DIGITAL TWINS AEROSPACE 4

From the drawing board to the Digital Twin: 40 years in aerospace engineering

Digital Twins 4 Aerospace - CAE modelling of future mobility

University of Rome “Tor Vergata”, 14 Dec. 2022

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Vere Novo Technologies
Mays International
19-01

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University of Rome “Tor Vergata”,

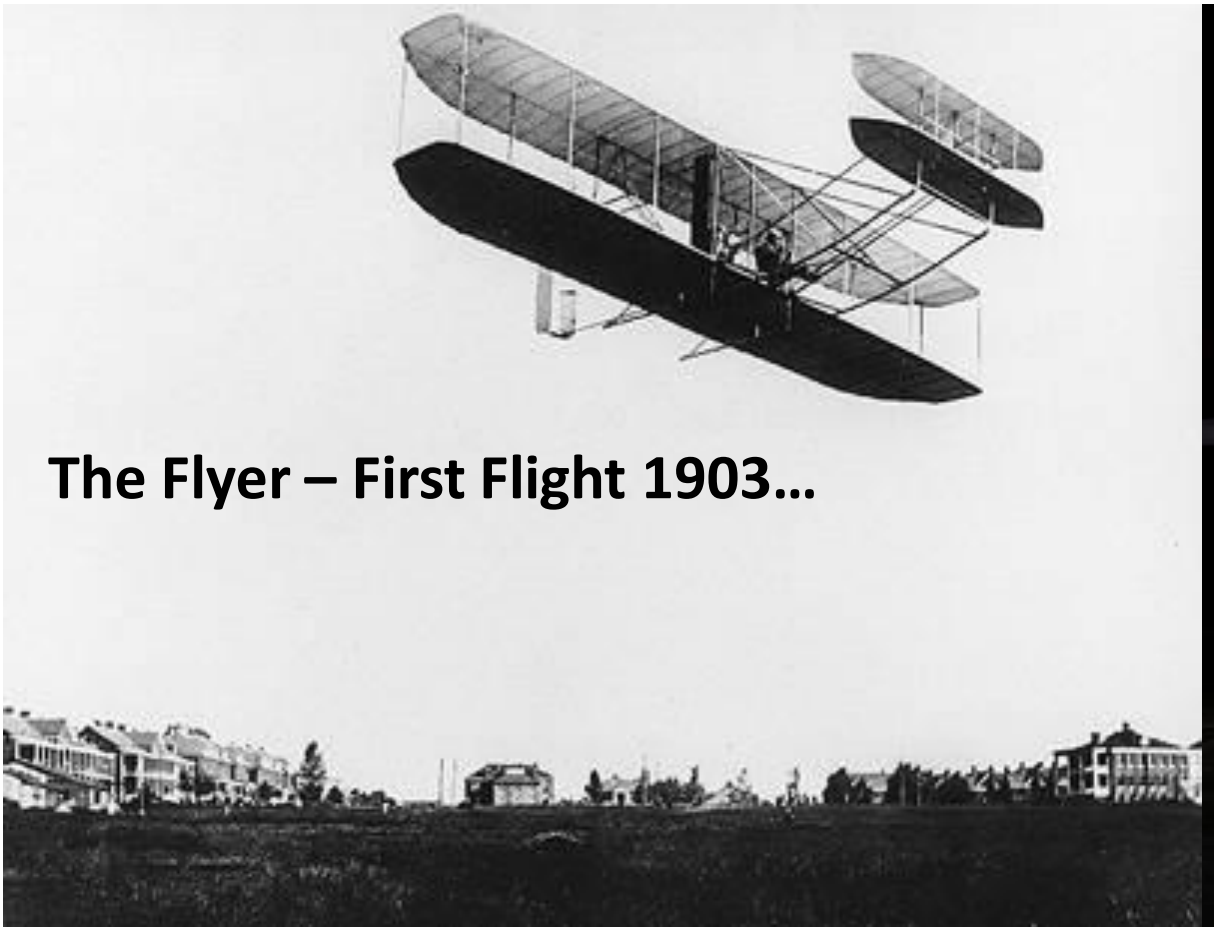
TOPICS

- Timelines
- Engineering in the ‘80s
- P.180 Avanti
- P.1XX
- P.1HH UAS
- Seaplanes
- WF-X

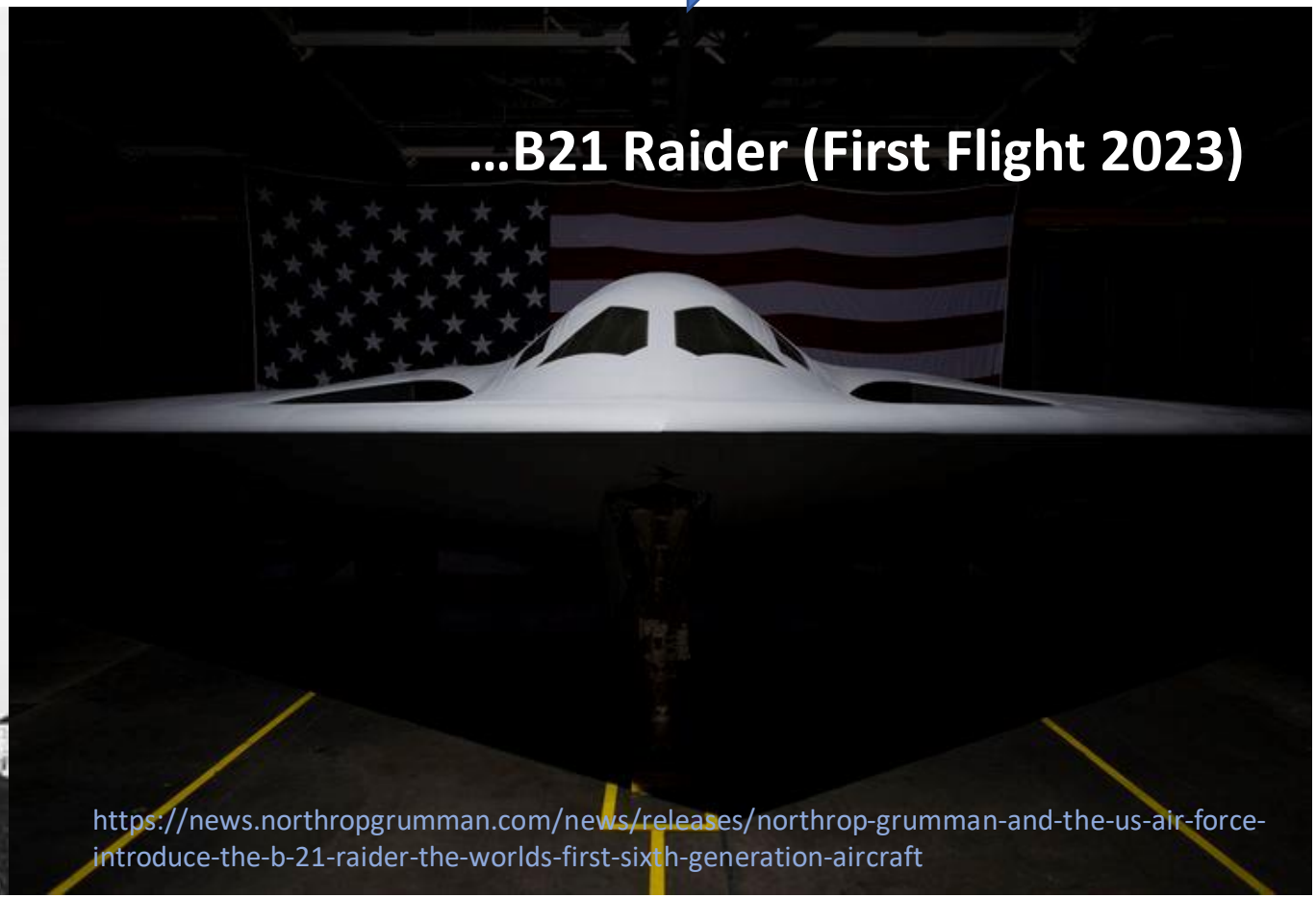
- Q&A-

From the drawing board to the Digital Twin: 40 Years in aerospace engineering

From the Flyer… **120 years** …to the Raider



The Flyer – First Flight 1903…



…B21 Raider (First Flight 2023)

https://news.northropgrumman.com/news/releases/northrop-grumman-and-the-us-air-force-introduce-the-b-21-raider-the-worlds-first-sixth-generation-aircraft

Aerospace timeline: from 1903 to now…

120 years

the Pioneer Era (1903-1914)	World War I (1914-1918)	Between the World Wars (1918-1939)	World War II (1939-1945)	The Postwar Era (1945-1979)	The Digital Age

1903-1913 | 1913-1923 | 1923-1933 | 1933-1943 | 1943-1953 | 1953-1963 | 1963-1973 | 1983-1993 | 1993-2003 | 2003-2013 | 2013-on

1903 the Wright Bros Flyer 1st powered flight

1909

1911

1926

1927

1933 D… Full … Mo… Tran… Aircraft

1930

1943

1946 Bell X-1 1st Supersoni… aircraft

1949

1956

1961

1967 … 1st Flight

1969 Apollo 11 - 1st man on the Moon … Concorde Supersonic Transport

1987 Airbus A320 Short-Medium Range Single Aisle

1994 Eurofighter Typhoon multirole fighter 1st Flight … General

1999 C27 J Spartan Military Transport aircraft 1st Flight

2005

2006

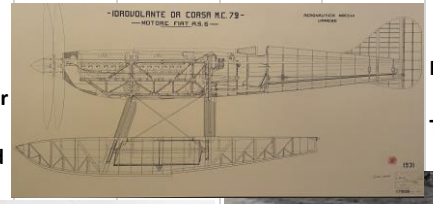
2011

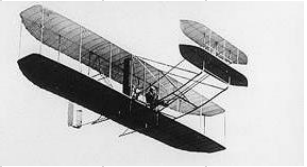
2014

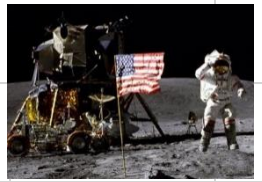
Regional Transport Aircraft 1st Flight

Beech Starship 1st Flight

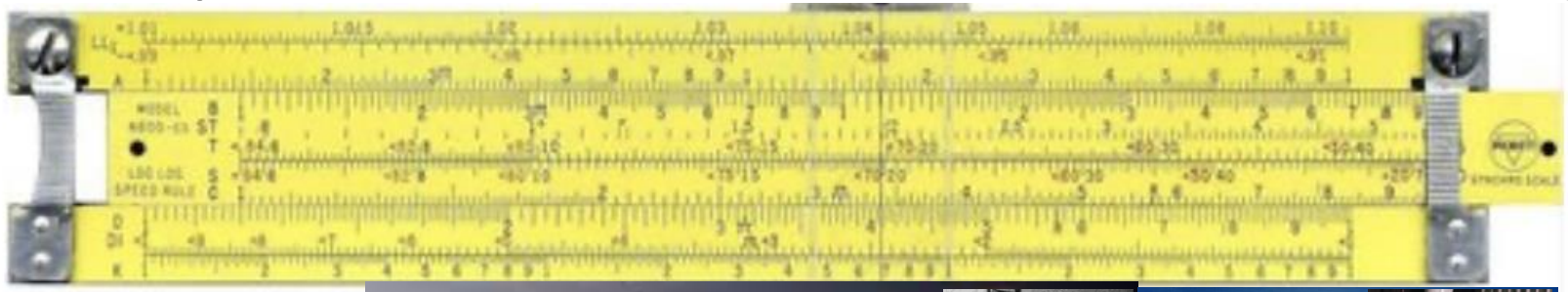
P.180 Avanti 1st flight







Computational timeline: the analogic era…



1964 SR-71
M 3.2 - FL850 (26km)
Range 5926 km
TurboRamJet variable cycle propulsion

1964 Saturn V
W 2970 tons
H 110 m
Payload
140 tons low altitude
49 tons lunar mission

1969 B747 Jumbo
M 0.85 – FL450
MTOW 397 – 448 tons
Pax 416-524

1969 Concorde
M 2.2 - FL600 (18km)
MTOW 185 tons
Pax 90-128
Range 7251 km

1903-1913		1913-1923								The Digital Age									2013-on
1903	1909	1911	**1926**							1984	**1986**	1987	1994	1999	2005	**2006**	**2011**	2014
the Wright Bros Flyer 1st powered flight	1st italian aircraft (FIAT)	Blériot XI Nieuport IVG Farman Corpo Servizio Aeronautico	**Macchi M39 Schneider Cup**							ATR 42 Regional Transport Aircraft 1st Flight	**Rutan Voyager No-Stop world flight** **ATR 72 Regional**	Airbus A320 Short-Medium Range Single Aisle Passeng	**Eurofighter Typhoon multirole fighter 1st Flight** General Atomics	C27 J Spartan Military Transport aircraft 1st Flight	Airbus A380 Largest Passenger Aircraft 1st Flight	**F-35 Stealth Multirole fighter 1st Flight**	**Northrop Grumman UCAS X47B 1st Flight**	P.1HH MALE UAS 1st Flight

