



DIPARTIMENTO DI
INGEGNERIA
INDUSTRIALE



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jPAD — A Java Toolchain of Computer Programs for Aircraft Design.

Software Engineering Best Practices
Applied to Aerospace Sciences

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jPAD — Java Programs for Aircraft Design

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- A software toolchain for aircraft preliminary design and MDO.
- A modern, user friendly, modular framework.
- Support for simultaneous management/analysis of several aircraft and/or 'varied' configurations of the same aircraft.
- Conceived for collaborative design activities.
- Interoperability with other tools/disciplines (CAD/CFD/FEM analysis).
- Started in early 2014. Approx. 120k lines-of-code.
- **Planning to go open source.**

What you can do with jPAD

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- Define parametric representations of wings, fuselages and nacelles with XML configuration/input files (similar to OpenVSP).
- Generate CAD geometries of aircraft assembly and sub-components (Open CASCADE, JNI Technology). Measure lengths, areas, volumes. Export in CAD formats (Brep, STEP, IGES, STL, Collada).
- Vary geometric parameters and regenerate internal representation of geometries programmatically.
- Import CPACS aircraft configurations files (Tigl Native Interface) and extract relevant properties. (Work in progress)
- Perform various types of analysis (L0, L0.5, L1): Aerodynamics, Stability & Control, Performance, Weight, Costs. (Structural TBD)
- Exports analysis results in XML (native/CPACS) and Excel formats.

Competency spectrum

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**Aircraft Design
Disciplines**

**Computer Science,
Software Engineering**

We are aerospace engineers ... Should we extend our capabilities?

Software engineering principles

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- *Software design patterns*: formalized best practices that the programmer can use to solve common problems when designing an application or system.
- Design patterns speed up the development process by providing tested, proven development paradigms.
- Examples of patterns:
 - ▣ Builder, Factory, Dependency Injection,
 - ▣ Strategy, Separation-of-Concerns,
 - ▣ Observer (Publish/Subscribe)
- Micro patterns (**design decisions in code**): DRY (Don't Repeat Yourself), Sampler (Controlled Creation),

Example of Java code

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```
Aircraft aircraft = new Aircraft("Baseline_AC_AGILE.xml");
OperatingPoint op = OperatingPointFactory.getPoint("OP_001.xml");
ACAnalysisManager analysis = new ACAnalysisManager(op, aircraft,
                                                    AnalysisTypeEnum.AERODYNAMIC,
                                                    AnalysisTypeEnum.BALANCE,
                                                    AnalysisTypeEnum.WEIGHTS,
                                                    AnalysisTypeEnum.PERFORMANCE,
                                                    AnalysisTypeEnum.COSTS);

analysis.calculateGeometryAuxiliaryData();
analysis.runAnalysis(AnalysisTypeEnum.AERODYNAMIC,
                    AnalysisTypeEnum.PERFORMANCE);

DataWriter dataWriter = new DataWriter(analysis);
dataWriter.exportToXML("Analysis_Baseline_AGILE_op_001.xml");
dataWriter.exportToXLS("Analysis_Baseline_AGILE_op_001.xlsx");

CADBuilder cadBuilder = new CADBuilder(aircraft);
cadBuilder.build().exportToSTEP("Baseline_AGILE_op_001.stp");

CPACSBuilder cpacsBuilder = new CPACSBuilder(aircraft); // TBD
cpacsBuilder.build().export("Baseline_AGILE_op_001.xml");

