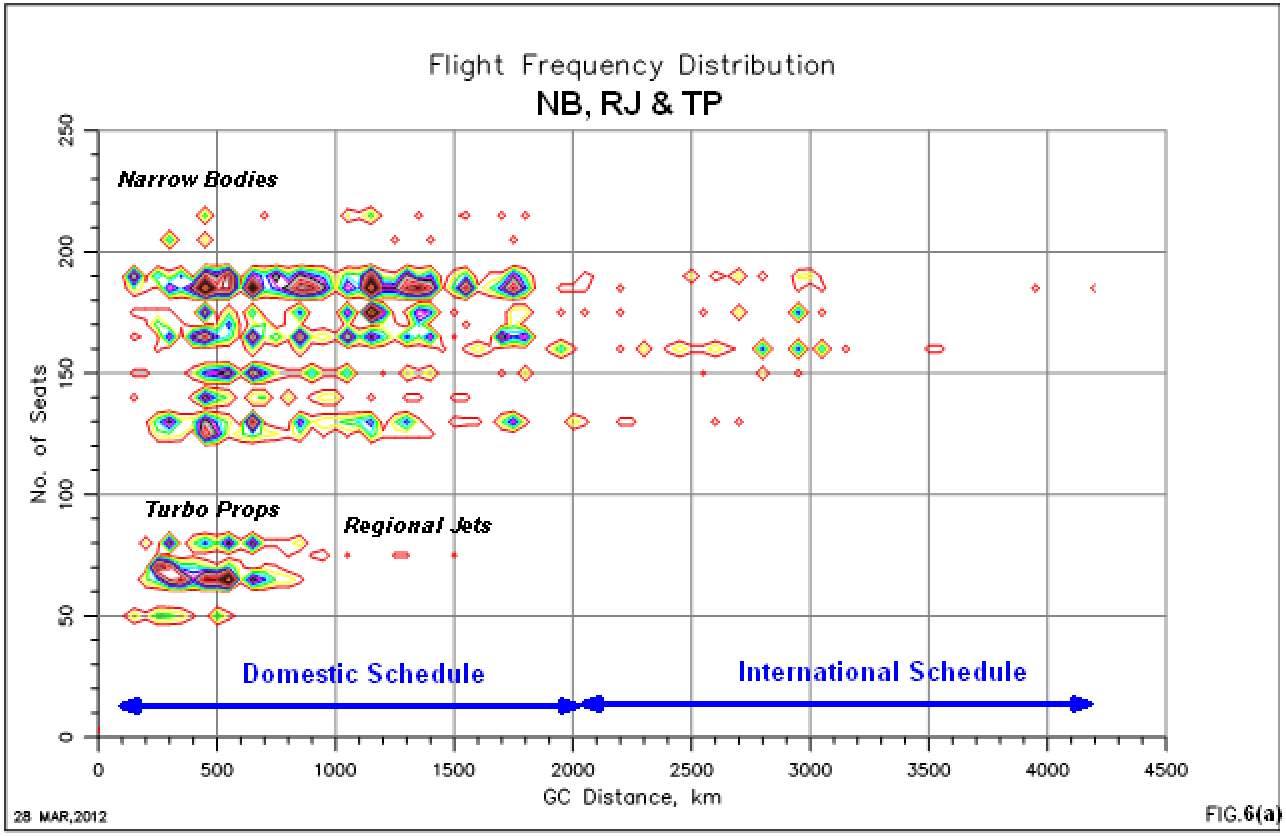
Deployment of Aircraft in India

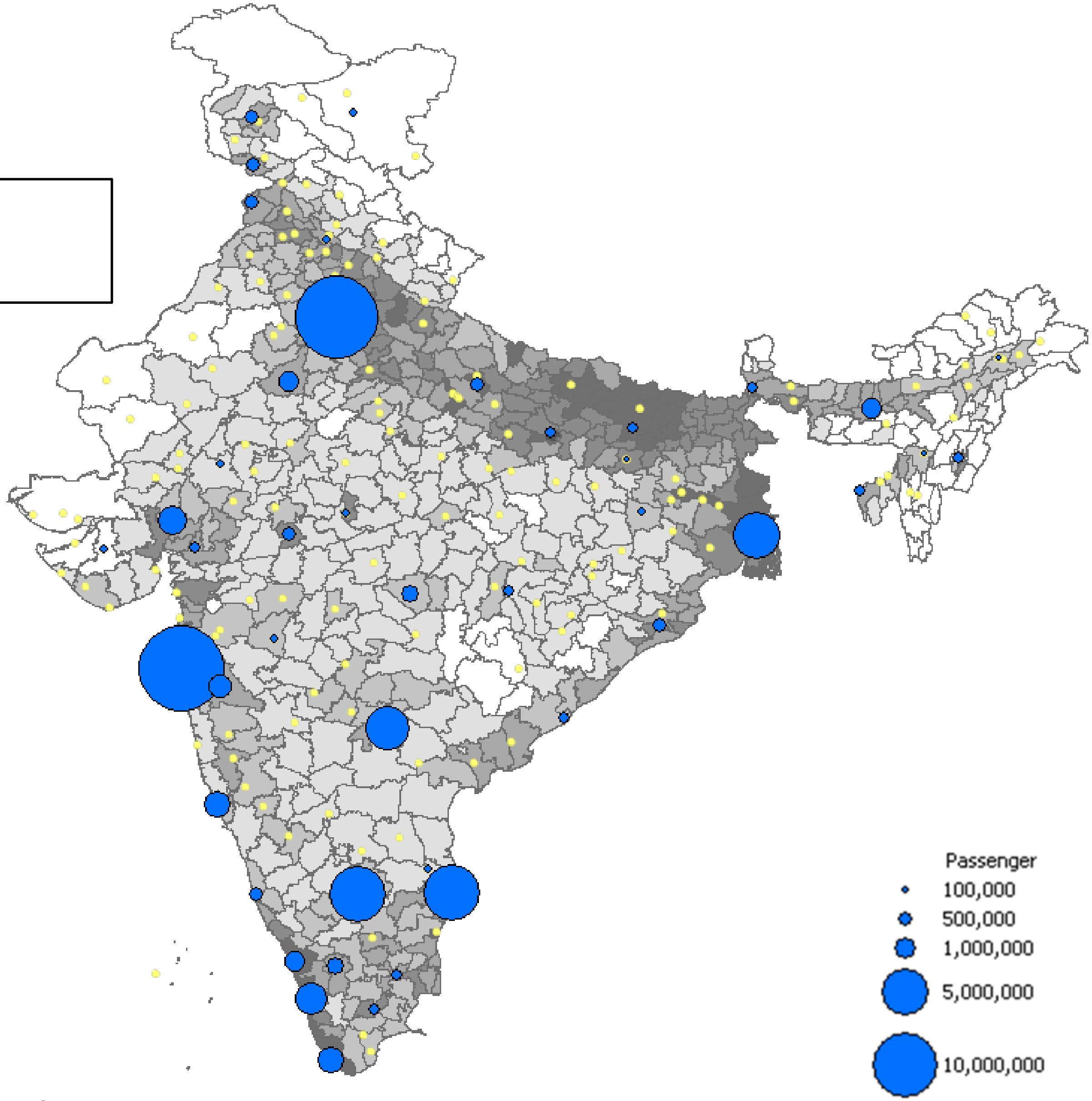


70% routes are less than 1000 kms- suitable for RA

Source : Jolly

Current Distribution of Passenger Traffic

70% of the traffic is between Metros



Analysis by Philippe Bonnefoy

Data source: Airport set and geographical location (DAFIF)
Note: * Source: Ministry of Civil Aviation of India

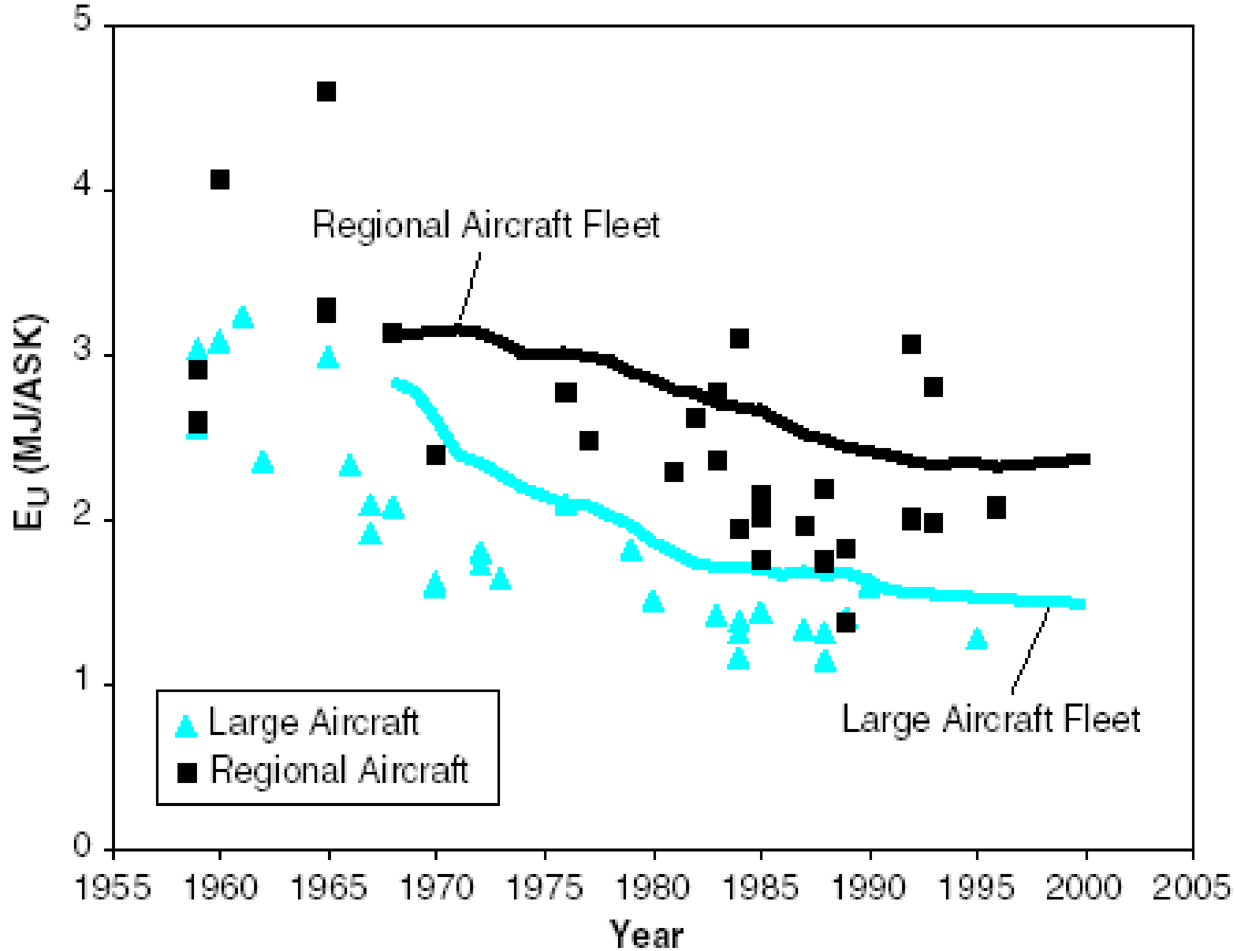
The State of Indian Civil Aviation

- Air Traffic in India is amongst the fastest growing in the World.
- But Civil Aviation in India is going through a turbulent phase : Only one profitable airline
- Poor connectivity to non metro airports
- Narrow body aircraft are deployed on the routes that are not suitable
- Regional aircraft operated in India are of vintage technology

The existing Regional A/C (Turboprops ATR-42/72, Q 400 etc) and Turbofans ERJ 145/170, CRJ 200/700 etc)

- Are costly to acquire
- Expensive to operate
- Need extensive maintenance
- Can operate only from well equipped Airfields
- High fuel consumption and emission levels
- Some of the Technologies are 2 to 2 1/2 decades old

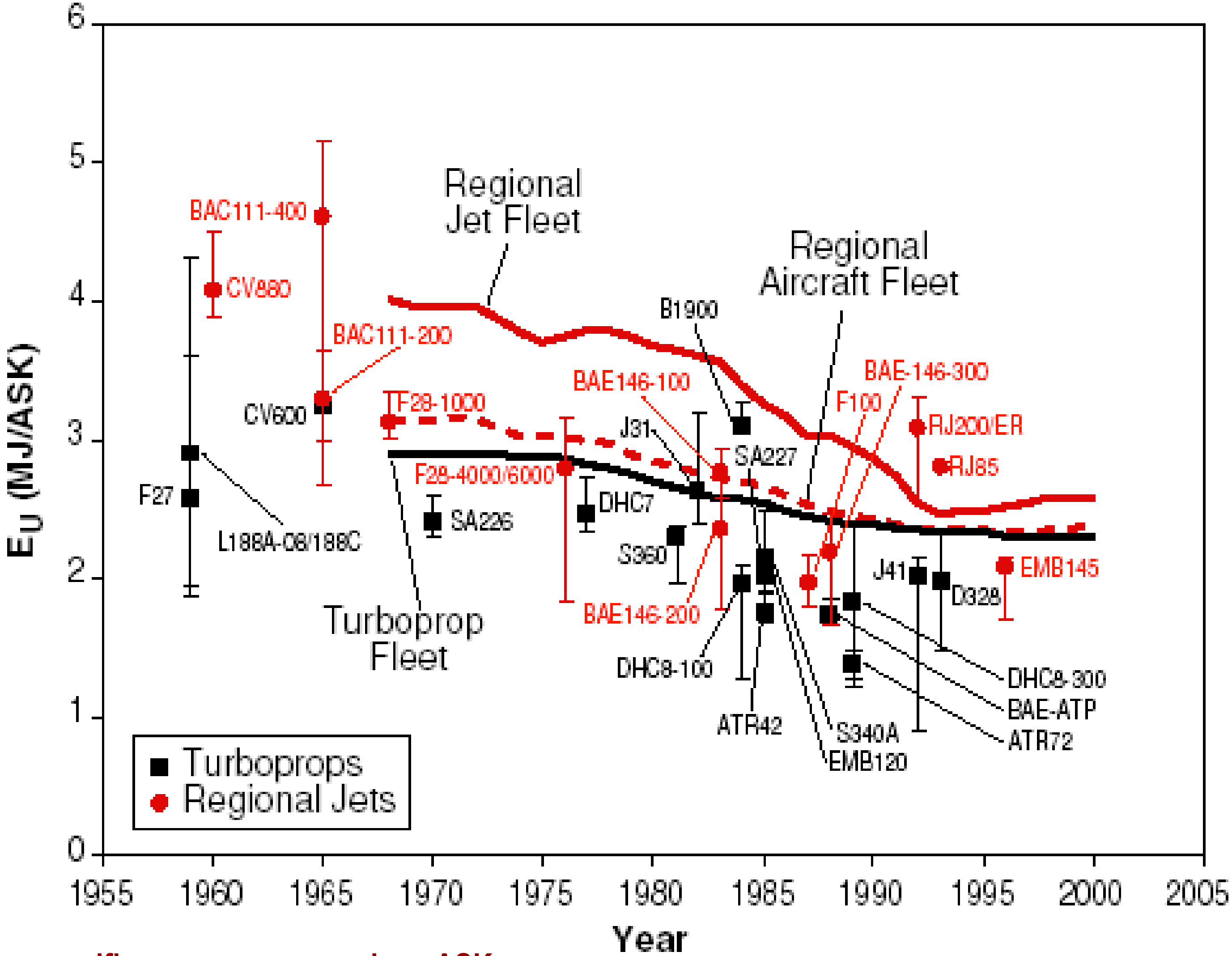
Technology progression and efficiencies in large/regional aircraft



Where Eu is the specific energy consumed per ASK

From : Raffi Babikian, Stephen P. Lukachko and Ian A. Waitz* Department of Aeronautics and Astronautics, Massachusetts Institute of Technology

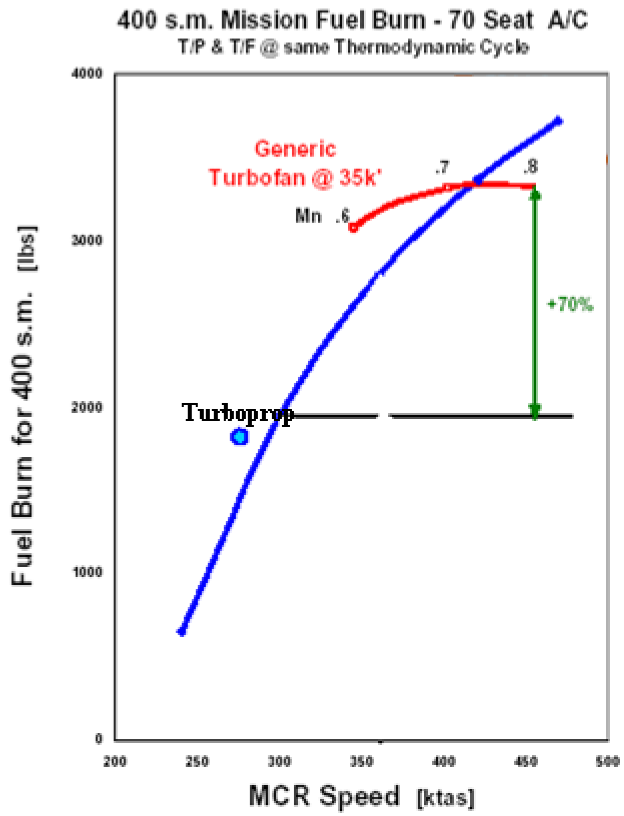
Technology progression and efficiencies in regional aircraft



where Eu is the specific energy consumed per ASK

From Raffi Babikian, Stephen P. Lukachko and Ian A. Waitz* Department of Aeronautics and Astronautics, Massachusetts Institute of Technology

FUEL EFFICIENCY AND GREENHOUSE GAS



300 ktas Turboprop
Yearly savings* compared to regional jet

2.3 million lbs. of fuel

7.3 million lbs. of CO_2

+

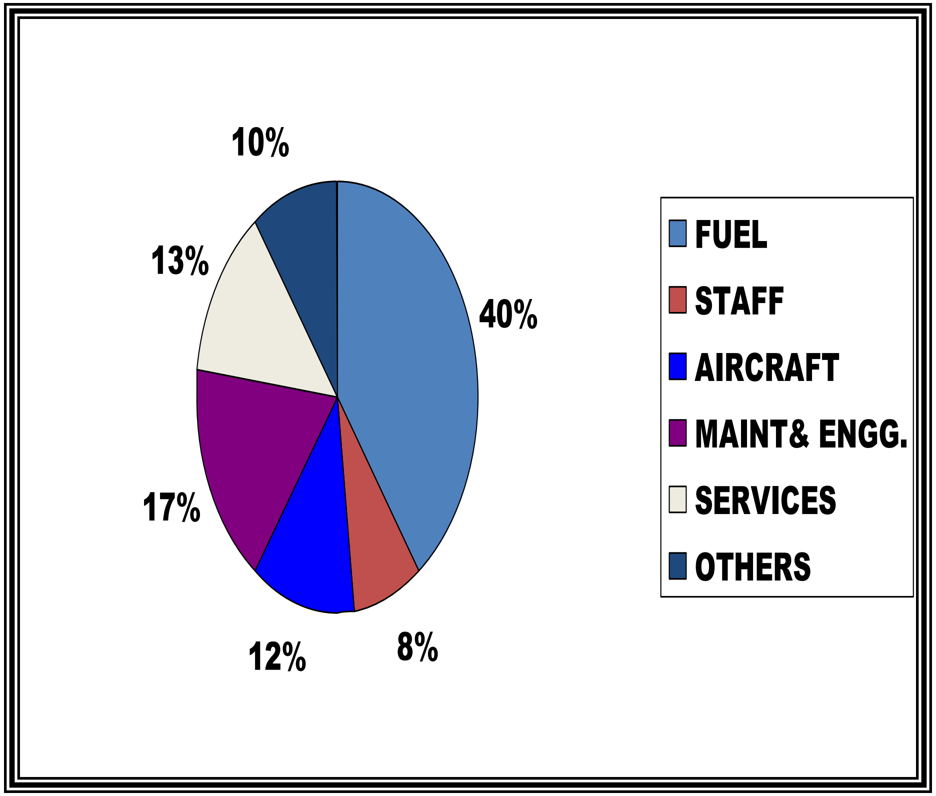
...up to $725K fuel cost

*70 seat A/C,2400 hrs/yr, fuel @ $2/usgal

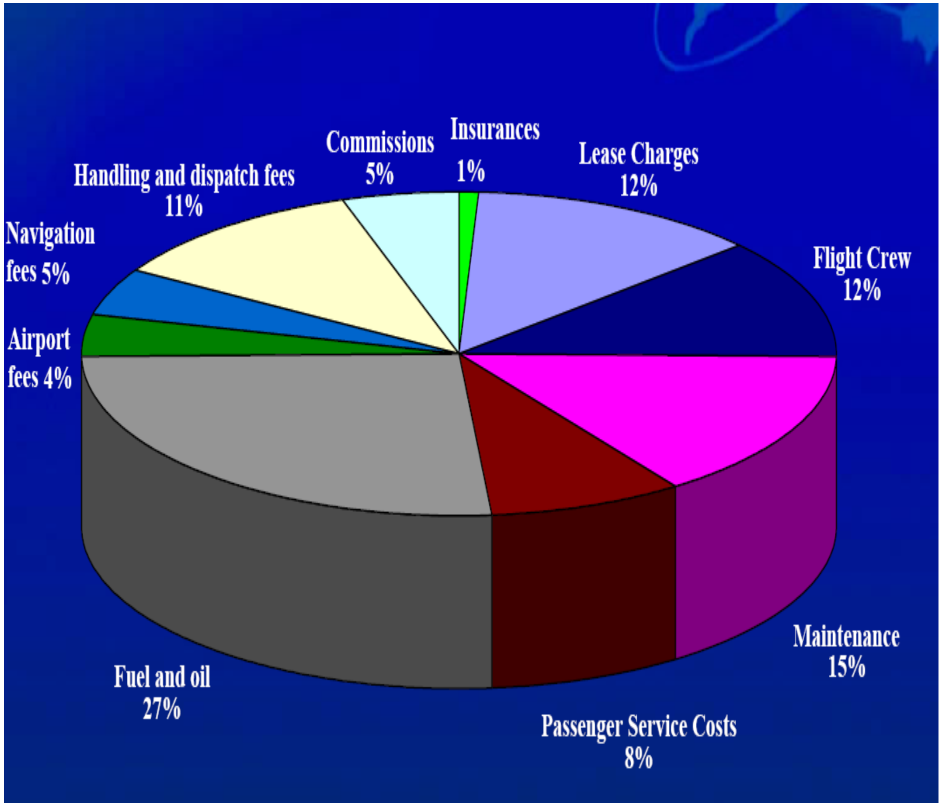
Turbo-props fuel burn is 70% lower than turbo-fans leading to lower Operating costs and emissions

Source: P&WC

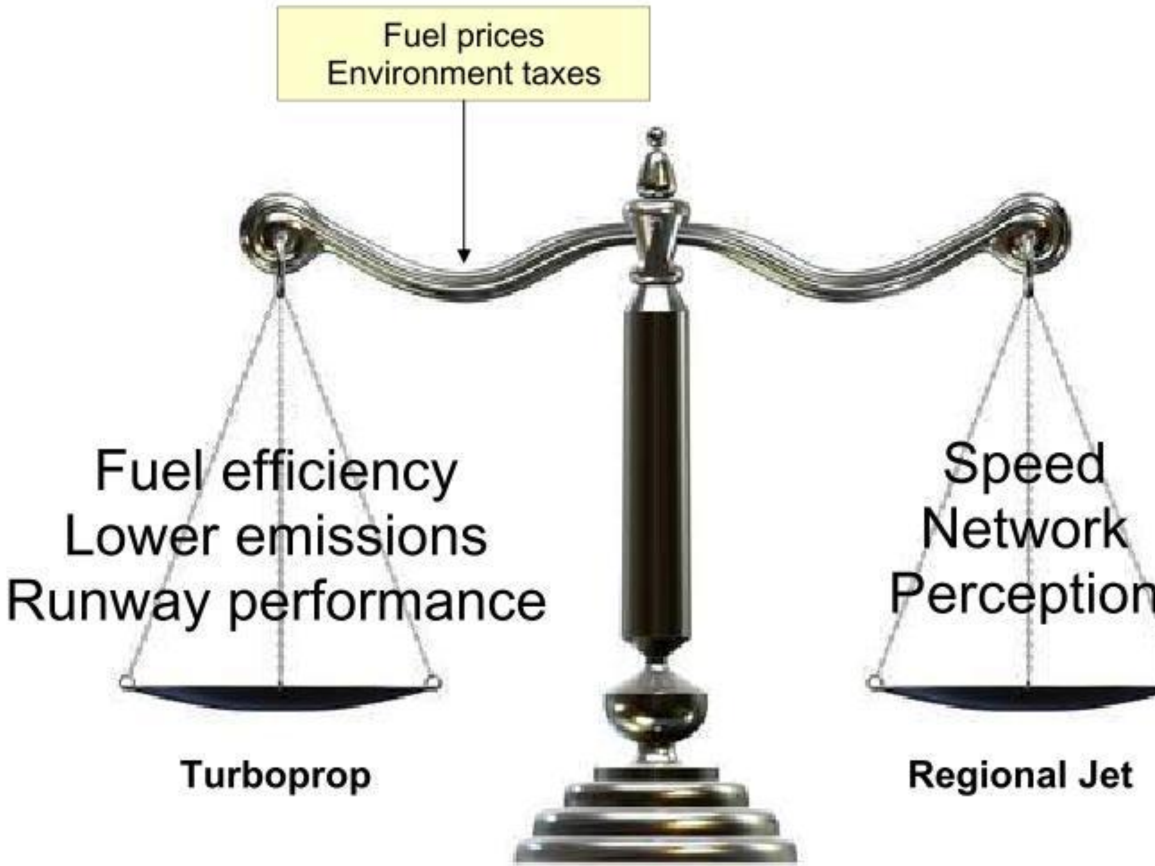
Typical Indian Operating Costs

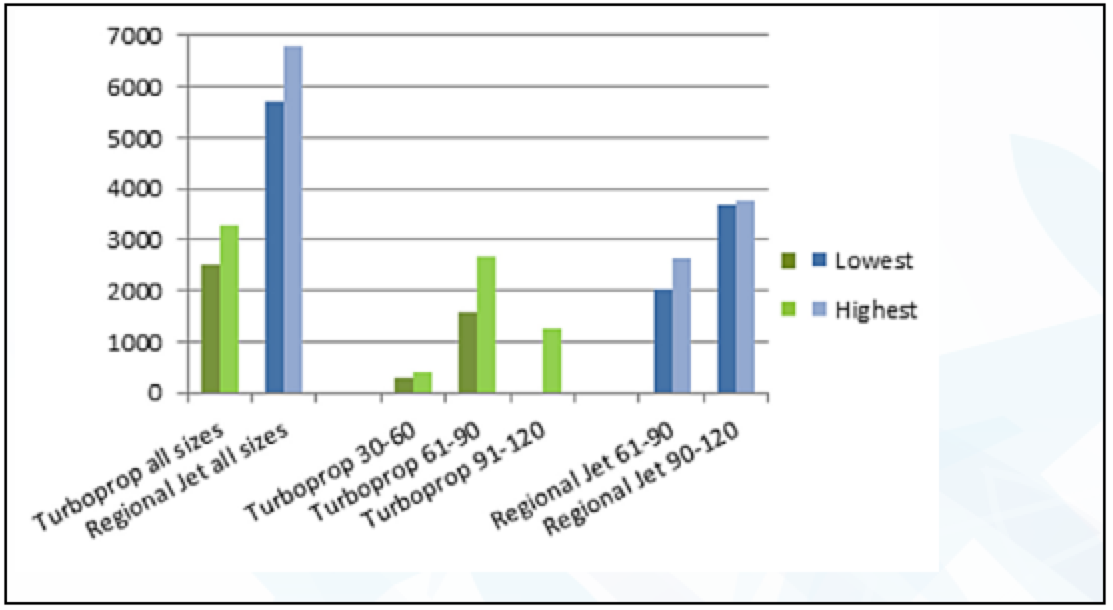


Typical International Operating Costs



BALANCING THE NEEDS





Regional A/C demand forecast to 2032

Source :ERAA,2014(ATR,Bombardier,Embraer,SJI)