Aircraft heritage from the “analogic” era…

Boeing

Last Boeing 747 rolls off line after half a century of production

Lockheed Martin Marks Delivery of 500th C-130J Super Hercules

Posted on April 3, 2022 by Richard R. Burgess, Senior Editor

flightglobal.com

FlightGlobal

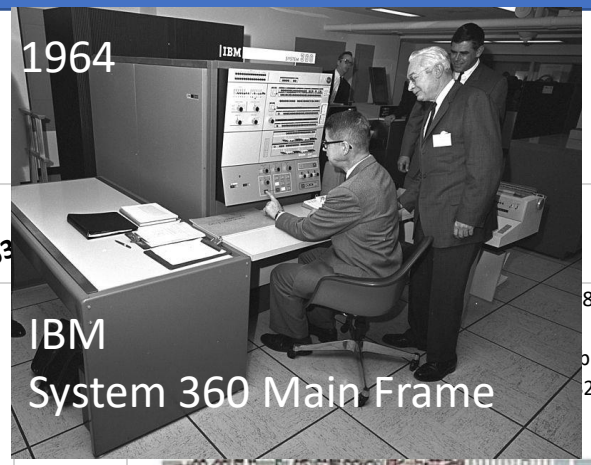
CH-47 Chinook production be stretched to 2025 using foreign sales

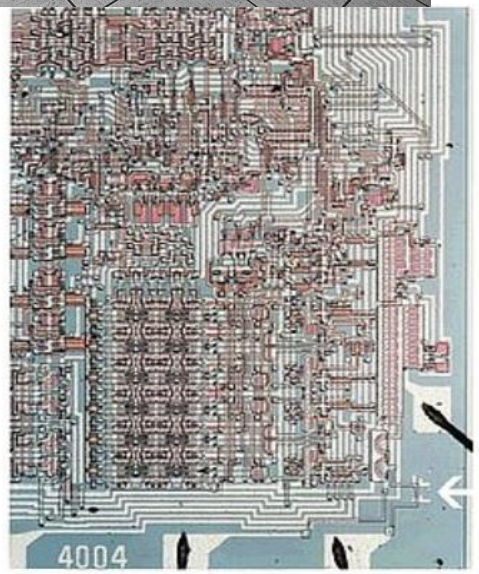
By Garrett Reim | 13 March 2020

Computational timeline: the start of the Digital Age …

120 years

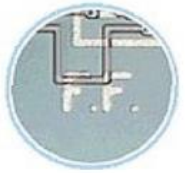
the Pioneer Era (1903-1914)		World War I (1914-1918)	Between the World Wars (1918-1939)		World War II (1939-1945)	The Postwar Era (1945-1979)					The Digital Age					
1903-1913		1913-1923		1923-1933		1933-1943		1943-1953		1953-1963		1963		1993-2003		2003-2013		2013-on
1903	1909	1911	**1926**	1927	1933	1930	1943	**1946**	**1949**	**1956**	**1961**	1967		1994	1999	2005	**2006**	**2011**	2014
the Wright Bros Flyer 1st powered flight	1st italian aircraft (FIAT)	Blériot XI Nieuport IVG Farman Corpo Servizio Aeronautico	**Macchi M39 Schneider Cup**	1st Atlantic crossing Charles Lindberg	**DC 1 Full Metal Modern Transport Aircraft 1st Flight**	Frank Whittle invents jet engine	1st Jet fighter Me 262	**Bell X-1 1st Supersonic aircraft**	**de Havilland Comet Jet Passenger Aircraft 1st Flight**	**AerFer Sagittario 2 1st Italian Supersonic aircraft**	**Soyuz 1st man in orbit**	B737 Short-Medium Range Passenger Aircraft - 1st Flight	**Concorde Supersonic Transport Aircraft - 1st Flight** B747 Jumbo Large Passenger/ Cargo Aircraft - 1st Flight	…87 …bus …20	**Eurofighter Typhoon**	C27 J Spartan	Airbus A380 Largest Passenger Aircraft 1st Flight	**F-35 Stealth Multirole fighter 1st Flight**	**Northrop Grumman UCAS X47B 1st Flight**	P.1HH MALE UAS 1st Flight



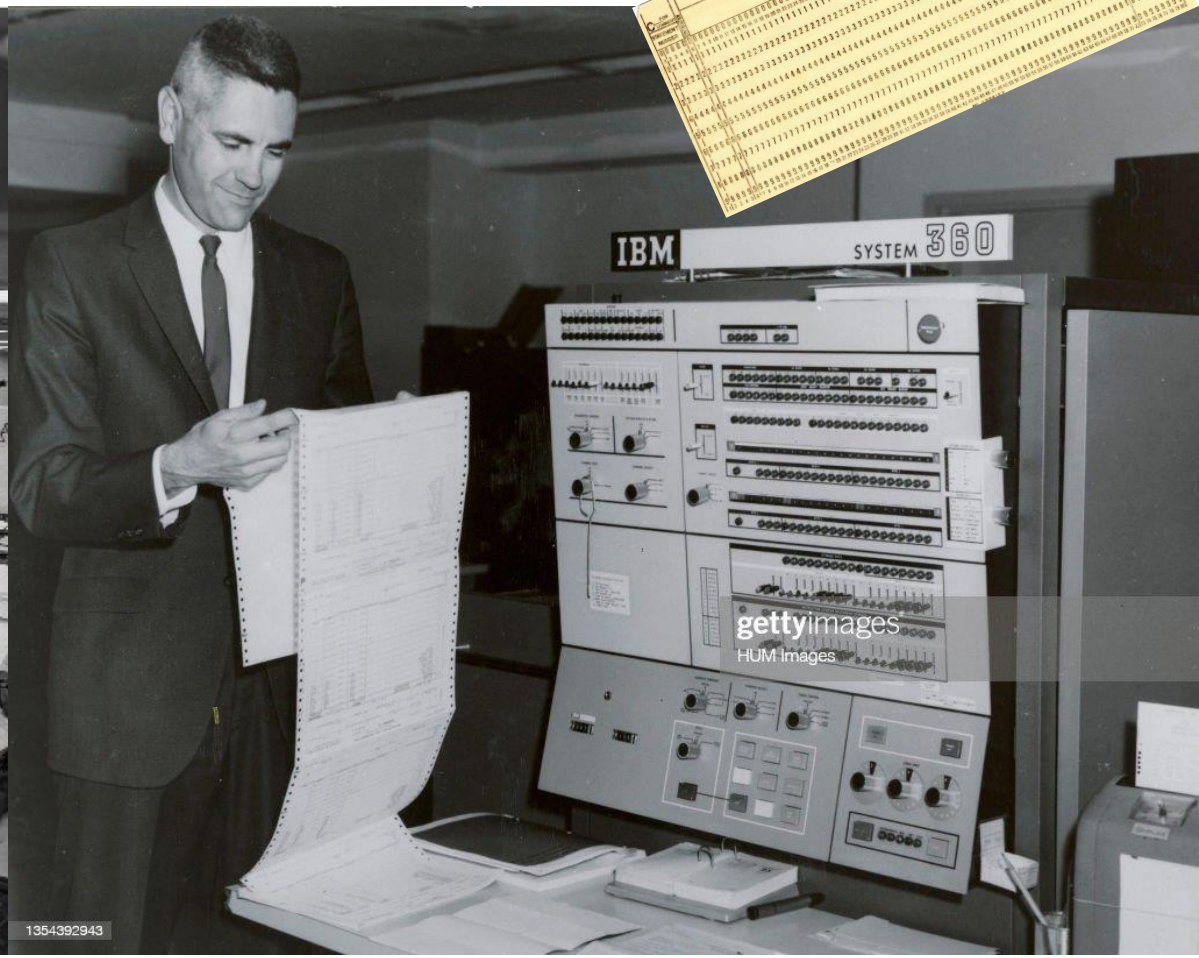


1971

Intel 4004



Engineering environment in the ’80s…



From the drawing board to the Digital Twin: 40 Years in aerospace engineering

Authors timelines –1983…

40 years

The Digital Age

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1903-1913		1913-1923		1923-1933		1933-1943		1943-1953		1953-1963		1963-1973		1973-1983		1983-1993		1993-2003		2003-2013			2013-on	
1903	1909	1911	1926	1927	1933	1930	1943	1946	1949	1956	1961	1967	1969	1974	1982	**1984**	**1986**	1987	**1994**	**1999**	2005	2006	2011	**2014**
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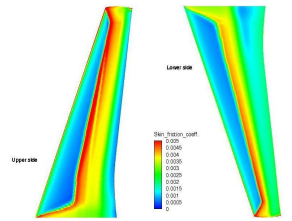
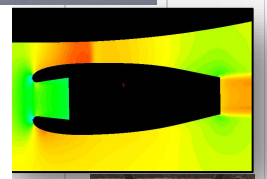
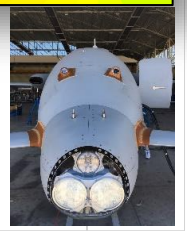
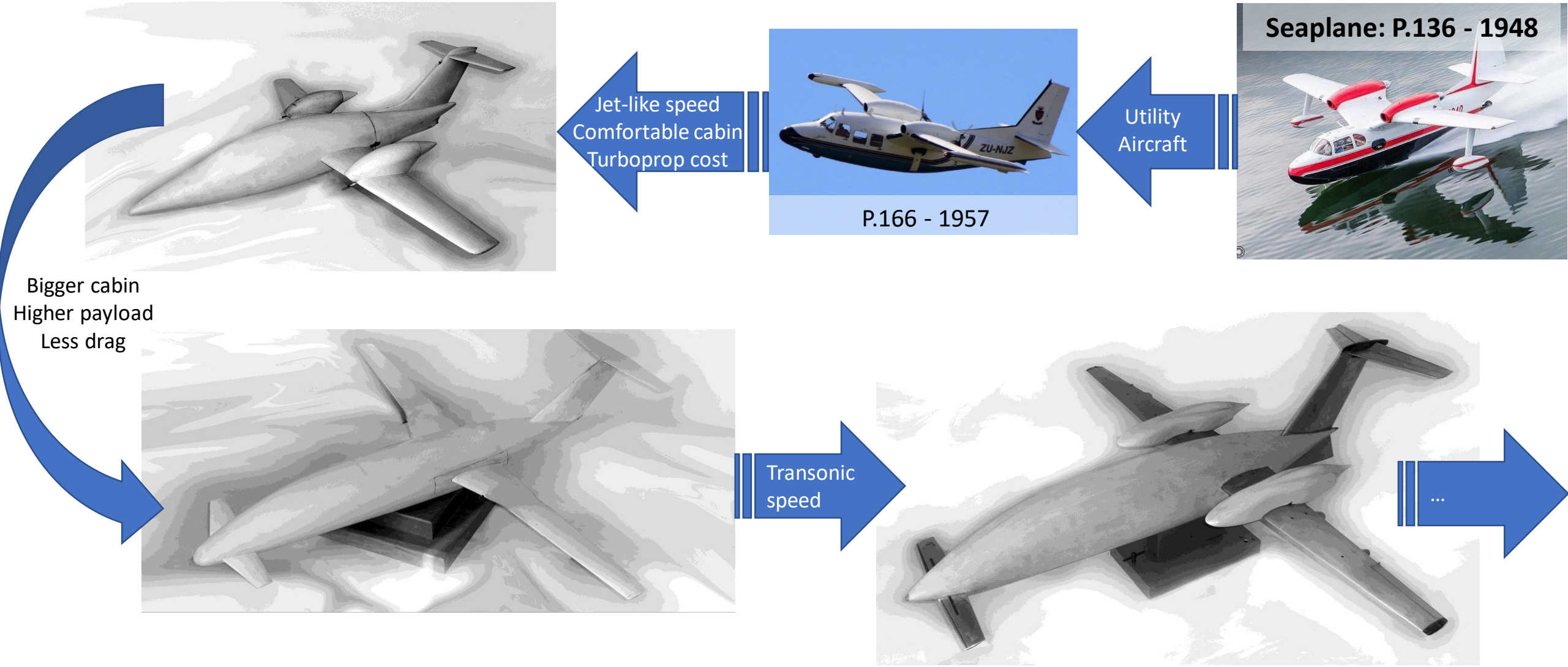