WriteUtils.serializeObject(aircraft, aircraft.getName());
```

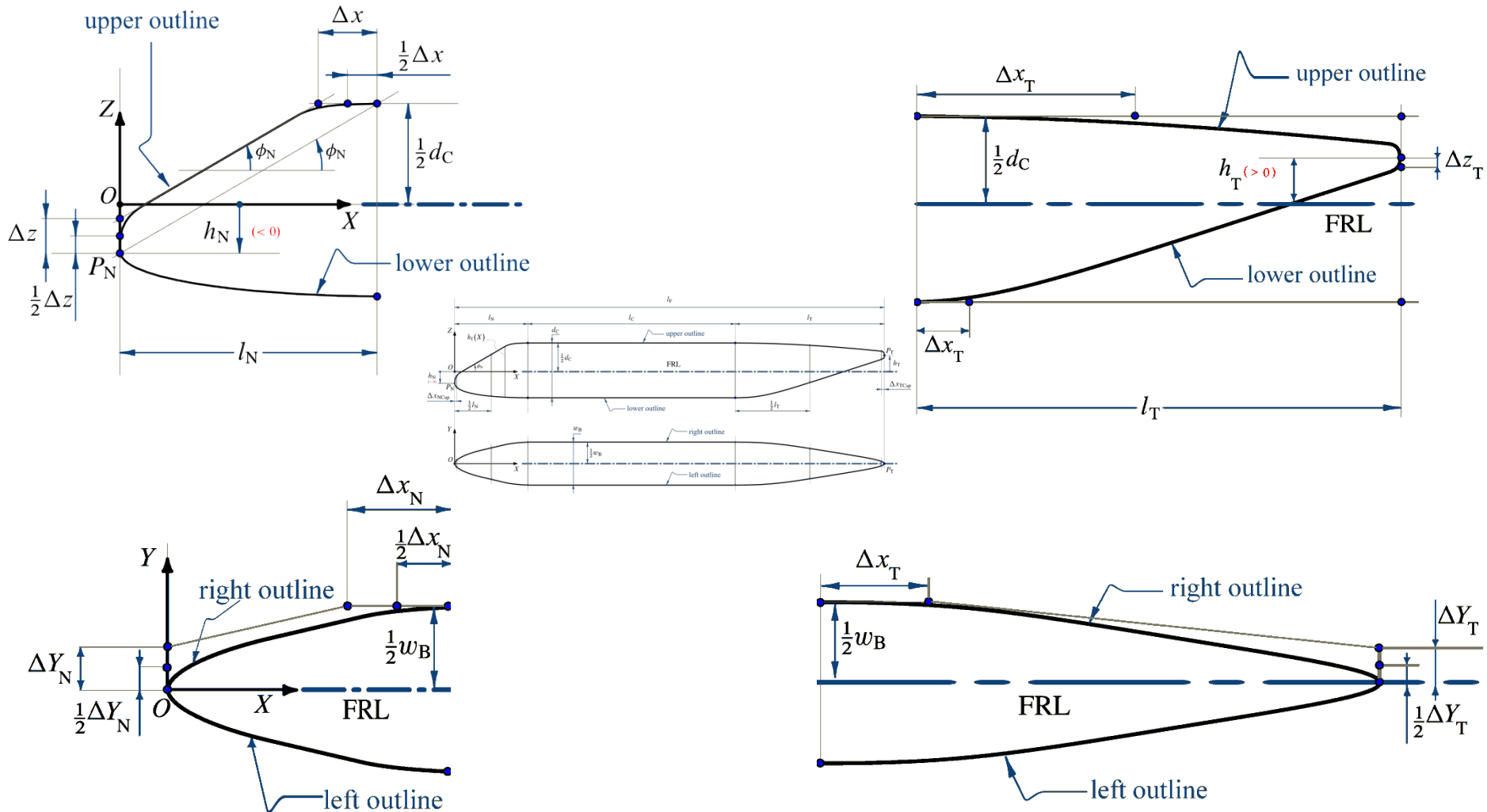
Java. Why?

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- “Compile once. Run it everywhere.” (well, almost)
- Widely supported, continuously updated and improved.
- Many open source libraries available, especially for I/O tasks and for complex mathematical operations.
- Widely supported GUI frameworks (SWT/JFace and JavaFX) and a GUI visual builders.
- Object-Oriented paradigm is naturally applied in the abstraction of typical Aircraft Design problems.
- Promotes modularity: easier to work with in an ever changing team.

Parametric Fuselage in jPAD

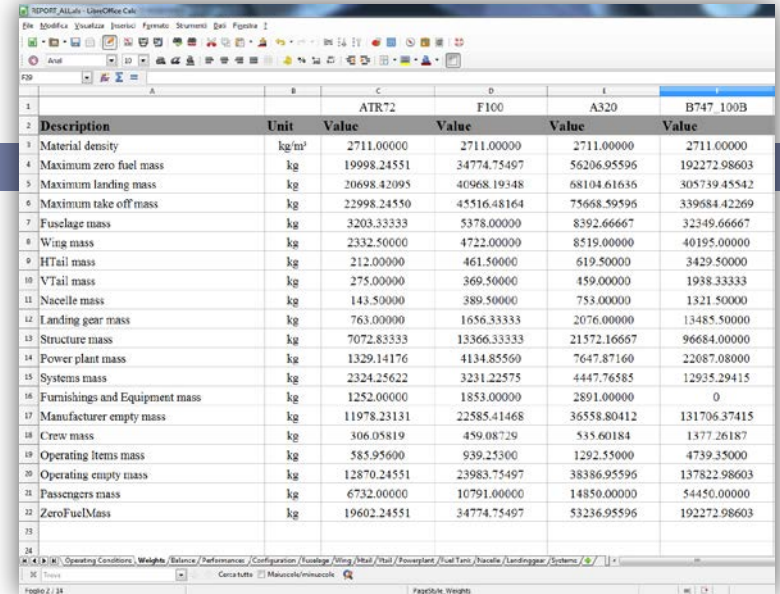
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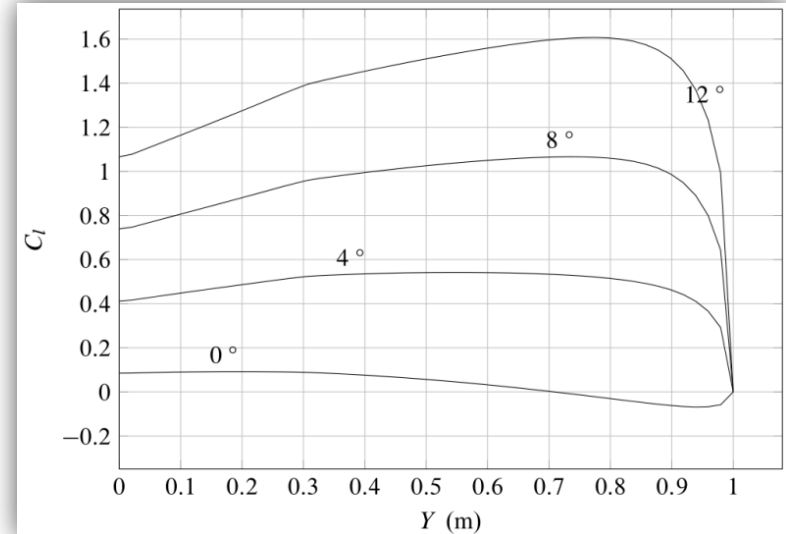
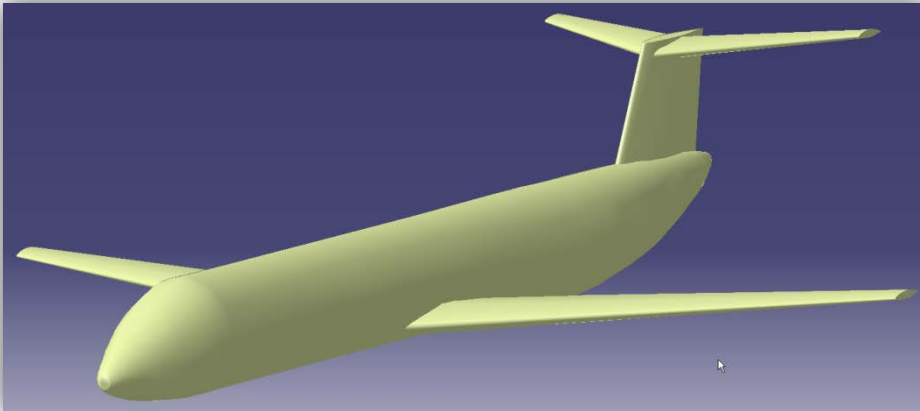
Output files

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- XML
- Microsoft Excel
- Charts
- CAD model ready to be meshed

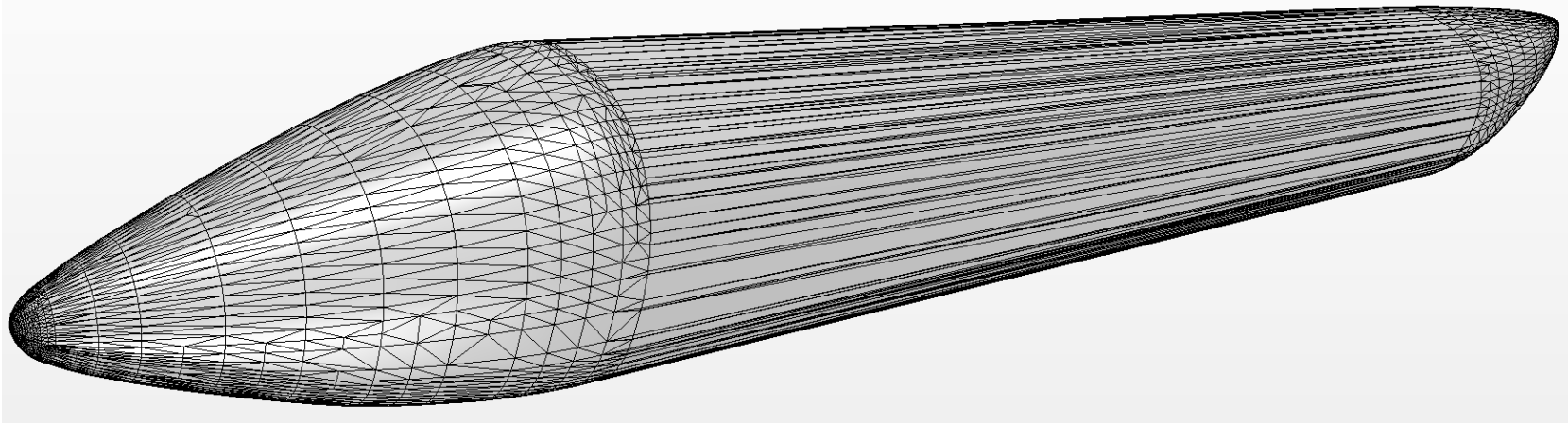


		ATR72		F100		A320		B747-100B	
	Description	Unit	Value	Value	Value	Value	Value	Value	Value
3	Material density	kg/m ³	2711.00000	2711.00000	2711.00000	2711.00000	2711.00000	2711.00000	2711.00000
4	Maximum zero fuel mass	kg	19998.24551	34774.75497	56206.95596	192272.98603	192272.98603	192272.98603	192272.98603