Results of limited Primary survey

- Survey covered travel by Rail, road & Air at a tier III city
- Price and availability are critical parameters
- Air travel could grow 10 times if ticket price is reduced to half
- With in a mode, time taken is not important
- Connectivity to the airport not critical

Discussions with operators

Discussions held with the airline operators of regional aircraft : Deccan, Air-India Regional, Jet Airways and Kingfisher

Experts from flight operations, network planning, costing, market analysis and maintenance participated

Discussions revealed that the operators had a view that a product superior to that being operated today would be of value as it would definetely improve Viability which was much needed

Points made :

- 20% reduction in fuel burn
- 25% (atleast) reduction in ownership costs
- Speed > 550 km/hr
- More Cabin baggage space
- Reduction in maintenance costs vital
- Improved ECS performance in hot conditions
- Ability to land in ill-equipped airfields : Use of on-board technology vs airfield equipment
- Stretch to 90 seater viable from an operator view point

DO-228(40+25+38)

HAL-HS 748 (59)

AN-12 (100)

Action for replacement of HS 748 is on the anvil
AN-12 also would need replacement in next 10 years

MILITAY AVIATION

REGIONAL AIRCRAFT

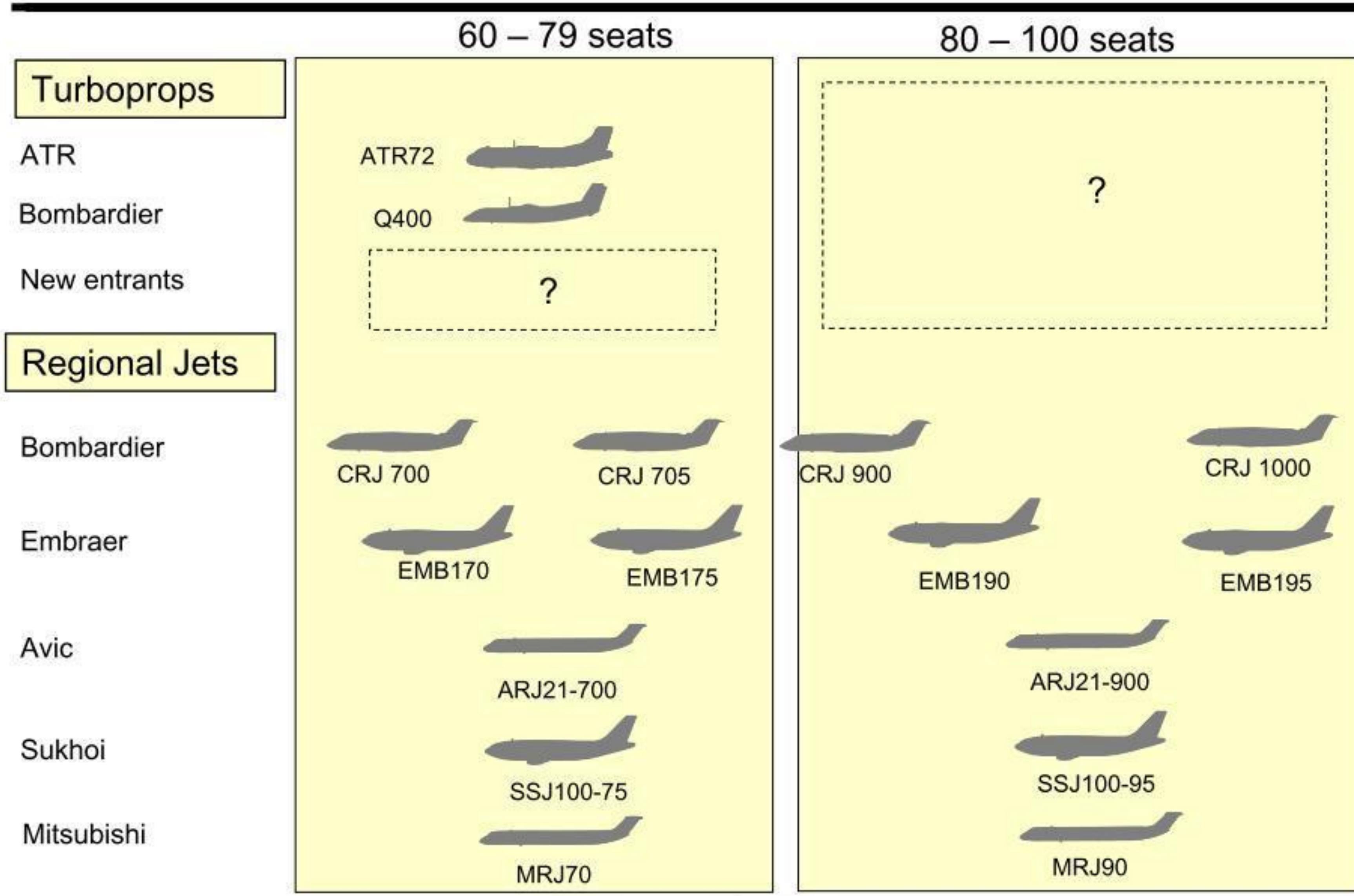
The Market

- **World wide**
  - **Prediction by Regional aircraft manufacturers indicate 6000-7500 aircraft in 20 years**
- **India**
  - **AeSI/NAL study suggests 240 additional regional aircraft in 20 years**
  - **Requirement from armed services as replacement for AN-32, Do-228, HS 748 aircraft estimated as 150.**

Civil Aviation:	**240**
Military Aviation:	**150**

Substantial Indian and world market exists for Regional Aircraft

AIRCRAFT OFFERING



NEW GEN REGIONAL AIRCRAFT

Requirements

- **Acquisition cost :25% lower**
- **Operating cost : 25% lower**
- **Fuel Consumption : 25 % lower**
- **Maintenance cost : 50% lower**

- **TO & land from unequipped airfields**
- **All weather operation**
- **Emissions lower by 70%**
- **Enhanced safety**

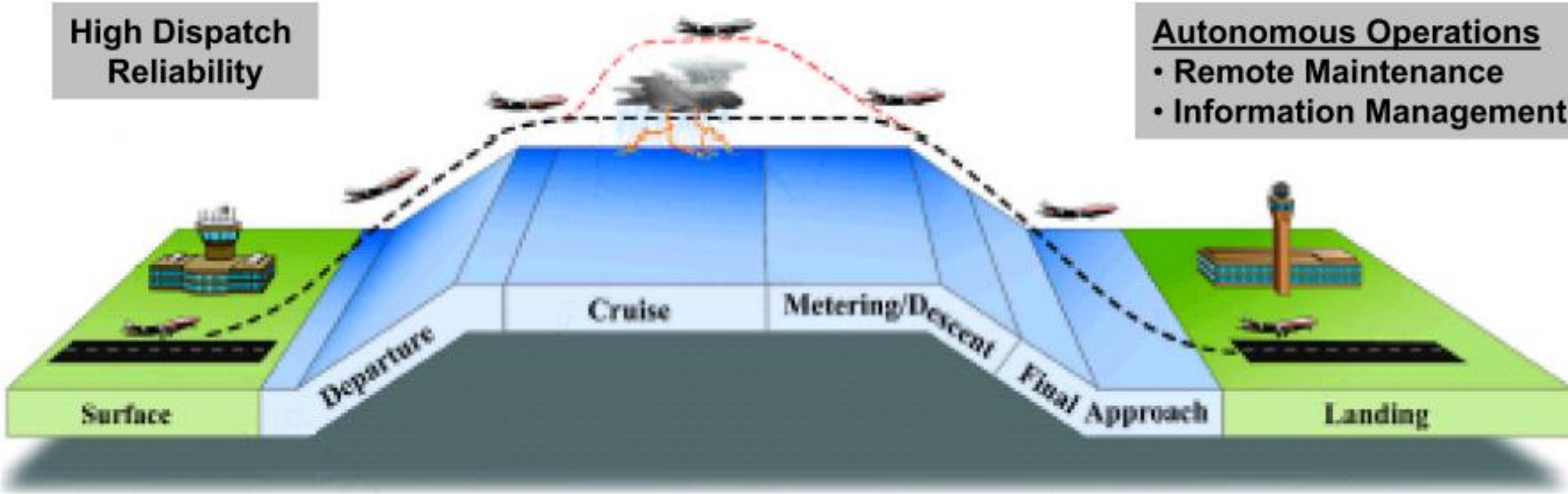
Commercial/Regional Aircraft Requirements from Take-Off to Touchdown

<u>"Green" Operations</u>
- Low Fuel Consumption
- Low Emissions
- Efficient Operations

<u>Efficient Operations</u>
- Required Communication Performance (CPDLC)
- Required Navigation Performance (RNAV, RNP)
- Required Surveillance Performance (TCAS, ADS-B)
- Situational Awareness (Terrain, Traffic, WxR)
- All Weather Operations

High Dispatch Reliability

<u>Autonomous Operations</u>
- Remote Maintenance
- Information Management



Performance Specifications
(Twin Engine Regional Turboprop)

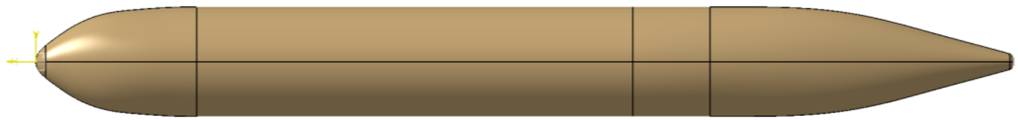
• Range with 90 Pax	2000 Km
• Range with Max fuel (70 Pax)	3000 Km
• Balanced TO Field Length (ISA, SL, MTOW)	900 m
• Landing Field Length (ISA, SL, MLW)	900 m
• Ceiling	30000 ft
• Cruise Speed	550 kmph

Design Should build stretch potential for a 100 seater with 2000 Km range

Differences between the Military cargo aircraft and the passenger transport aircraft

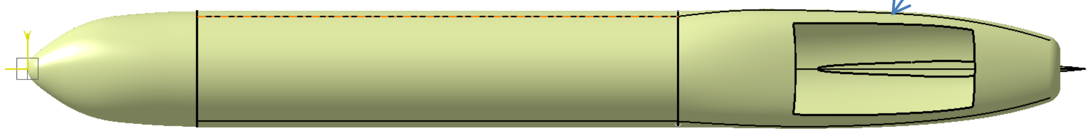
- Rear fuselage(Rear Cargo Door Loading)
- Floor location to maximize cargo size
- No of windows and doors
- Cabin interior
- Hot and high performance of military cargo version needing development of high lift devices and matching engine performance
- Landing gear design for operating from semi prepared runways

PASSENGER FUSELAGE

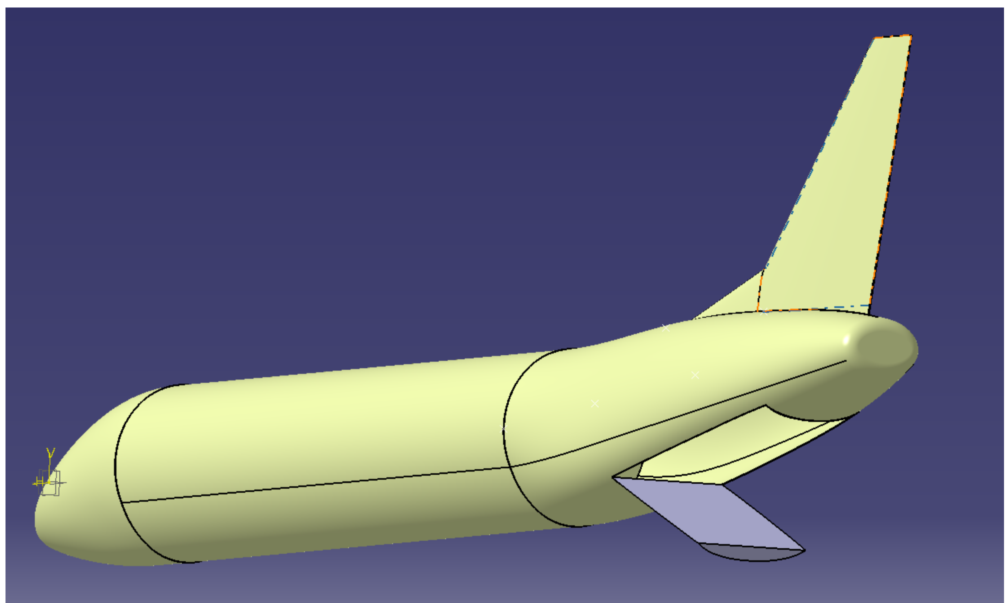


CARGO FUSELAGE

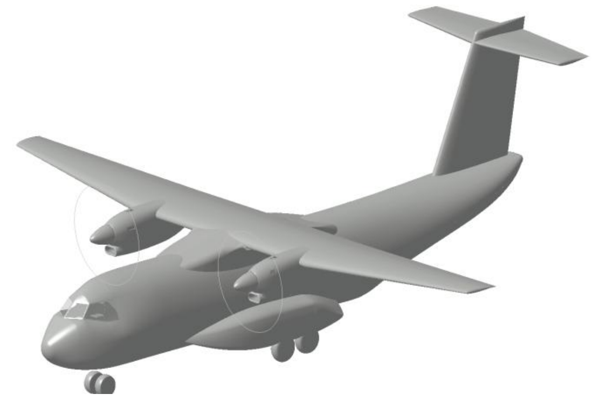
WIDTH REDUCTION STARTS MUCH LATER

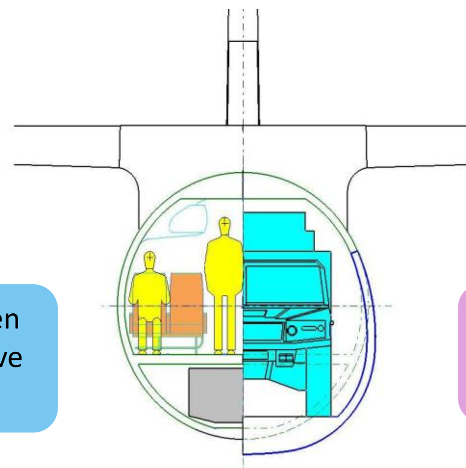


CARGO LOADING



Next Gen Turbo Prop: Potential for a Military Transport & Mission Derivative





Design Commonality & Convergence between the Civilian Baseline and its Military Derivative

An innovative way to keep our Product Line ready for the Future

TECHNOLOGIES OF RTA - 70

Advanced Aerodynamics

Next generation power plant

Fly by wire flight control system

- Open distributed modular AVIONICS
- GPS-WAAS-LAAS
- ADS-B
- Advanced Display Systems
- Active Vibration and Noise control

- Composite airframe
- Structural Health Monitoring

RTA - 70

Maintenance Concepts that reduce maintenance by 50%

- IVHM
- SHM
- Faster Trouble shooting

- Self clean coatings
- Deicing coatings
- Abrasion resistant coatings

Lean Ground Infrastructure

More Electric aircraft systems

$$\text{Aircraft Range} = \frac{\text{Velocity}}{\text{TSFC}} \left(\frac{\text{Lift}}{\text{Drag}} \right) \ln \left(1 + \frac{W_{fuel}}{W_{PL} + W_{O}} \right)$$

- Engine Fuel Consumption
- Aerodynamics
- Empty Weight

Distance traveled for given amount of fuel: Breguet Range Equation

	Fuel Burn	LTO NO_x	Noise
Vehicle:			
➡ -10% C_{D_i}	-4.4%	No change	-0.6 dB cum
➡ -10% C_{D_0}	-6.5%	No change	-0.9 dB cum
➡ +10% $(L/D)_{cruise}$	-9.6%	No change	-1.2 dB cum
➡ -10% OEW	-3.1%	No change	-1.2 dB cum
➡ -10% SFC	-11.1%	No change	-0.6 dB cum
Engine:			
➡ +2 pts. Fan η_p	-2.5%	-2.8%	-0.4 dB cum
➡ +2 pts. HPC η_p	-2.2%	-7.5%	-0.1 dB cum
➡ +2 pts. HPT η_a	-2.3%	-2.7%	-0.1 dB cum
➡ +2 pts. LPT η_a	-2.6%	-1.9%	-0.2 dB cum
➡ -20% Charg. Cooling	-1.3%	-1.5%	-0.1 dB cum
➡ -25% Pod Weight	-3.2 %	No change	-0.4 dB cum

Performance Sensitivities for a Fixed Engine Cycle and Airframe Configuration (Current Generation, Single-Aisle Midsize Airplane)

New Technologies that need to be addressed

1.Drag reduction (<20%)

- Laminar airframe – Natural Laminar flow (Hybrid ?)
  - Nano Coatings
- Reduction of Turbulent drag – Riblets /Alternate concepts
- Reduction of Induced drag- winglets,AR,Planform

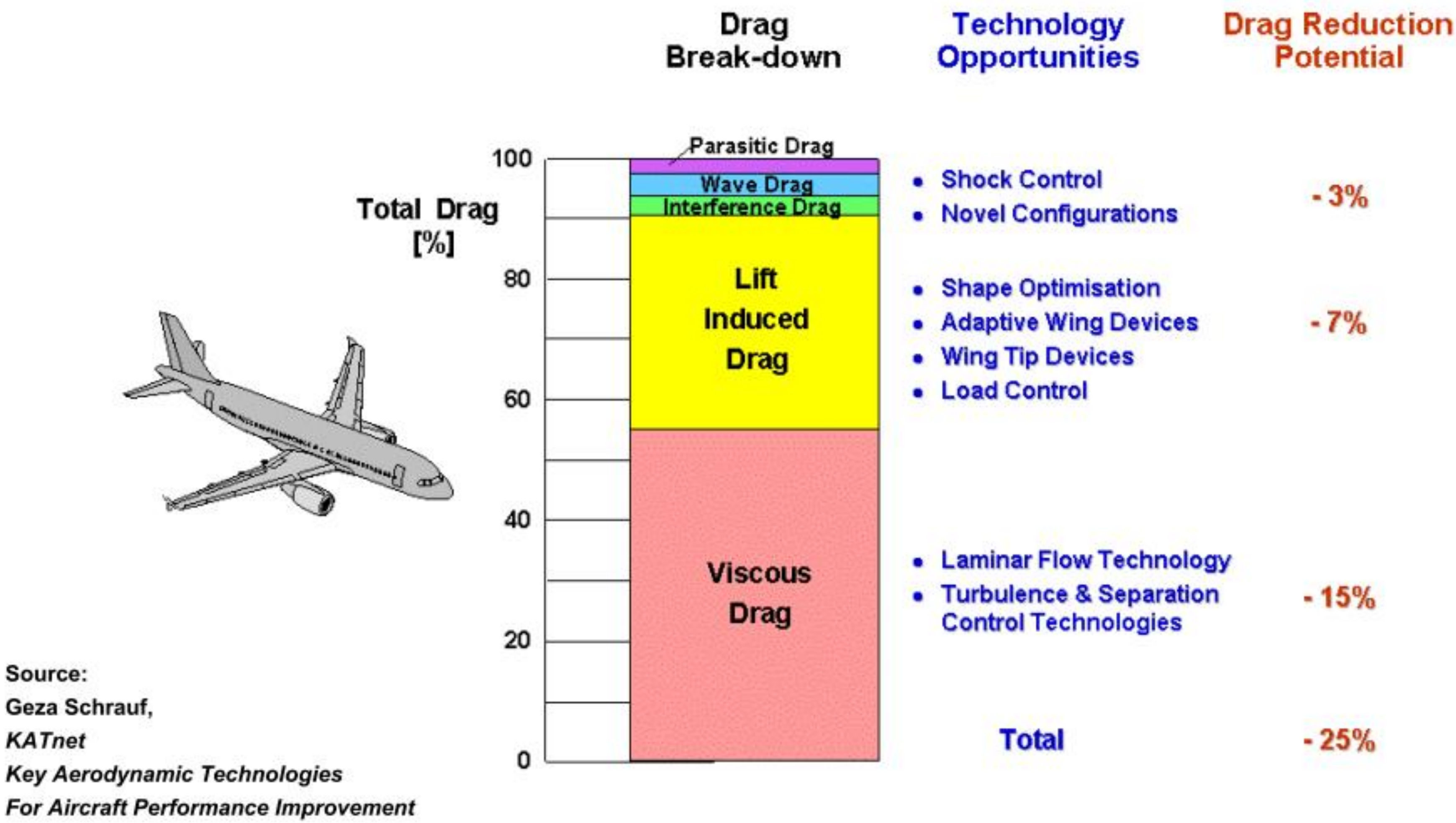
2. Airframe (weight < 20% , Cost < 30%, maintenance < 50%)

- Composite airframe
  (fuselage, inaddition to wing & empennage)
- Design concepts
- Crash requirements
- CFRP wind shield, pressure bulk head
- Lightning protection improvements
- Complex fitting development
- Reduce parts count
- Reduce cost
- Structural health monitoring

New Technologies that need to be addressed (Contd.)

5. Affordable fly by wire systems
    - Reduced hardware replication
    - Shared use of sensors
    - Reusable software
    - New generation computers
    - New design methodologies
6. More electric systems (cost < 30% , Maintenance < 50%)
    - ECS
    - Electric Landing gear retraction
    - Electrical brakes for Landing gear
    - Anti icing system
7. IVHM/SHM
8. Active noise & Vibration Control

Airframe – Aerodynamics



Source :DLR

Laminar Flow Control: Potential and Challenges

Challenges

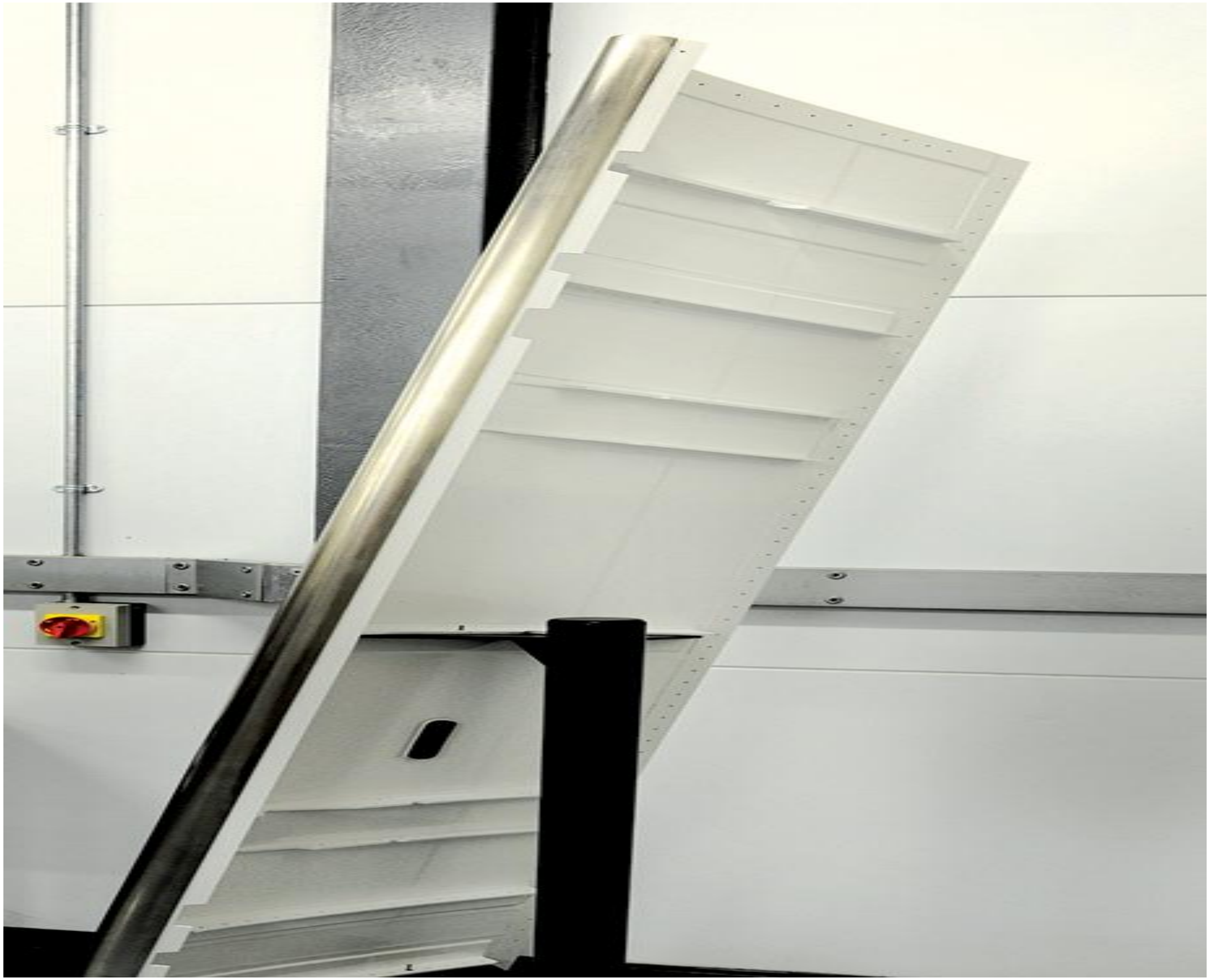
- Suction System Complexity
- Anti-Contamination System (Insects)
- De-Icing System
- High-Lift System Wing Design
- Surface Quality & Integrity
- Mass Production Concepts

