UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

JPAD MODELLER, A KNOWLEDGE-BASED GEOMETRIC MODELLING APPLICATION FOR AIRCRAFT PRELIMINARY DESIGN WORKFLOWS

V. Trifari, A. De Marco

University of Naples Federico II, Naples, 80125, Italy

INNOVATIVE STARTUP & ACADEMIC SPIN-OFF COMPANY

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

- 9 RESEARCH PROJECTS
- 10 RESEARCH AGREEMENTS
- 70+ PUBLICATIONS
- 30+ CONFERENCES

http://www.daf.unina.it/

- 2 AIRCRAFT DESIGN SOFTWARE

JPAD

- 1 FLIGHT SIMULATOR INTERFACE

JSBSim

Open Source Flight Dynamics

http://www.smartup-engineering.com/
info@smartup-engineering.com

SMARTUP CORE BUSINESS

Design

Support innovative design

- Aircraft Design
- Propeller Design
- Surrogate Models
- Flight Models
- Test Models
- CAD Modelling

Analysis

Perform accurate analysis

- Aerodynamics
- Stability & Control
- Flight Simulations

Software

Develop outstanding software

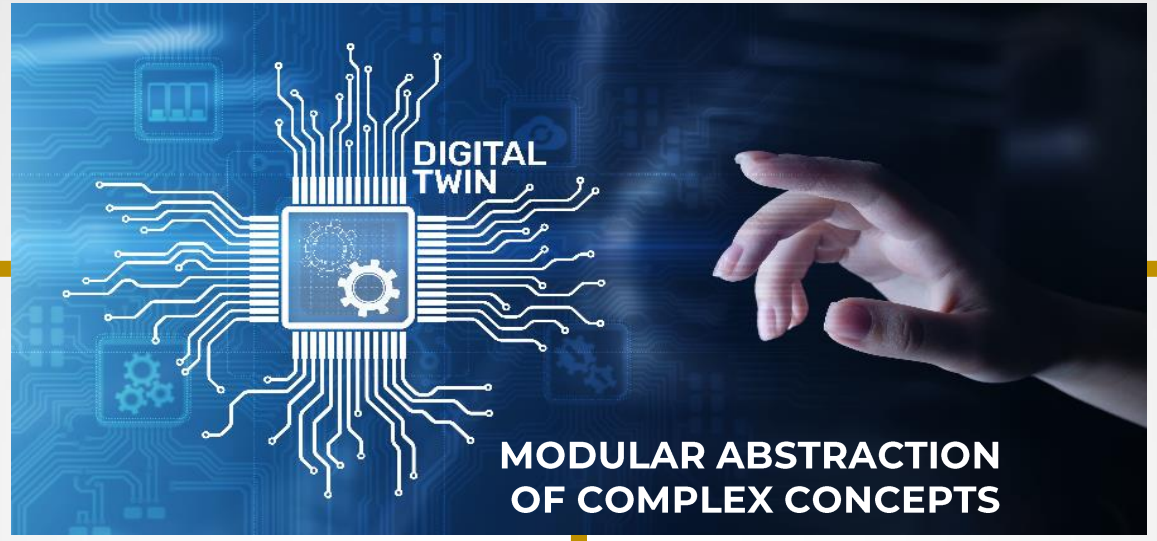
- JPAD family
- Software for R&D
- On-demand customization
- Arduino Interface

Testing

Product testing

- Wind tunnel tests (in collaboration with University of Naples Federico II)
- Scaled Flight Tests
- Aircraft Flight Tests
- Instrumentation (design, production and set-up)

THE DIGITAL TWIN SCENARIO



Easy data management and thanks to parametric models

Testing of the system throughout all design and production stages

Multi-fidelity analysis workflows from early design stages

Multi-disciplinary approach in all design and production stages

AIRCRAFT DESIGN & DIGITAL TWIN

Preliminary Aircraft Design
The digital twin allows for fast prototyping of several aircraft concepts before production

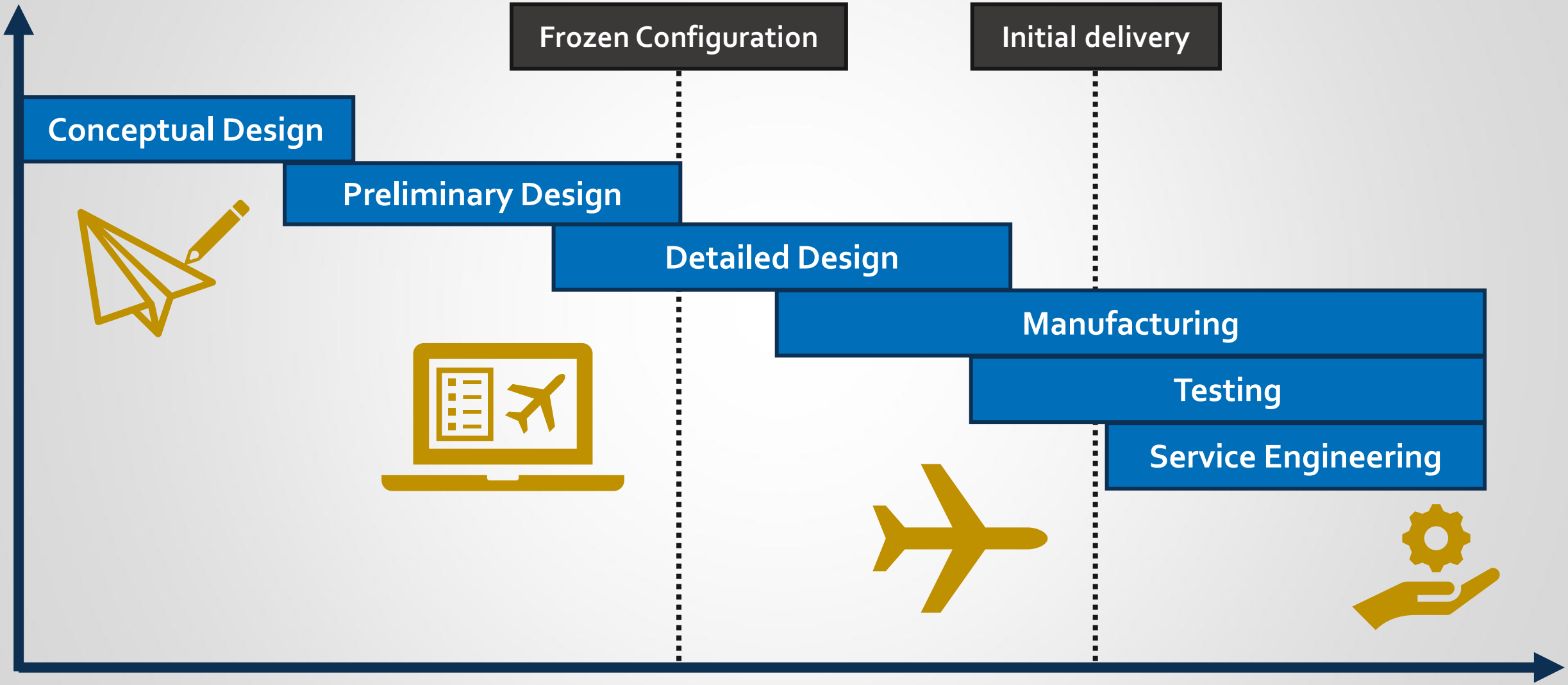
Parameterized Aircraft model
The starting point an efficient digital twin aircraft suitable for multidisciplinary analysis workflows

DIGITAL TWIN AIRCRAFT

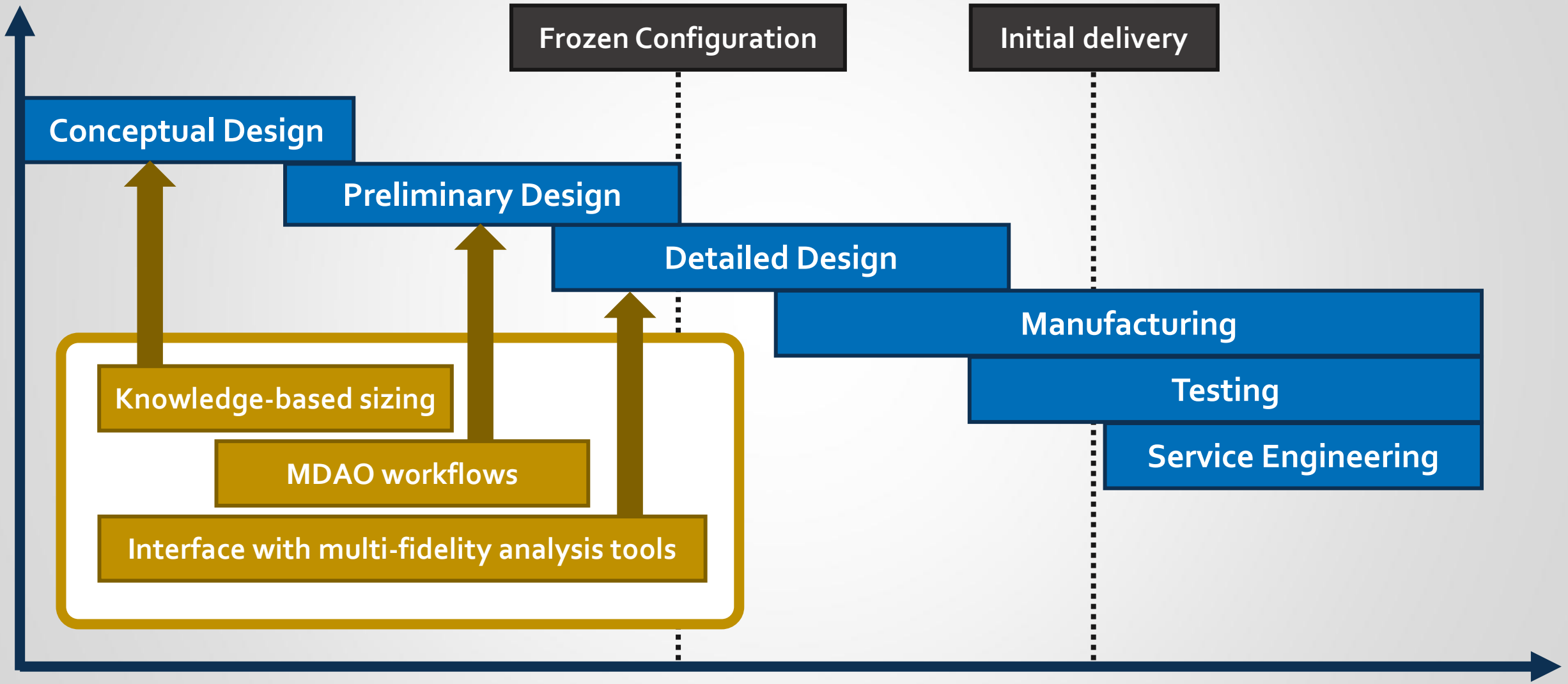
Aircraft performance simulation
The digital twin used in aircraft design applications allows for fast and efficient operability checks