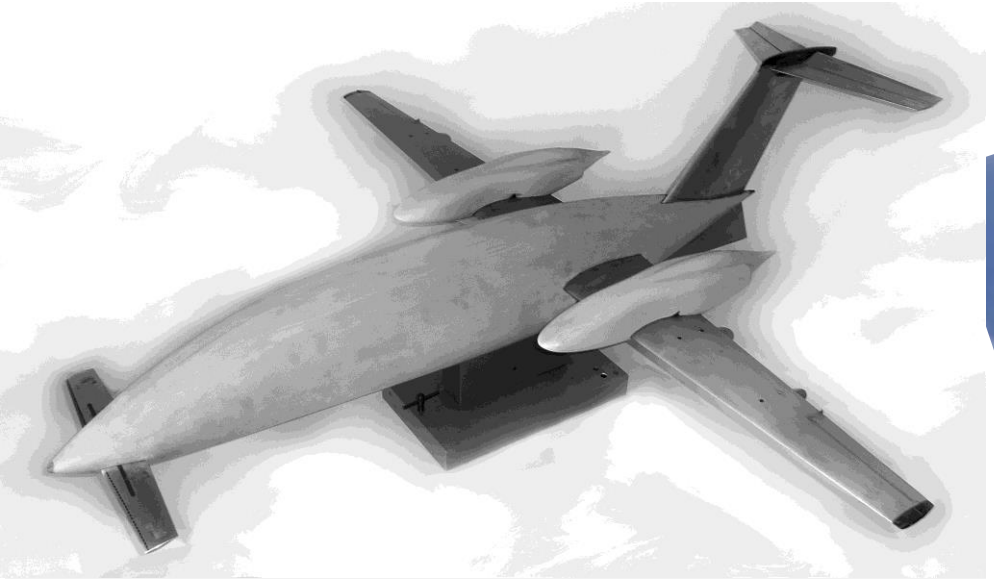


Italian Aircraft Masterpiece from the ’80s…

Witnessing an “analogic” configuration development process: P.180 Avanti WTT models



P.180 Avanti – the fastest civil turboprop in service



P.180 Avanti (certificate 1990)

- MTOW 11550 lbs
- M 0.67 - 388 knots – fastest propeller driven civil AC
- FL410
- Laminar Flow Wing
- 7-9 passengers – Best in class cabin
- Twin Turboprop 2x850shp less -30% fuel vs. Jets
- Range 1520 Nm
- Production >250...

Upgrading a flying masterpiece (with no damages…): P.180 Avanti II and Avanti EVO

P180 Avanti II

- Certification 2005
- Increased payload (+MTOW, +MZFW)
- Enhanced perfo: M0.70 -402knots
- Digital avionics
- Simplified airframe
- New interiors

P.180 Avanti EVO

- Certification 2015
- Additional range
- Reduced Certified Community noise level
- Improved climb
- New Landing Gear

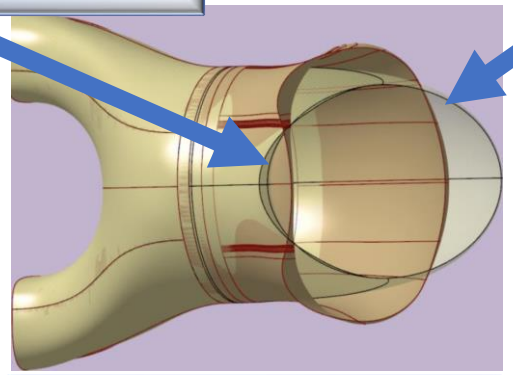
P.180 Avanti Low Noise Exhaust optimization: how to shave 6dB of community noise

Original conical exhaust

Pusher propeller, exhaust flow impact prop blades

PROs:
- No anti-ice system
- Cabin quiet and comfortable

CONs:
- Airflow on blades «disturbed» by exhaust
- Significant noise signature



DESIGN THEME

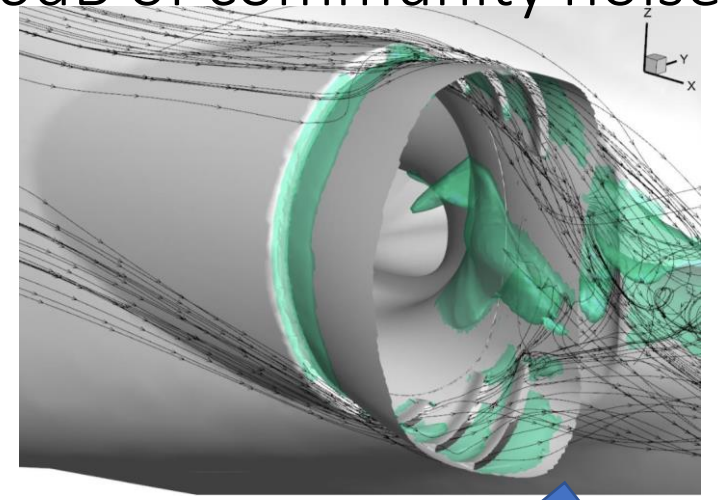
How to redesign exhaust stubs

1. minimize impact on propeller blades
2. without jeopardizing aircraft performance and certification.

«Bean-shaped» Low noise exhaust

PROs:
- Low noise
- Similar anti-icing perfo

CONs:
- **High turbine back-pressure**
- Lower thrust from exhaust

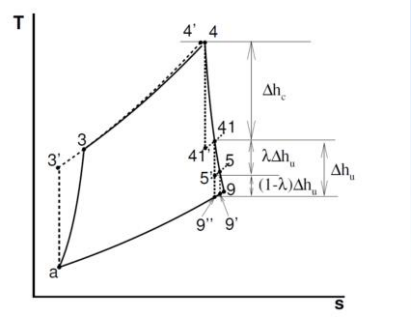


SOLUTION

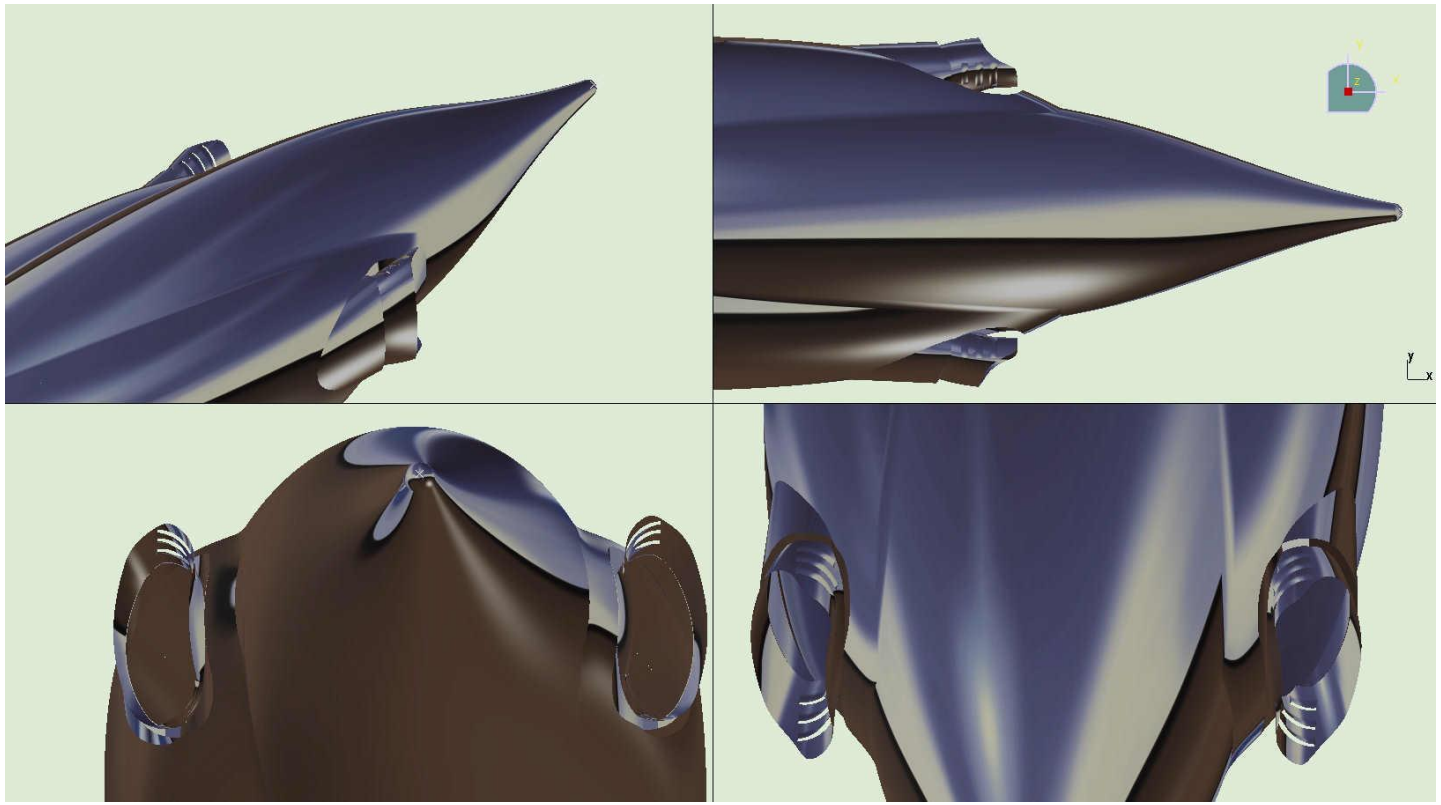
Louvers ingesting nacelle boundary layer flow inside the duct

PROs:
- Cooler, slow speed airflow.
- Larger Enthalpy Head by the turbine
- Lower nacelle drag