Potential Savings (aircraft level):

Wing:	- 12%
Tail:	- 3%
Nacelles:	- 1%

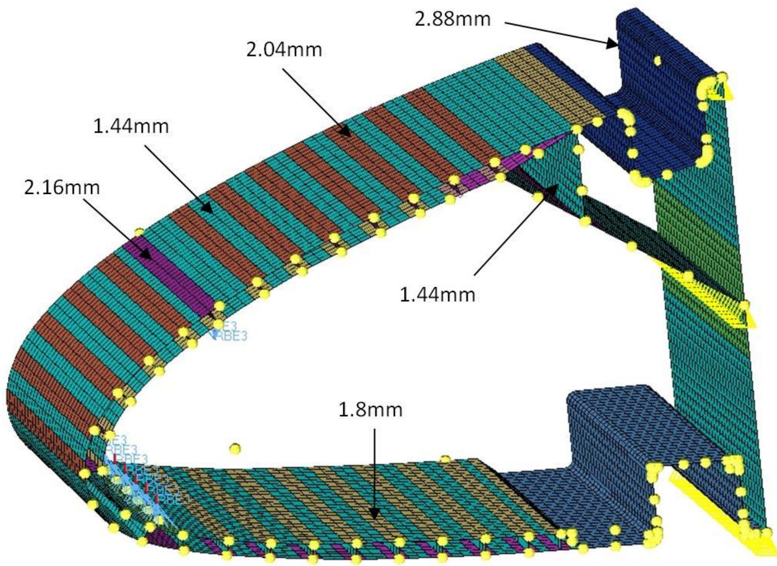
Fuselage: not feasible due to high Reynolds numbers

Source : DLR



GKN Wing section for Airbus Laminar flow experiment,
Anti contamination surface coating, Shielding Krueger L E Flap tests on A-340

Analysis Details and Results for drooping of leading Edge for RTA



Material Used : GFRP BD

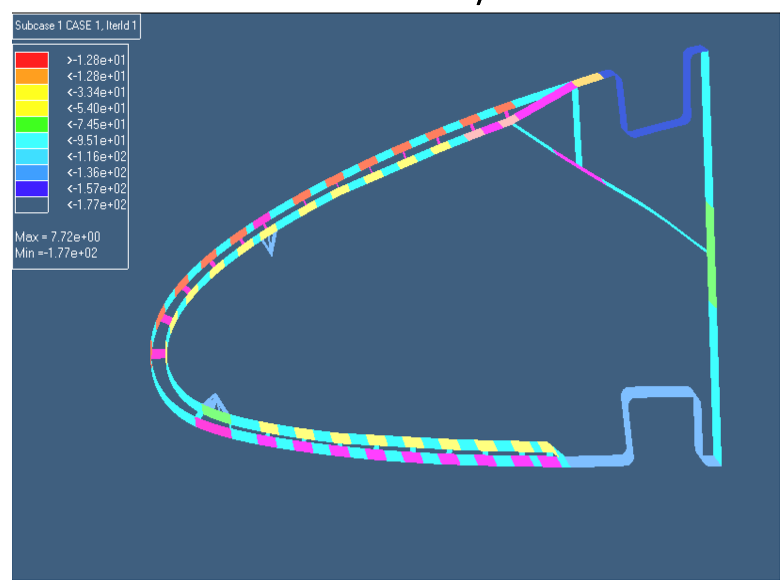
Thickness of each ply : 0.12mm

Load applied : 136 kg (Total)

GFRP properties : E_1,E_2= 2.1E4 N/mm^2

G = 3000N/mm^2 , μ =0.3

Orientation : +/- 45^0



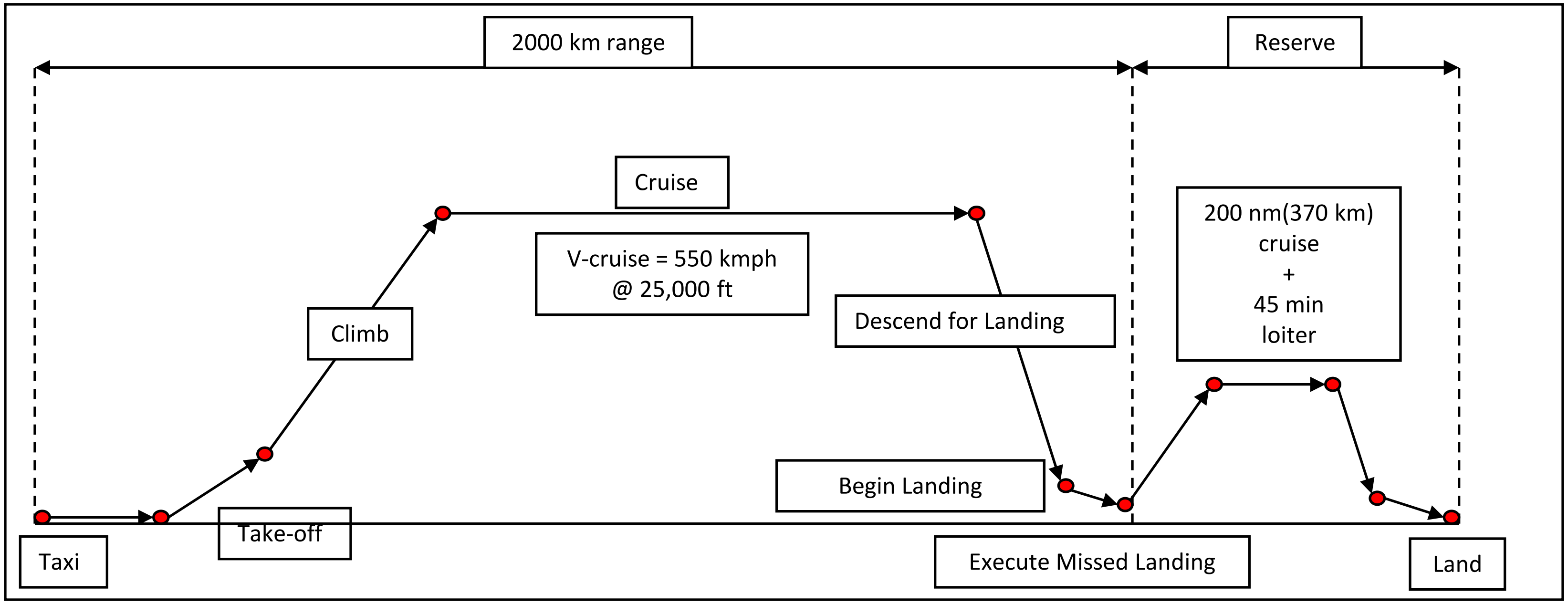
<u>Results obtained</u>

Maximum Tip Deflection – 177 mm

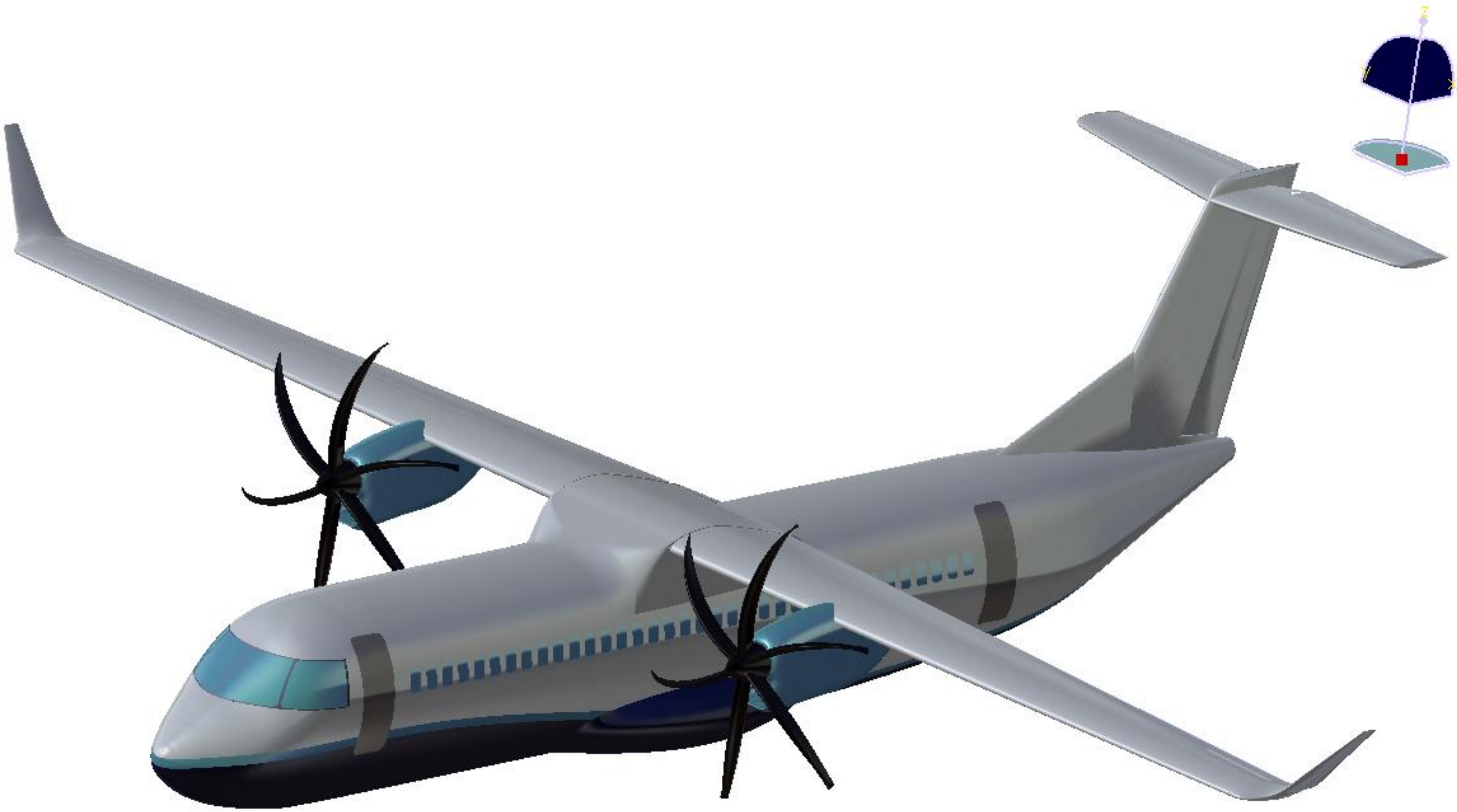
Angle obtained – 20^0 (approx)

Sizing Mission Profile

- Payload – 70 PaX @ 95 Kg ea.
- Cruise Range – 2000 km
- Cruise Speed – 550 kmph
- Cruise Altitude – 25000 ft

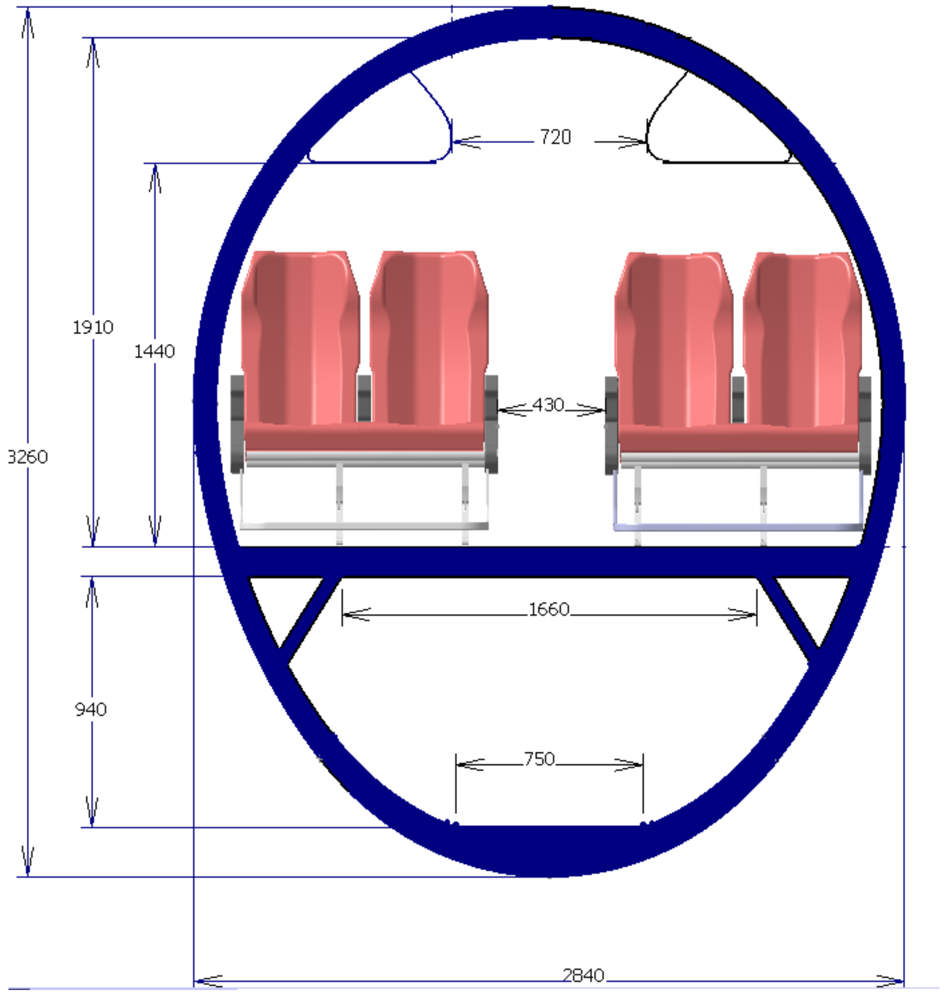


RTA 70 Conceptual Baseline (Conventional Nose)

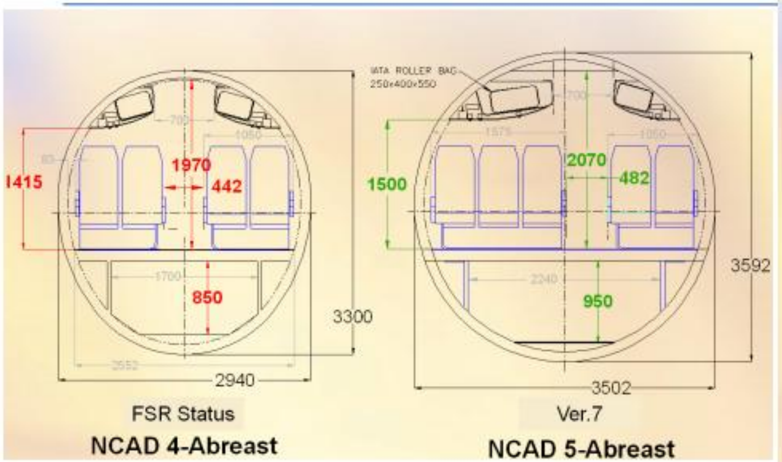


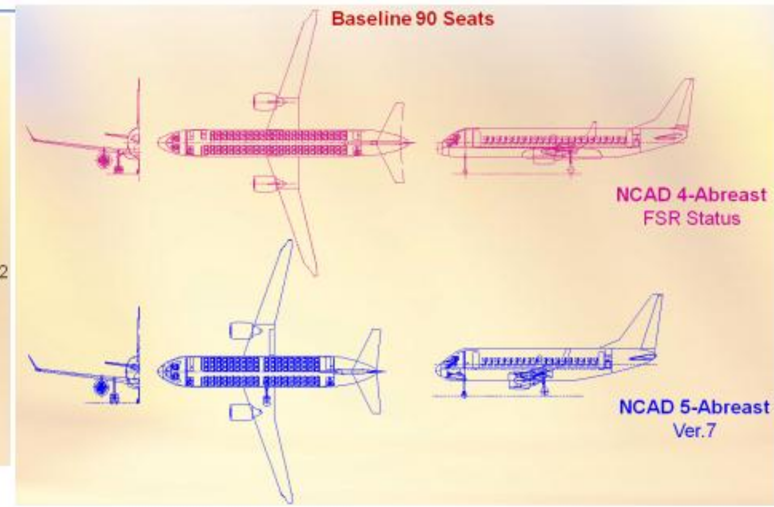
Laminar Nose

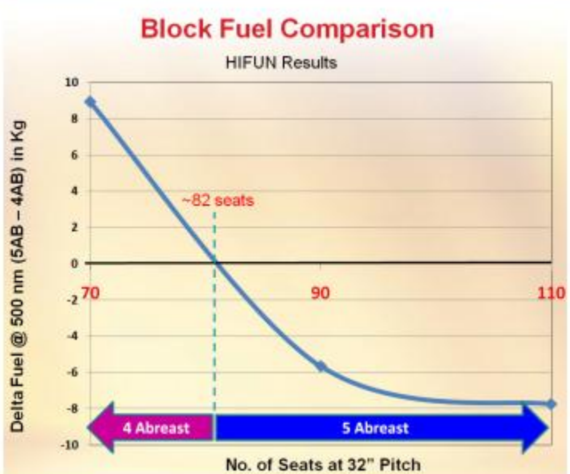
RTA 70 Conceptual Baseline Fuselage Cross Section



4 abreast vs 5 abreast lay out studies

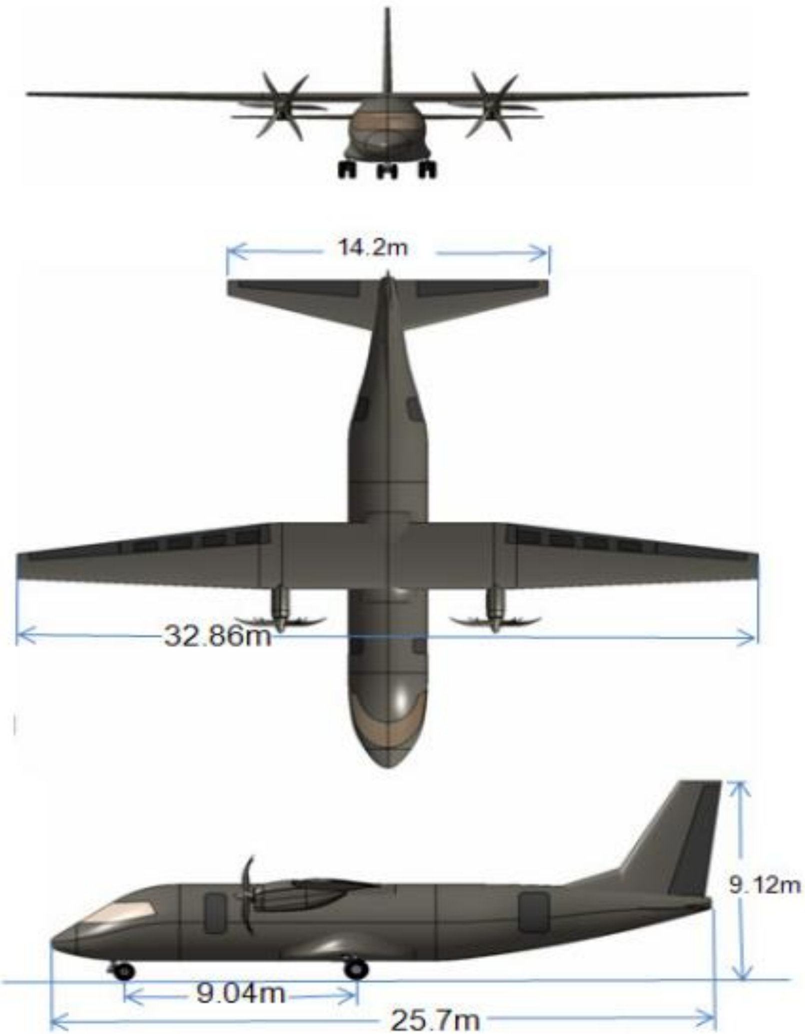


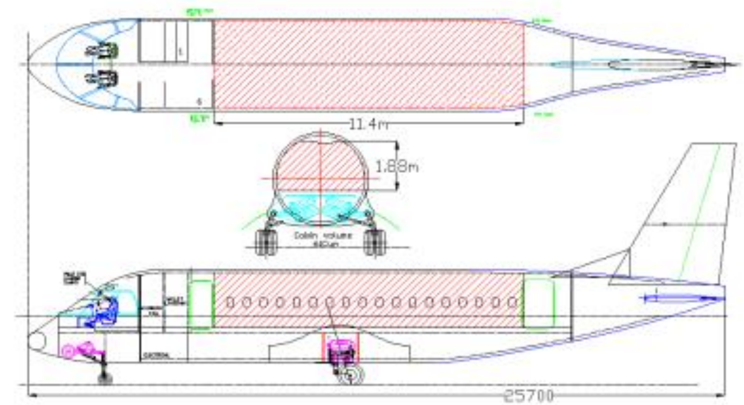




- **Advantages of 5-Abreast layout:**
  - **Extra Comfort & Easier Cargo Handling**
  - **Easier Systems Integration**
  - **More space for LG retraction**
  - **Less Longitudinal CG Travel**
  - **More attractive for 90+ seats**
  - **Growth potential to 140 seats**
- **Detailed design studies initiated**

Studies on Military version

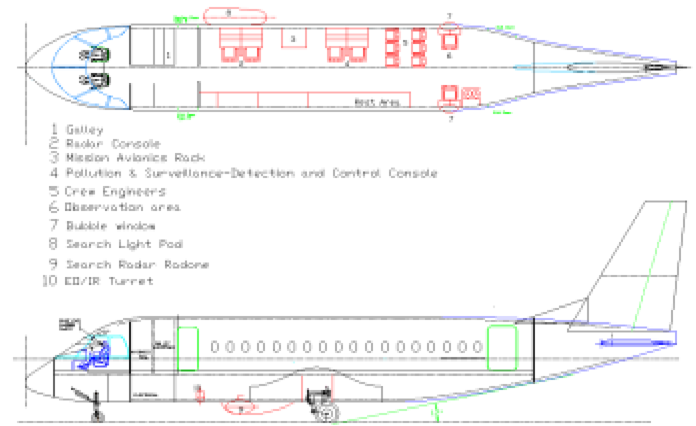




Feasible Military A/C Configurations

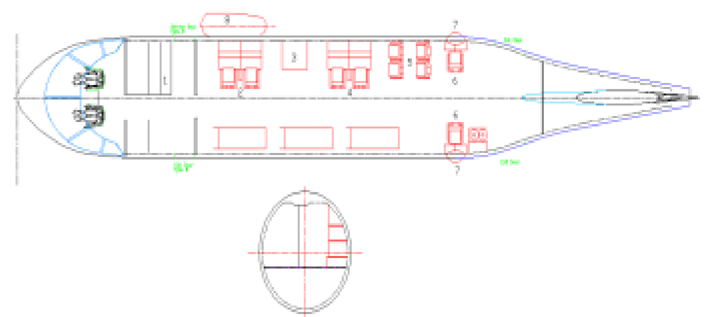
- Maritime patrol
- Surveillance / reconnaissance
- Medical evacuation
- Cargo carriage and drop
- General transport : VIP / Personnel

If required, variant with rear ramp loading configuration can also be developed for palletized surveillance / electronic suites

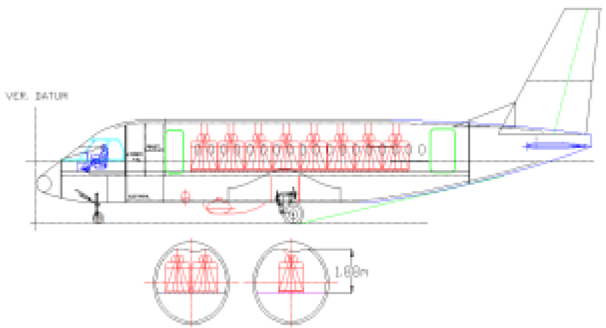


SURVEILLANCE CONFIGURATION

- Design based on family concept which can be suited to different customer segments.
- High degree of commonality (upto sixty percent) in systems and airframe amongst variants.