Aircraft optimization
Thanks to its parametric nature and the use of fast multidisciplinary workflows, the digital twin allows for efficient aircraft shapes optimization

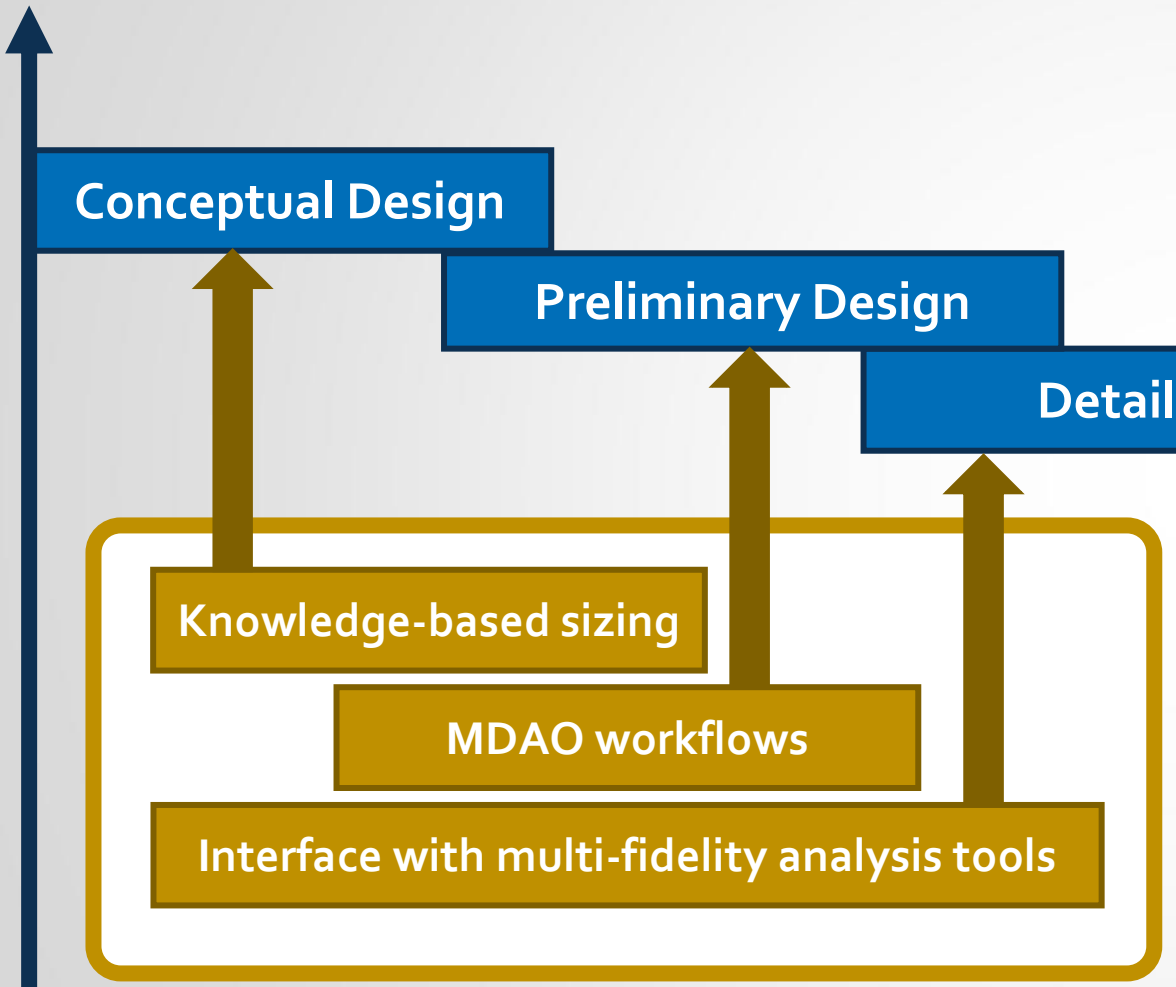
THE DESIGN STAGES



THE TARGET

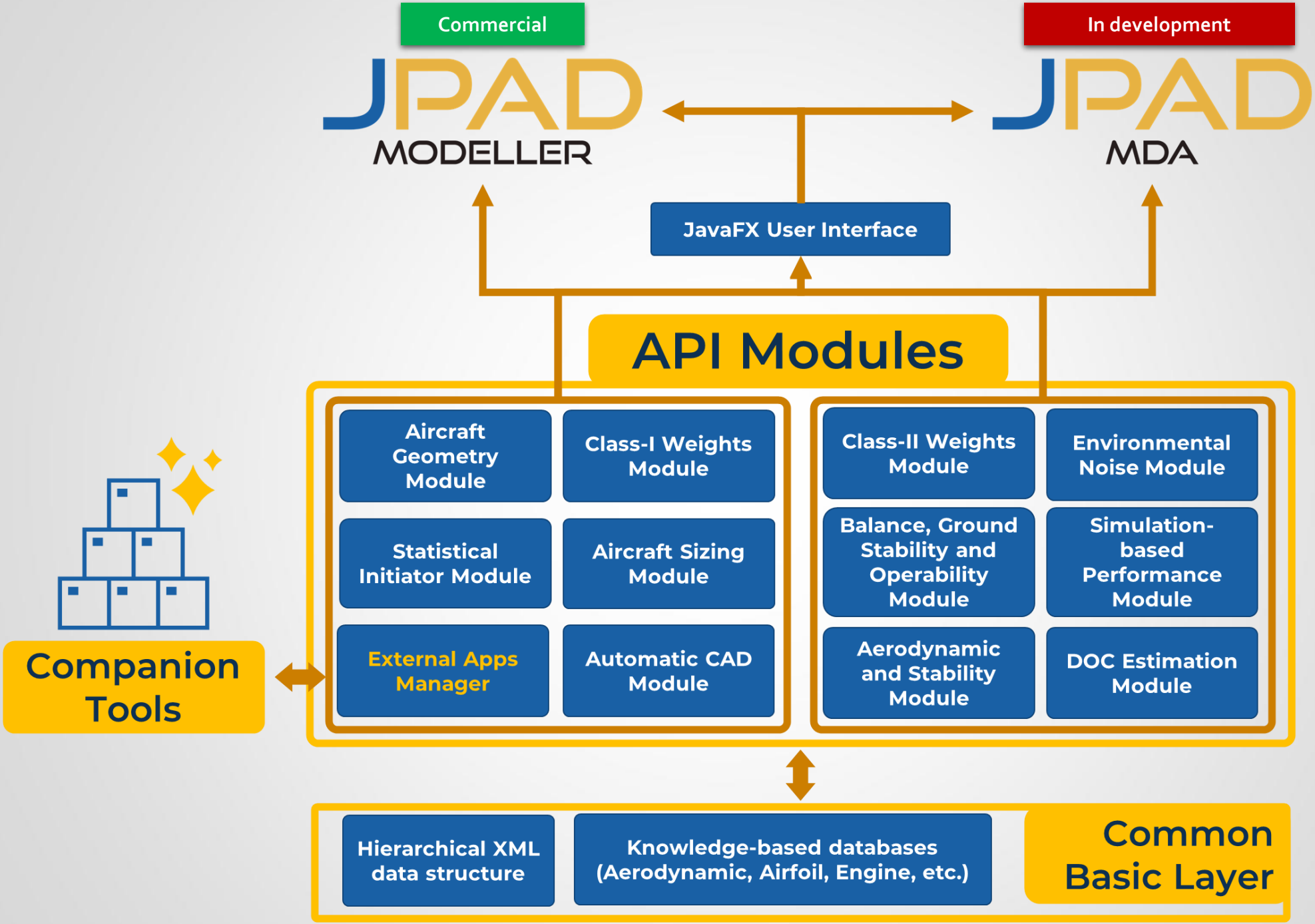

Frozen Configuration
Initial delivery
Conceptual Design
Preliminary Design
Detailed Design
Manufacturing
Testing
Service Engineering
Knowledge-based sizing
MDAO workflows
Interface with multi-fidelity analysis tools

THE BENEFITS



More knowledge since early design stages providing for less iteration loops and so to a reduced time-to-market

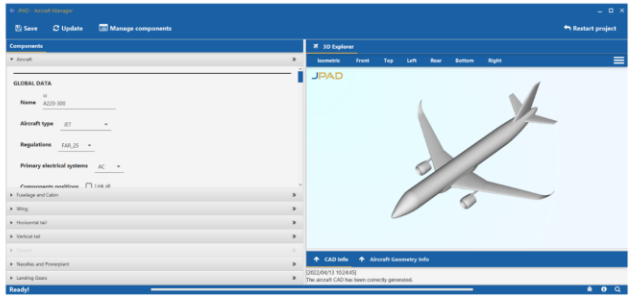
Shorter design stages allow to reduce the costs related to the project a new aircraft


Commercial
In development
JPAD MODELLER
JPAD MDA
JavaFX User Interface
API Modules
Aircraft Geometry Module
Class-I Weights Module
Statistical Initiator Module
Aircraft Sizing Module
External Apps Manager
Automatic CAD Module
Class-II Weights Module
Environmental Noise Module
Balance, Ground Stability and Operability Module
Simulation-based Performance Module
Aerodynamic and Stability Module
DOC Estimation Module
Companion Tools
Hierarchical XML data structure
Knowledge-based databases (Aerodynamic, Airfoil, Engine, etc.)
Common Basic Layer

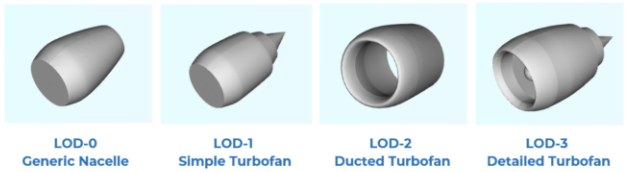
WHAT IS JPAD MODELLER ?