CONs:
- Manufacturing complexity



P.180 Avanti Low Noise Exhaust optimization: how to shave 6dB of community noise

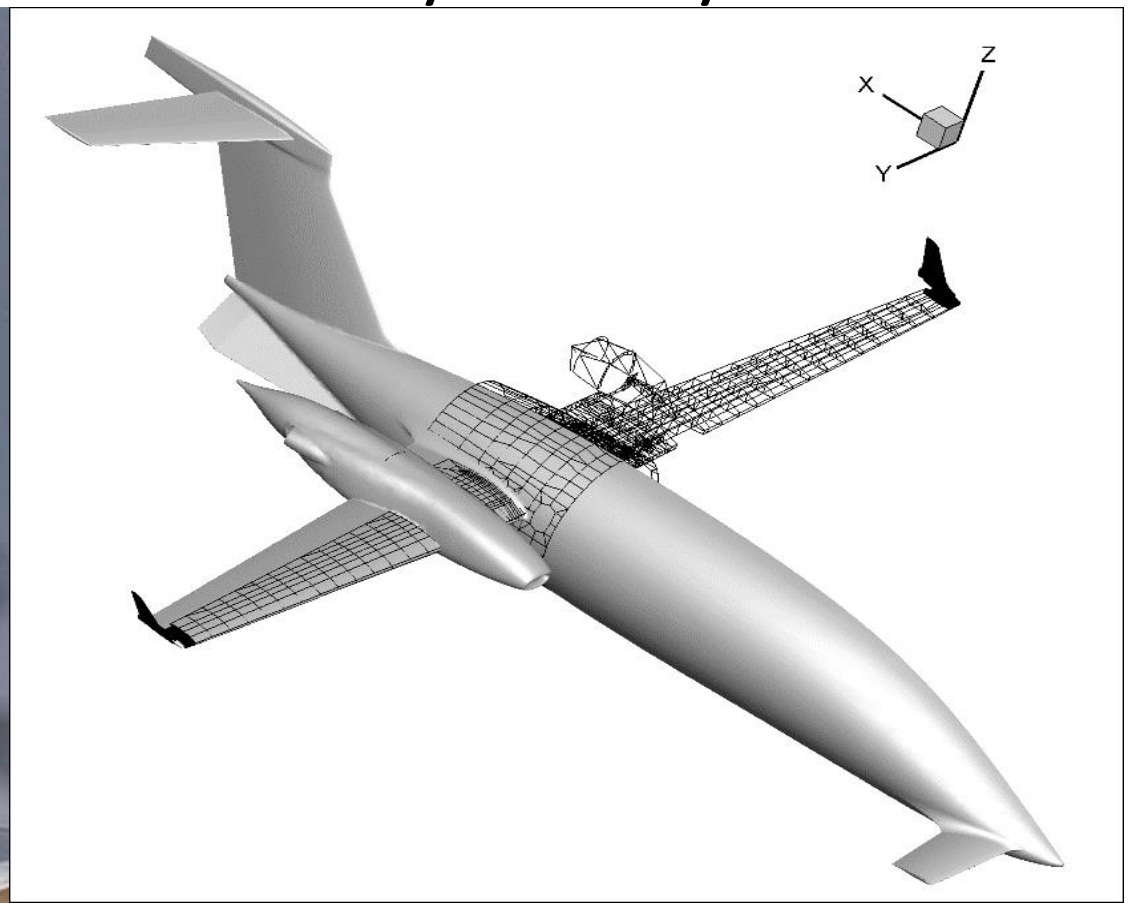


P.180 Avanti EVO 2015: winglets

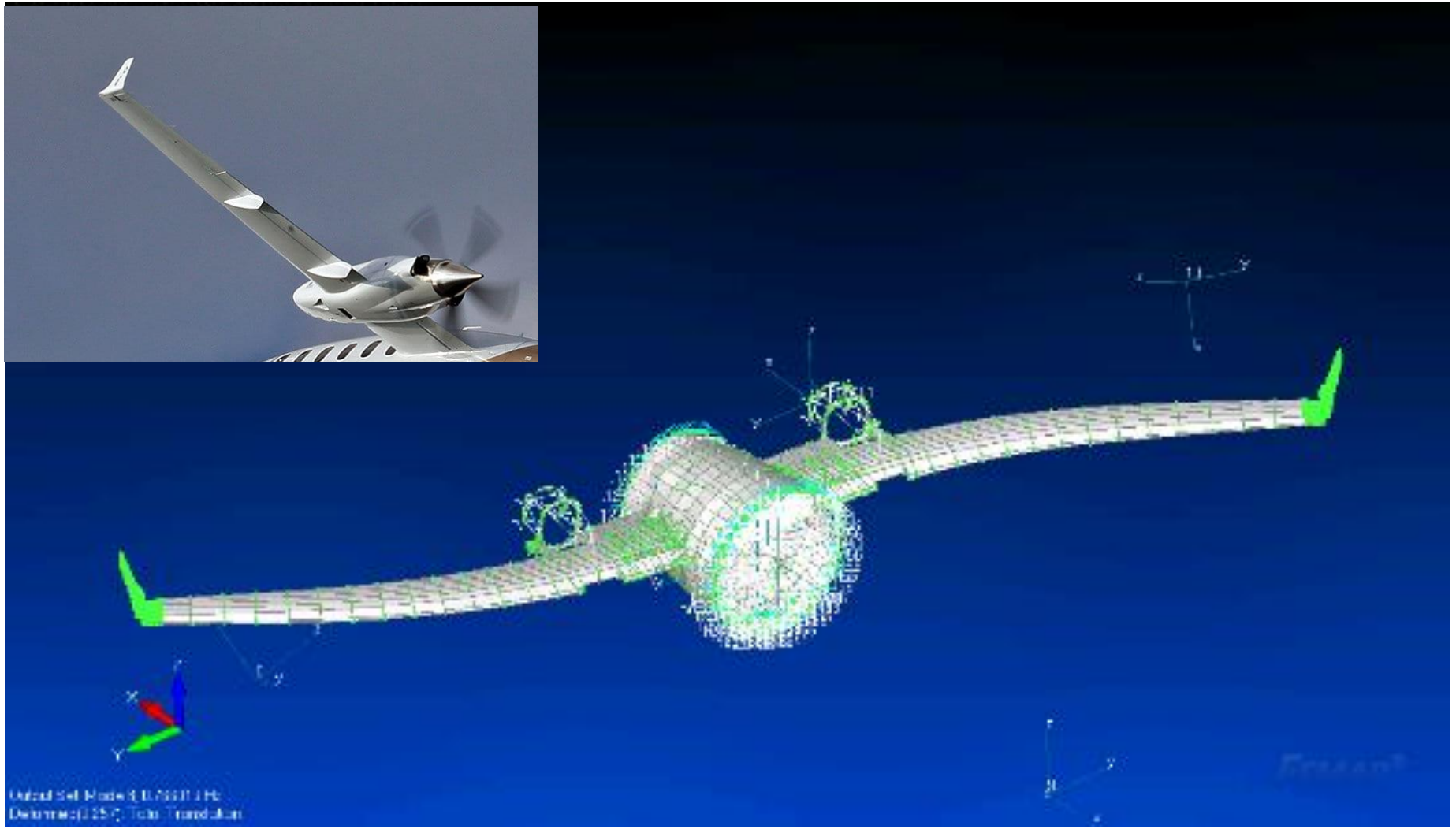
P.180 winglet design case critical for:

1. Flight Control System Muscular Power only
2. High aspect ratio wing
3. Wing slender box with heavy power plant mass

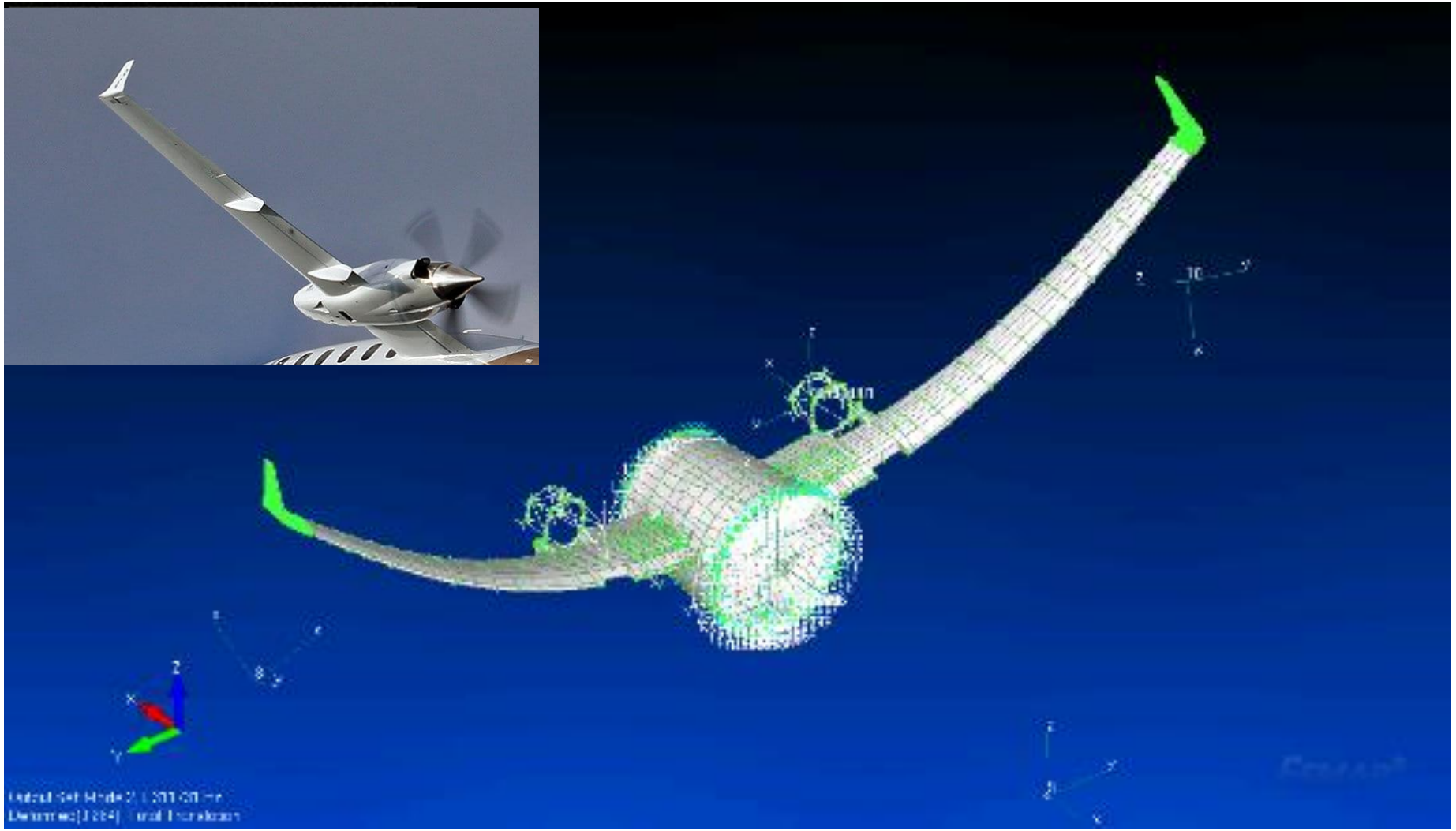
P.180 Avanti EVO 2015: Aeroelasticity analysis



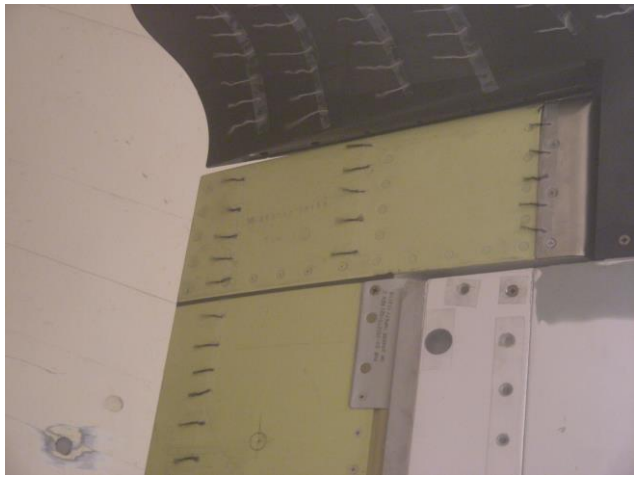
P.180 Avanti EVO 2015: Flexural Modes/1



P.180 Avanti EVO 2015: Flexural Modes/2



P.180 Avanti EVO Winglet: Wind Tunnel Tests



P.180 winglet close proximity to aileron with purely muscolar command define an unique design challenge for functional and safety cases:

1. hinge moments (α & β)
2. Ice accretion w.out anti-ice
3. local vortex in the gap b.twn fixed structure-movable

P.180 winglet Wind Tunnel Test campaign:

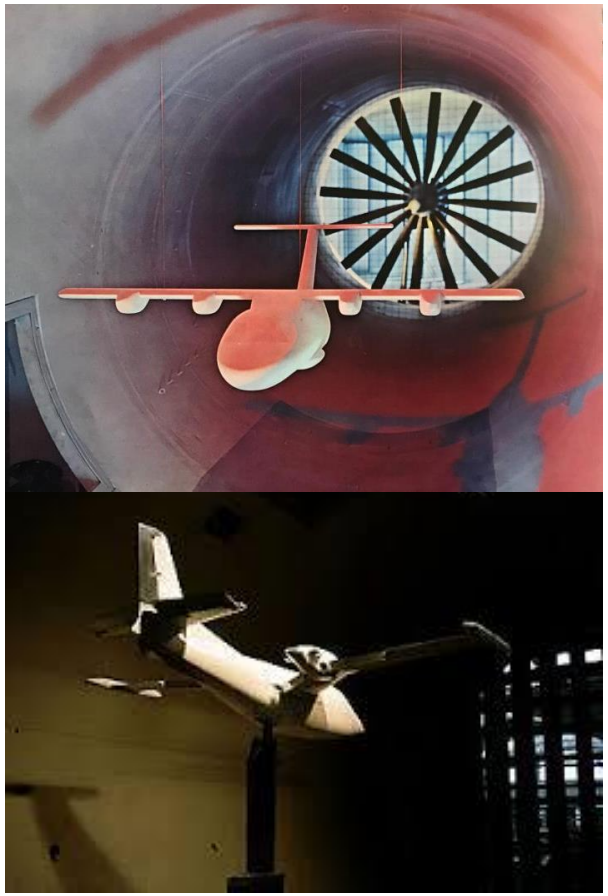
- Full scale test article, with real production components, in α & β:
- Validation of

1. Aileron Hinge moment
2. Ice accretion influence on safety and pilot-handling

Piaggio Aero Wind Tunnel Test facility

Proprietary Wind Tunnel Test facility in Finale Ligure was essential in the Piaggio Aero design history, since P.8 seaplane

Designed by **Giuseppe Gabrielli (1903-1987**) in 1928, with an open flow configuration shared spaces with production dept.