9Nos. Standard NATO Stretchers with dedicated oxygen port +2attendent seats



A22_CDS Bundles (8 Nos. in Single row, 16 in Parallel rows)

Configuration shown along with electronic suites. Full fledged Medevac configuration without electronic suites also possible

Airfoil optimization (Aerodynamics)

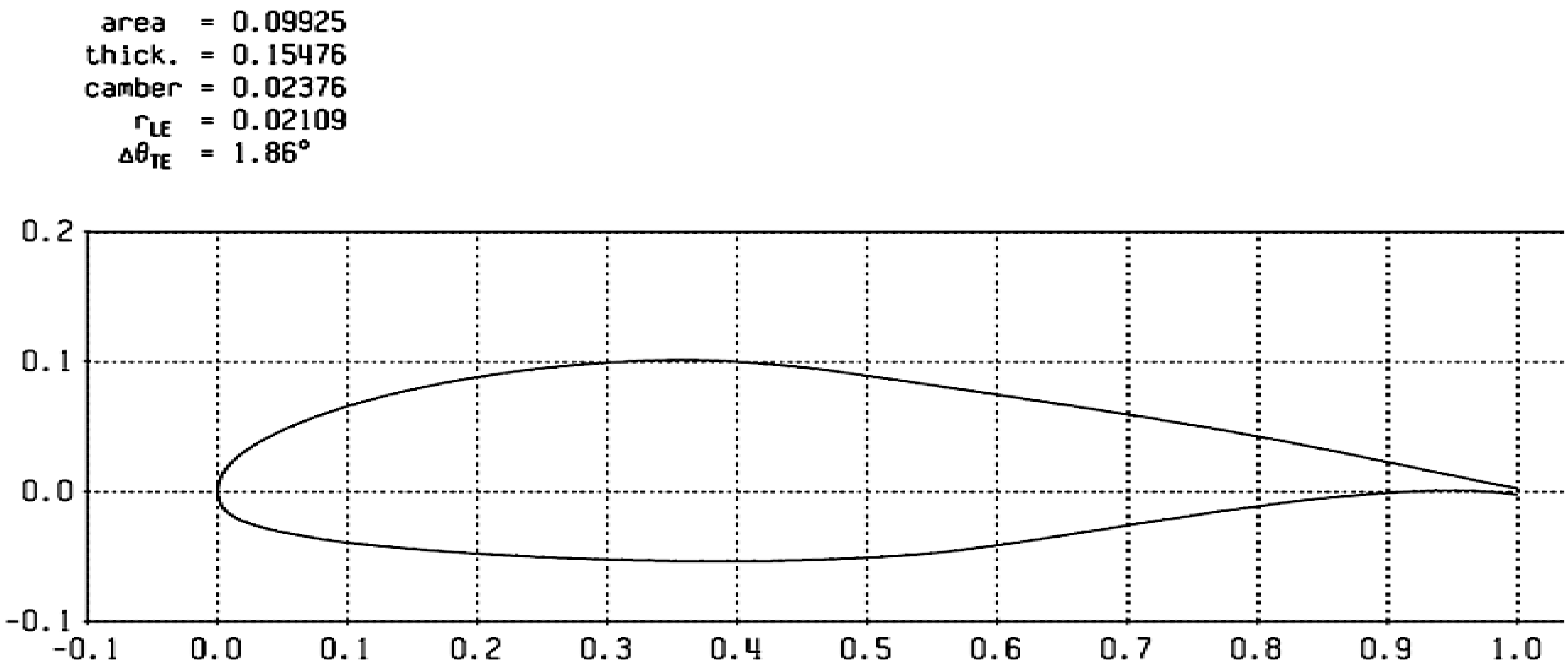
Airfoil Characteristics

- Low Profile Drag at typical design conditions mentioned earlier
- High CL Max clean ~ 1.6 at 8 Million R.No
- CL Max to be insensitive to leading edge contamination (safety requirement)
- Smooth Stall
- Low Pitching Moment Coefficient
- High t/c (fuel storage, actuation system stowage, Low weight)
- MDD as per standard norms

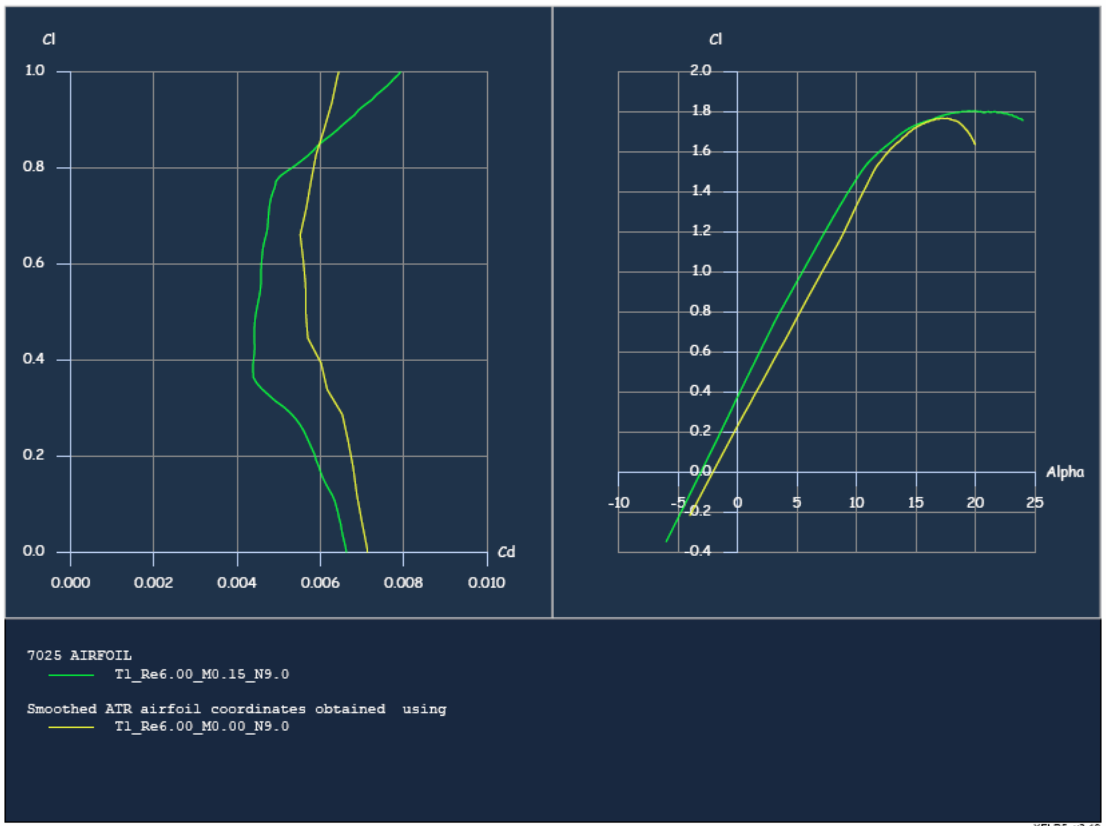
Airfoils Evaluated

- ATR Airfoil 14.5% thick
- Dornier DO 228 Airfoil 17%
- NASA SC(2) – 0414, 14%
- NAL NLF 7025, 15.5%
- NAL Laminar Supercritical 05143, 14%
- NAL NLF 21463, 14.5%
- IITK NLF Airfoil, 15%

NLF Airfoil NAL 7025



Comparison of Airfoils
NLF Vs Turbulent Airfoil



NLF Issues

- 2D & 3D Codes for accurate prediction of **transition**
- Effect of leading edge contamination on NLF performance

  (coatings)

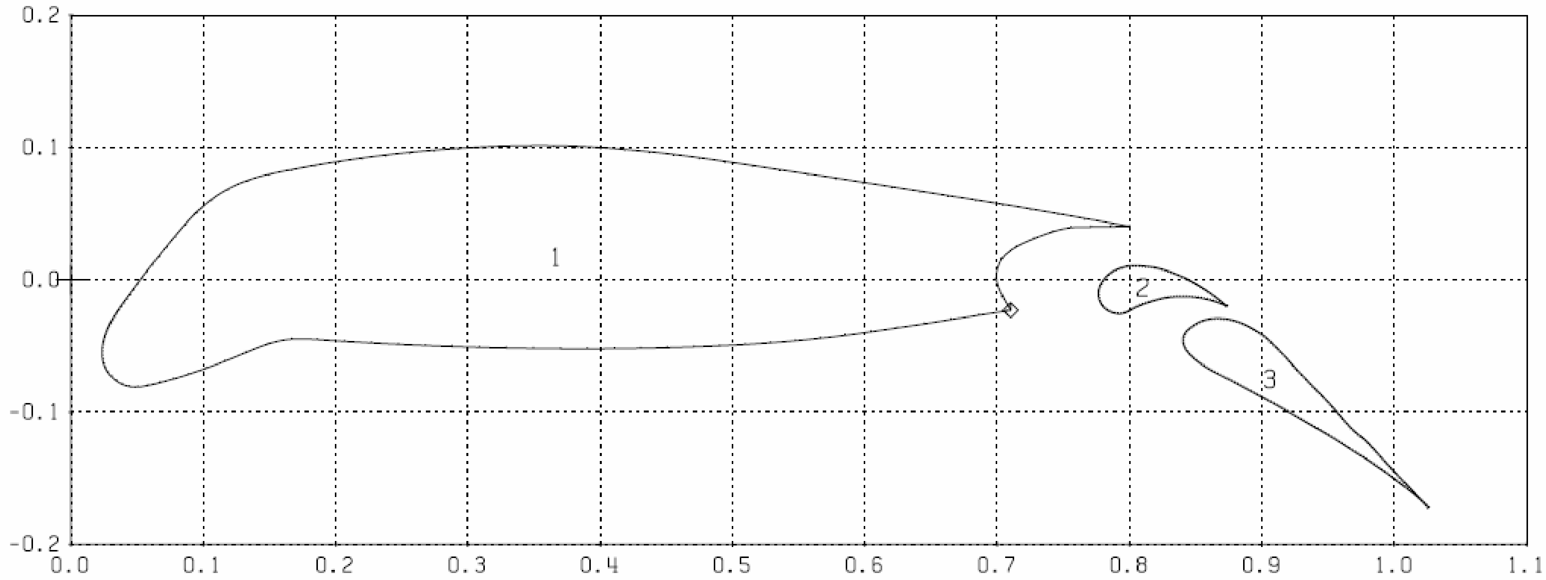
- Effect of surface roughness & waviness

  (criteria on Manufacturing tolerances)
- Effect of propeller wake on stability of laminar flow

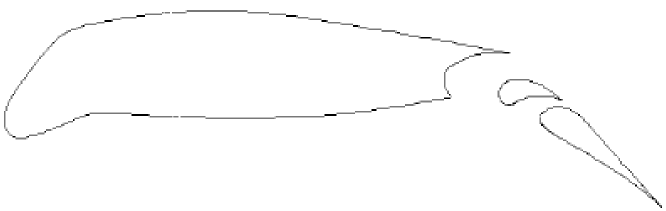
  (To be studied - CFD & wind tunnel investigations)

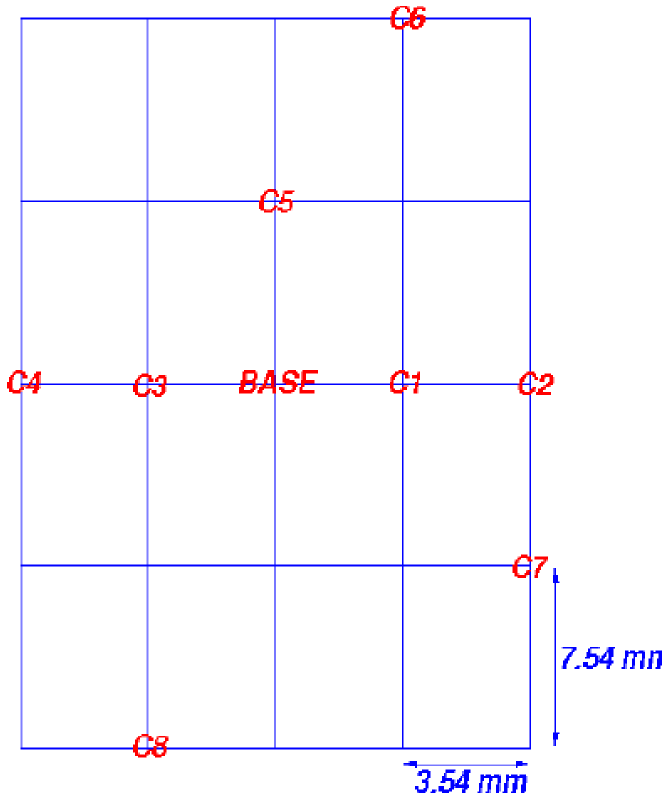
High–lift device optimization (Aerodynamics)

Double-Slotted Flap with LE Droop



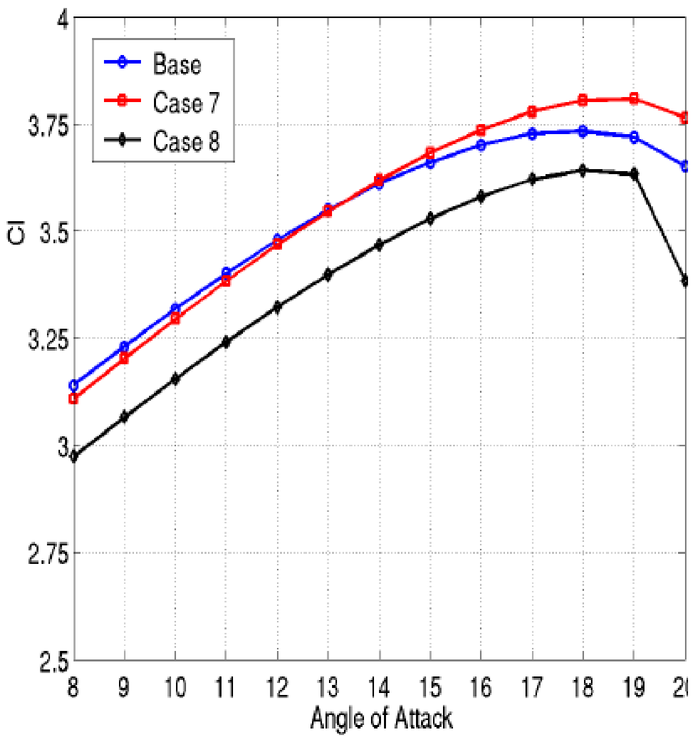
Configurations test matrix



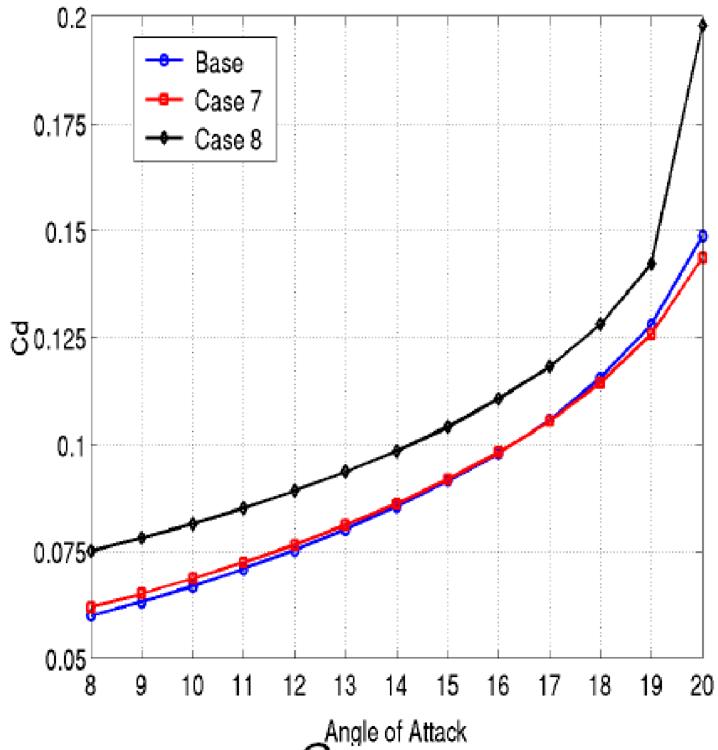


- Positions of the flaps are changed with respect to main aerofoil.
- Relative positions of flaps are not changed with respect to each other.