- SET OF TLAR
- PRE-DEFINED AIRCRAFT MODEL
- EMPTY AIRCRAFT

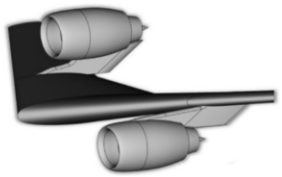
JPAD MODELLER



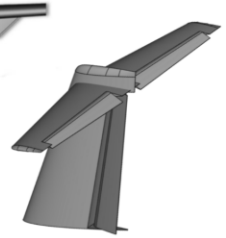
AUTOMATIC ADVANCED CAD FEATURES



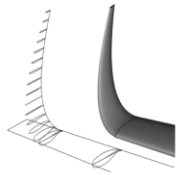
LOD-0 Generic Nacelle | LOD-1 Simple Turbofan | LOD-2 Ducted Turbofan | LOD-3 Detailed Turbofan



Engine pylons

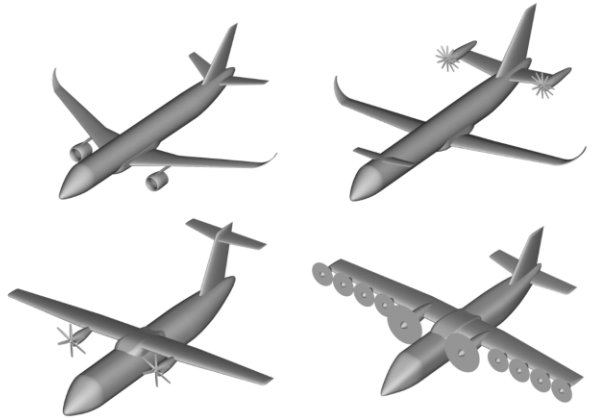


Movables



Winglets

AUTOMATICALLY GENERATED AIRCRAFT MODELS



- THIRD-PARTY CAD SOFTWARE

EXPORT OPTIONS

FLIGHTSTREAM

TiGL

cpacs
A Common Language for Aircraft Design

OPEN VSP

- PRELIMINARY AIRCRAFT DESIGN ANALYSES

“A knowledge-based and versatile pre-processor to simplify aircraft designers' life!”

JPAD MODELLER

JPAD Modeller allows you to generate high-definition and fully parametric aircraft models, as well as their highly detailed parametric CAD solid, IN SECONDS!

JPAD Modeller aims at supporting designers in conceptual and preliminary aircraft design task, providing a useful pre-processor for typical aircraft design workflows

JPAD Modeller can natively export aircraft and CAD models toward the following external companion tools and file formats: CPACS, OpenVSP, FlightStream®, STEP, BREP, IGES, STL

PREDESIGN

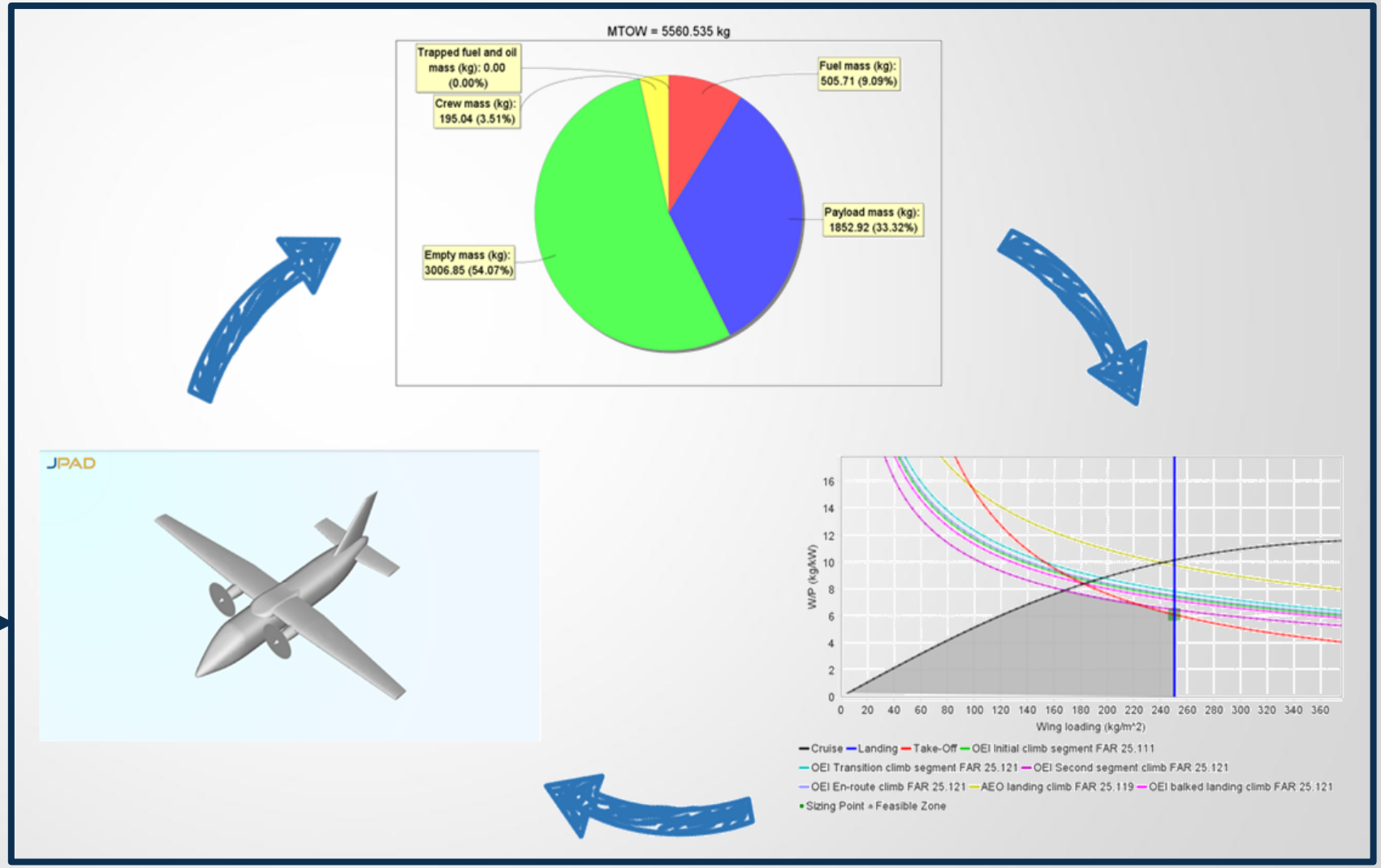
Automatic aircraft definition from a set of Top Level Aircraft Requirements. Class-I weights estimation and Sizing Plot.

INPUT

- **TLAR**
- **Aircraft Configuration**
- **Aircraft Category**
- **Mission profile**
- **Basic aerodynamic data**

WORKFLOW

- **Statistical pre-design**
- **Main Aircraft parameters override**
- **Preliminary estimation of aerodynamic efficiencies, Oswald factors and CLmax**
- **Geometry and operability consistency checks and model auto-fix**