5	Maximum landing mass	kg	20698.42095	40968.19348	68104.61636	305739.45542	305739.45542	305739.45542	305739.45542
6	Maximum take off mass	kg	22998.24550	45516.48164	75668.59596	339684.42269	339684.42269	339684.42269	339684.42269
7	Fuselage mass	kg	3203.33333	5378.00000	8392.66667	32349.66667	32349.66667	32349.66667	32349.66667
8	Wing mass	kg	2332.50000	4722.00000	8519.00000	40195.00000	40195.00000	40195.00000	40195.00000
9	HTail mass	kg	212.00000	461.50000	619.50000	3429.50000	3429.50000	3429.50000	3429.50000
10	VTail mass	kg	275.00000	369.50000	459.00000	1938.33333	1938.33333	1938.33333	1938.33333
11	Nacelle mass	kg	143.50000	389.50000	753.00000	1321.50000	1321.50000	1321.50000	1321.50000
12	Landing gear mass	kg	763.00000	1656.33333	2076.00000	13485.50000	13485.50000	13485.50000	13485.50000
13	Structure mass	kg	7072.83333	13366.33333	21572.16667	96684.00000	96684.00000	96684.00000	96684.00000
14	Power plant mass	kg	1329.14176	4134.85569	7647.87160	22687.08000	22687.08000	22687.08000	22687.08000
15	Systems mass	kg	2324.25622	3231.22575	4447.76585	12935.29415	12935.29415	12935.29415	12935.29415
16	Furnishings and Equipment mass	kg	1252.00000	1853.00000	2891.00000	0	0	0	0