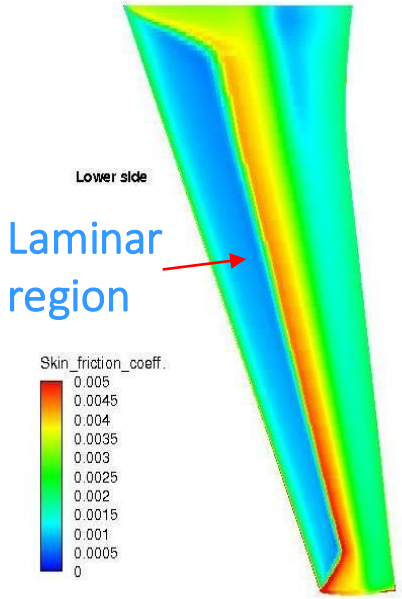
https://www.treccani.it/enciclopedia/giuseppe-gabrielli_%28Dizionario-Biografico%29/

- Continuosly updated and upgraded during the years, WTT was estremely useful for analysis at low Reynolds
- WTT was decomissioned Dec.2014, following the shut-down of the Finale L. Plant.
- The last WTT task was P.180 Winglet design validation

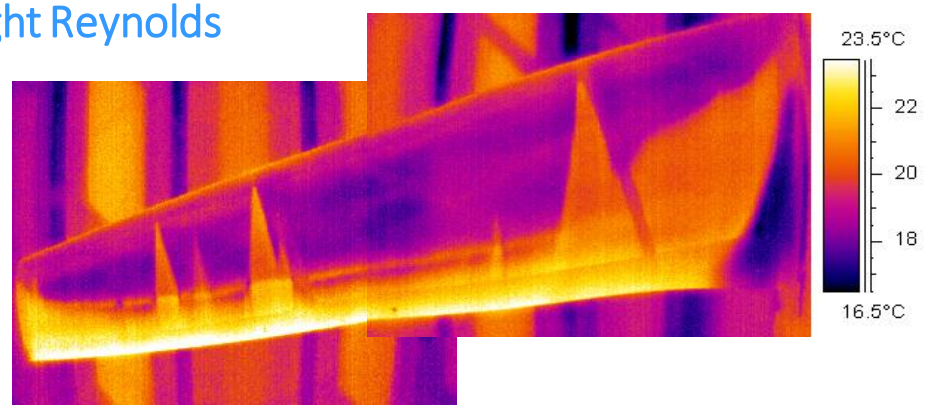
Transonic Natural Laminar Flow wing design

Laminar Flow MMO 0.70

Laminar Flow MMO 0.80

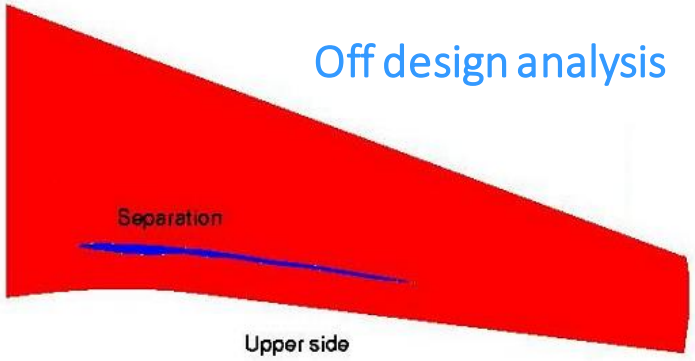


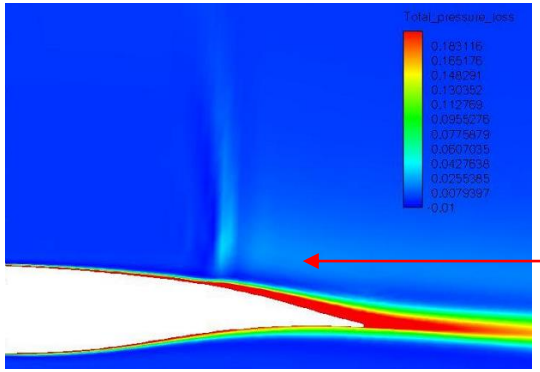
Experimental testing in transonic wind tunnel tests at flight Reynolds



Infrared visualization of laminar flow

Off design analysis



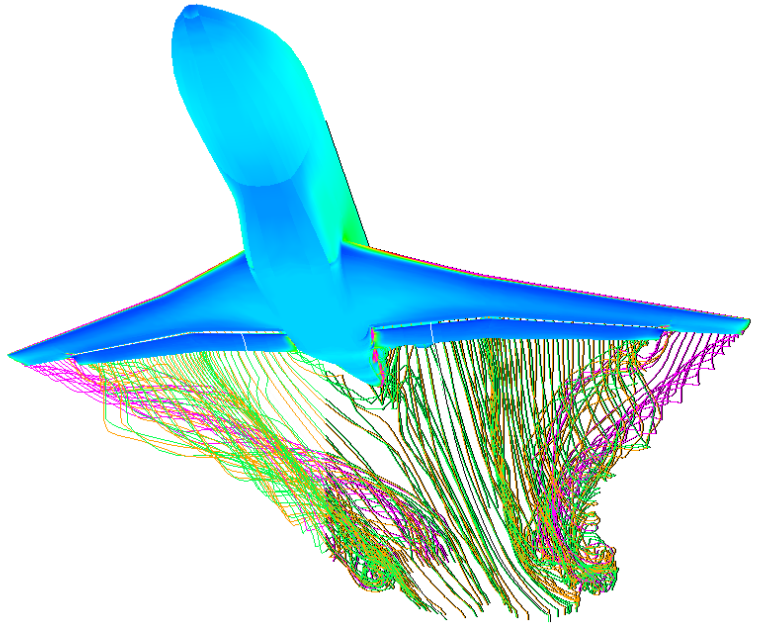


Shock development in off design condition and interaction with boundary layer

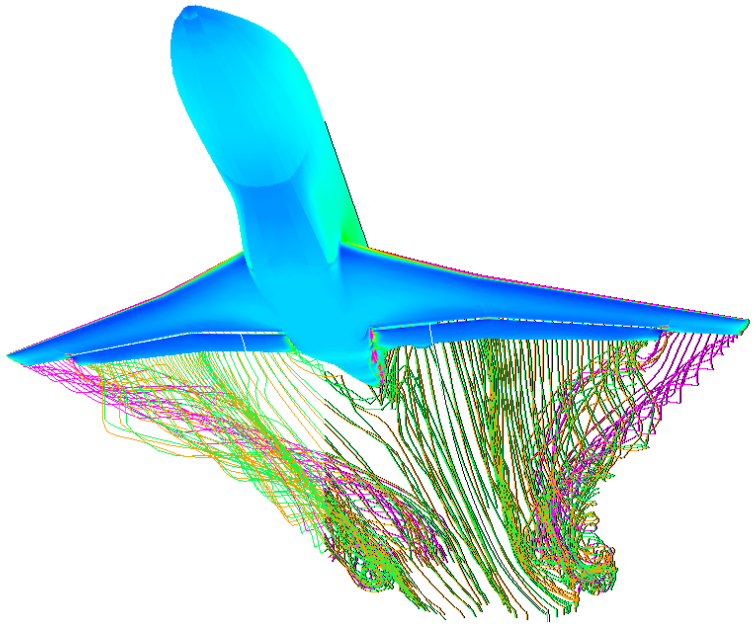
P.1XX –Business Jet

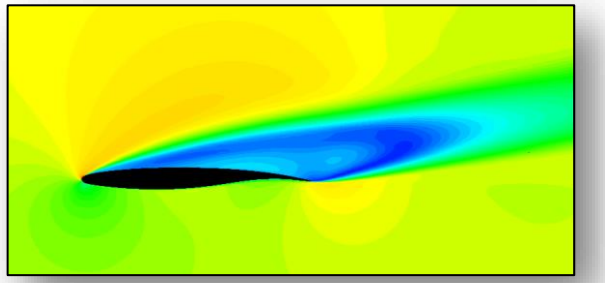
P.1XX Business Jet

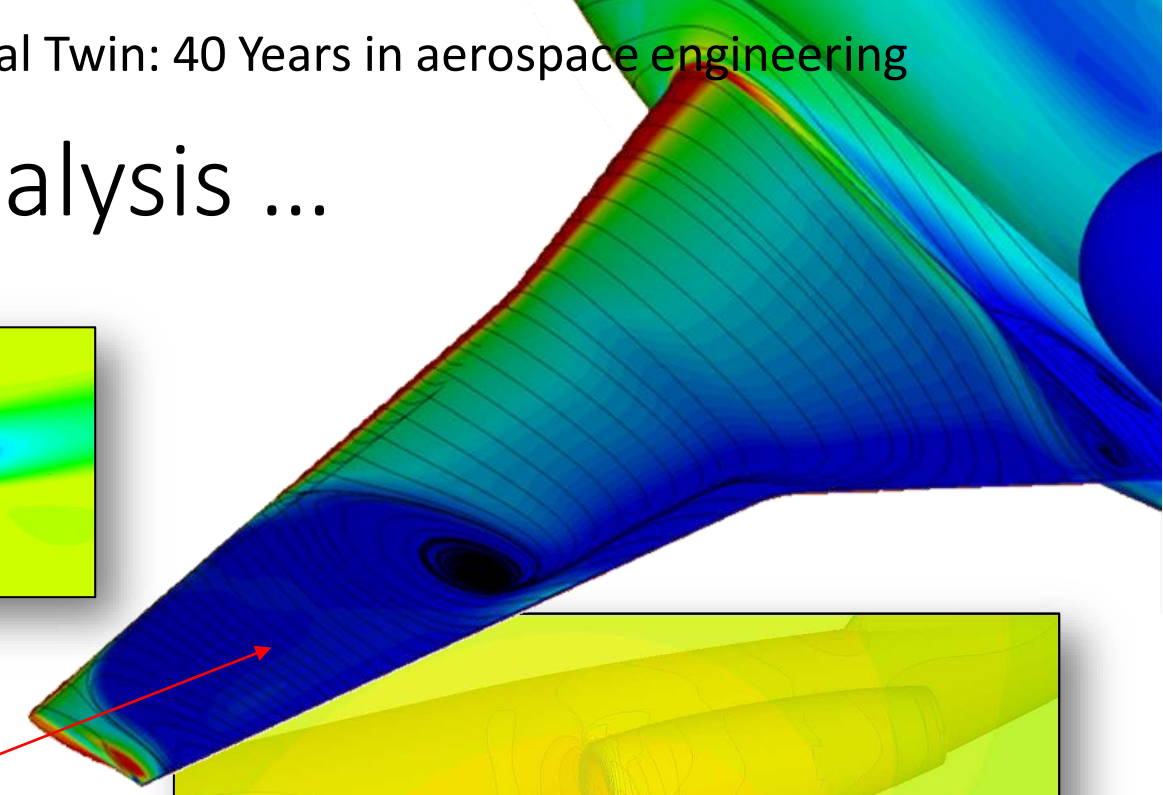
Studies for a family of jets in the Midsize category - 2006-2010
M0.82-0.85 - FL430
MTOW up to 34.000lbs
Range up to 3800Nm
Double Club seats arrangements



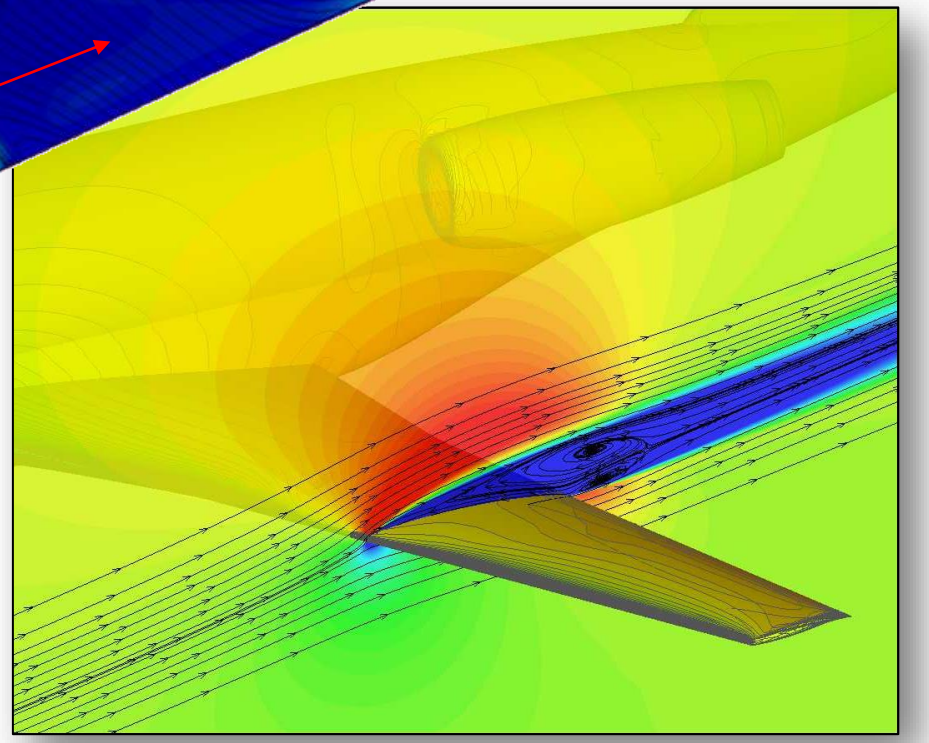
P.1XX - High lift performance analysis …

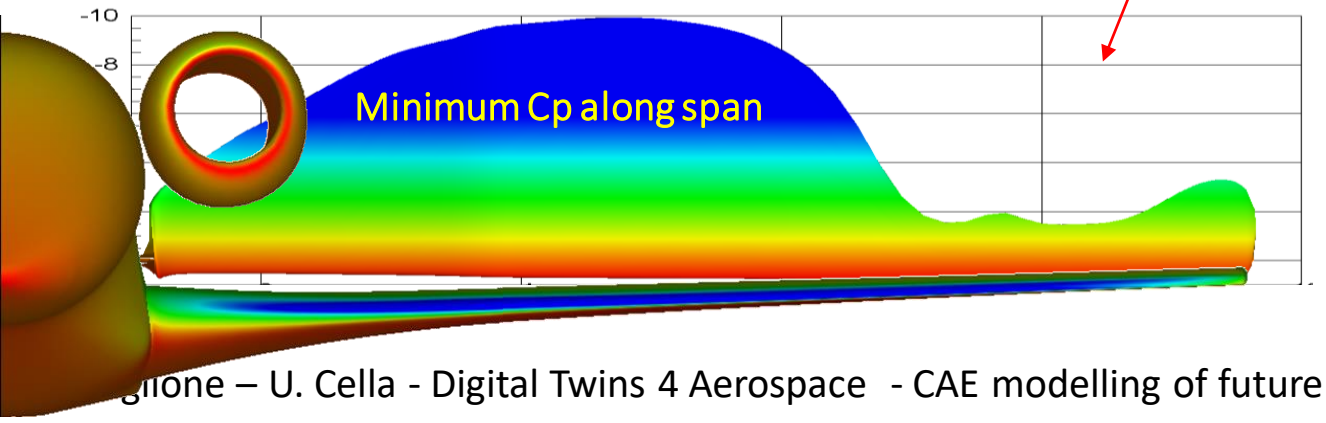




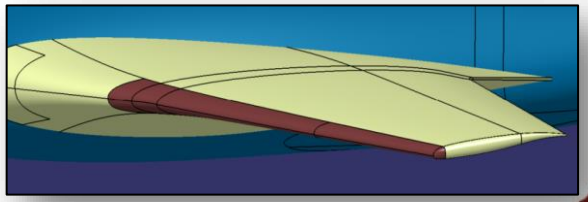


Outer wing leading edge Stall !!