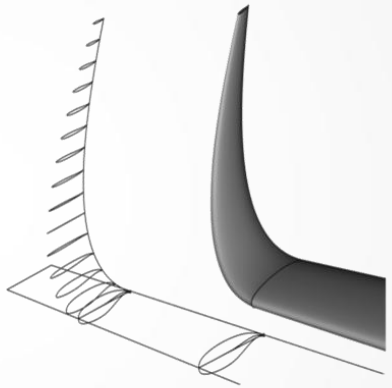


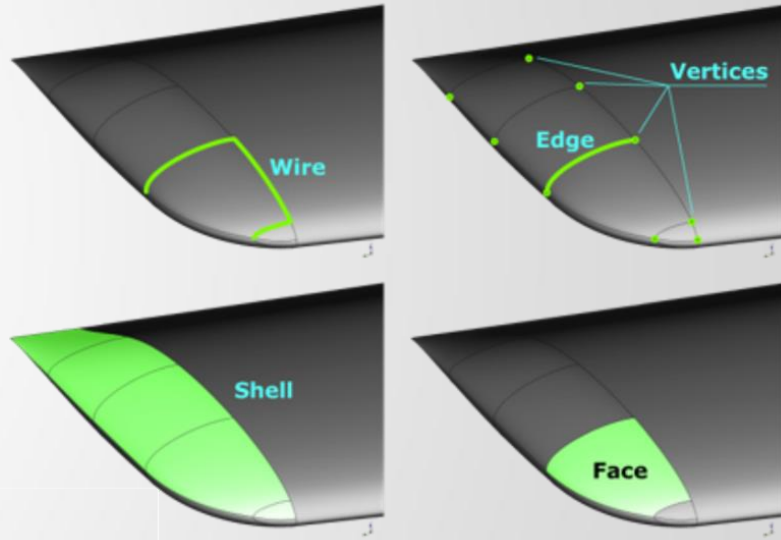
Automatic CAD generation

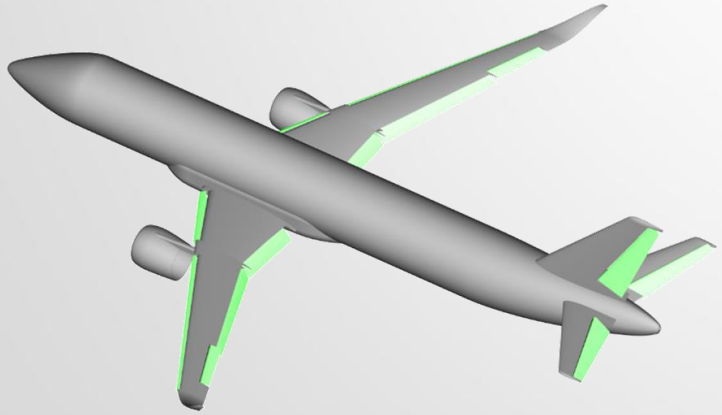
ADVANCED CAD FEATURES

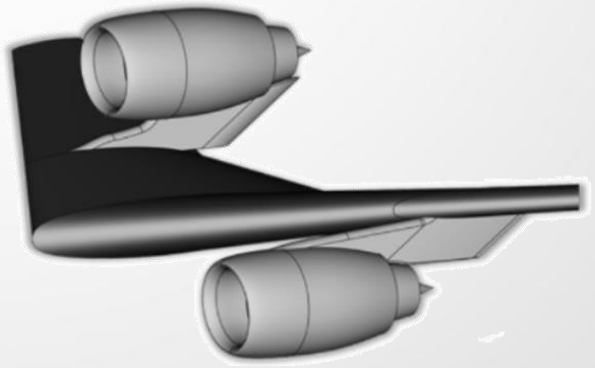
JPAD Modeller can automatically genertate the following CAD components:

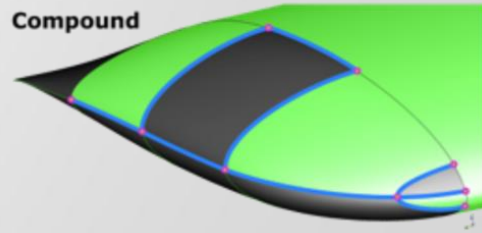
- LITING SURFACES TIPS
- WINGLETS
- WING-FUSELAGE FAIRINGS
- CANARD-FUSELAGE FAIRINGS
- ENGINE PYLONS
- PROPELLER DISKS WITH SPINNERS
- NACELLES (with different Levels of Detail - LOD)
- DETAILED MOVABLES AND CONTROL SURFACES







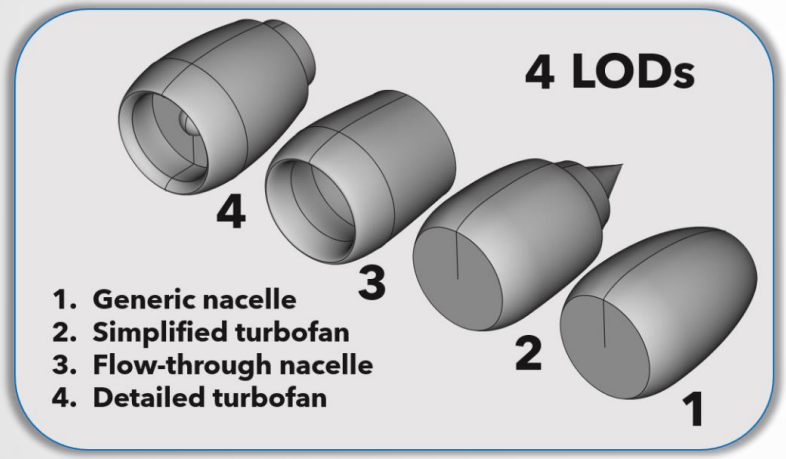


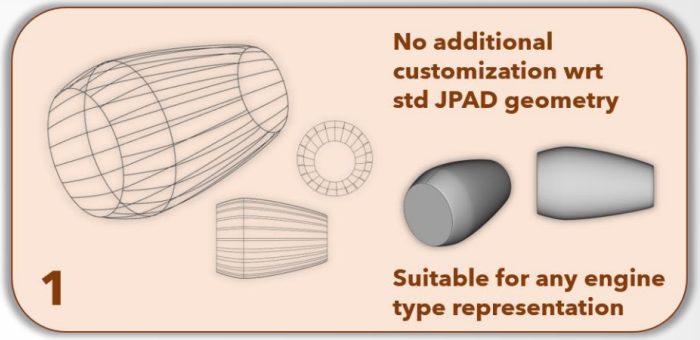


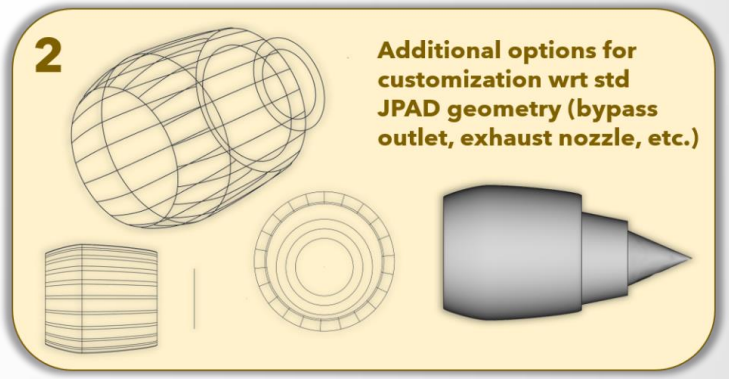
ADVANCED CAD FEATURES

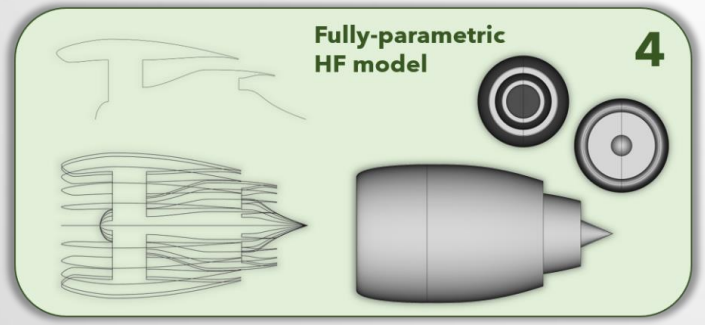
Engine Levels Of Details (LOD)

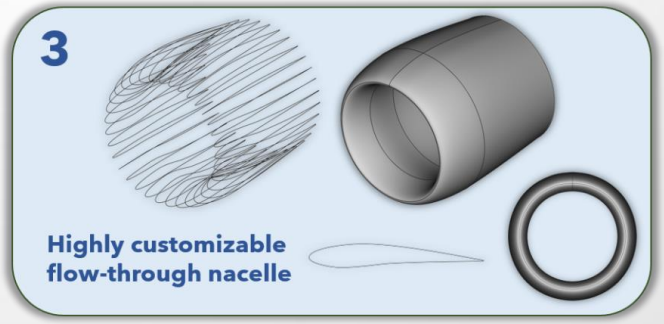
LOD: Level Of Detail







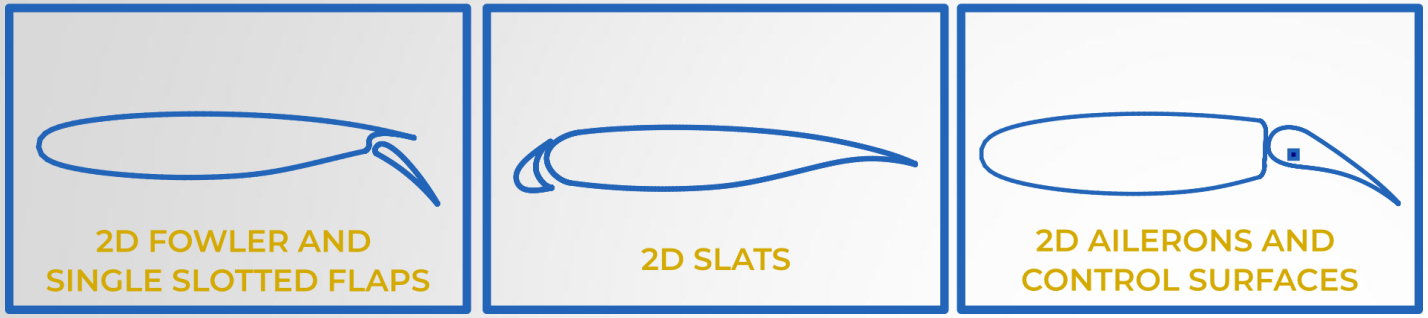




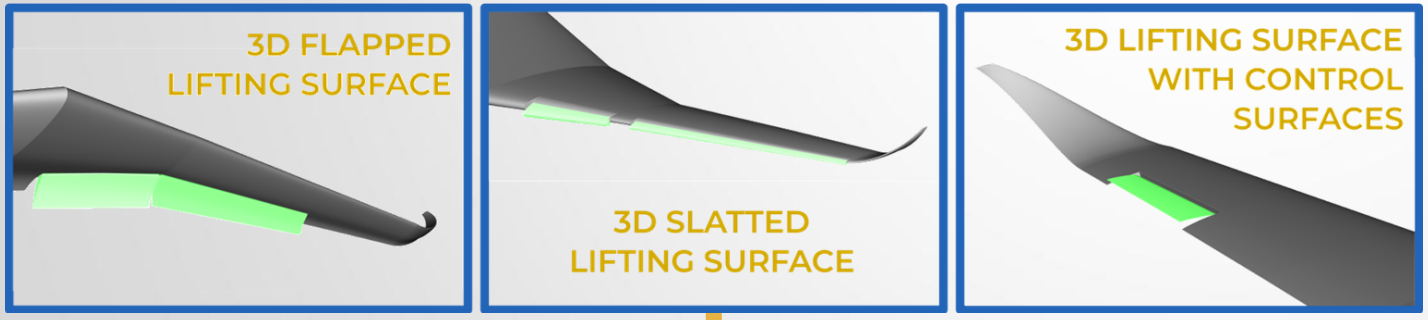
MOVABLES
CONTROL SURFACES

Detailed modelling and automatic generation of movable surfaces in seconds staring from 2D inner and outer section parameters.