17	Manufacturer empty mass	kg	11978.23131	22585.41468	36558.80412	131706.37415	131706.37415	131706.37415	131706.37415
18	Crew mass	kg	306.05819	459.08729	535.60184	1377.26187	1377.26187	1377.26187	1377.26187
19	Operating Items mass	kg	585.95600	939.25300	1292.55000	4739.35000	4739.35000	4739.35000	4739.35000
20	Operating empty mass	kg	12870.24551	23983.75497	38386.95596	137822.98603	137822.98603	137822.98603	137822.98603
21	Passengers mass	kg	6732.00000	10791.00000	14850.00000	54450.00000	54450.00000	54450.00000	54450.00000
22	ZeroFuelMass	kg	19602.24551	34774.75497	53236.95596	192272.98603	192272.98603	192272.98603	192272.98603

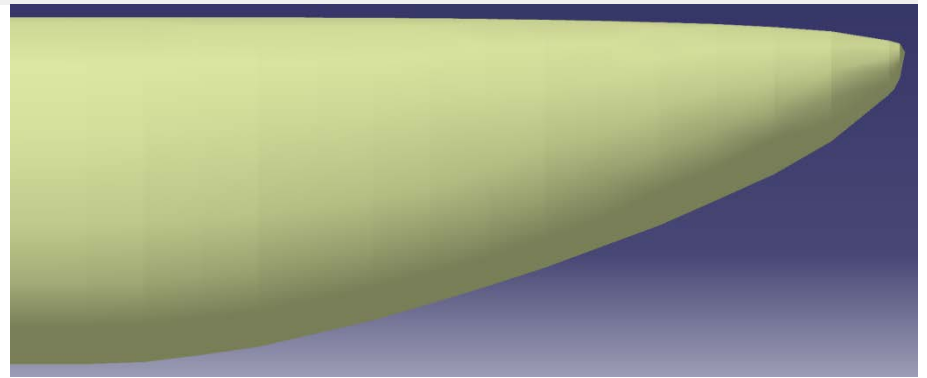


Example of jPAD output

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External fuselage shape
exported as STEP file



Example of jPAD output

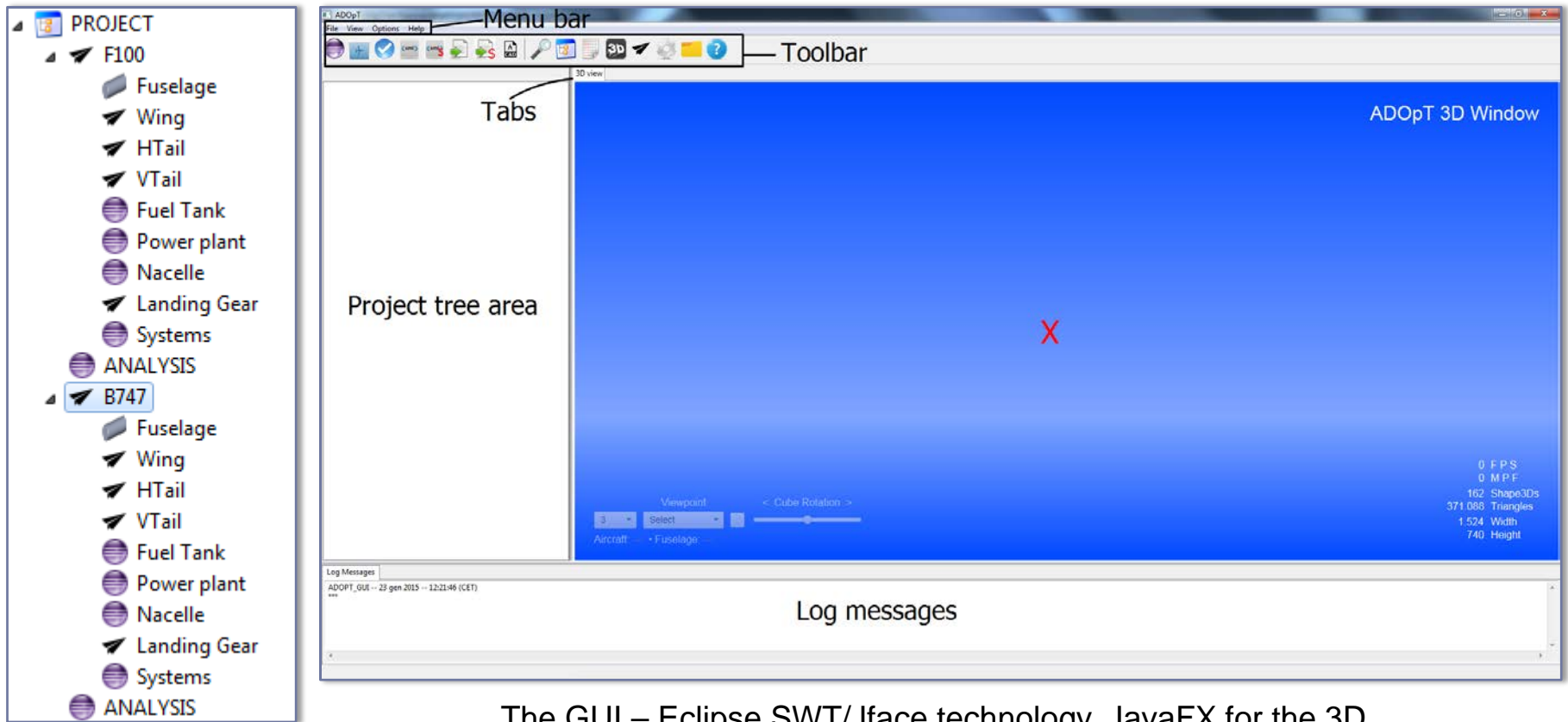
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[Multiple aircraft analysis result comparisons](#)

	A	B	C	D	E	F
			ATR72	F100	A320	B747_100B
2	Description	Unit	Value	Value	Value	Value
3	Material density	kg/m ³	2711.00000	2711.00000	2711.00000	2711.00000
4	Maximum zero fuel mass	kg	19998.24551	34774.75497	56206.95596	192272.98603
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11	Nacelle mass	kg	143.50000	389.50000	753.00000	1321.50000