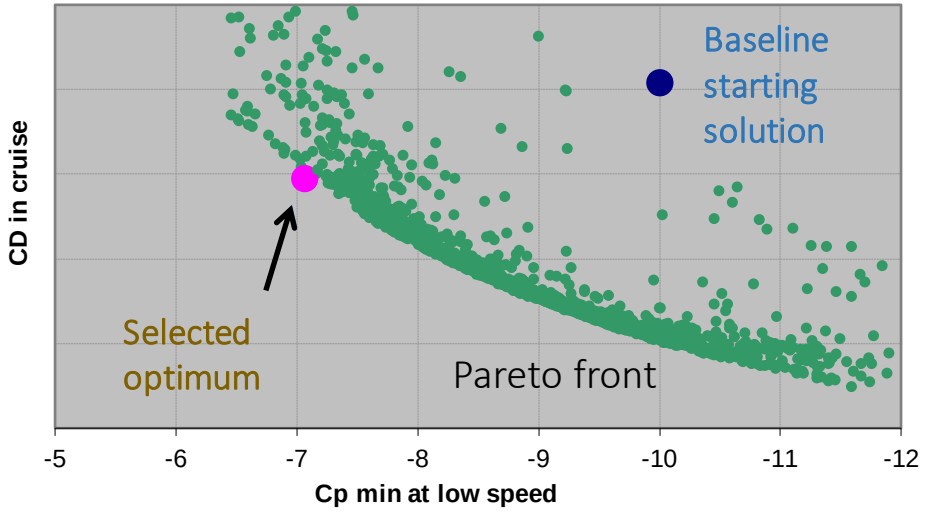


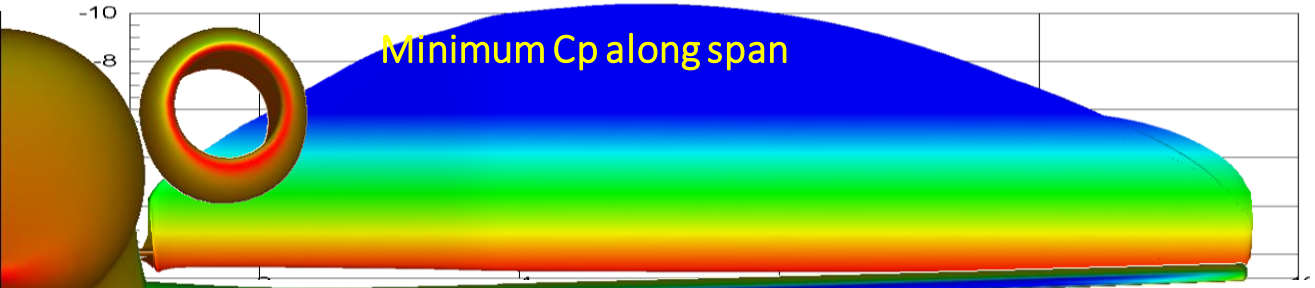


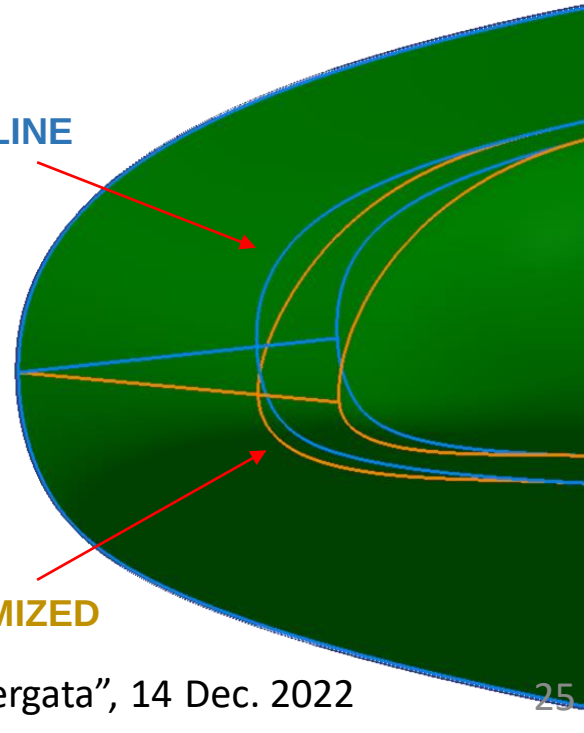
… and improvement



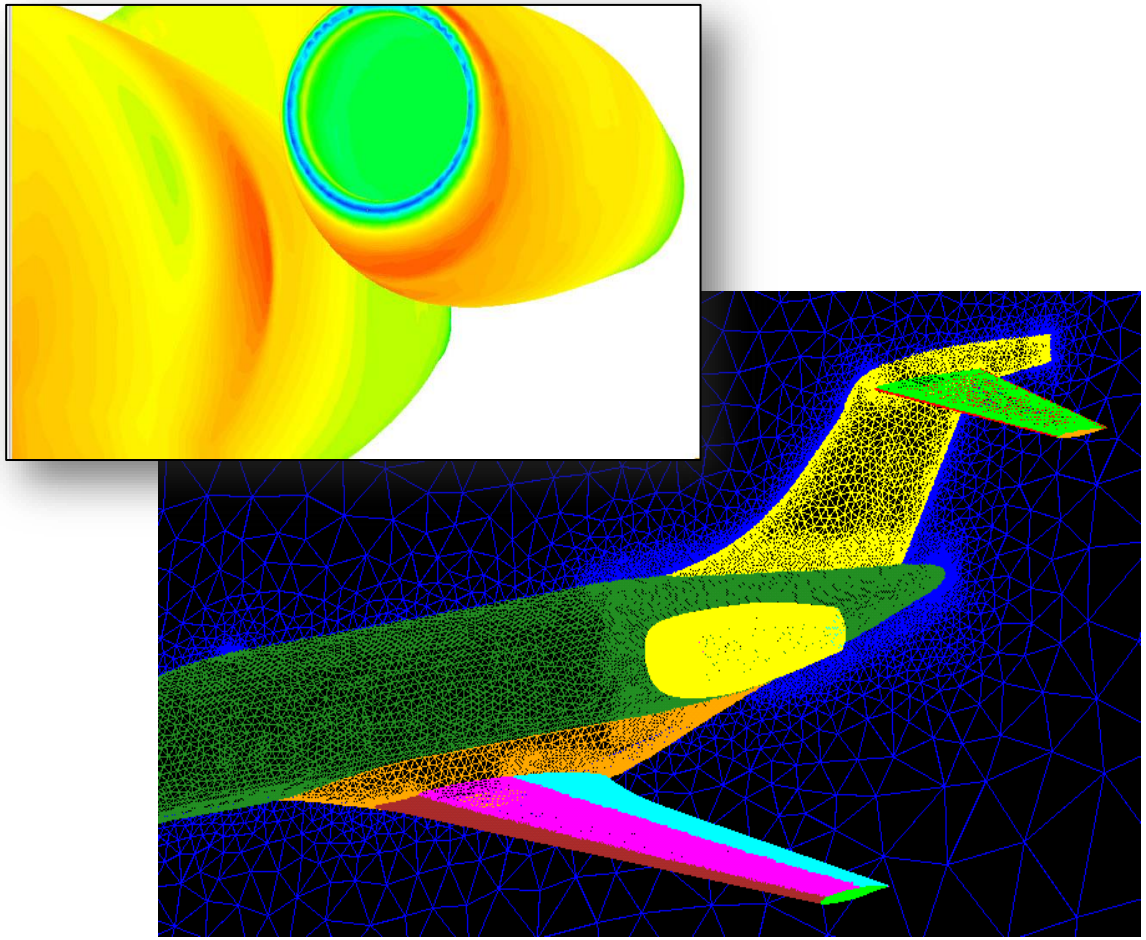
Multi objective airfoil optimization

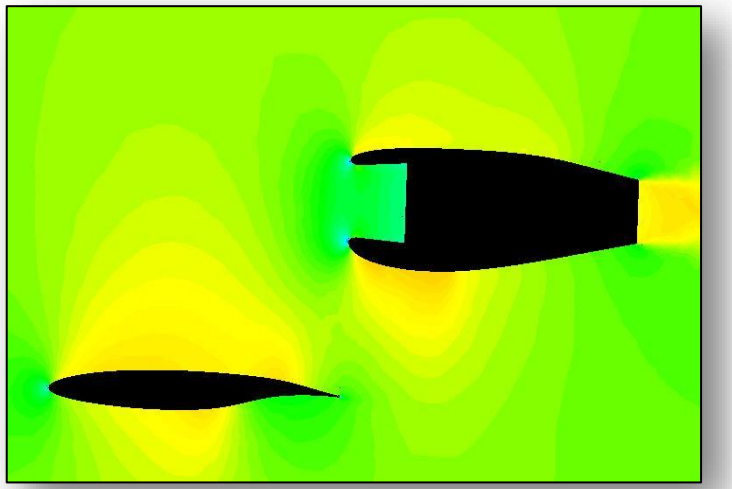


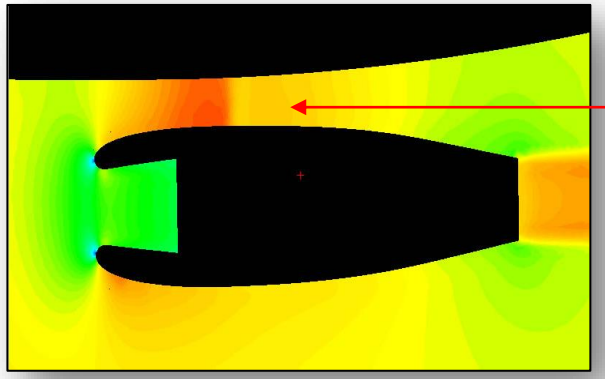