Comparison of integrated force coefficients



$C_l - \alpha$ curve

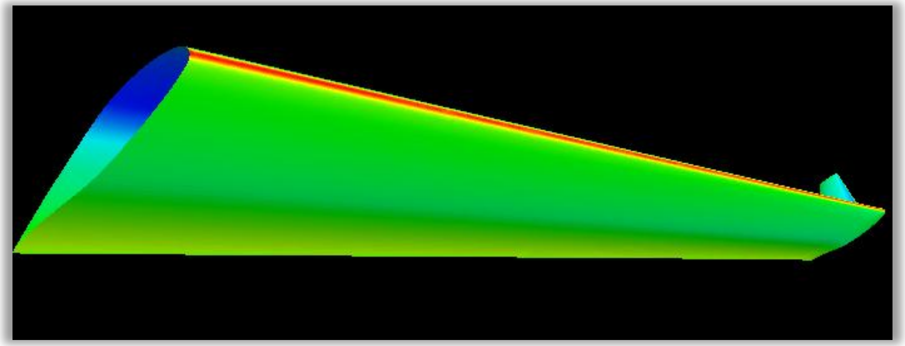


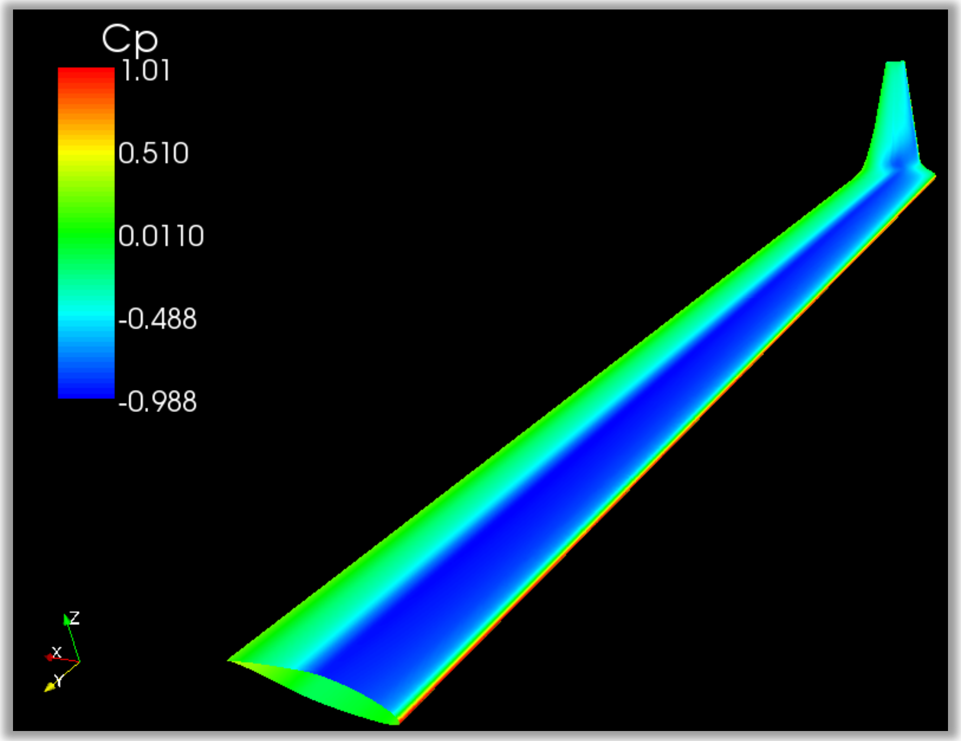
$C_d - \alpha$ curve

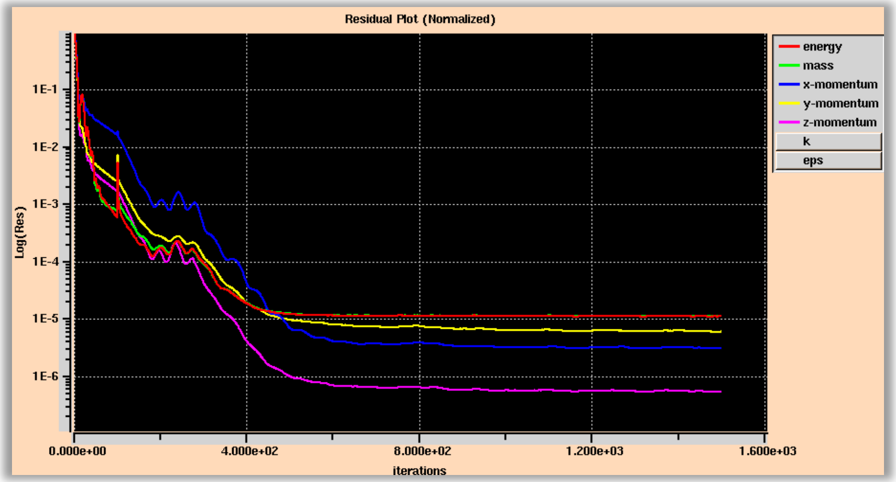
3D CFD SIMULATIONS USING SUPERCOMPUTER EKA AT PUNE

Simulation Results

Cp Distribution along wing surfaces



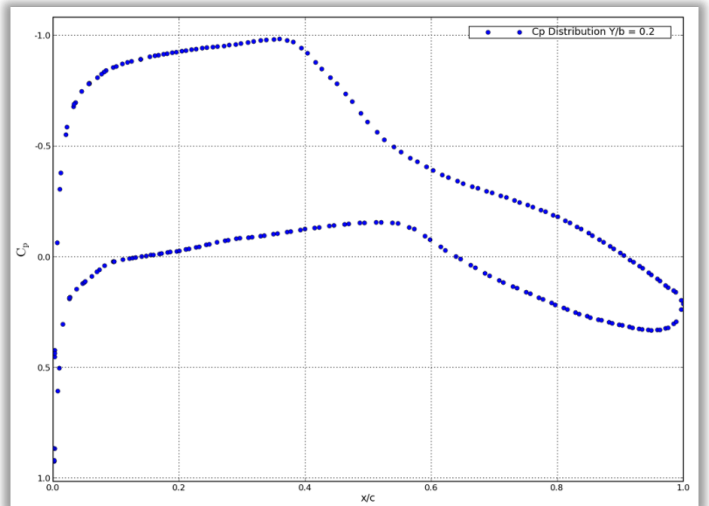




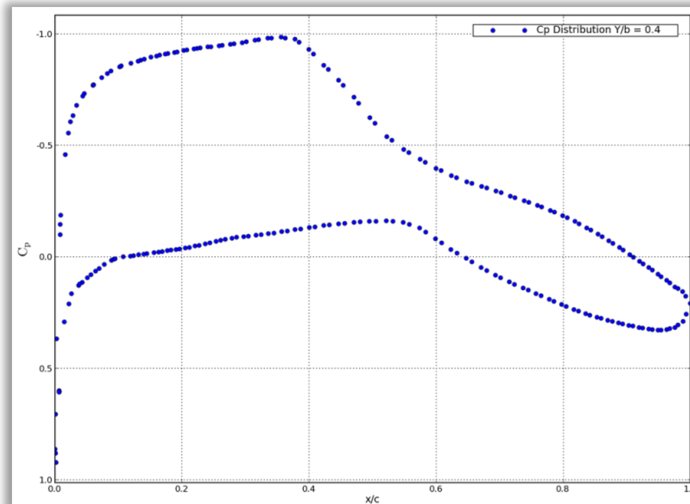
Residual Convergence

Cd	Cl
0.0161	0.4156

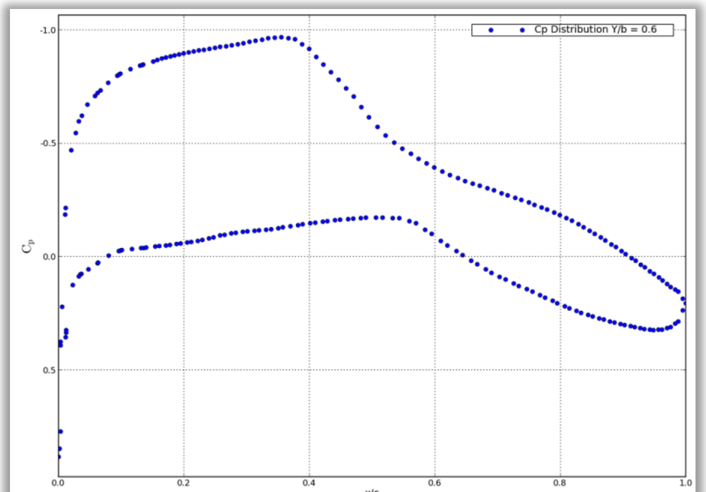
Cp Distribution at Cut Sections



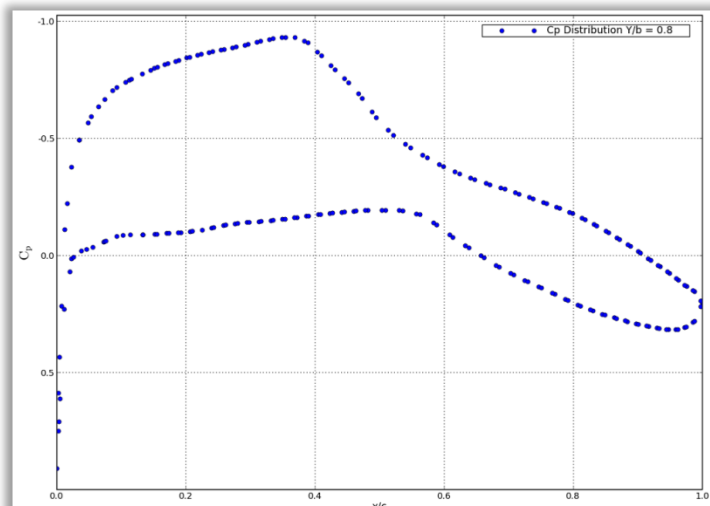
Y/b = 0.2



Y/b = 0.4

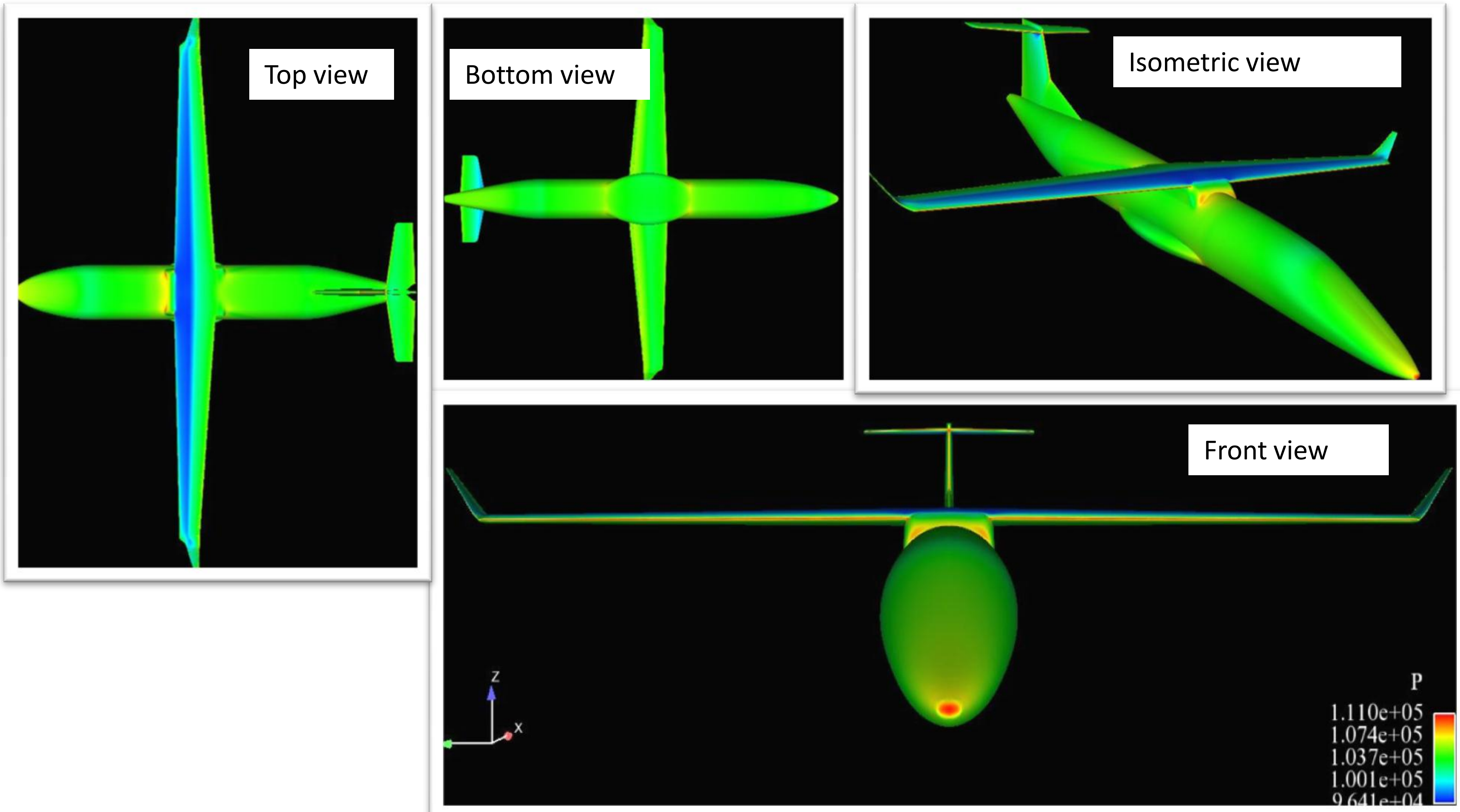


Y/b = 0.6

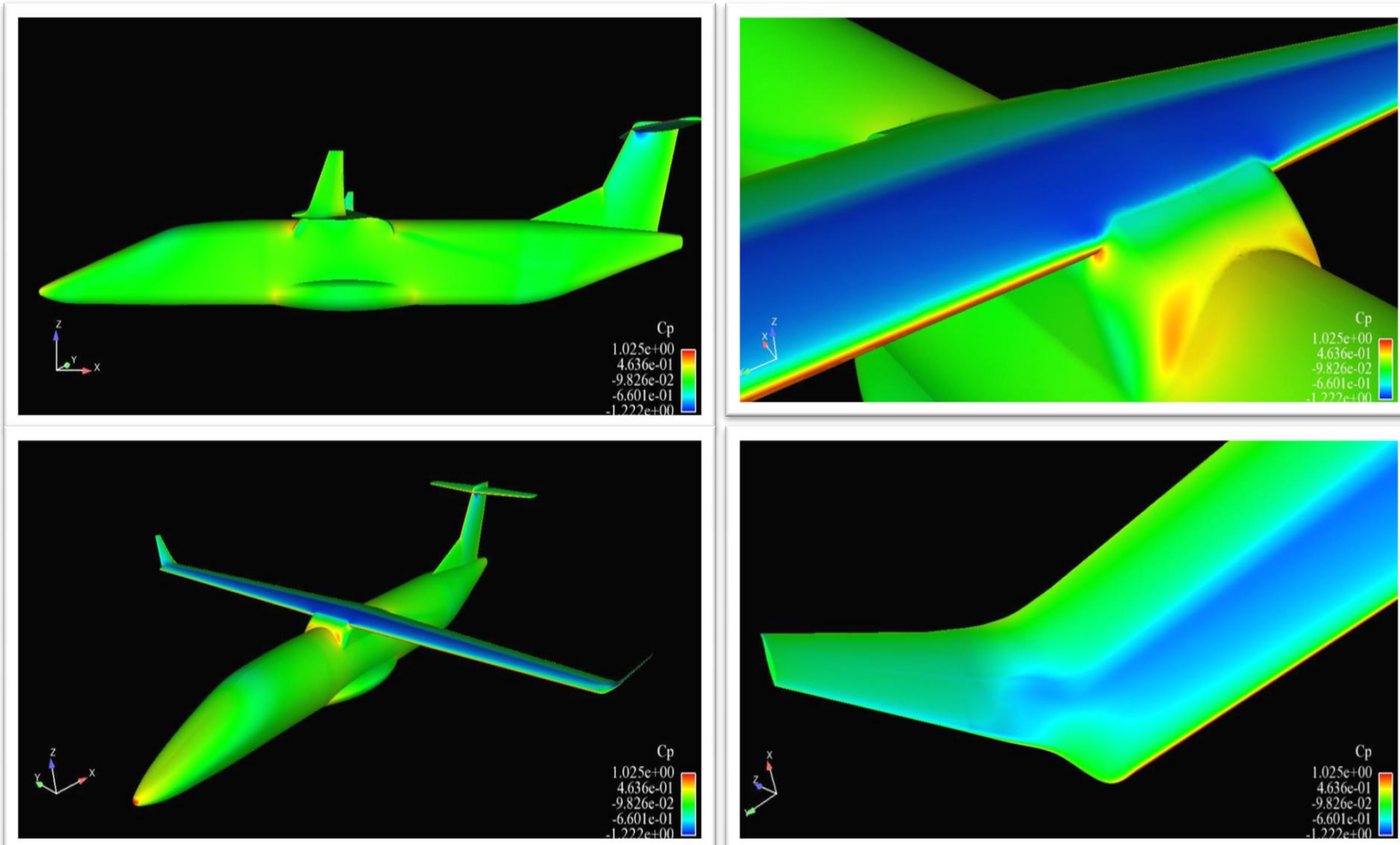


Y/b = 0.8

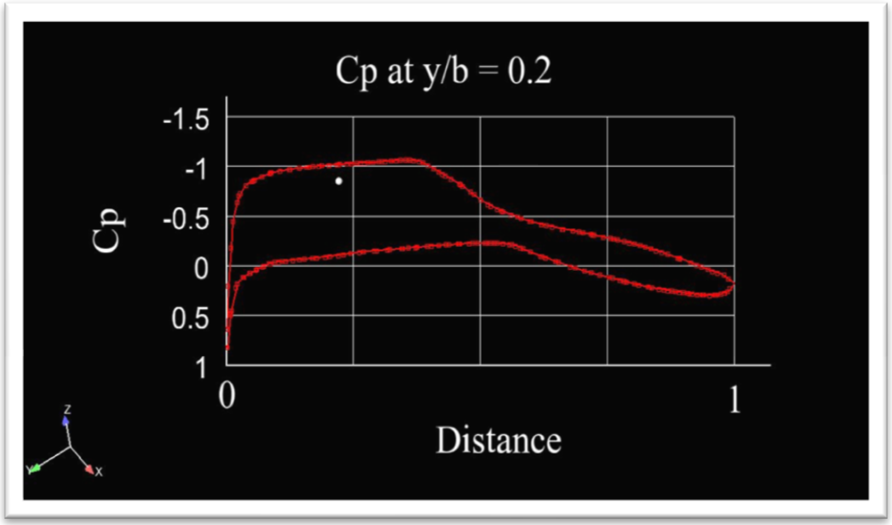
Simulation Results: Pressure Contours

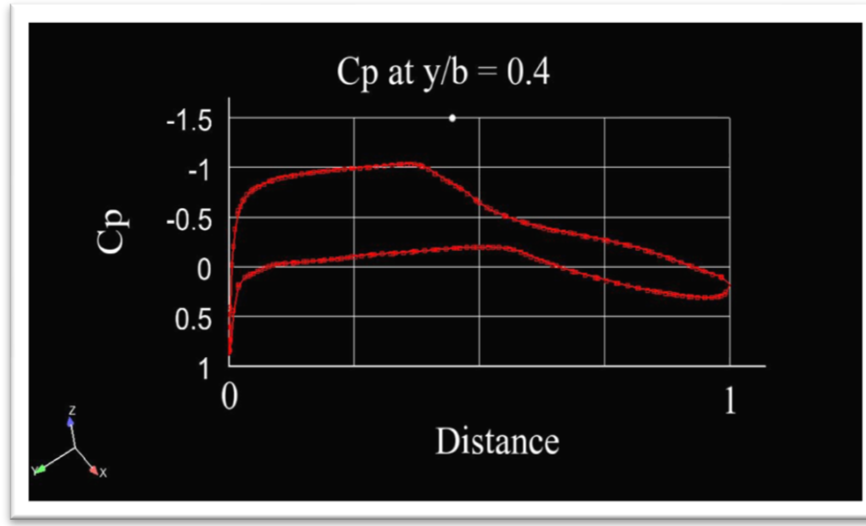


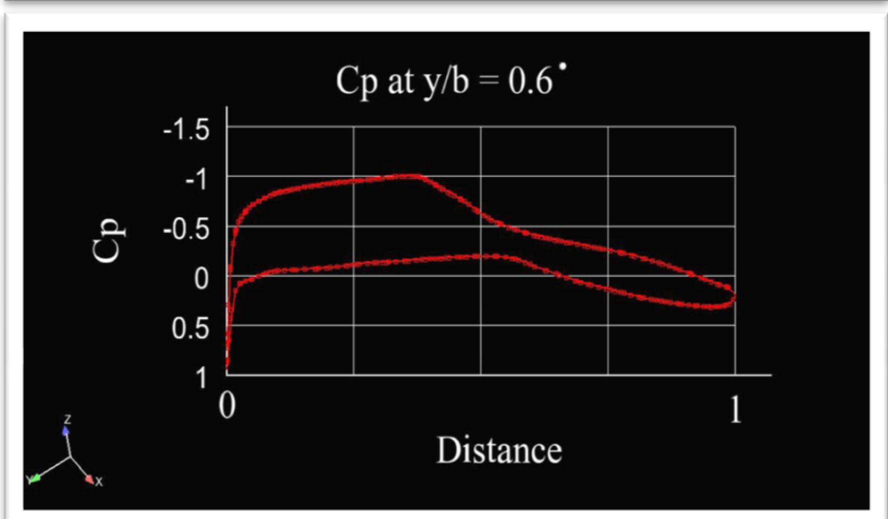
Simulation Results: Cp Contours

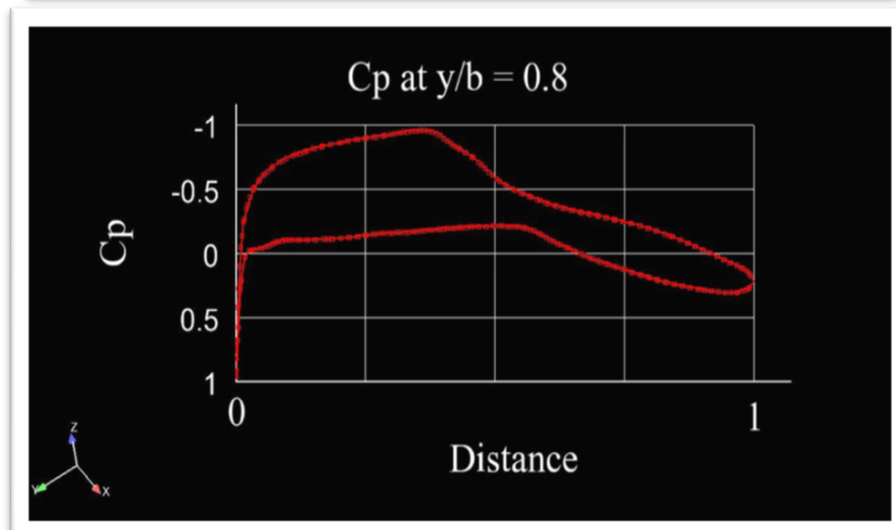


Simulation Results: Cp plots at various sections of wing









Optimization of Wing-Propeller Configuration

Optimization

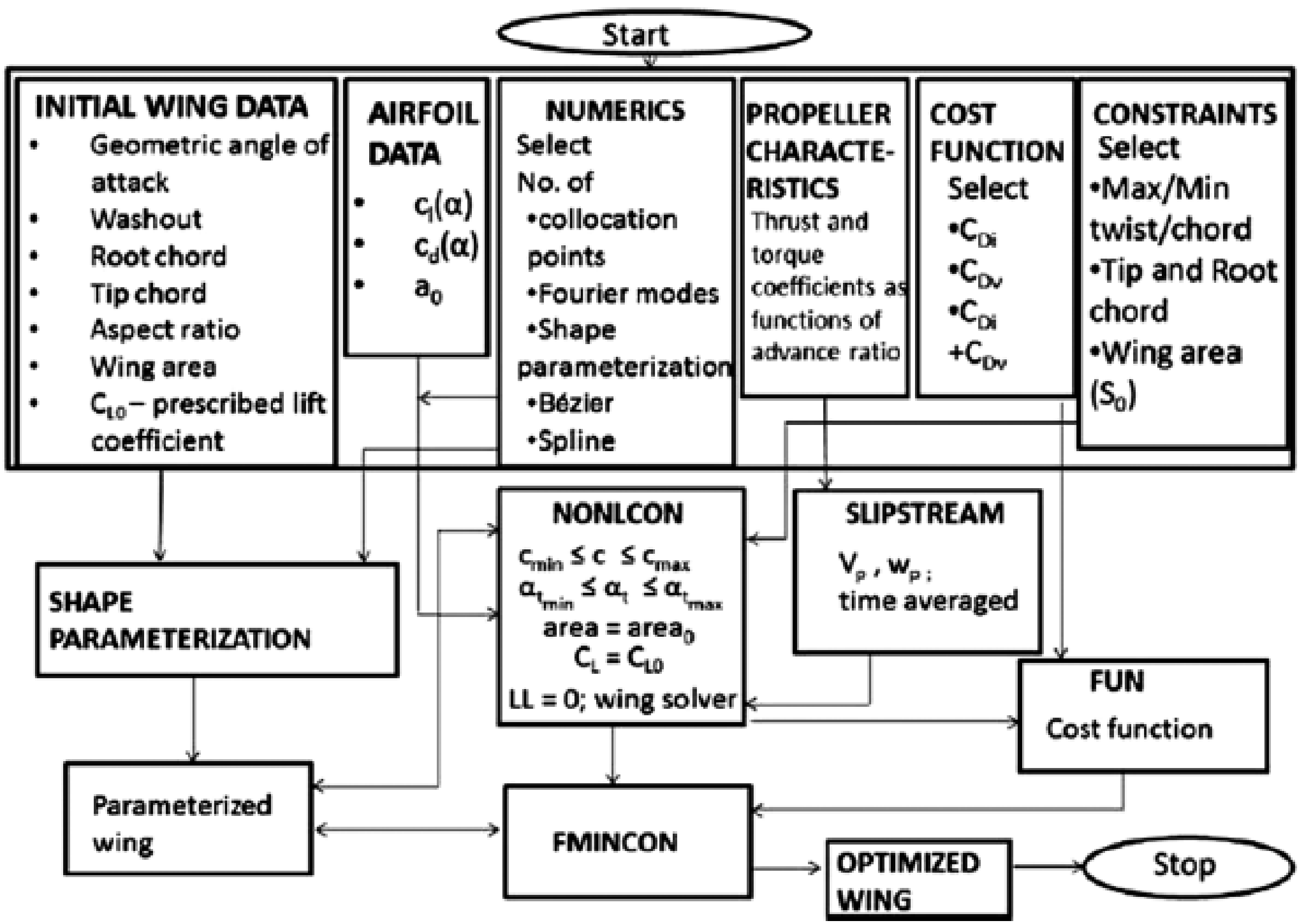
- Minimise total drag (induced + profile) for wing-propeller configuration wrt chord and twist distribution
- Cost function

$$
\begin{aligned}
J &= D_i + D_p \\
&= J(A_1 \ldots A_{n_f}, c_1 \ldots c_{n_c}, \alpha_{t1} \ldots \alpha_{tn_c}) \\
D_p &= \int_{-s}^{s} \frac{1}{2} \rho c_{dp} V(y)^2 c(y) dy
\end{aligned}
$$

  - D_i Induced drag
  - D_p Profile drag
  - c_{dp} is obtained by c_l vs c_{dp} data of selected aerofoil section at each spanwise station
  - Could include other parameters for e.g. wing root bending moment

– Source: RN 2014, A GAME-CHANGING CIVIL-MILITARY TRANSPORT AIRCRAFT FOR INDIA, AeSI, Hyderabad

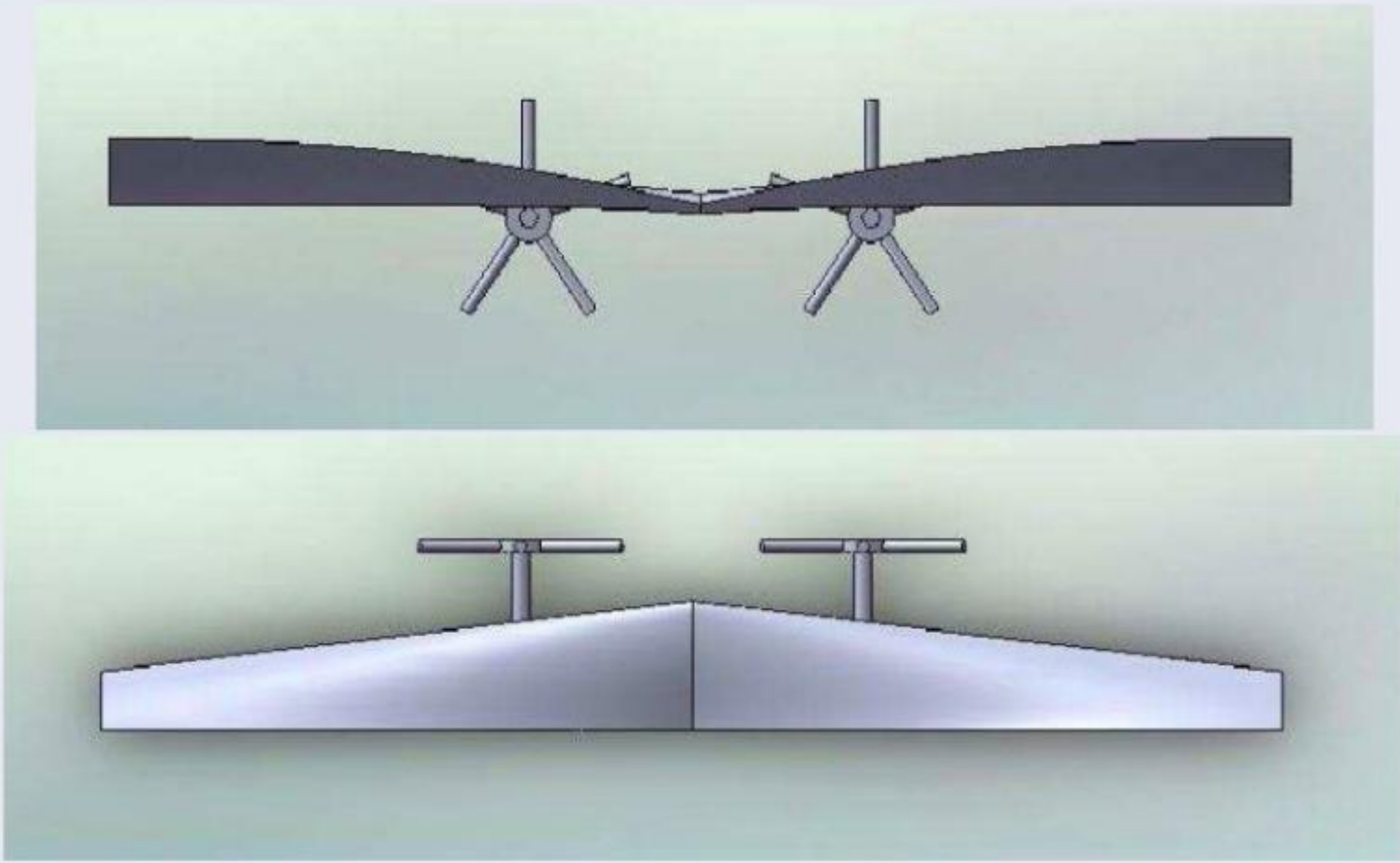
PROWING



– Source: RN 2014, A GAME-CHANGING CIVIL-MILITARY TRANSPORT AIRCRAFT FOR INDIA, AeSI, Hyderabad

Standard Wing

$C_L = 0.38$, wash out twist (twist magnified by 20 times!!!), AR $= 12$

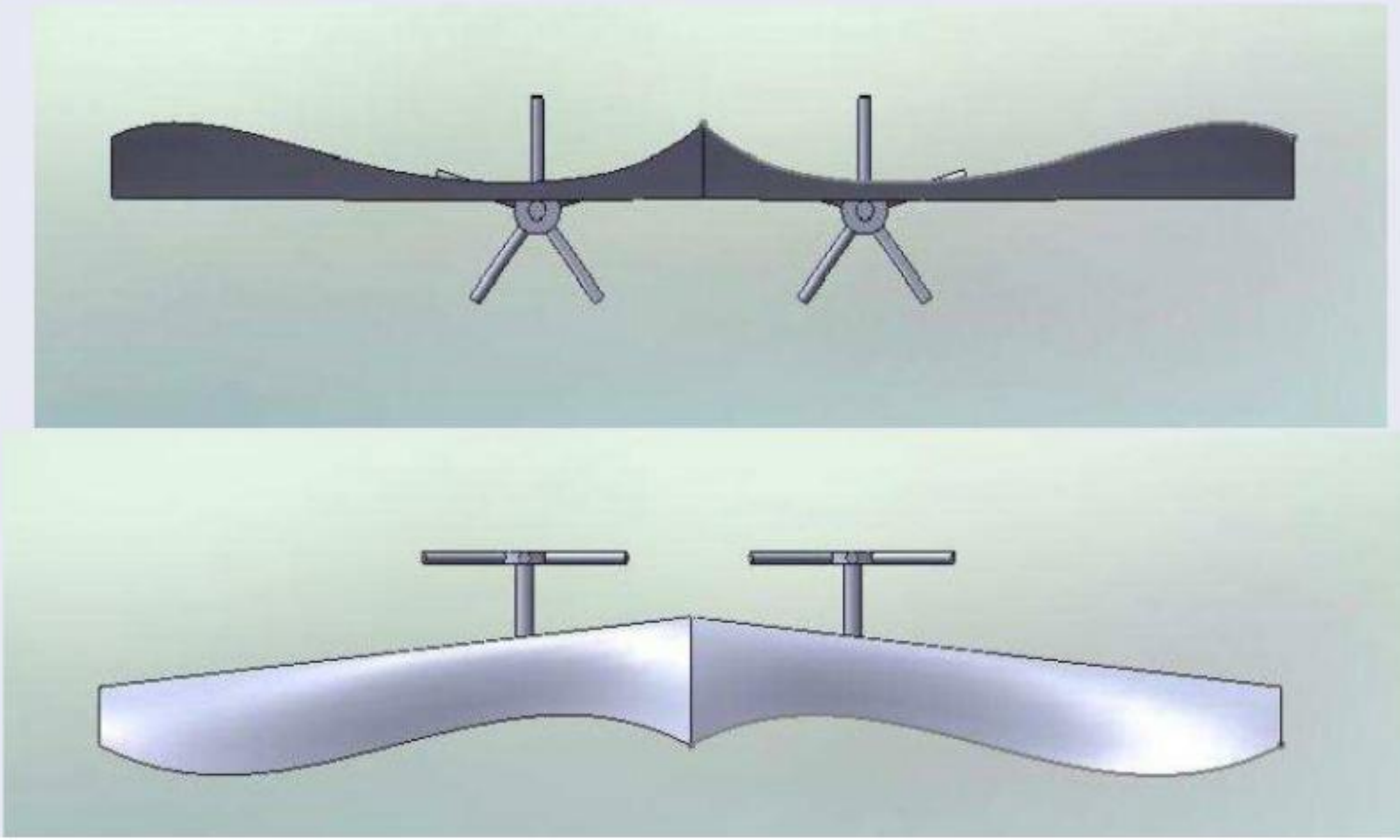


Bottom: Planform. Top: Twist seen from trailing edge, wing lower surface in dark, upper surface in white

Source : Prof Narasimha

The New Optimized Wing

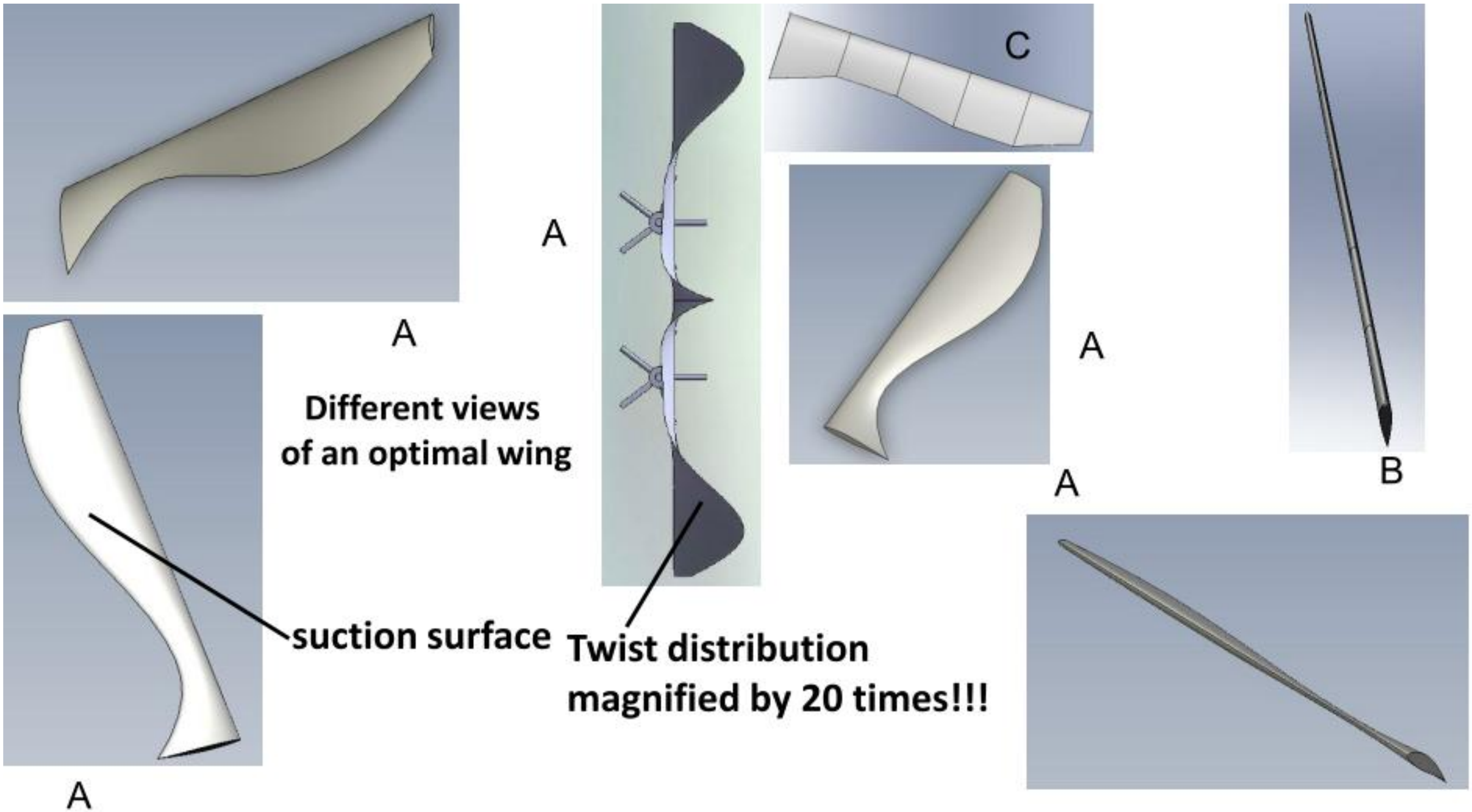
$nc = 320$, $nf = 48$, $nwc = 4$, $nwt = 4$, $-14^o \leq \alpha_t \leq 14^o$, $C_L = 0.38$, twist magnified by 20 times!!!, AR $= 12$, $c_m = 1.0717s$, $c_t = 0.5359s$, $\Delta C_d = 3.82\%$, $\Delta C_{di} = 9.35\%$, Up-Inboard