12	Landing gear mass	kg	763.00000	1656.33333	2076.00000	13485.50000
13	Structure mass	kg	7072.83333	13366.33333	21572.16667	96684.00000
14	Power plant mass	kg	1329.14176	4134.85560	7647.87160	22087.08000
15	Systems mass	kg	2324.25622	3231.22575	4447.76585	12935.29415
16	Furnishings and Equipment mass	kg	1252.00000	1853.00000	2891.00000	0
17	Manufacturer empty mass	kg	11978.23131	22585.41468	36558.80412	131706.37415
18	Crew mass	kg	306.05819	459.08729	535.60184	1377.26187
19	Operating Items mass	kg	585.95600	939.25300	1292.55000	4739.35000
20	Operating empty mass	kg	12870.24551	23983.75497	38386.95596	137822.98603
21	Passengers mass	kg	6732.00000	10791.00000	14850.00000	54450.00000
22	ZeroFuelMass	kg	19602.24551	34774.75497	53236.95596	192272.98603
23						
24						

ADOpT: a GUI for jPAD

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Example of project tree

The GUI – Eclipse SWT/Jface technology, JavaFX for the 3D view

ADOpT: a GUI for jPAD

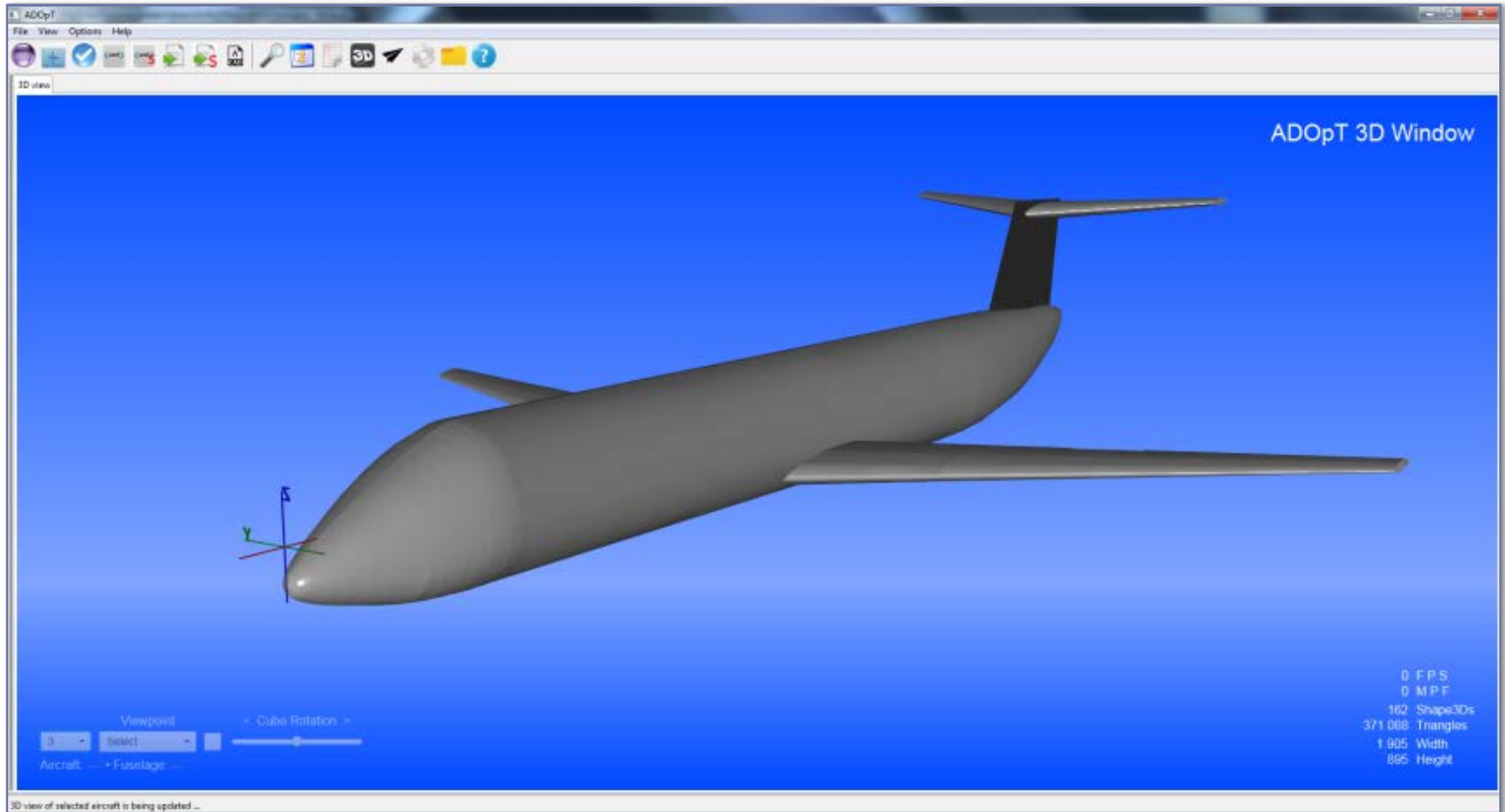
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The screenshot displays the ADOpT software interface. On the left is a project tree with categories like AIRCRAFT and ANALYSIS. The main area is divided into a 'Settings' panel and a '3D view' panel. The 'Settings' panel includes sections