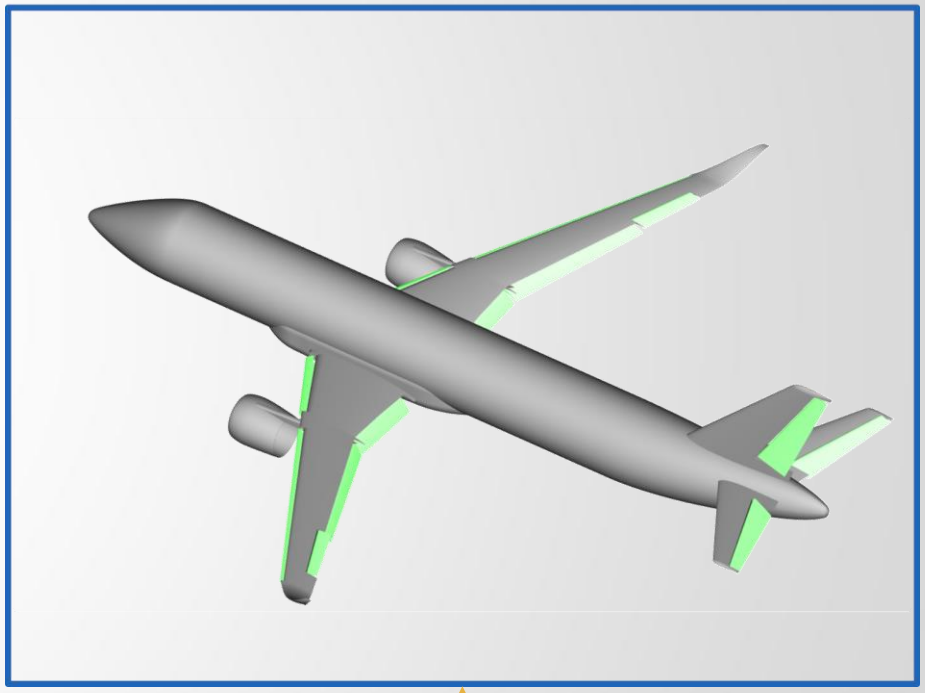
From 2D sections geometrical parameters



To the movable 3D model



Up to the full aircraft CAD model



Export Options toward many companion tools

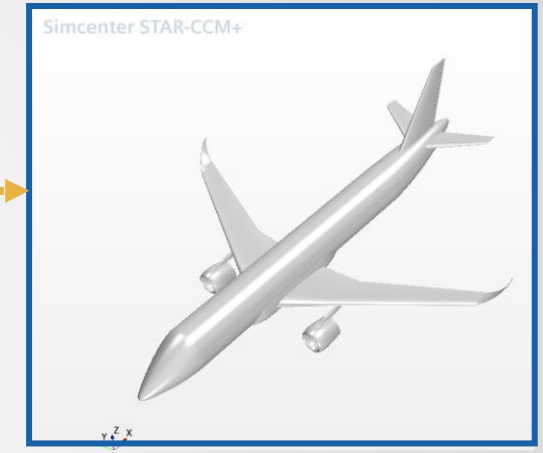
JPAD MODELLER

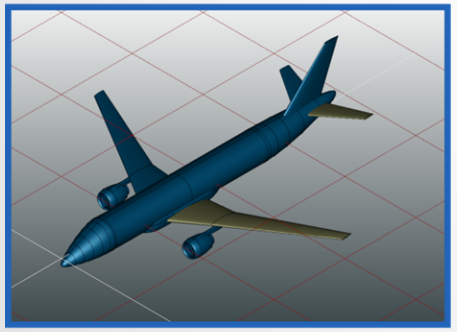
X-ROTOR

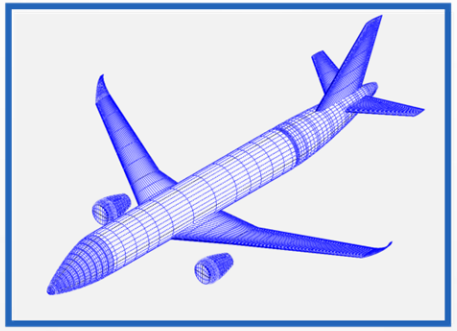
AVL

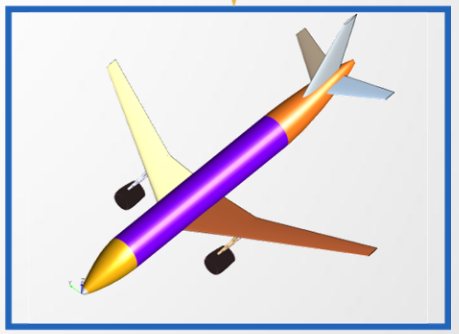
DIGITAL DATCOM

STAR-CCM+









TiGL

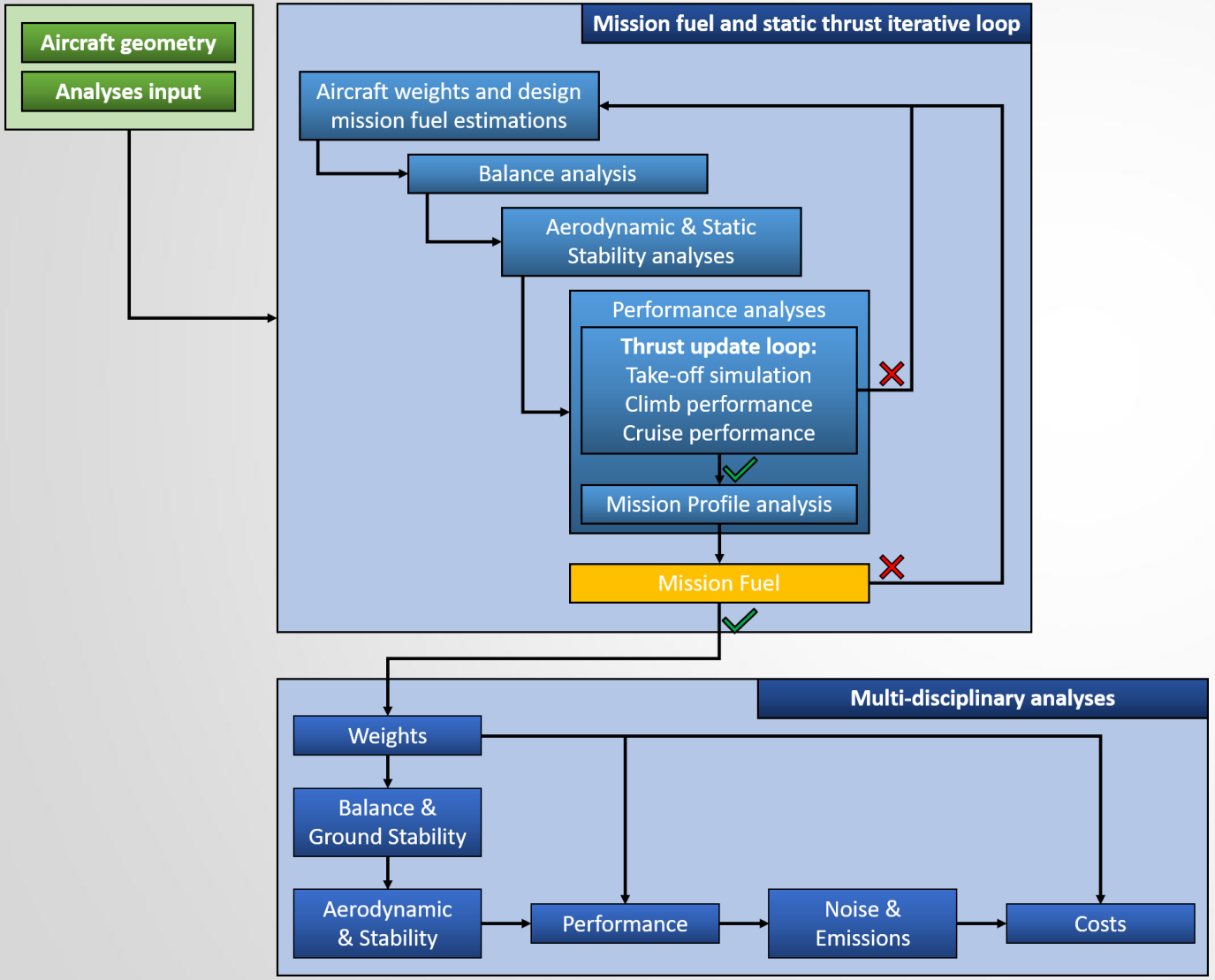
cpacs
A Common Language for Aircraft Design

OpenVSP

FLIGHTSTREAM

WHAT IS JPAD MDA ?