Induced drag down 9.35%, total drag down 3.82%

Source : Prof Narasimha

3 types of Optimized Wings



A: Standard optimum
B: Opt. with thickness varying linearly along span
C: Opt. with t.e. of straight segments

Rakshith++ 2012

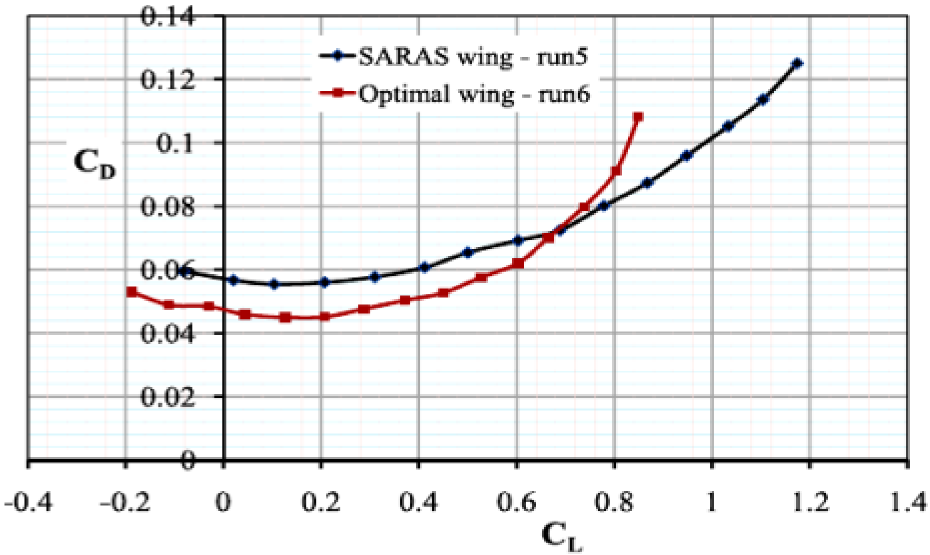
Tunnel Tests at NAL

Control - SARAS-c testing

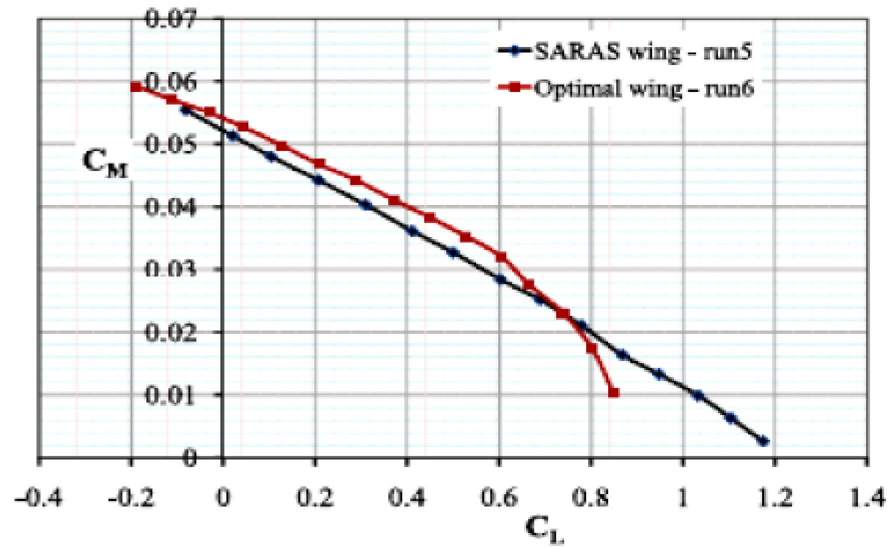
Optimal - SARAS-o

Source : Prof Narasimha

Tunnel Test Results



Comparison of drag polar between
Runs 5 and 6

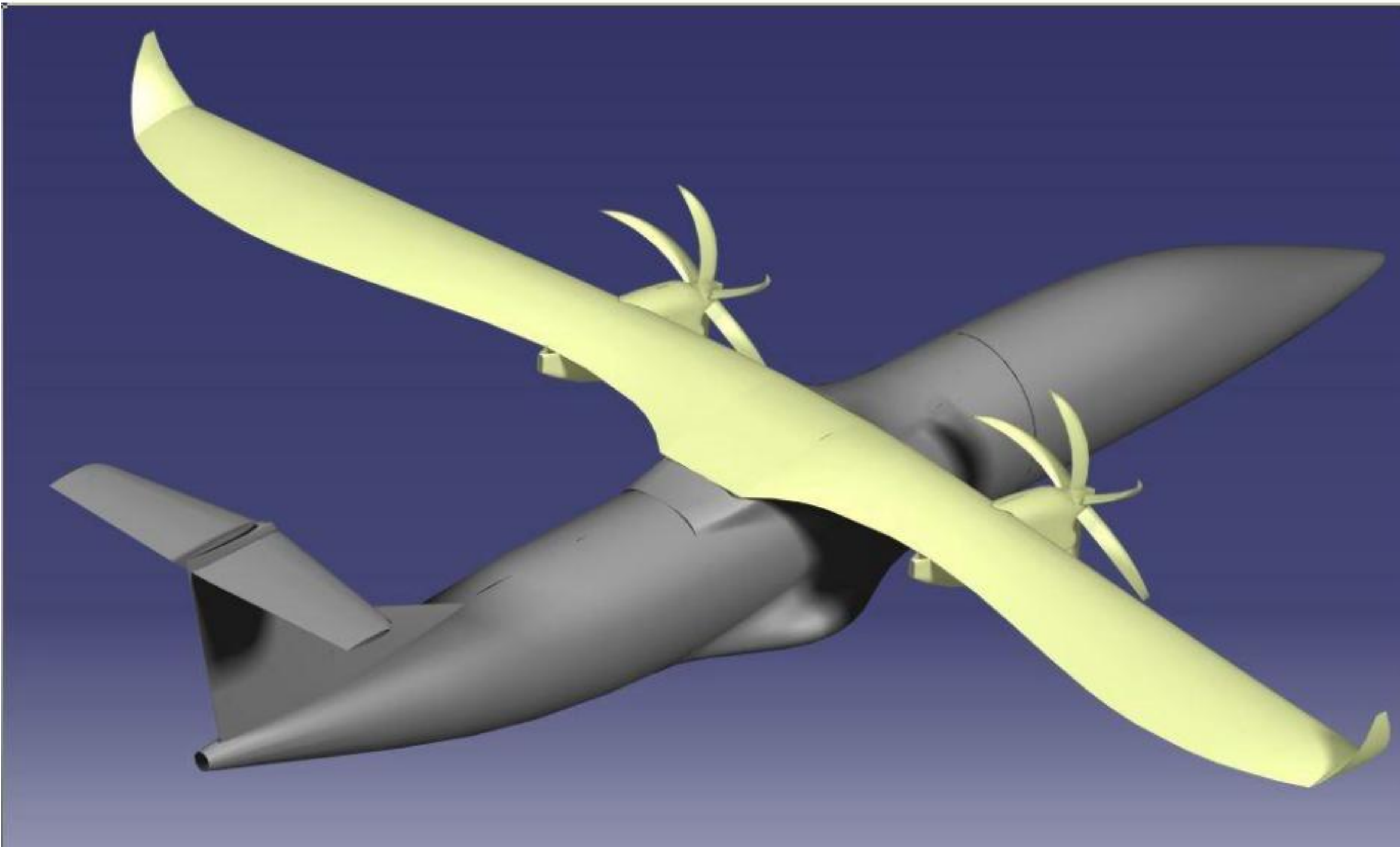


Comparison of pitching moment variation with C_L curves between runs 5 and 6

Aircraft drag down 18% at cruise (C_L = 0.4)

Source : Prof Narasimha

Next Gen Turbo Prop ?



Source : Prof Narasimha

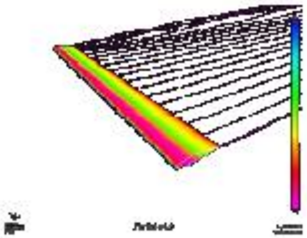
Airframe

- Airframe design with laminar flow characteristics.
- More efficient high lift systems.
- Use of composites to reduce cost, weight, part count , maintenance and enhance fatigue life
- Development of new topologies for efficient use of advanced composites for lifting surfaces and **fuselage.**
- Smart materials / Nano materials & coatings.
- Health monitoring of total airframe.

New Technologies that were addressed: Airframe

Drag reduction (<20%)

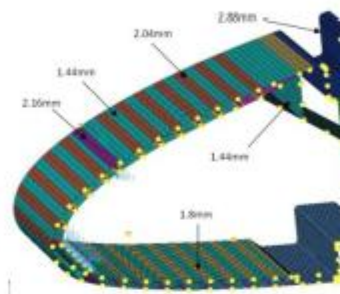
Laminar airframe – Natural Laminar flow - Nano Coatings, Reduction of Induced drag- winglets



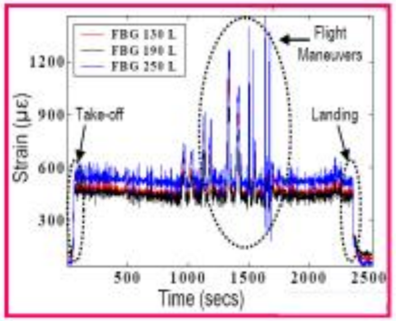
Composite airframe

Reduce part count 60-70%
Reduce Fasteners 90%
Reduce weight 20-25%
Reduce Manufacturing cost 15-30%

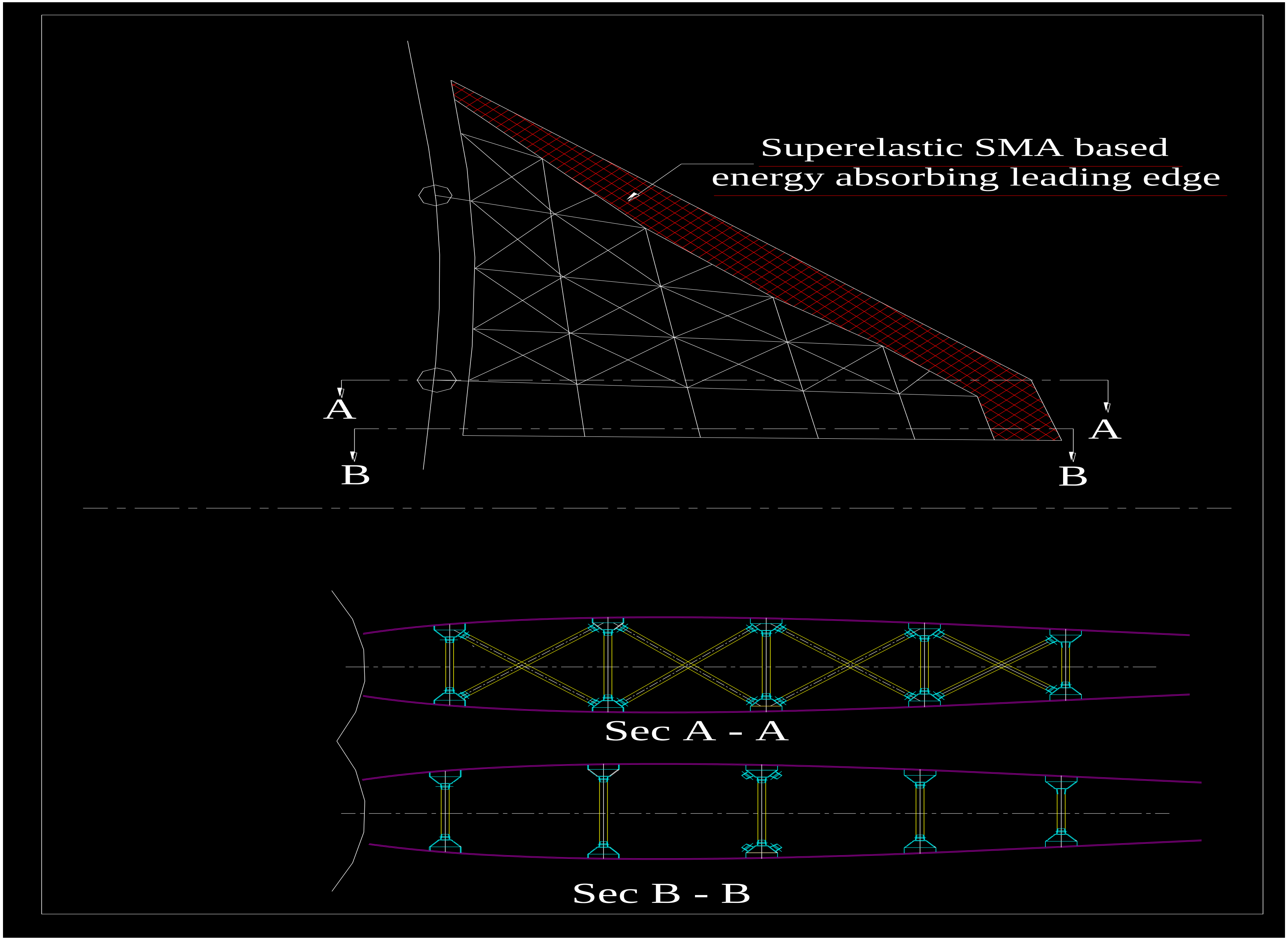
Design concepts
Crash requirements
CFRP wind shield, pressure bulk head
Lightning protection improvements
Complex fitting development
Structural health monitoring



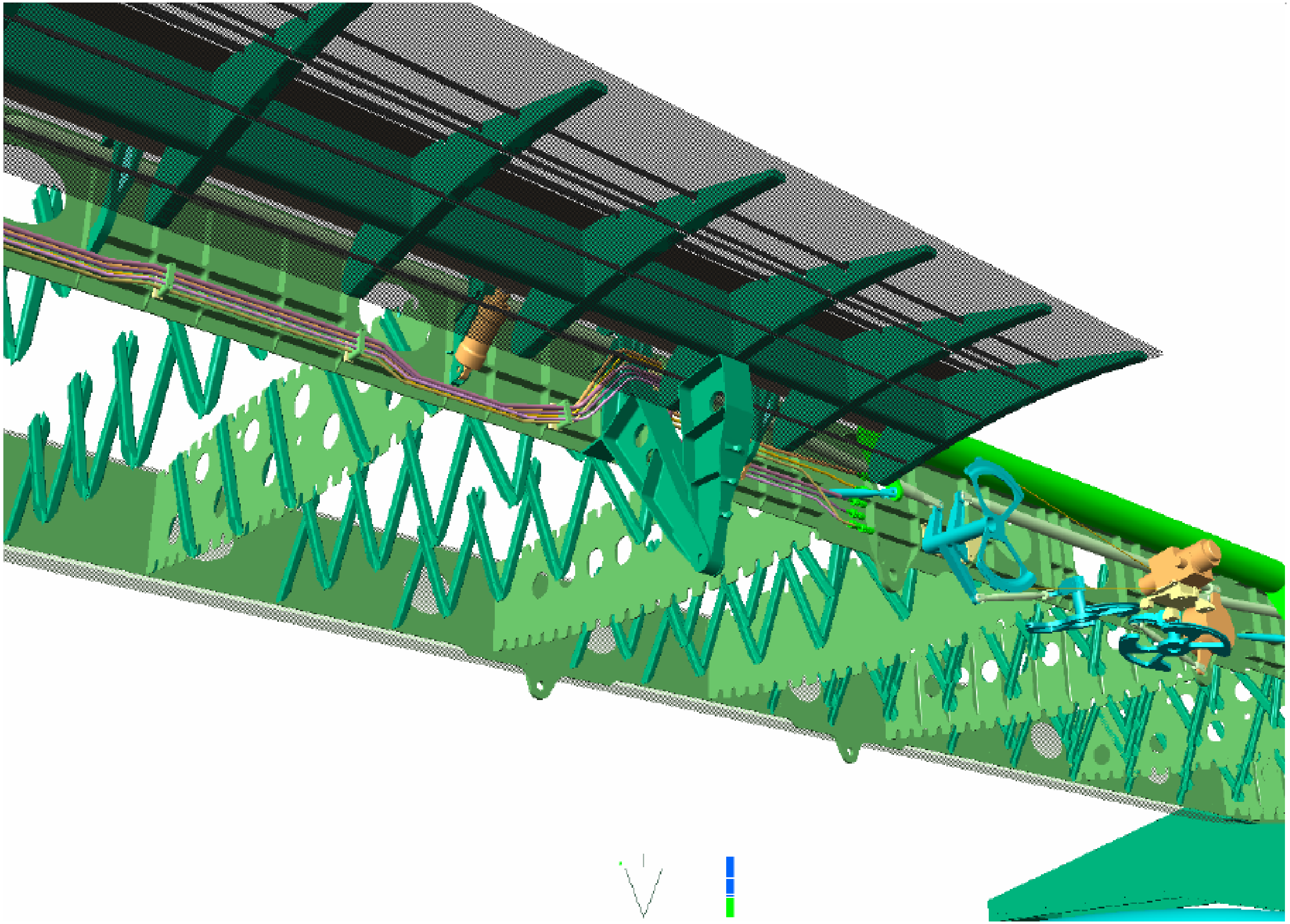
Droop as a HL devic



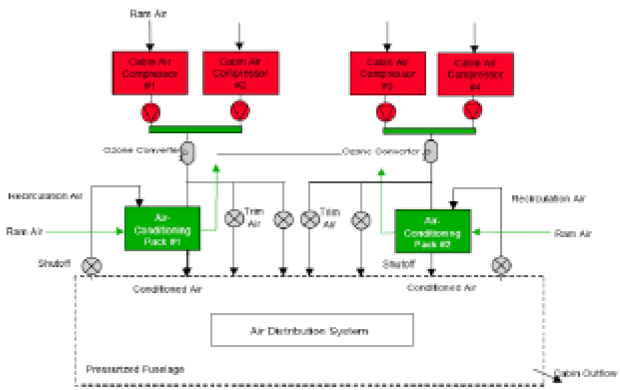
Health monitoring



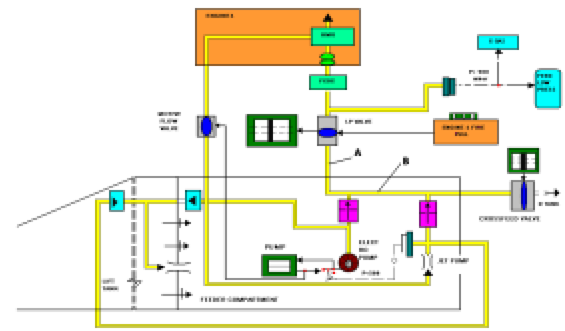
Isogrid Based Wing structure



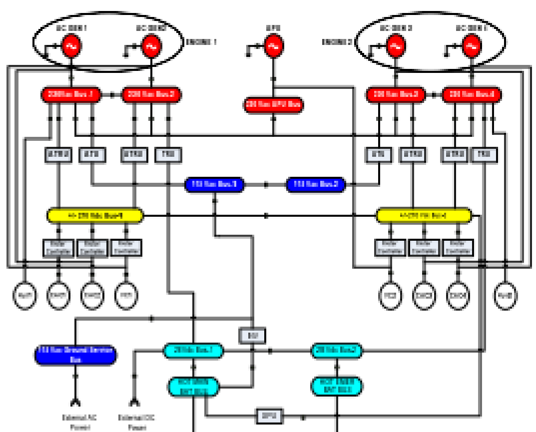
Aircraft Systems



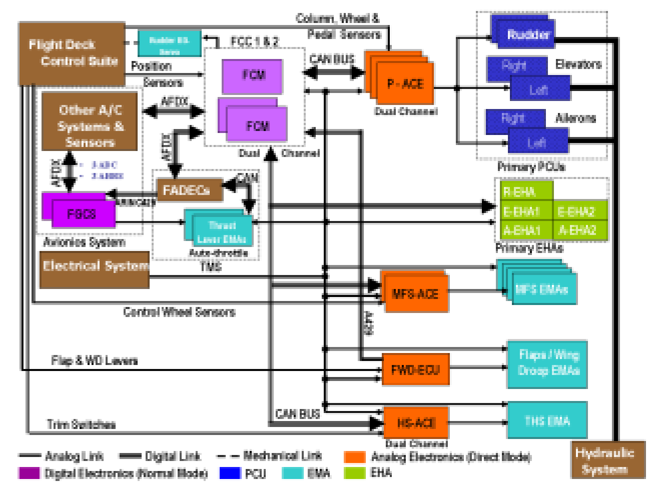
Bleedless ECS



Fuel system



New generation elec architecture



Affordable fly by wire systems

RTA PFCS/AFCS - CTQs

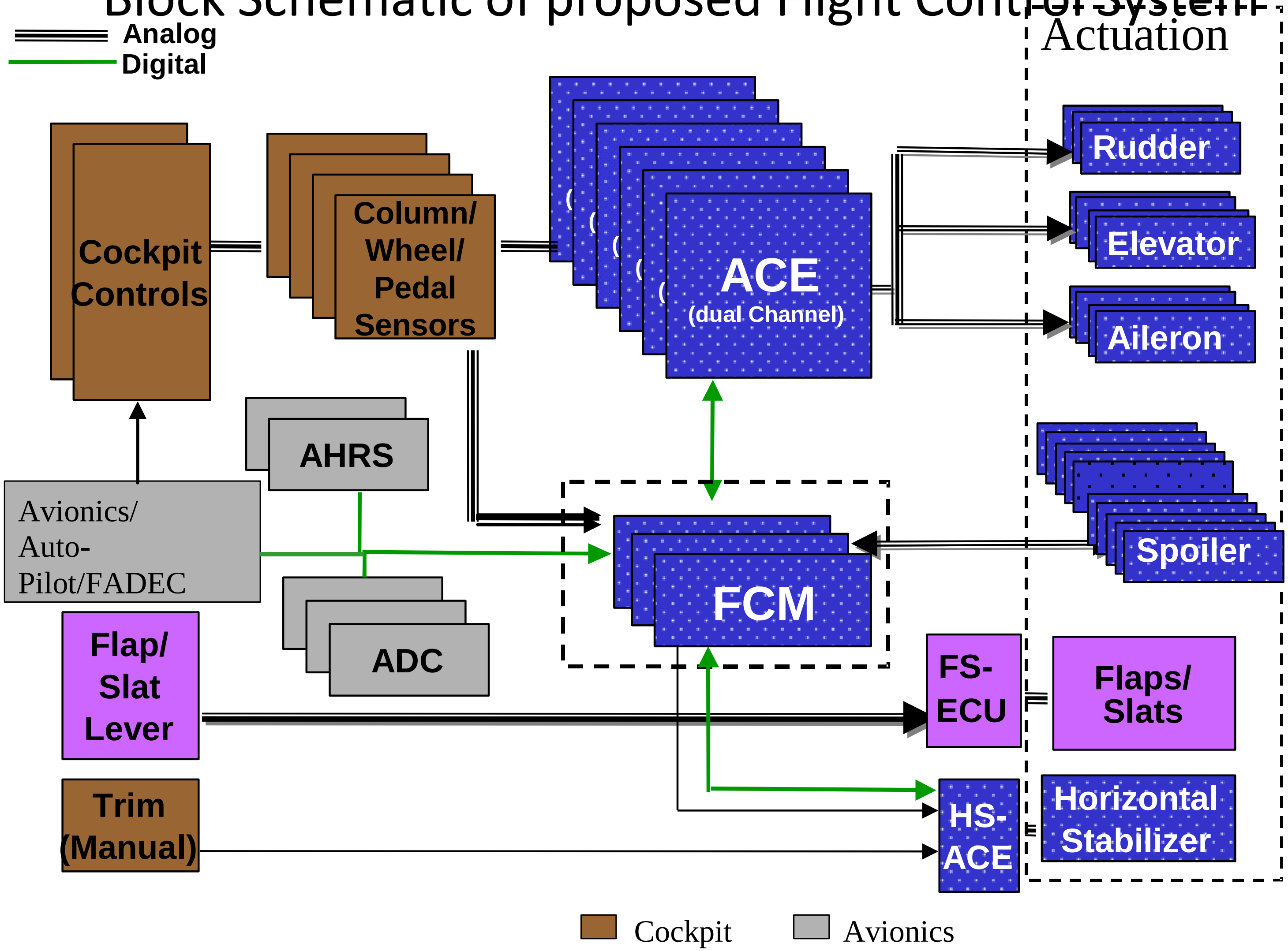
- Will be a fly by wire Primary Flight Control System
- AFCS will meet FAR-25, FAR-121 and meet or exceed TSO-C9c, TSO-C52a.
- Design Assurance Level will be adhering to DO178B Level-A standard.
- System will have flight envelope protection and gust load alleviation
- AFCS will be designed to provide passenger ride comfort
- System will be designed for fuel consumption optimization
- System will have integrated flight & engine control
- Provision to modify gain and schedule during flight tests.
- Automatic rigging of sensors
- Provision to include additional augmentation functions if required, without changes to hardware

Applicable standards

- FAR-25
- FAR-121
- TSO-9c
- TSO-52b
- ARINC 417
- ARINC 653
- RTCA DO-178B
- RTCA DO-160F
- RTCA DO-254
- FAA AC-1329b
- SAE ARP 4761
- SAE ARP 4754

Block Schematic of proposed Flight Control System

•



RTA PFCS/AFCS - Features

RTA FCS will be Fly By Wire and it will provide the following features:

- Three axis control
- Control and Stability Augmentation in three axis
- Secondary surface controls - Spoilers
- Flight Director Guidance
- Automatic/Manual pitch trim
- Turn Co-ordination, Configuration trim, Mach trim from AFCS
- Auto Throttle
- Autoland depending on Avionics & Airport support
- Support for Fault Recording on CMC/IVHMS and Maintenance tests
- Mode selection through a pilot selection panel
- Artificial Feel Control

RTA PFCS/AFCS - Functionalities

- The features will be provided as part of the following 3 functionalities:
  - PFC includes following functionalities:
    - **Stability and Control Augmentation**
    - **Turn Co-ordination**
    - **Forward path shaping for required handling qualities**
    - **Suitable logic for smooth transition from pilot commands to autopilot**
  - FGCS includes following functionalities:
    - **Flight Director guidance**
    - **Autopilot integrated with Auto throttle**
    - **Autopilot Pitch Trim (Automatic/Manual)**
    - **Autoland**
  - TMS includes following functionalities:
    - **Autothrottle (AT)**
    - **Electronic Thrust/Trim System (ETTS)**
    - **Thrust Rating Selection (TRS)**