P.1XX - Wing-engine-fuselage installation and interference analysis

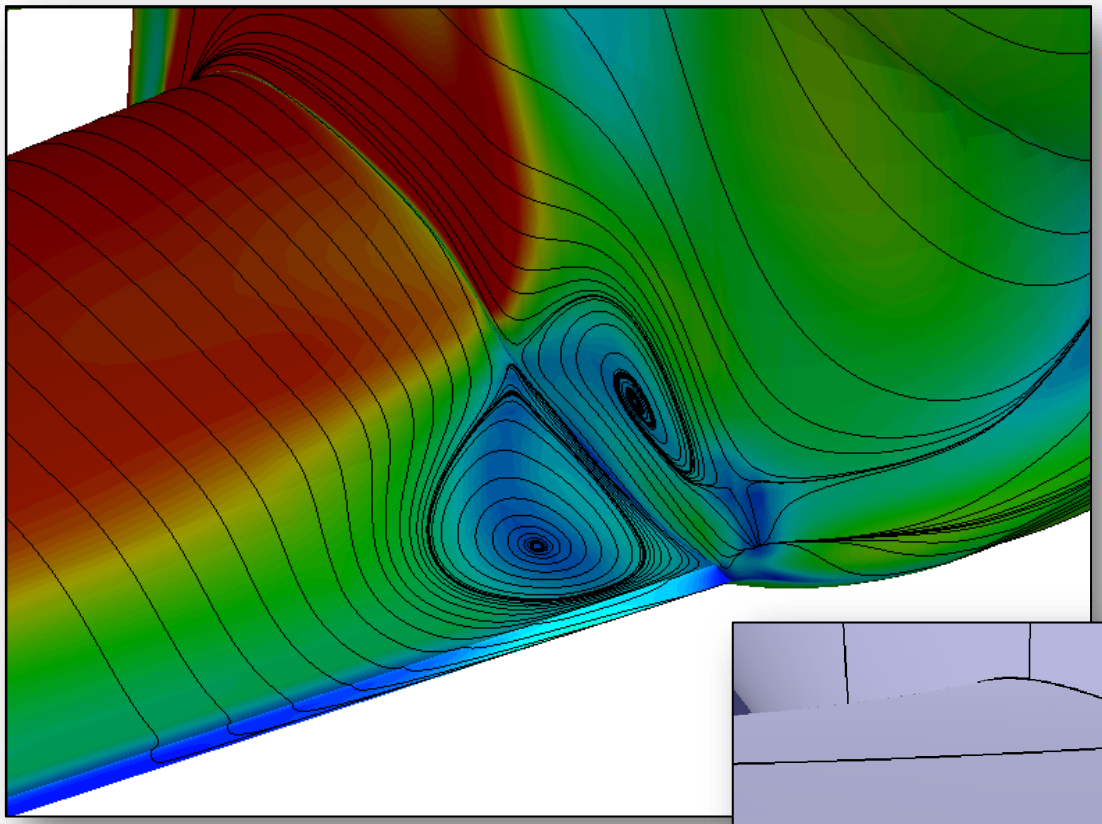


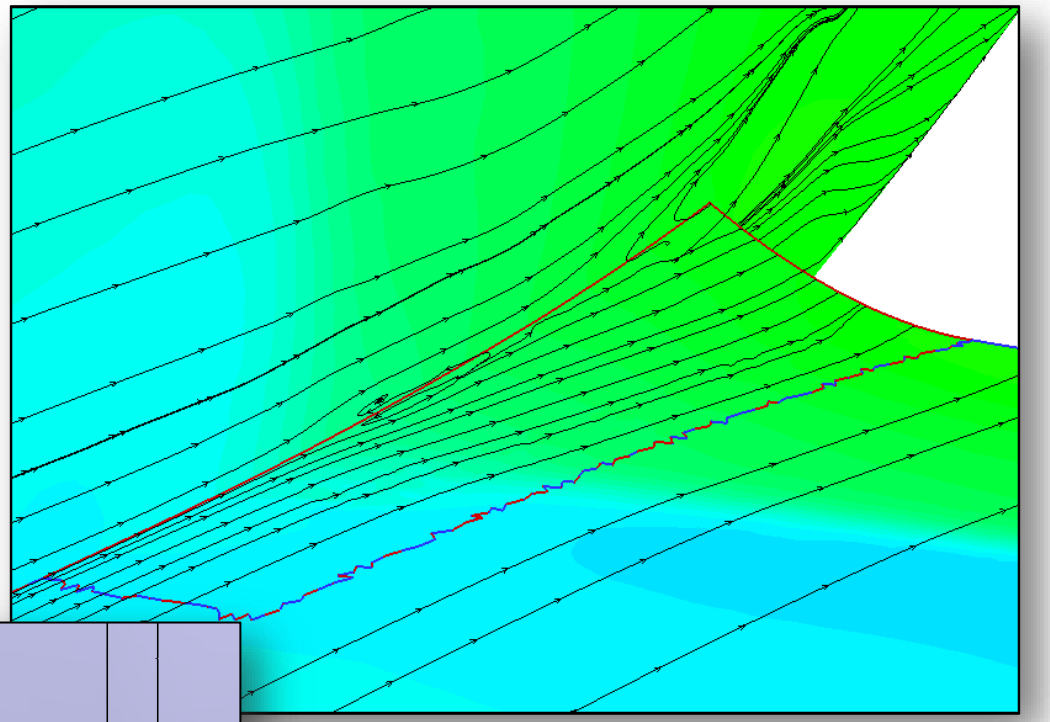


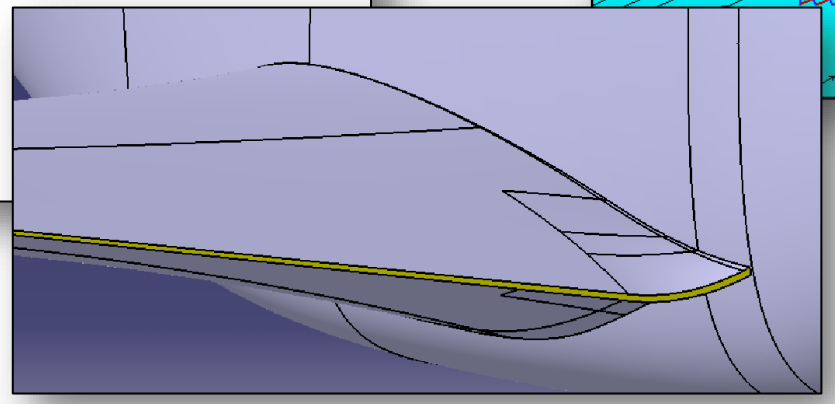


Shock development

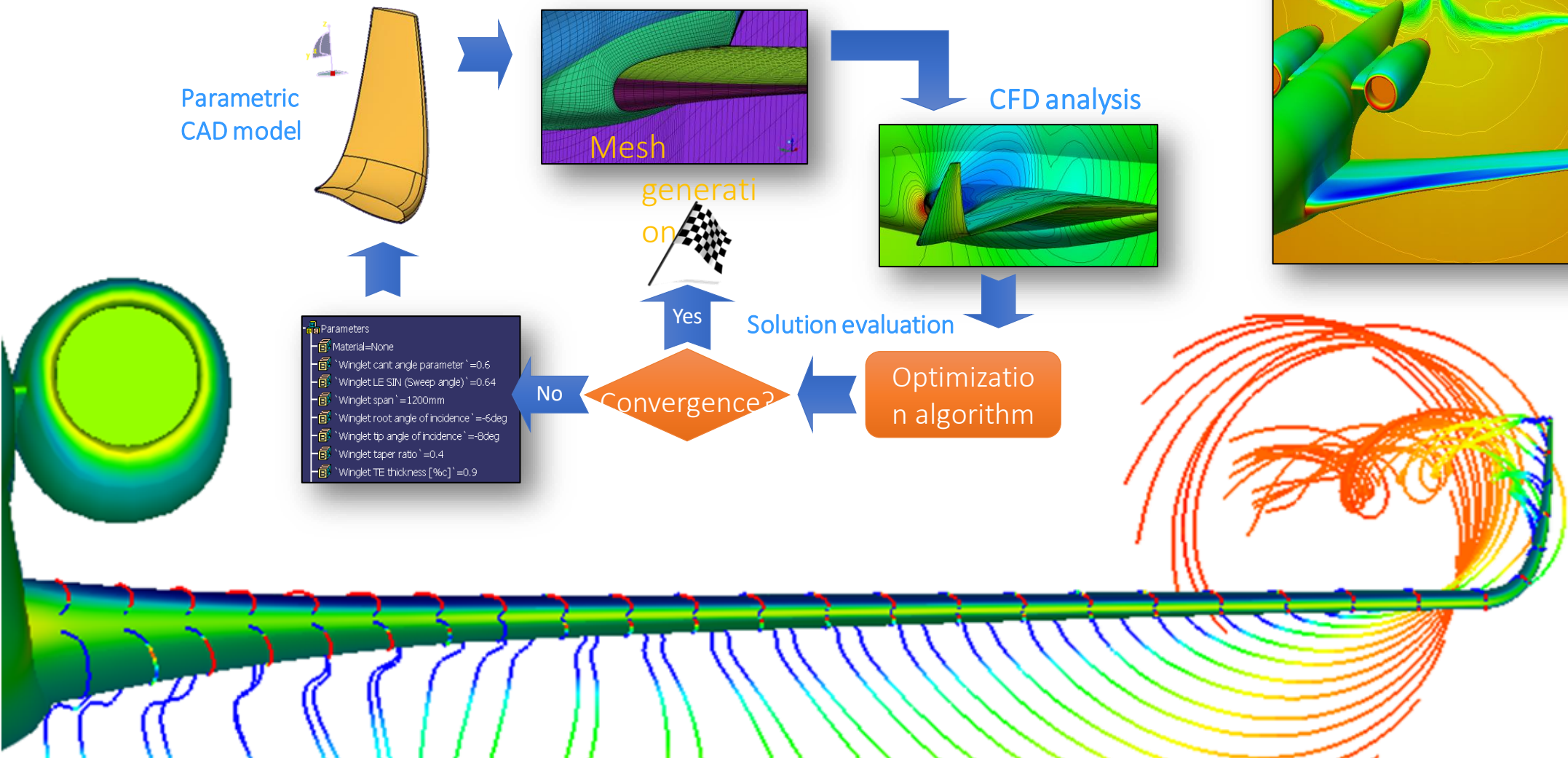
P.1XX - Wing-fuselage interference correction