for 'Import fuselage file', 'Fuselage Nomenclature', 'Fuselage length' (with parameters l_F , l_N , l_C , l_T), 'Section Data' (with 'Section Shape' set to 'Cylindrical Body'), and 'Fuselage Height' (d_C). It also includes 'Fuselage Nose tip' (h_N), 'Fuselage Tail tip' (h_T), 'Nose Length Ratio' ($\rho_N = l_N/t$), and 'Central Length Ratio'. The '3D view' panel shows a 'Side View' plot of the fuselage outline. The plot has an X-Axis (m) from -5.43 to 32.6 and a Z-Axis (m) from -16.3 to 16.3. Three outlines are shown: a blue line for the 'Upper outline', a red line for the 'Lower outline', and a black dashed line for the 'Camber outline'. A legend at the bottom of the plot identifies these lines. At the bottom of the window is a 'Log Messages' area with the text: 'ADOPT_GUI -- 23 gen 2015 -- 10:56:47 (CET) ... A new aircraft is being created ...done' and 'Aircraft created'.

Varying geometric parameters

ADOpT: a GUI for jPAD

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CAD generated from parametric representation

ADOpT: a GUI for jPAD

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The screenshot displays the ADOpT software interface. On the left is a project tree with categories like AIRCRAFT, ANALYSIS, and Systems. The main area is divided into several panels:

- Settings:** Includes buttons for 'Import wing file', 'Import', and 'Wing Nomenclature'.
- Equivalent Wing, Input Geometry Data:** A table of parameters:

Surface	S_W	100.000 m ²
Aspect Ratio	AR	12.0
Taper Ratio	λ	0.63
Sweep c/4	$\Lambda_{c/4}$	1.40°
Span station kink	η_K	0.34
Extension LE	ΔX_{le}	0.00
Extension TE	ΔX_{te}	0.00
Delta X Wing-Fuselage Position	ΔX_{wf}	11.00 m
- Actual Wing, Output Geometry Data:** A table of calculated parameters:

Surface	S_W	61.000 m ²
Span	b	27.06 m
Taper Ratio Cranked Wing	λ	0.702
Inner Panel Semi-Surface Cranked Wing	S_{ip}	15.250 m ²
Inner Panel Aspect Ratio Cranked Wing	AR_{ip}	2.90
Outer Panel Semi-Surface Cranked Wing	S_{op}	15.250 m ²
Outer Panel Aspect Ratio Cranked Wing	AR_{op}	10.21
Inner Panel Taper Ratio Cranked Wing	λ_{ip}	1.000
Outer Panel Taper Ratio Cranked Wing	λ_{op}	0.702
Sweep LE Inner Panel Cranked Wing	Λ_{leip}	0.0°
Sweep c/4 Inner Panel Cranked Wing	$\Lambda_{c/4ip}$	0.0°
Sweep LE Outer Panel Cranked Wing	Λ_{leop}	0.0°
- I/O:** Includes 'Save status file' and a 'Save' button.
- 3D View:** Shows a 'Wing-Body' plot with X-Axis (m) from -2 to 34.1 and Y-Axis (m) from 0 to 15.53. The plot shows a curved fuselage (Body) and a rectangular wing (Wing) structure.

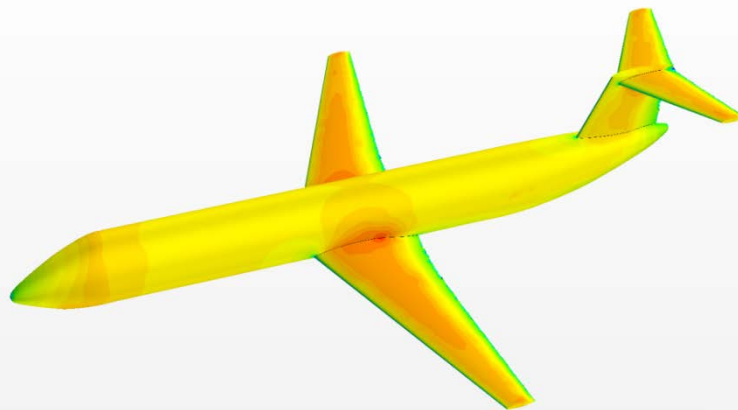