RTA FCS – Primary Flight Control Functionality

- PFC includes following functionality:
  - Variable Control gains as a function of airspeed and altitude for the rudder, elevators and ailerons
  - Angle of Attack Limiting command and Bob Weight Function for the elevators
  - Thrust Asymmetry Compensation, Yaw Damper and Turn Coordination commands for the rudder (YD & TC will be computed by AP)
  - Aileron Droop command for the ailerons
  - Variable Trim Rate, Auto-Trim and Mach Trim commands for the Horizontal Stabilizer
  - Force fight compensation commands for primary surface actuators
  - Spoiler Speed brake and Ground Lift Dumping
  - Configuration Trim on Horizontal Stabilizer
  - Rudder Authority Limiting Augmentation function
  - Redundancy Management
  - Critical Monitoring of FCS
  - Flutter and Oscillatory Fault Protection

RTA FCS – Primary Flight Control Functionality

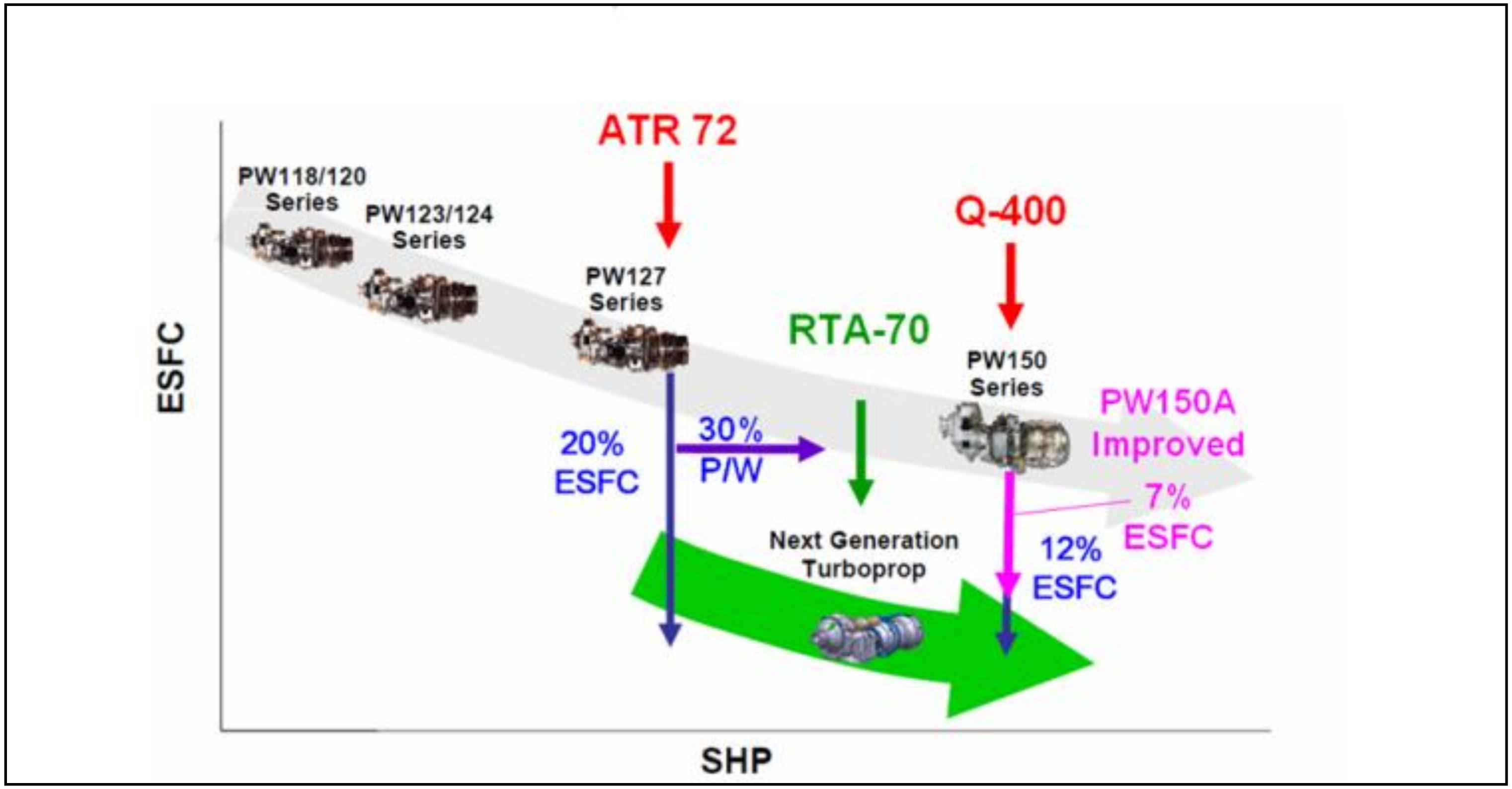
- Angle of Attack Limiting Function: AoA limit function is used to limit AoA in order to avoid the stall condition.
- Bob Weight Function: The Bob Weight command augments the pilot command based on aircraft normal acceleration to provide a near constant stick force/g. This results in the pilot having to increase the column input to hold a constant elevator position as the aircraft normal acceleration increases.
- Thrust Asymmetry Compensation: The Thrust Asymmetry compensation provides yaw moment compensation for cases where one engine is lost in running for take off.
- Aileron Droop Command: The Aileron Droop function provides a symmetric aileron trailing edge down deployment to provide increased wing lift for take off and landing.
- Configuration Trim: Pitch trim compensation due to the extension and retraction of the landing gear and speedbrake spoilers.
- Force fight compensation: Small differences in rigging errors, system gain/bias errors, kinematic errors and other tolerances can result in a mis-match between the two adjacent actuators on a control surface. This mis-match results in a force-fight between the actuators, which can lead to fatigue of the local aircraft structure. Force fight compensation helps reduce this error.

RTA FCS – Primary Flight Control Functionality

- Spoiler (Flight Mode and Ground Mode): Deployed symmetrically (for Turbo Fan only) in response to Speedbrake handle commands to increase drag and reduce lift.

- Ground Lift Dumping: Deploys symmetrically all spoilers to reduce lift, helping the aircraft settling after touch down and reducing landing roll out distance. Ground Lift Dumping is automatically activated and it is interlocked with WOW logic to ensure that it is accidentally not deployed in air.

POWER PLANT FOR NGRT



PW150C

Program progressing on schedule

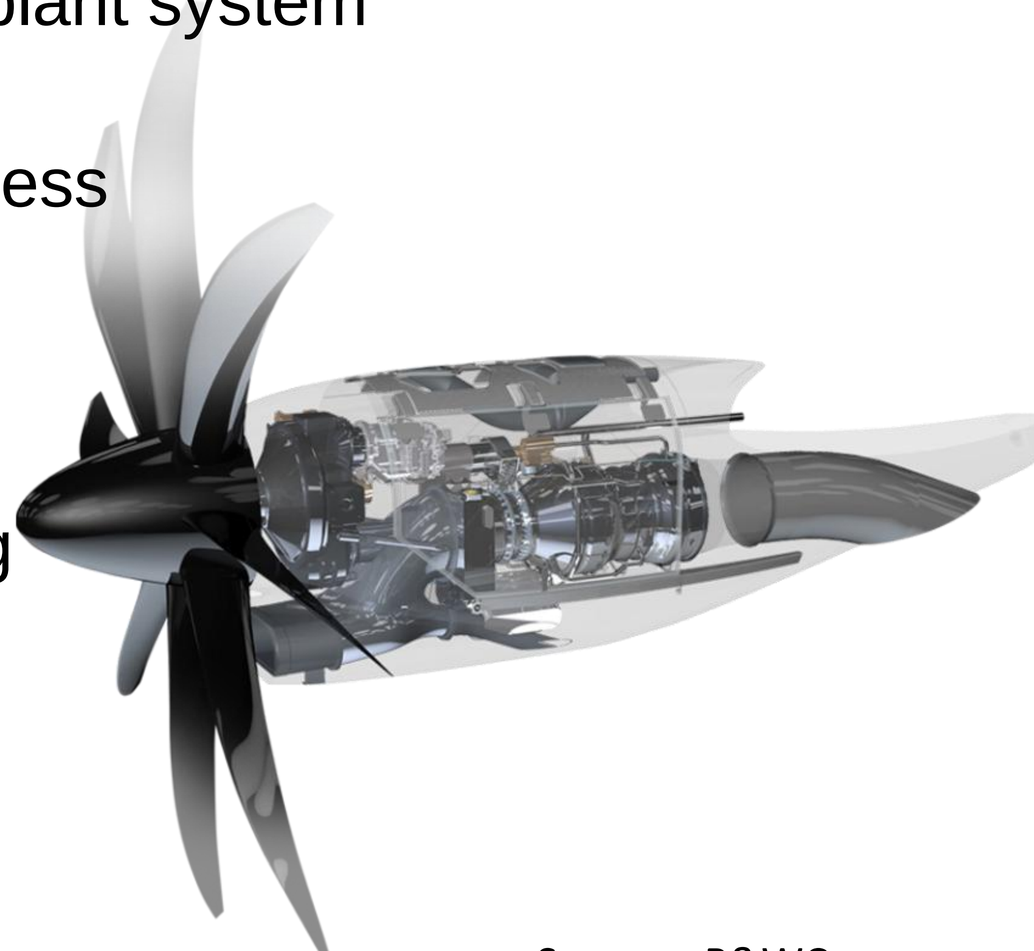
Engine certification in 2018

New gearbox, power turbine and modified compressor

Source :P&WC

NGRT: A TOTALLY NEW CENTERLINE ENGINE

Platform for 70-100 pax aircraft
Fully integrated powerplant system
Performance
Environmental friendliness
Maintainability
Compressor demo
- Phase 1 completed
- Phase 2 progressing



Source : P&WC

AVIONICS SYSTEM - CTQs

1) <u>LOW COST</u>

-Reduction in Acquisition Cost by 25%

- Reduction in Operating Cost by 25%
- Reduction in Maintenance Cost by 50%

A) Reduction in Acquisition Cost is achieved by

- Use of COTS Components, COTS Cards, Open System Architecture,

Open Standards like- OGL, Ethernet, IMA, VME, PMC,CPCI, ARINC 664- Commercial RTOS like RT LINUX, Vx Works, Integrity etc.& Reusable Software Modules

B) Reduction in Maintenance Cost is achieved by extensive use Condition Health & Trend monitoring (both on line & off line) of all Systems (including Mechanical, Flight Control & Propulsion Systems).

Provision of

1) Extensive Built in Test (BIT) for all LRUs & LRMs,
2) Embedded Smart Sensors in Mech. LRUs
3) Use of End to End System Level Tests &
4) Built in Diagnostics

will help in reducing Maintenance Cost.

AVIONIC SYSTEM – CTQs (CONTD.)

2) SCALABILITY with built in features for growth potential for addition of new functions & new technology.

3) REUSABLITY with extensive use of reusable H/W & S/W Modules with Open Industry Standards like ARINC 661 & ARINC 653

4) SAFETY FEATURES with the use of Design Features like Fault Tolerant H/W & S/W, Fault Tolerant Architecture, Redundancy etc.

5) TAKE OFF AND LANDING FROM NON TOWERED & UNEQUIPPED AIRPORTS using

a) Satellite Based Nav Systems including Augmentation Systems like WAAS. EGNOS & GAGAN

b) Concept of Self controlled area, Conflict Detection & Alert System & Decision Support System

c) Synthetic & Enhanced Vision on Low Cost HUD

AREAS FOR TECHNOLOGY DEVELOPMENT

1) Studies on use of ADS-B for enhanced Situation Awareness-

- Studies on Reconfigurable ADS-B combining 1090 ES &UAT using Software Defined Radio Technology
- Studies on use of ADS-B for Transmission of Weather Radar Data
- Studies on Multi Sensor Data Fusion of ADS-B Data, Data from Surface Surveillance Radars for Integrated presentation of Situation Awareness of Airport Traffic on ground both for the Pilot & ATC

AREAS FOR TECHNOLOGY DEVELOPMENT (CONTD)

2) Satellite Based Navigation Systems

- Selection/Development of Low Cost Nav Sensor using MEMS based Gyro, Solid State Accelerometer & GPS.
- Integration of Nav System with GAGAN & other SBAS & GBAS Systems.
- Study of GPS based Landing using LAAS for CAT 3 A Performance.

AREAS FOR TECHNOLOGY DEVELOPMENT (CONTD)

3) Synthetic/Enhanced Vision For Landing in Unequipped Airports in Adverse Weather Conditions-

- Display of 3-D Digitized Terrain Map on MFD & HUD & Integration with EGPWS Data & Flight Directors & Flight Path Markers
- Study on use of Sensors like CCD Camera, IR Sensors & mm Wave Sensors for use in Adverse Weather conditions
- Study of Highway in the Sky (HITS) Concept

4) Low Cost HUD

AREAS FOR TECHNOLOGY DEVELOPMENT (CONTD)

5) Operation from Non Radar Airspace & Non Towered Airports-

- Studies on the Concept of Self Controlled Area (SCA) around an Airport.
- Concept of Operations (CON OP) of the new Concepts
- On Board Conflict Detection, Alerting & Related Flight Guidance Algorithms
- On Board Decision Support System For Pilots
- Ground Based Airport Management Module Algorithm

Areas for Technology Development

6) Study on Up linking Weather Data from Ground Weather Radar Stations-

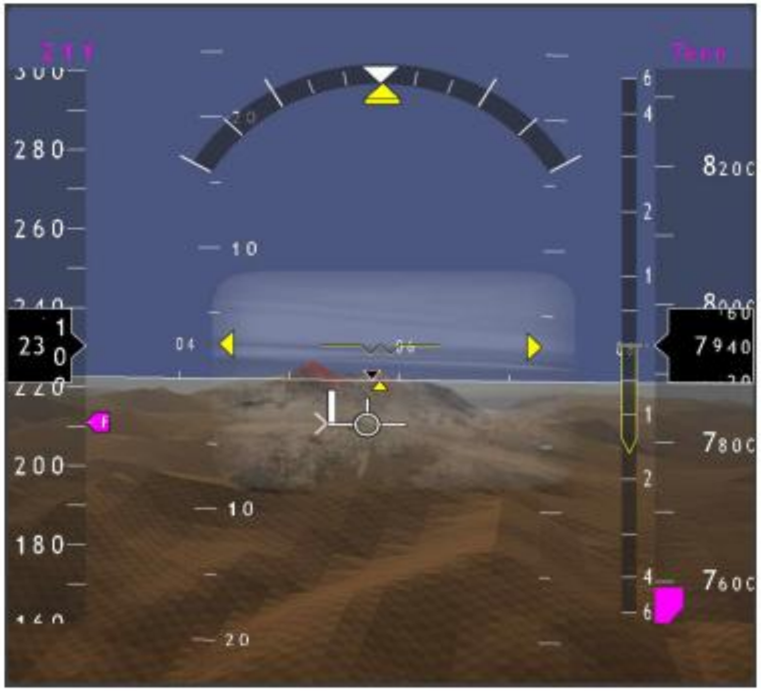
- Study on Net working of Existing Ground Weather Radar Stations
- Algorithms for Data Fusion of Weather Data from different Stations
- Studies on Integrating Weather Data into the existing VHF/ HF/Satellite Data Links
- Studies in Integrating Data from Ground & On Board Weather Radar & Presentation to Pilot

AREAS FOR TECHNOLOGY DEVELOPMENT (CONTD)

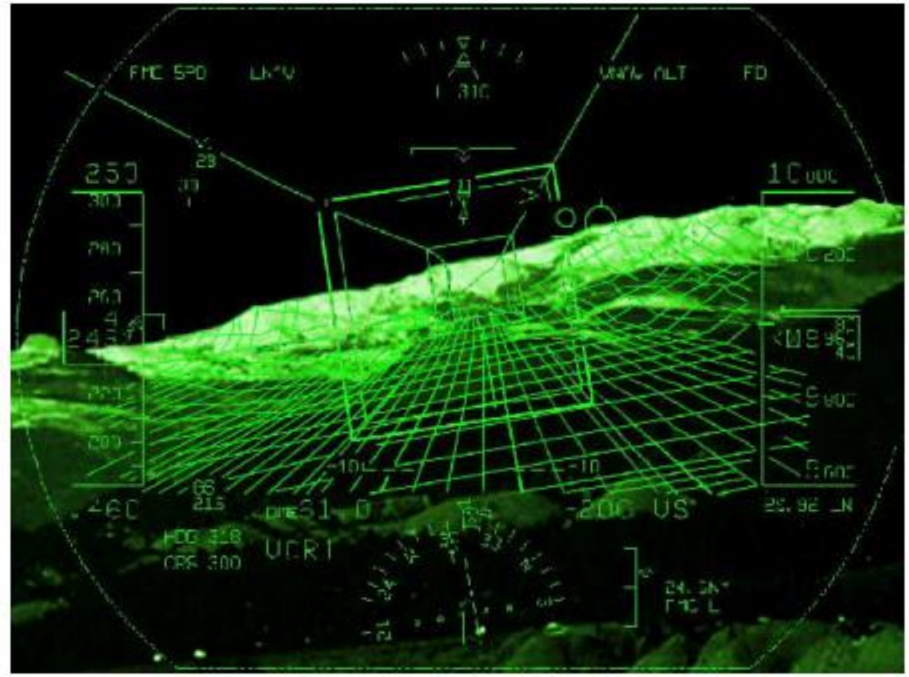
7) Studies on Communication Systems-

- Studies on Data Rate Requirements
- Selection of VDR & Sat Com Equipments
- Studies on Integration with ICAO Aeronautical Telecommunication Network (ATN)
- Studies on Integration with CPDLC & ACARS
- Studies on Network Centric Communication Architecture
- Studies on Required Communication Performance (RCP)

Displays and Situational Awareness – Trend Towards Synthetic and Enhanced Vision



Head Down SVS PFD
w/EVS Inset Image



Head Up Display
w/Wireframe SVS

Opportunity for "Equivalent Visual Operations"

Weather – Trend Towards Integration of Uplinked Weather with Weather Radar

Datalink and Satellite Broadcast Weather

- Strategic Weather Information from Ground-Based Sources

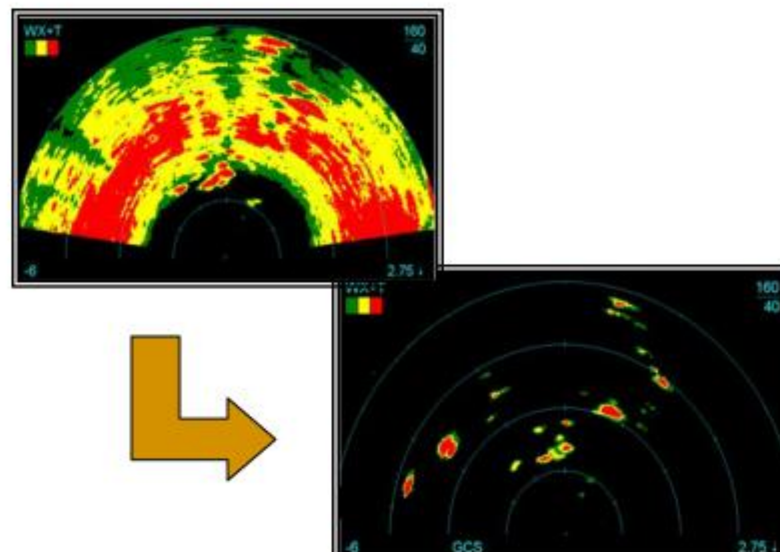
Nexrad

Satellite Imagery

Winds Aloft

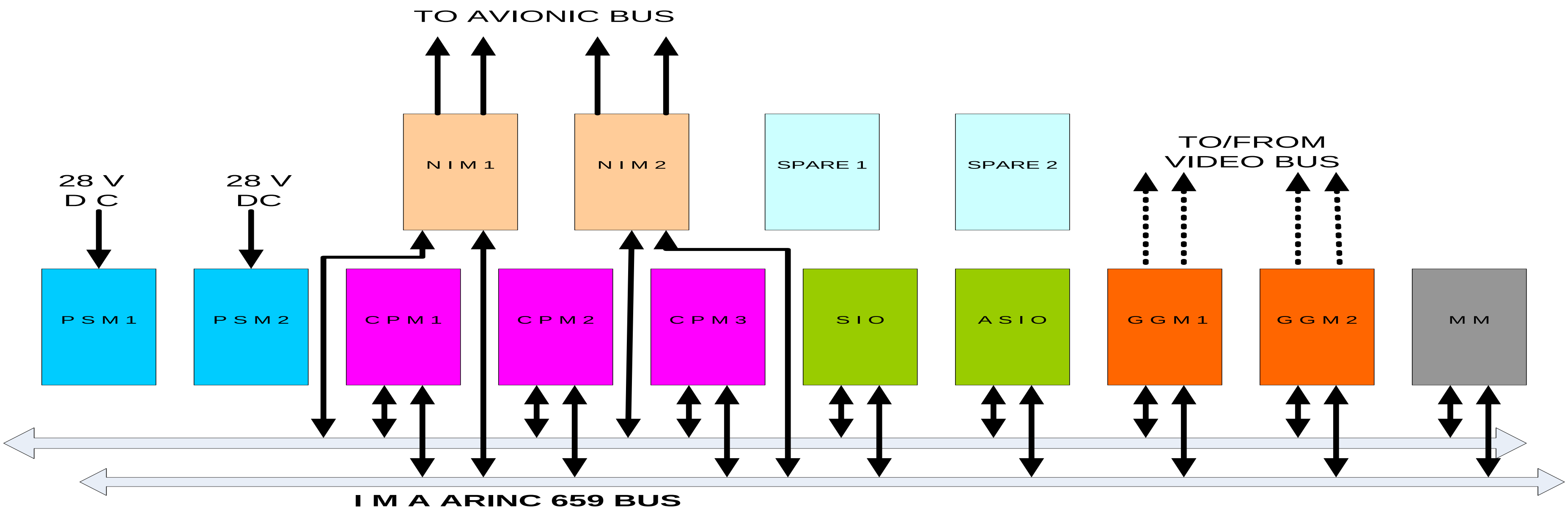
Weather Radar

- MultiScan™ Technology
- Digital Signal Processing Eliminates Ground Clutter
- Automated Operation
- World-Wide Geographic Weather Correlation



CABINET LEVEL ARCHITECTURE- PROPOSED

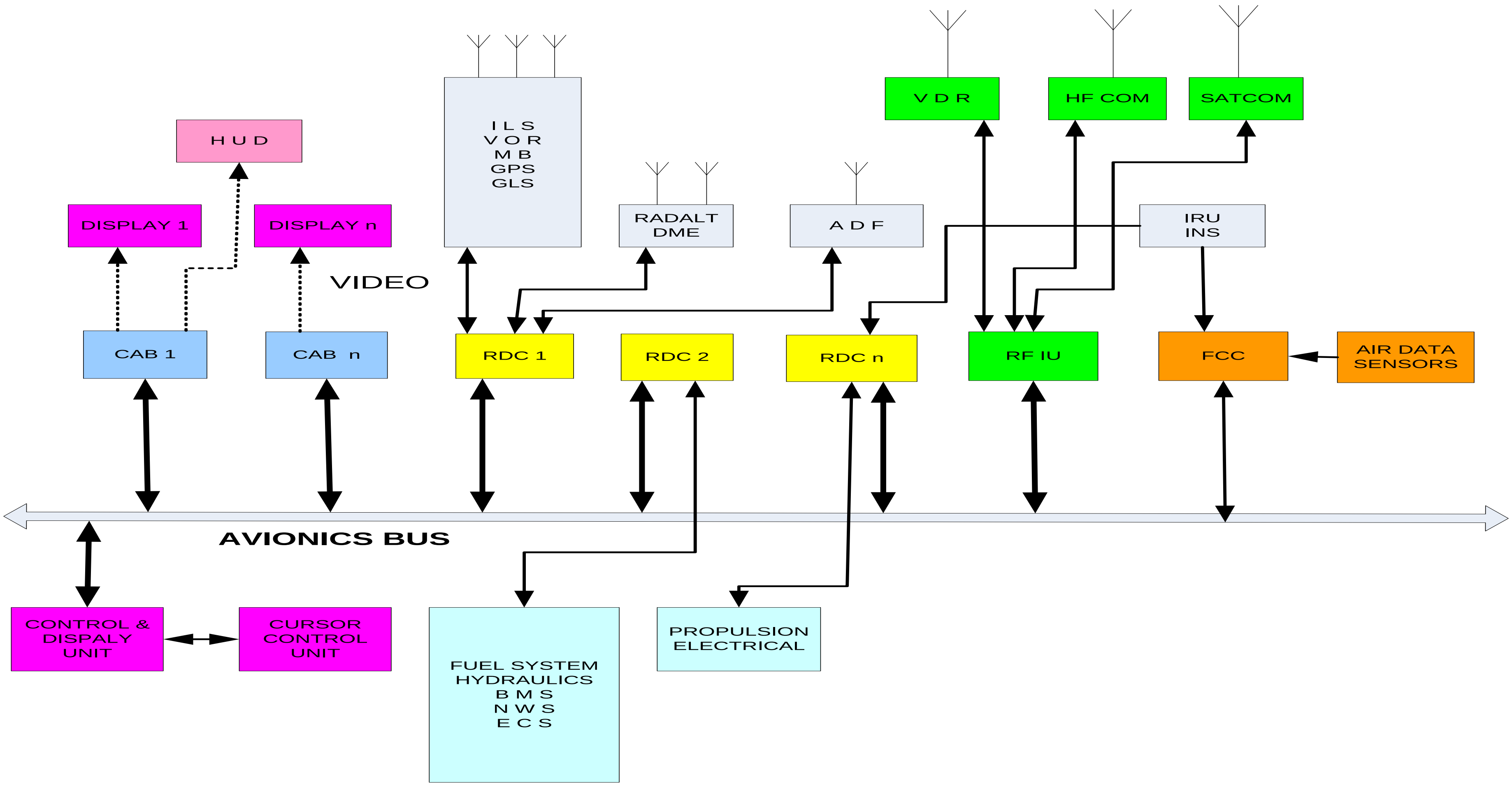
PSM – POWER SUPPLY MODULE
CPM – CENTRAL PROCESSING MODULE
GGM – GRAPHICS PROCESSING MODULE
NIM – NETWORK INTERCONNECT MODULE
MM – MEMORY MODULE
SIOM – STANDARD I/O MODULE
ASIOM – APPLICATION SPECIFIC I/O MODULE