JPAD MODELLER

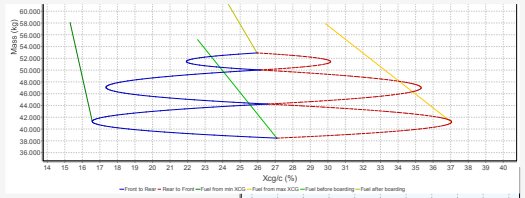


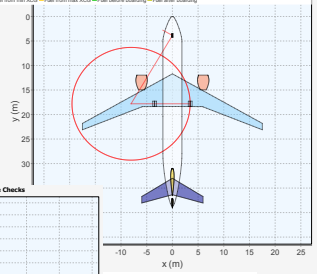
- **Possibility to analyze the aircraft behavior on a given design mission or to size the maximum take-off weight on it using a mission fuel iterative loop.**
- **Possibility to automatically adjust the engine static thrust according to one or more aircraft requirements.**
- **Possibility to perform a complete analysis loop or to invoke each discipline in a standalone mode.**

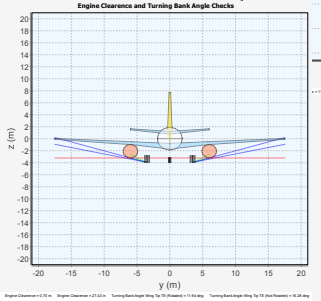
Multidisciplinary analysis of the JPAD Modeller aircraft

Weights, Balance and Ground Stability

- Class-II weights
- Components CG and Boarding diagram
- Aircraft inertias
- Ground stability assessment

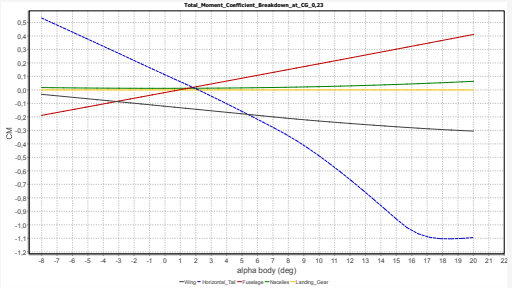


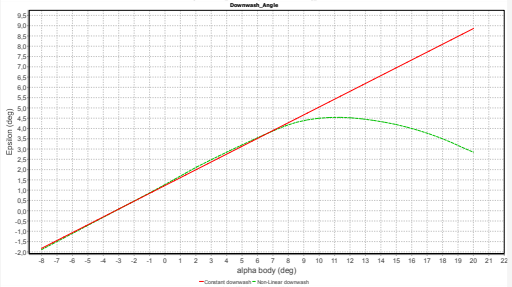


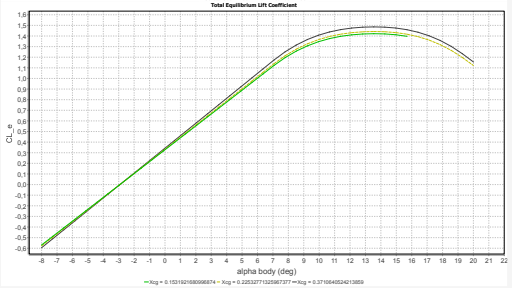


Aerodynamics and Stability

- Semiempirical approach + VLM + In-House Surrogate Models

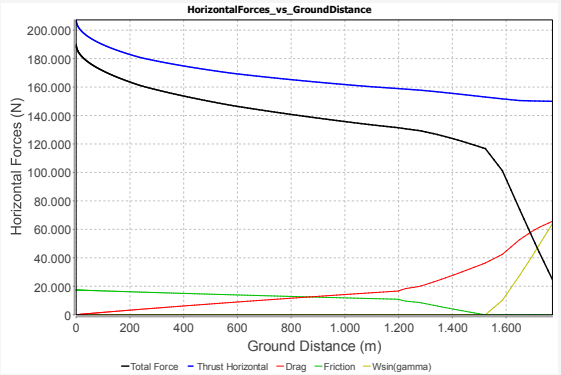






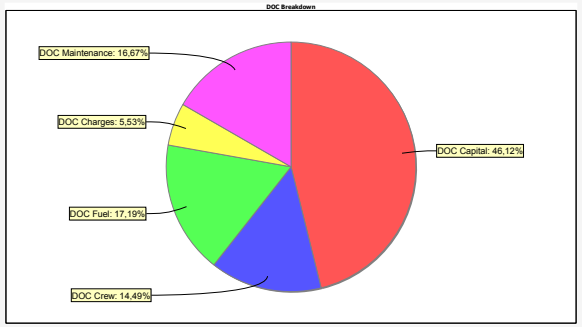
Simulation-based Performance

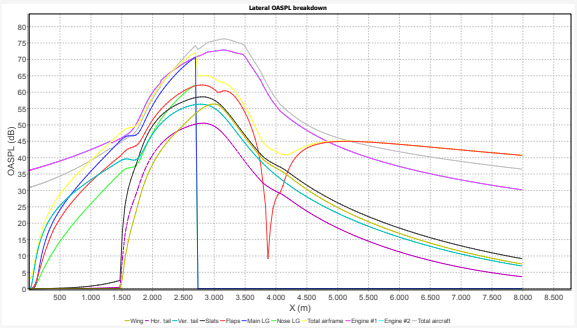
- Take-off (Simulation, BFL, VMC)
- Landing (with touch-down RD check)
- Mission Profile simulation (with emissions assessment)
- Payload-Range diagram
- Certification noise trajectories simulation
- V-n Diagram



Costs and Noise

- Environmental Noise
- Direct Operating Costs





APPLICATION - INTRO

Knowledge-based digital twin CAD details

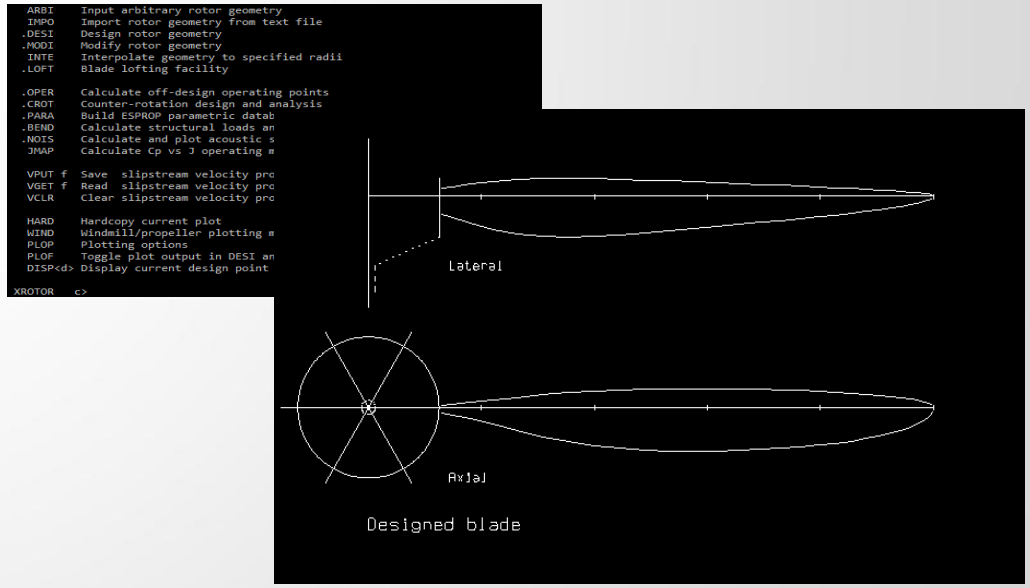
The **«propeller»** component is the latest addition to the CAD features of the *JPAD* API

Case study

A modelling sub-module, **able to automate the propeller design workflow, to generate a CAD model automatically. The propeller specifications are retained.**

«What is the next external tool?»

XRotor an interactive computational program of rotor design and analysis



APPLICATION – COMPANION TOOL

X-Rotor contains **a set of menu-driven routines**, conceived to perform specific functions. These functions are:

- **Design of the minimum induced loss rotor**
- **Analysis of a designed rotor with a set of choices of operating parameters**
- **Generation of an arbitrary rotor geometry on a prompted input**
- **Optimization of twist distribution of an arbitrary rotor for minimum induced loss**
- **Structural analysis and corrections for twist distribution under applied loads**
- **Acoustic analysis with noise level predictions**

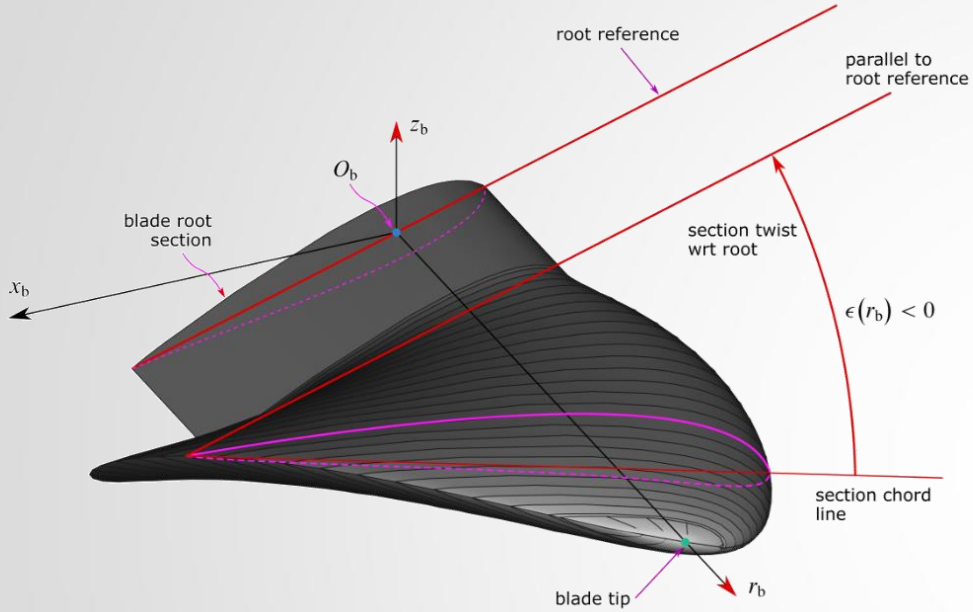
DESIGN OUTPUT DATA

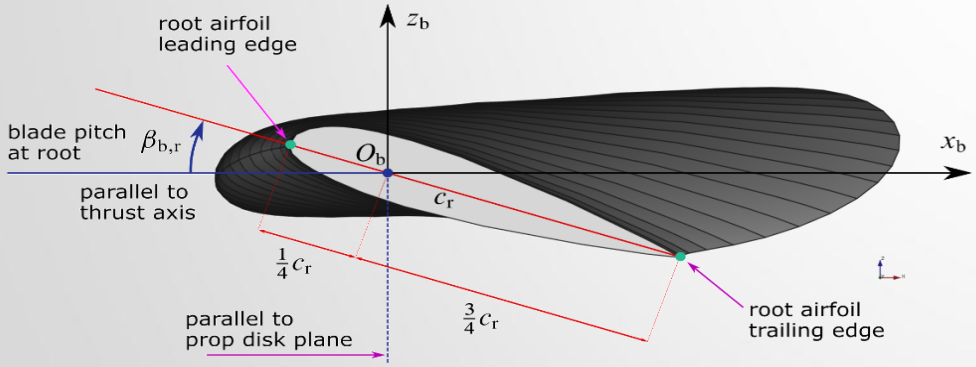
- **Blade r-wise chord distribution**
- **Blade r-wise pitch angle distribution**