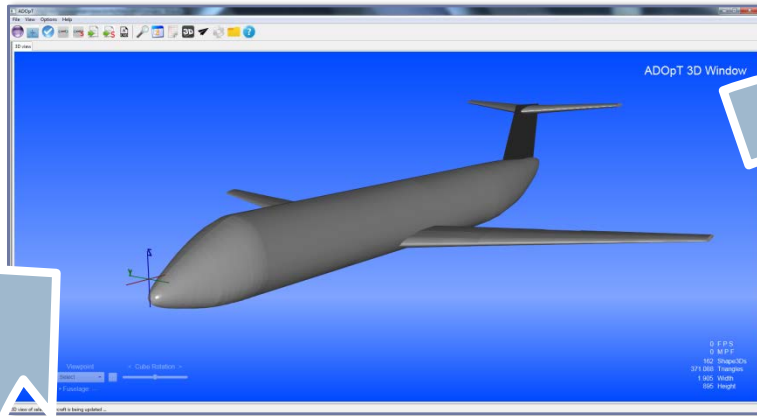
At the bottom, a 'Log Messages' window shows the following text:

```
ADOPT_GUI -- 23 gen 2015 -- 10:56:47 (CET)
***
A new aircraft is being created ...done
3D view of selected aircraft is being updated ...
The ADOpT | fuselage initiator: null
```

Configuring the aerodynamic analysis

Interface with external CFD tools

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Key Points

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- Java programming language (JDK \geq 1.8)
- Eclipse IDE
- Great effort to make code easily maintainable
- In-house solutions for:
 - Importing/exporting data (including CPACS via Tigl interface)
 - Array handling
 - GUI design (SWT/JFace libraries, JavaFX)
 - Building the CAD model (via Open CASCADE libraries/Java Native Interface JNI)
 - CAD 3D viewer (JavaFX)
 - DATCOM-like database for Aerodynamics/Performances/Stability & Control analysis modules (Hierarchical Data Format, HDF)

Conclusions

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- Main features and general arrangement complete
- Work in progress:
 - Loads
 - Stability & Control module
 - Collaborative features:
 - CPACS
 - United States Air Force Stability and Control Digital DATCOM
 - FlightGear simulator input XML file