CABINET LEVEL ARCHITECTURE

70 SEAT REGIONAL TRANSPORT AIRCRAFT AVIONICS

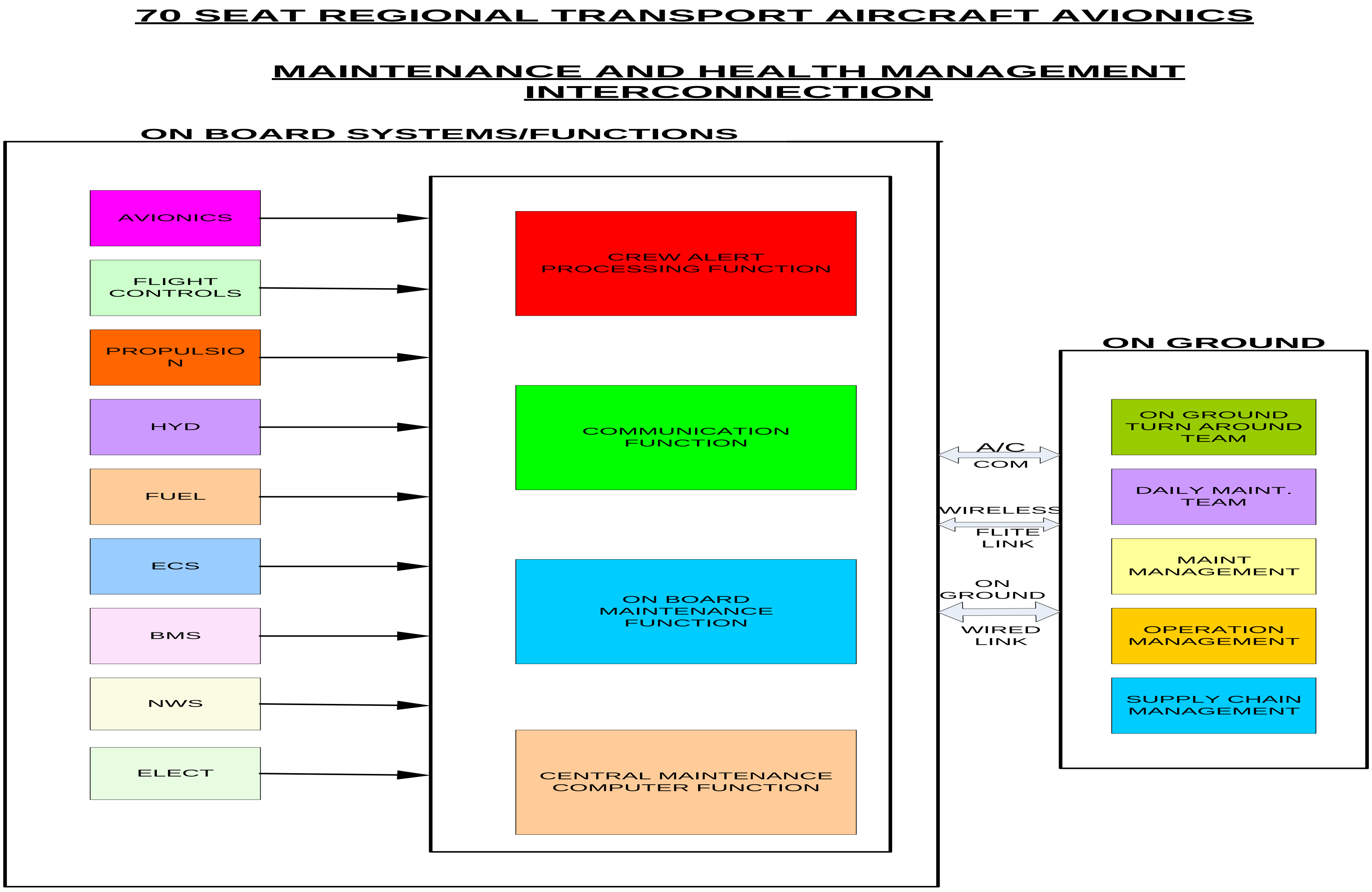
AVIONICS ARCHITECTURE AIRCRAFT LEVEL



AVIONICS BUS ARCHITECTURE – AIRCRAFT LEVEL

70 SEAT REGIONAL TRANSPORT AIRCRAFT

MAINTENANCE & HEALTH MANAGEMENT



New technologies addreses Avionics

Costs < 50%

- Enhanced safety
- Enhanced functions: EVS, SVS, HUD, EGPWS
- Future Transfer to “ Free Flight Network”
- Wide band communication
- Satellite navigation with WAAS
- Weather & topology info
- Air space integration
- Real time support network
- Airspace & ground control integration

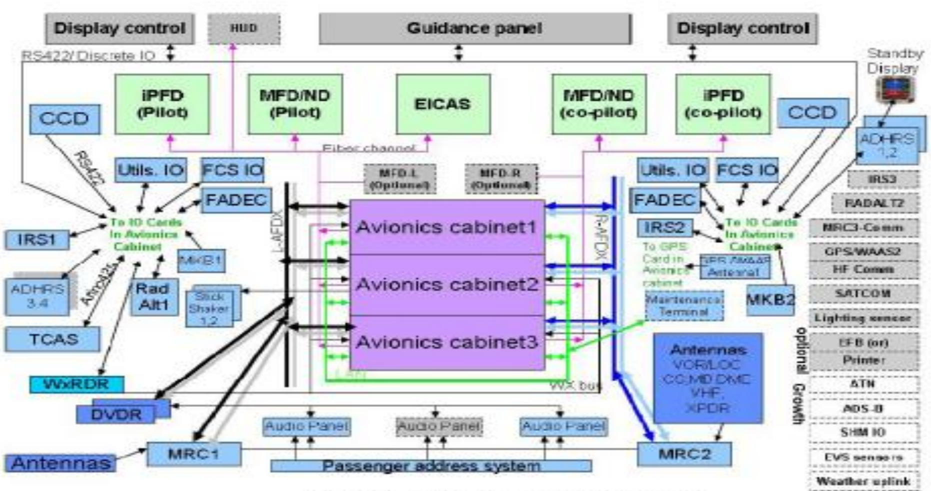


Figure 5 RTA Open Architecture

India’s Regional SBAS called GAGAN can provide CAT I landing capabilities

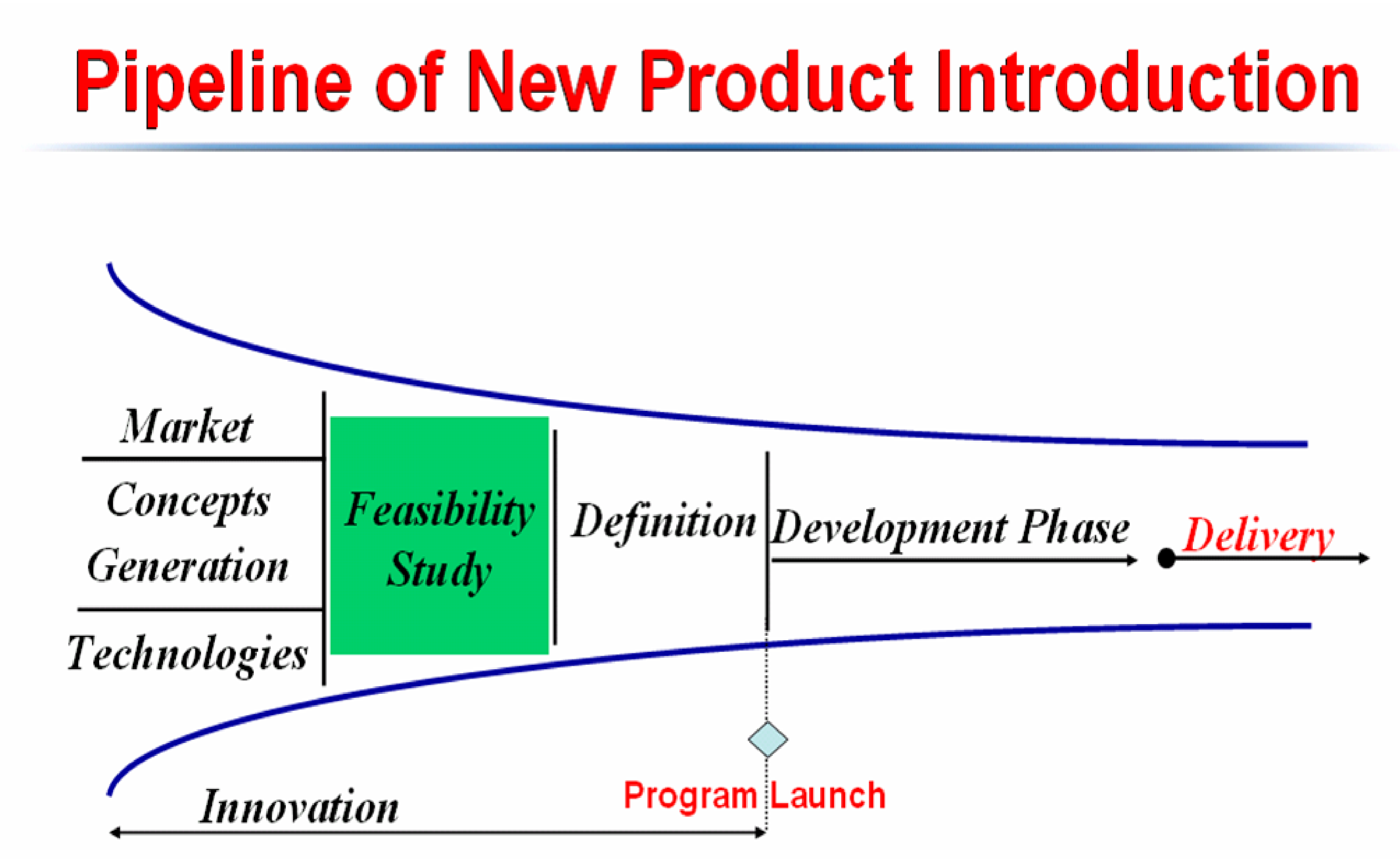
Integrated Enhanced and SyntheticVision System (IESVS) for RTA-70

NEW TECHNOLOGIES DEVELOPED: AEE- Aircraft Engineering Simulator

Enabling Technology

Model based Systems Engineering

Innovation Pipeline



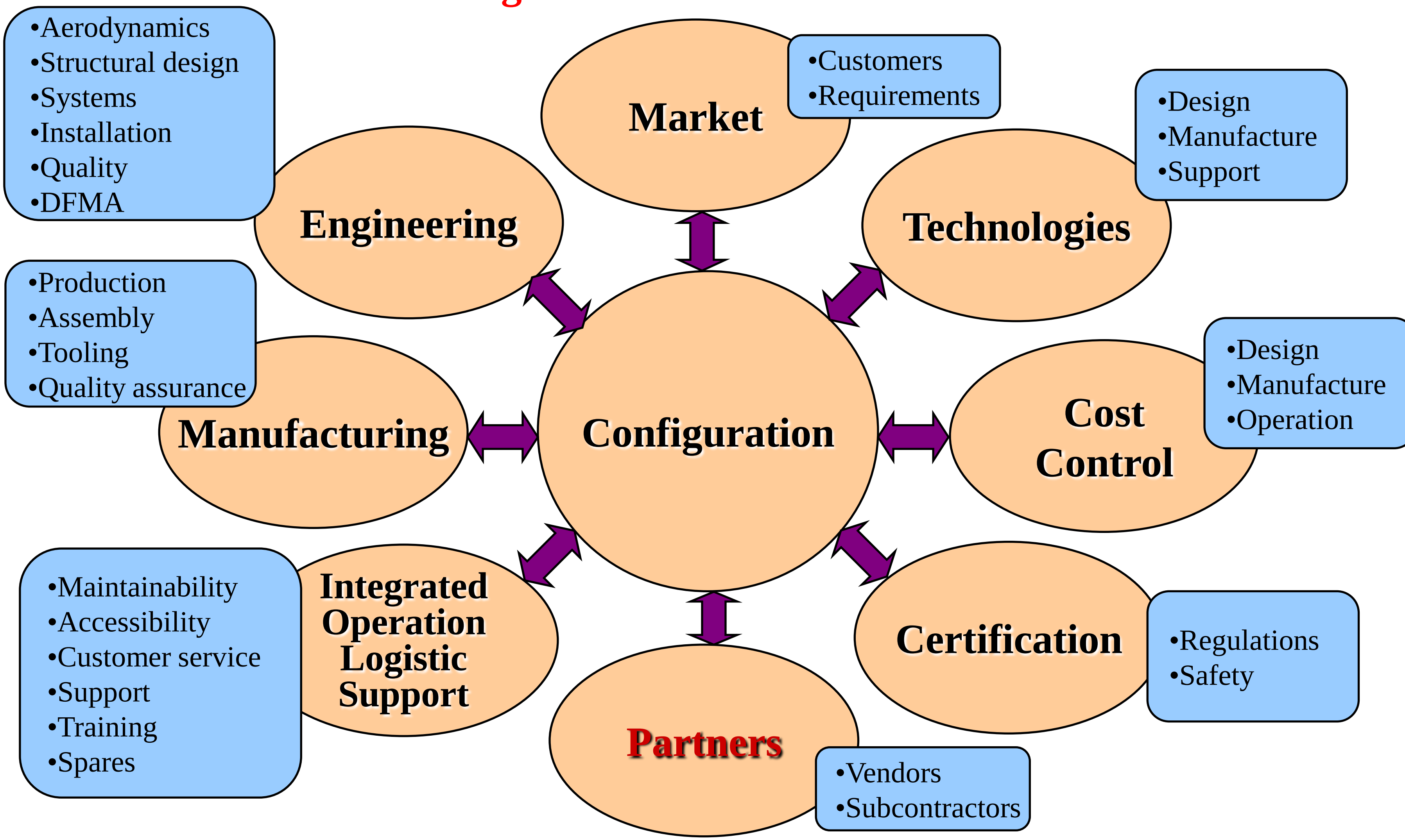
Feasibility Scope

- **The Feasibility Study is an iterative process, the main goal of which is to verify the technical and commercial viability of new products, including:**
  - **Evaluate potential customers' requirements**
  - **Analyze the market trends and potential competitors**
  - **Recommend the product market-positioning (Design-Point)**
  - **Define potential aircraft configurations (Geometry, Systems concepts, Structural & Materials concept, Manufacturing & Assembly concept)**
  - **Conduct configuration trade-off studies**
  - **Evaluate the performance of the potential configurations**
  - **Evaluate candidate advanced technologies**
  - **Prepare a preliminary cost model**
  - **Prepare a preliminary business plan**
  - **Plan in-detail the activities of the next phase – Definition Phase**

The Definition Phase

Integration of all required Disciplines in Iterative Process to get

High Level of Substantiation

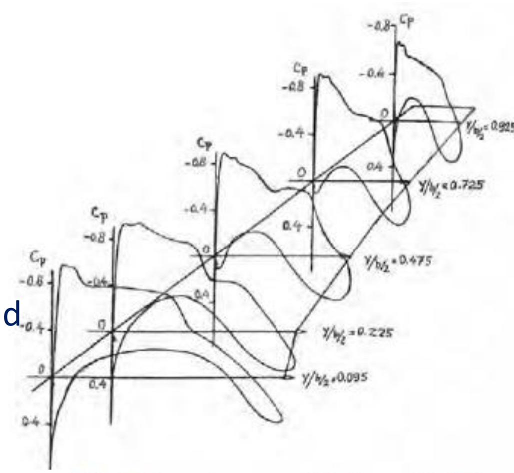


THANK YOU

Airfoil Optimization

- A combination of Direct & Inverse Optimization
  - Direct Optimization for Exploring the Design Space.
  - Inverse Optimization for fine tuning, if required.

- Airfoil Parameterization
  - Kulfan (class shape function) transformation [1]
  - Flexibility in specifying geometric constraints
  - Bounds selection based on the visualization of the design space.



Airbus A340 spanwise pressure distribution near the design condition.
Source: AGARD CP-547, Paper No. 11

- Optimization Problem

  Design Objective: Multi Point L/D Maximization at Cruise & Climb

  Design variables: Coefficients of the polynomial Seven on each upper and lower surfaces

  Constraints: M_{DD}, C_m , C_{Lmax} & Geometric Constraints

- Tools

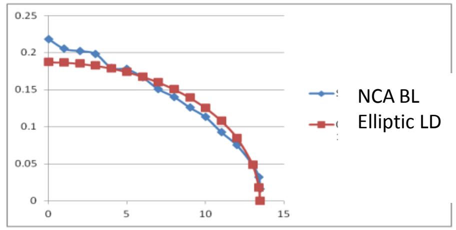
  A Mixture of CFD & Semi-Empirical methods
  - **CFX (RANS)**
  - **MSES (EULER +BL)**
  - **ESDU (C_{LMAX})**

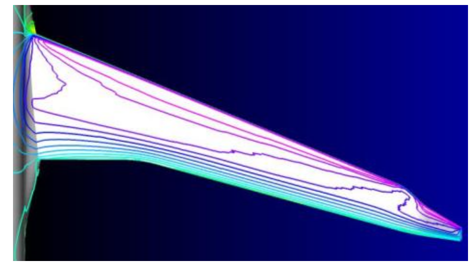
[1] A Sobester , "Exploiting patterns of Kulfan Transformations of supercritical airfoils", 9th AIAA Aviation technology, integration and operation conference, AIAA 2009-6951

Wing Optimization

- Optimization Problem

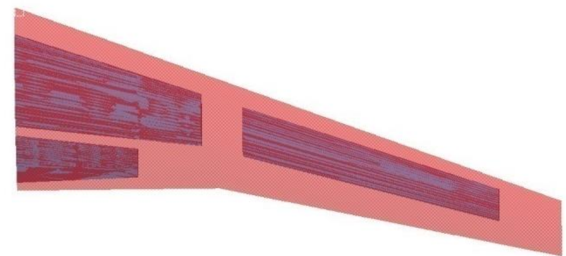
Design Objective: Multi Point L/D Maximization at Cruise & Climb





Considerations:

1. Maximizing ‘e’
2. Keeping Pressure Isobars as straight as possible
3. Volume for LG Integration, Fuel & Control Surface
4. Buffet Margins
5. Weight



Design Variables:

Stage-I: Twist & Taper

Stage-II: TBD based on MDA to meet design objectives.

- Tools

•CATIA-V5, NASTRAN

•A Mixture of CFD & Semi-Empirical methods

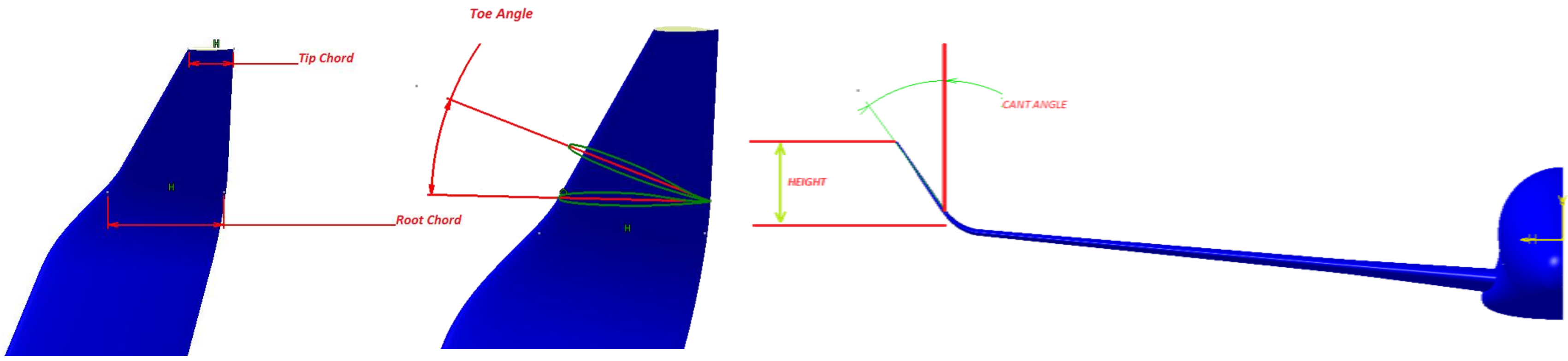
- **CFX (RANS)/ HIFUN**
- **HYENA (EULER)**
- **MSES (2D, EULER +BL)**
- **ESDU (C_{LMAX})**

Winglet Optimization

- Optimization Problem

Design Objective: Multi Point L/D Maximization at Cruise & Climb with minimum increase in Weight (BM).

Design Variable: Cant Angle, Toe Angle, C_r, C_t, & Height



- Tools
  - CATIA-V5
  - CFX (RANS)
  - HYENA (EULER)
  - NASTRAN

Winglet Optimization

Optimization Strategy

Stage-I: Aerodynamics Optimization with BM as Constraint

Stage-II: Coupled Aero Structure Optimization with Weight vs RBM Correlation

Stage –III: Coupled Aero Structure Optimization with Aeroelasticity

Typical Result from Stage-1 Optimization

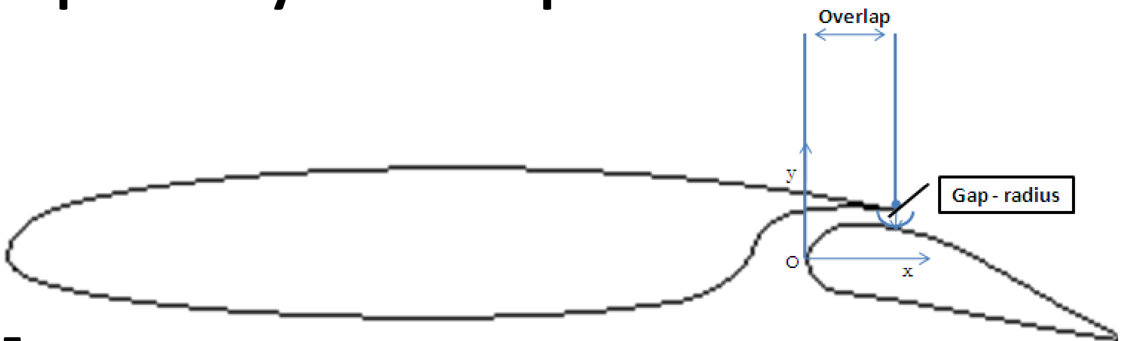
Parameter	**Baseline**	**Optimised**
C_r (m)	1	0.63
C_t (m)	0.35	0.13
Height(m)	0.522	0.76
Cant (deg)	40	35.8
Toe (deg)	-2.7	1.05

Parameter	**Baseline**	**Optimised**
Cmx	0.07401	0.07405
Cdo	0.02146	0.02151
K	0.02850	0.02783

Issues

- Efficient Grid Generation
- Modeling Flow Separation

Gap & Overlap Aerodynamics Optimization



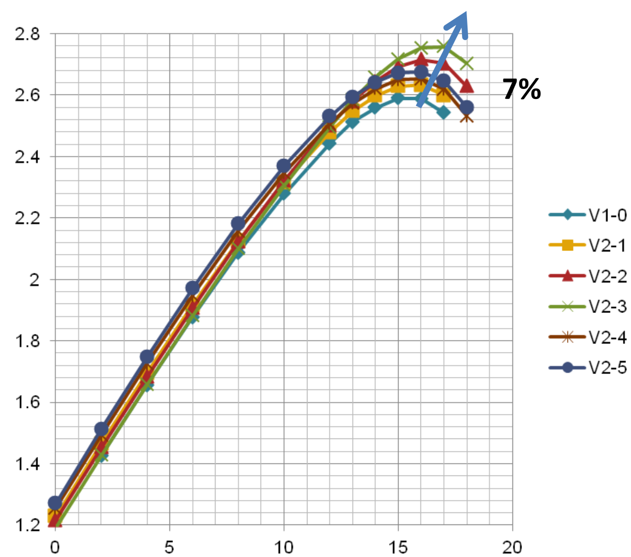
Tools:

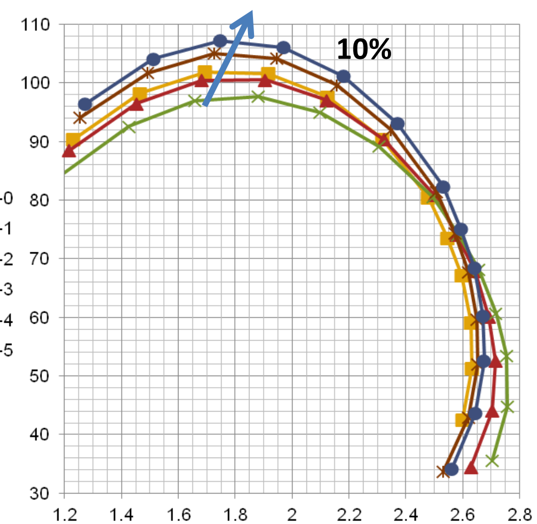
CAD: CATIA-V5

CFD: CFX

Stage-I: Aerodynamics

Name	Δx (mm)	Δy (mm)
V2-1 (base)	0	0
V2-2	-10	0
V2-3	-20	0
V2-4	0	10
V2-5	0	20





Stage-II: Aerodynamics + Kinematics

Wing-Body Fairing Optimization

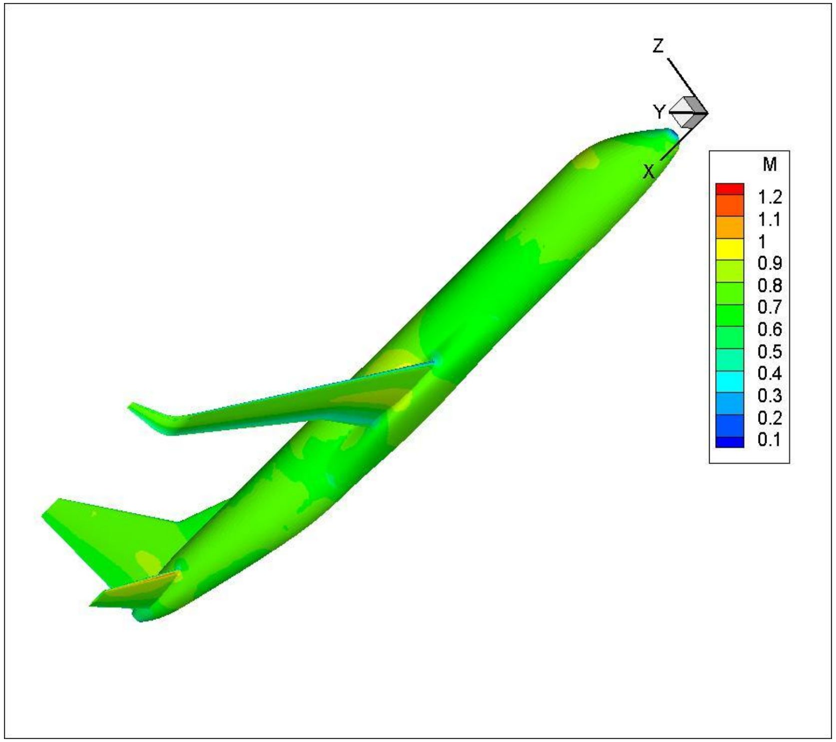
- Optimization Problem

Design Objective: Drag Minimization

Design Variables: Fineness Ratio & Geometric Contour.

Constraints: Volume Required.

Tools: CATIA-V5
HYENA (Euler)
CFX



Nacelle Placement Optimization

- Optimization Problem

  Design Objective: Drag Minimization

  Design Variables: H & X_f.

  Tools: CATIA-V5
  HYENA (Euler)