AERODYNAMIC OUTPUT DATA

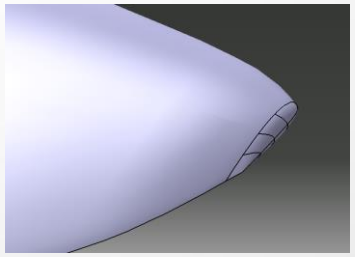
- **Propeller coefficients for third-party analysis tool (e.g., FlightStream, Actuator Disk solvers, etc.)**

APPLICATION – CAD GENERATION





CAD blade directives	
Blade airfoil name	**NACA23018**
Root chord, $c_{r,b}$	$0.0995\ m$
Root rigging angle, $\beta_{b,r}$	$72.901\ deg$
CAD blade output	
Normalized radii, $r_{b,i}/R_b$	**ARRAY**
Normalized chords, $c_{b,i}(r_{b,i})/R_b$	**ARRAY**
Twist, $\varepsilon_i(r_{b,i})$	**ARRAY**

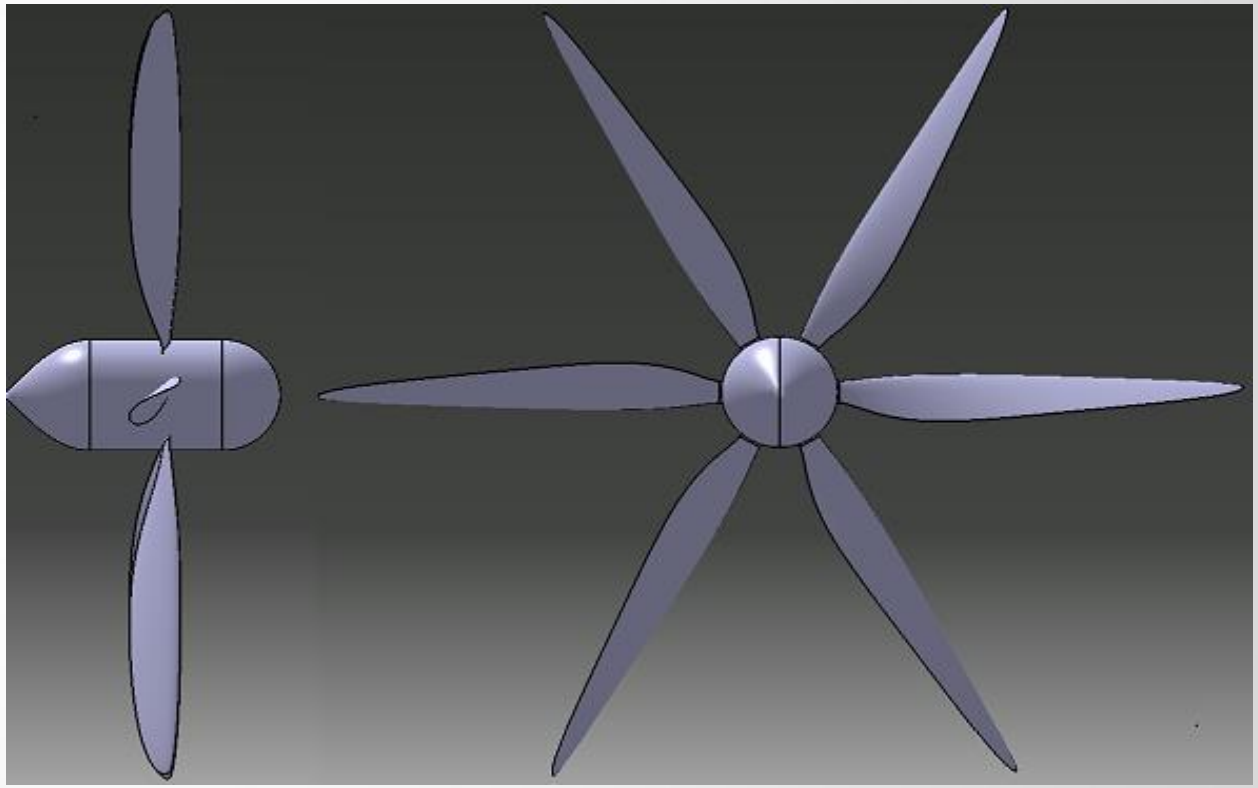


$$\varepsilon(r_b) = \beta(r_b) - \beta_{b,r}$$

APPLICATION – CASE STUDY

ATR42 propeller design parameters	
Atmosphere model	Standard
Number of blades, N	6
Radius, R	$2.000\ m$
Hub Radius, R_h	$0.250\ m$
Hub wake displacement body radius, R_w	$0.025\ m$
Airspeed, V	$60.000\ m/s$
Angular velocity, n	$1000.000\ rpm$
Thrust, T	$16000.000\ N$
Lift coefficient, C_L	0.700

ATR42 propeller



APPLICATION – LOW FIDELITY

Fluid properties

Fluid	Air
Atmosphere model	Standard atmosphere
Free stream	Constant
Altitude, h	$0.000\ m$ (SL)
Airspeed, V	$60.000\ m/s$
Angle of attack, α	$4.000\ deg$

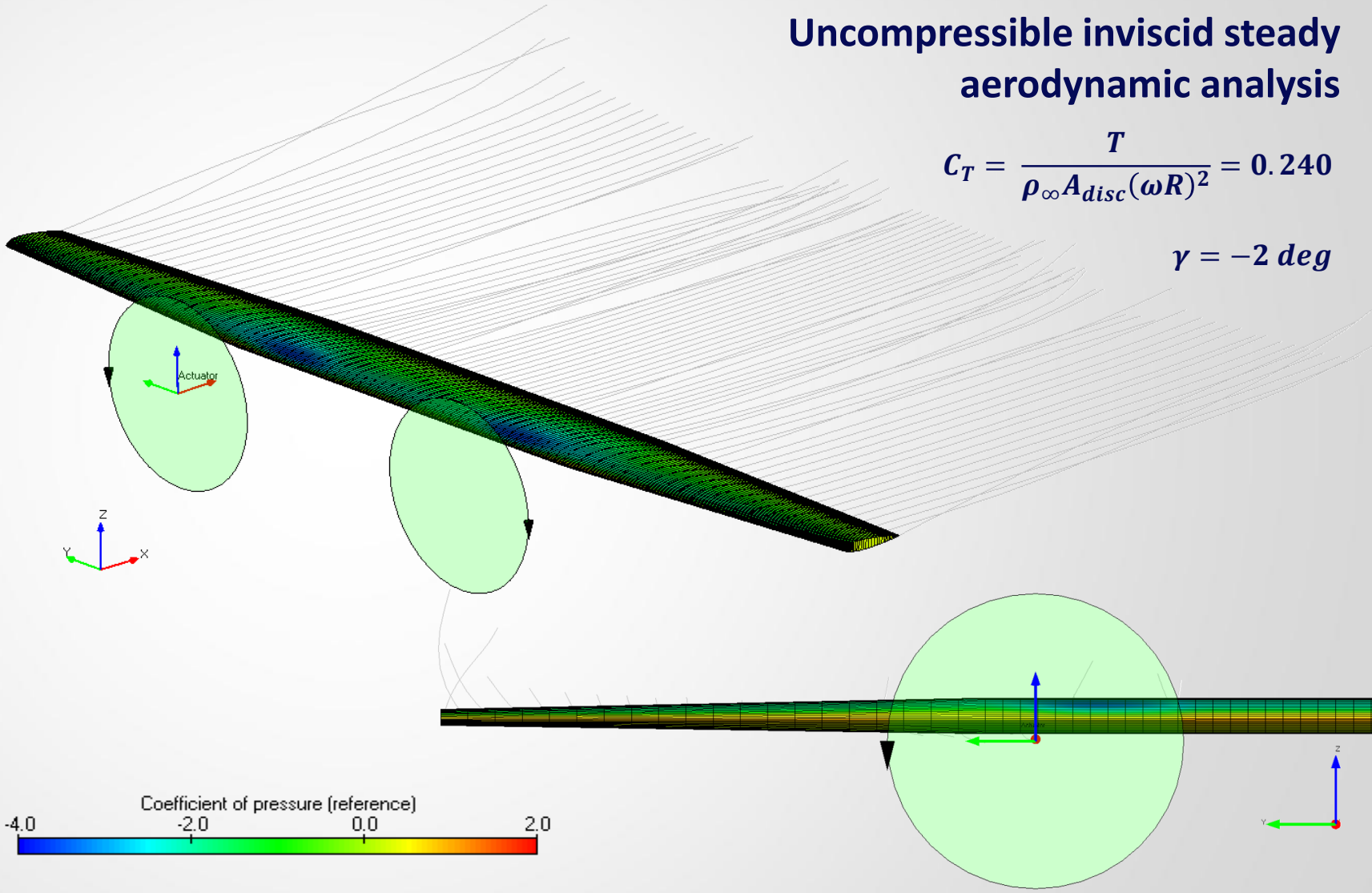
Actuator model initialization data

Radius, R	$2.000\ m$
Thrust, T	$16000.000\ N$
Angular velocity, n	$1000.000\ rpm$