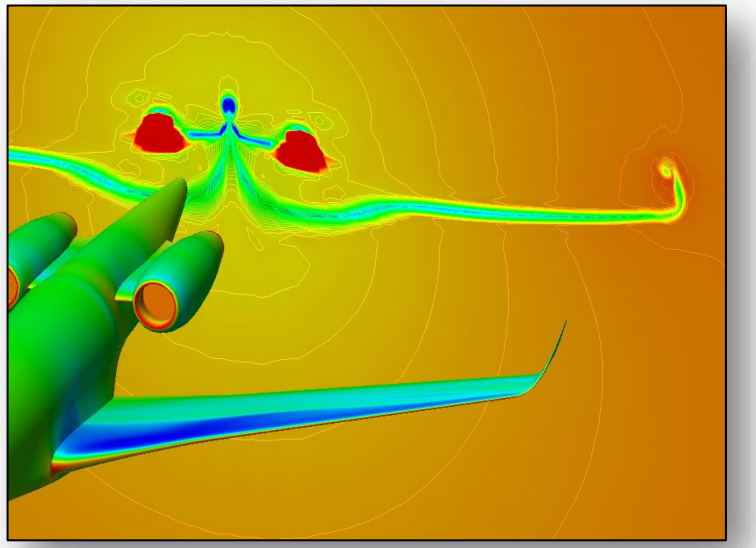




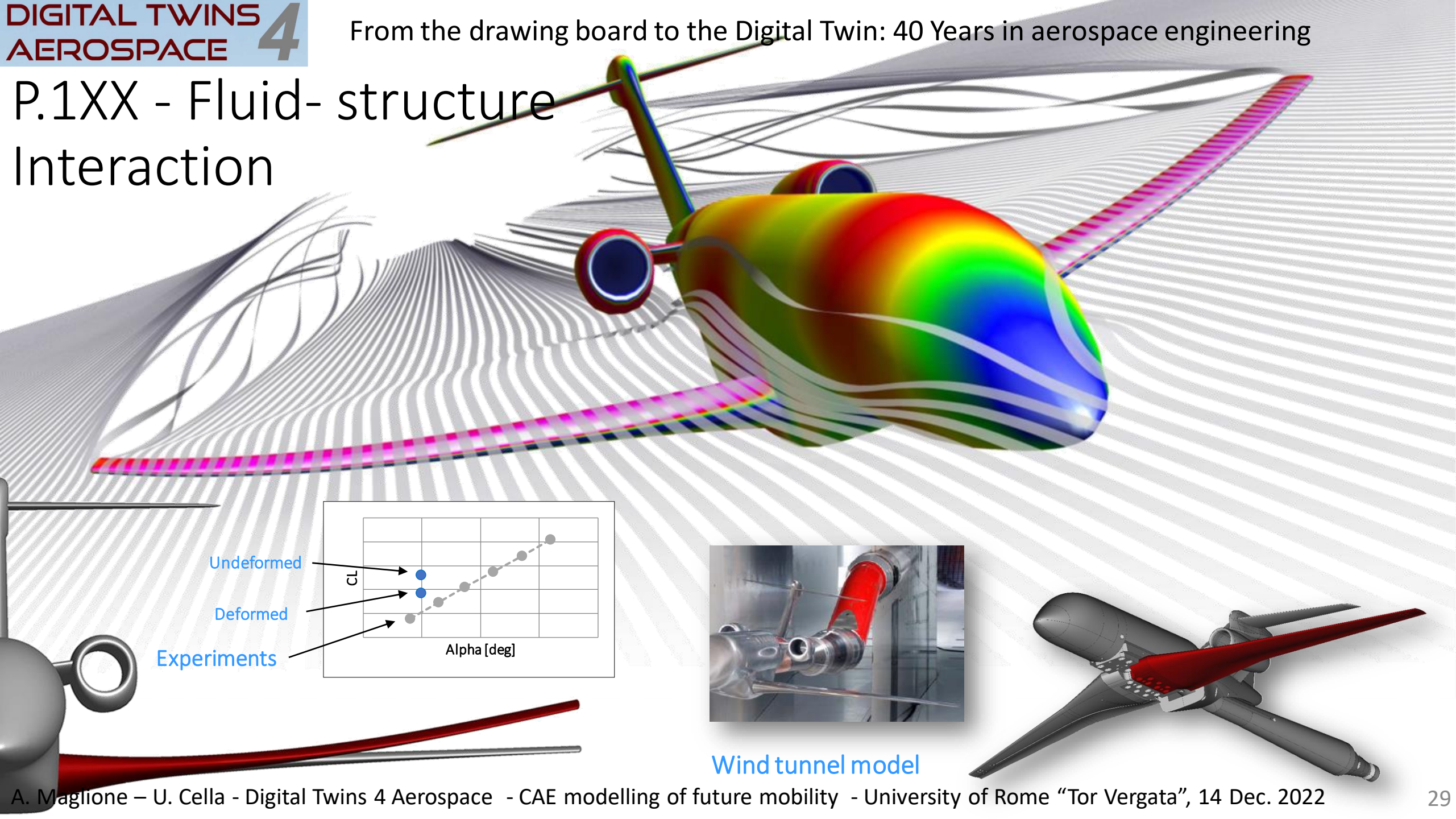


P.1XX - Optimization of winglets





P.1XX - Fluid- structure Interaction



Wind tunnel model

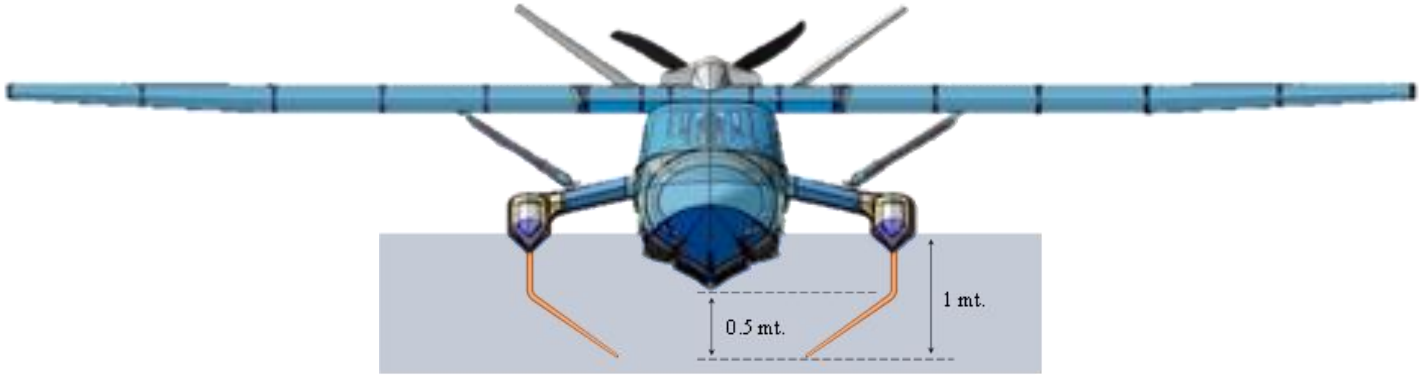
P.1HH Unmanned Air System Medium altitude Long Endurance - Intelligence, Surveillance and Reconnaissance

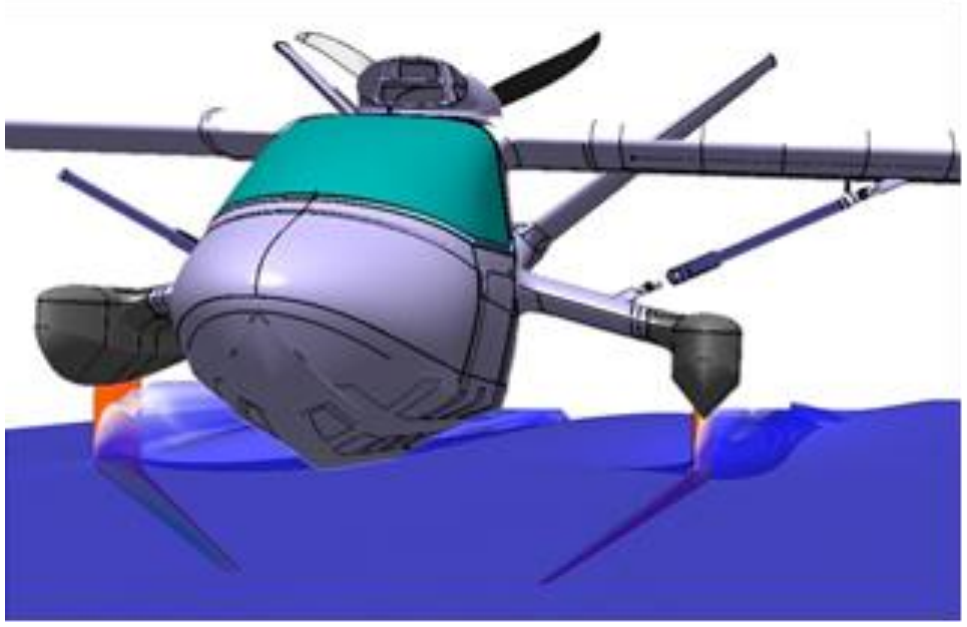
P.1HH UAS MALE ISR

2010 - xxxx
M0.70 FL410
MTOW 16.500lbs
ENDURANCE – 16H

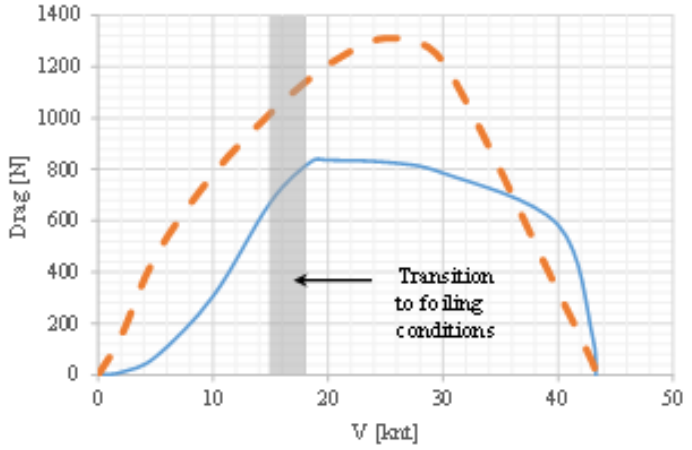
P.1HH DEMO First Flight
https://youtu.be/C2ovfJw29nM

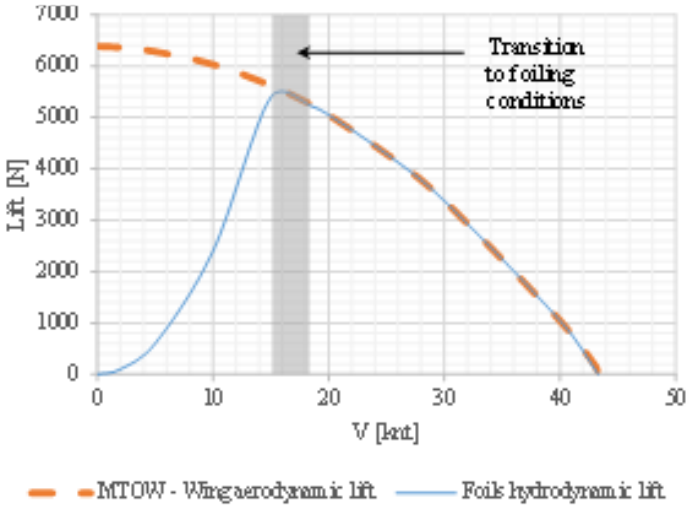
Seagull - Study of innovative solutions for seaplanes





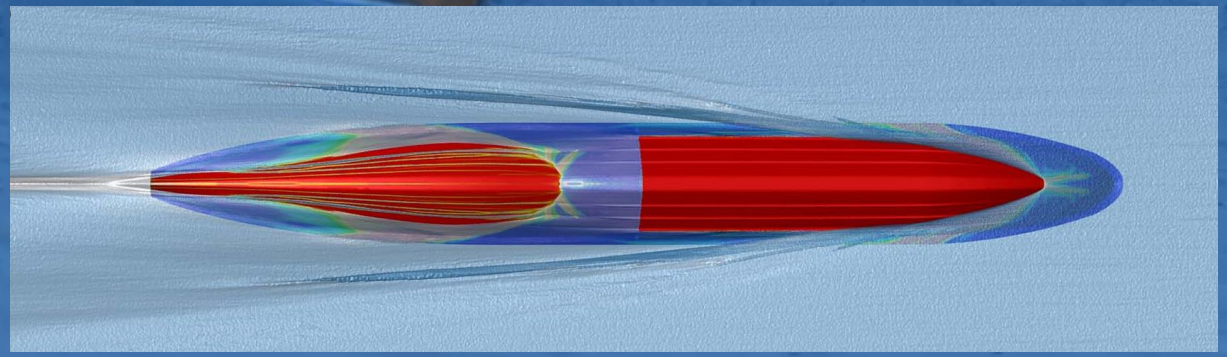
- reduction of dynamic pressure on the hull to less than 20%.
- hull lift-off speed from 44 knots to approximately 20 knots.

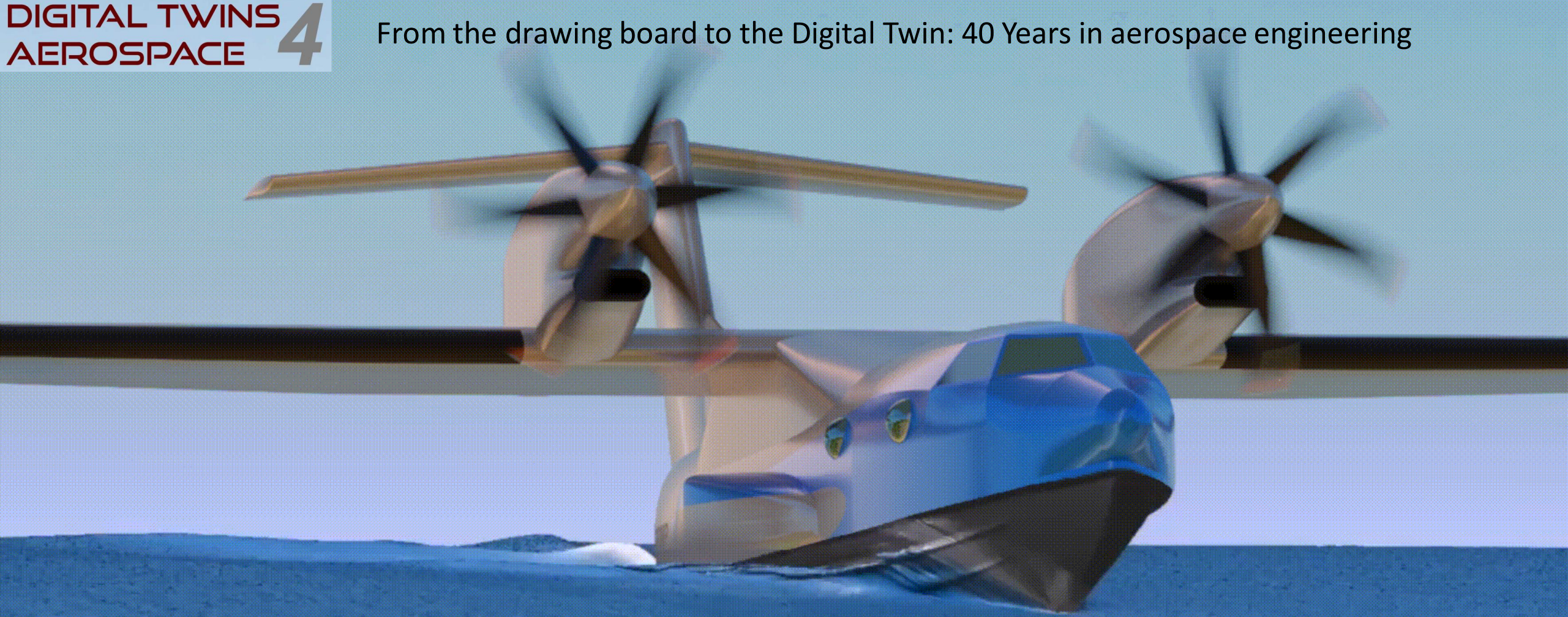




WF-X - Study of innovative seaplane for Firefighting

Work in progress…





Thank you for your attention