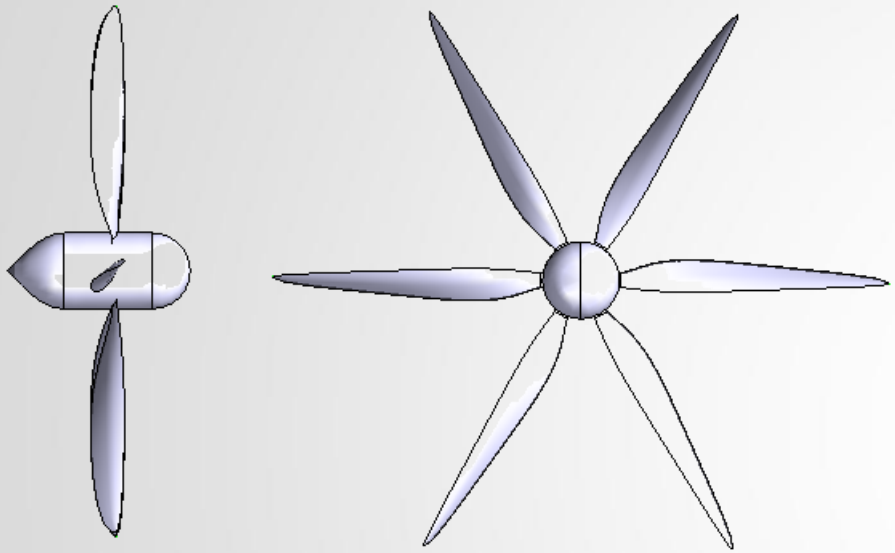
Uncompressible inviscid steady aerodynamic analysis

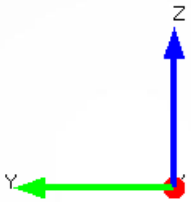
$$C_T = \frac{T}{\rho_\infty A_{disc}(\omega R)^2} = 0.240$$

$$\gamma = -2\ deg$$



APPLICATION – HIGH FIDELITY



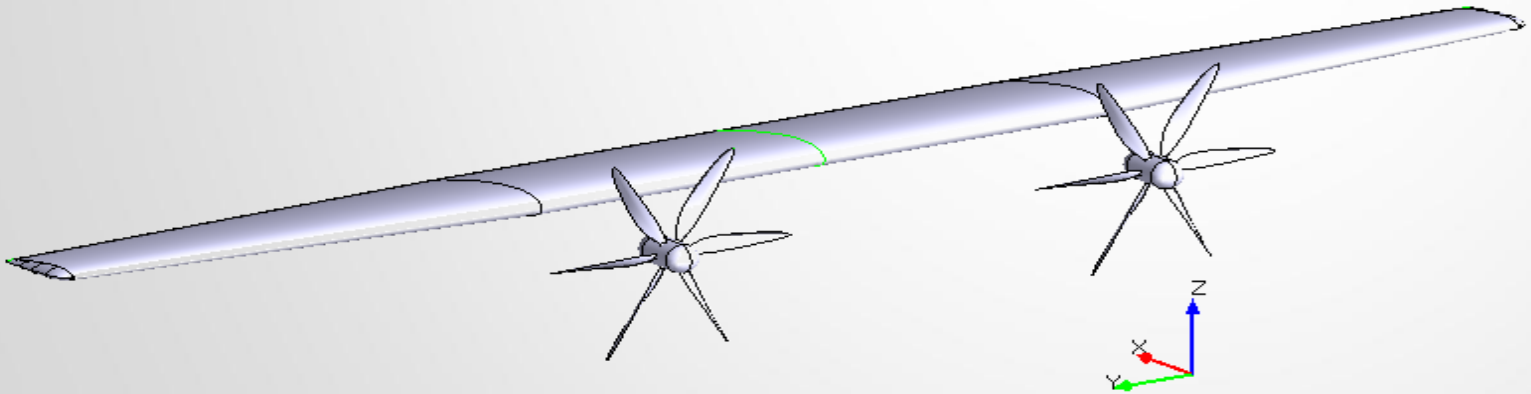


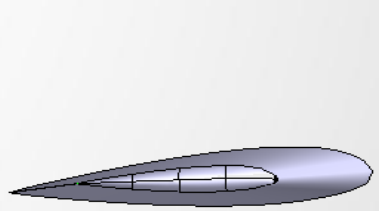
ATR42 propeller CAD model generated with the JPAD automated design workflow

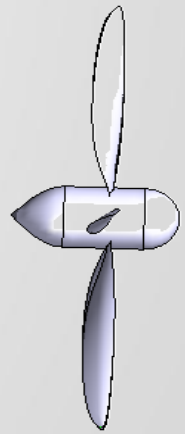
Uncompressible inviscid unsteady aerodynamic analysis

Wing-propeller configuration

Tilting angle, γ $-2\ deg$







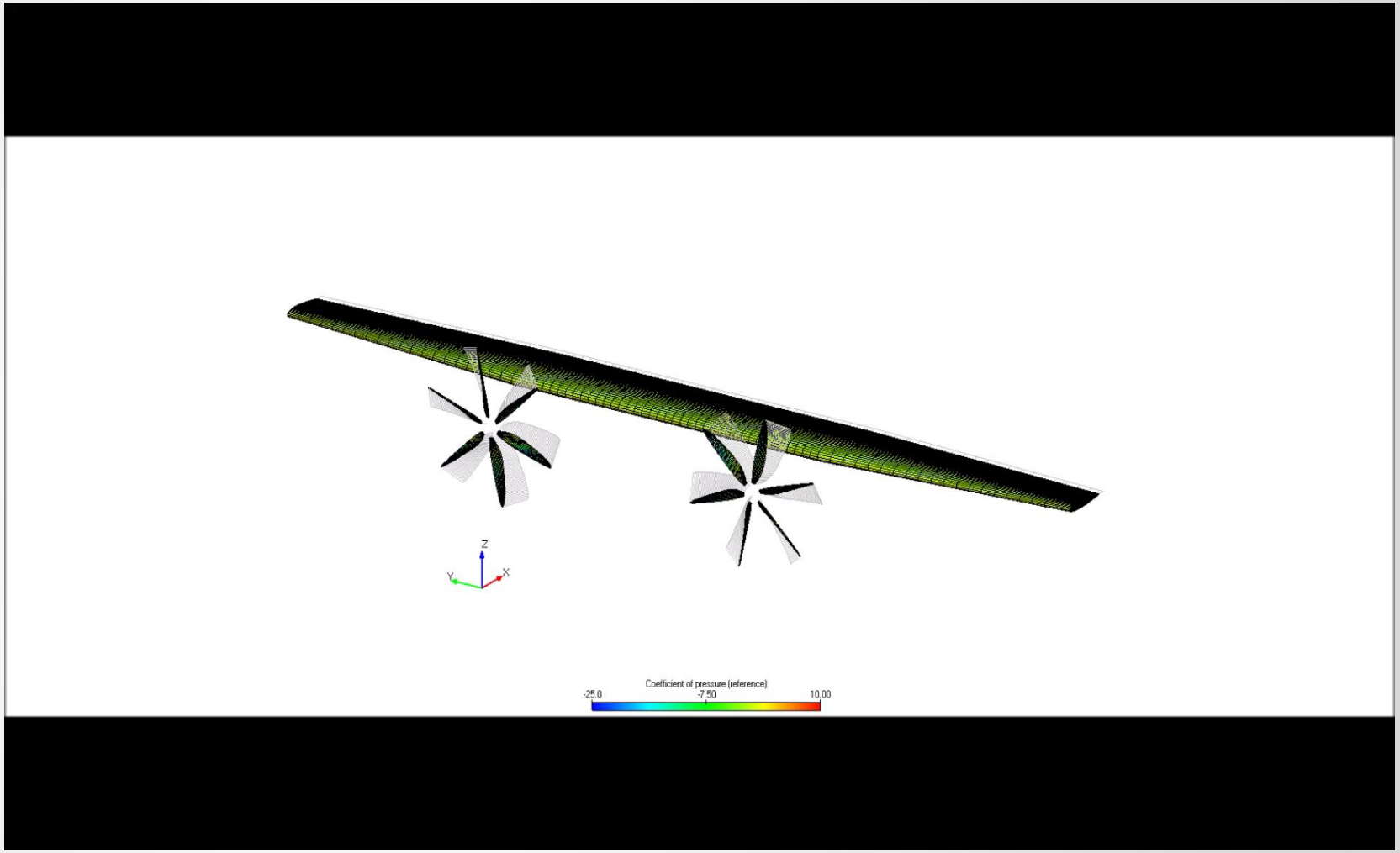
APPLICATION – UNSTEADY ANALYSIS

Fluid properties

Fluid	Air
Atmosphere model	Standard
Free stream	Constant
Altitude, h	$0.000\ m$ (SL)
Airspeed, V	$60.000\ m/s$
Angle of attack, α	$4.000\ deg$

Propeller motion initialization data

Time increment, Δt	$0.030\ s$
Time-stepping iterations, n_t	100
Angular velocity, n	$1000.000\ rpm$



Uncompressible inviscid unsteady aerodynamic analysis

CONCLUSIONS

Knowledge-based generation of complex geometries (e.g., propellers) and their integration inside the aircraft digital model in seconds.

Automatic parametric models and CAD components ready for low- to high-fidelity analyses

JPAD MODELLER

DIGITAL TWIN AIRCRAFT

UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

THANK YOU FOR YOUR ATTENTION
ANY QUESTIONS?

http://www.smartup-engineering.com/
http://www.daf.unina.it/
info@smartup-engineering.com