



26th annual **INCOSE**
international symposium

Edinburgh, UK
July 18 - 21, 2016

Defining an Architecture Trade off Management Capability

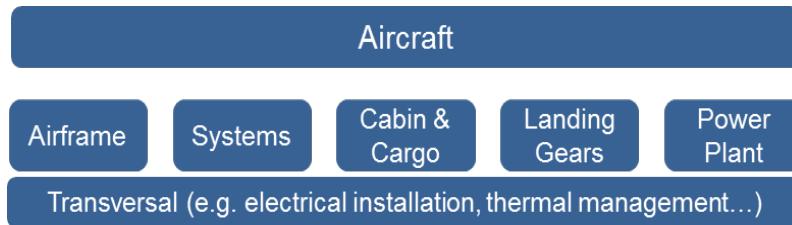
Anne Monceaux, Alexandre Arnold (Airbus Group), and Pascal Gendre (Airbus SAS)



ARCHITECTURE CONVERGENCE PROCESS

Product development layers

The development process is broken down into Product Development Layers



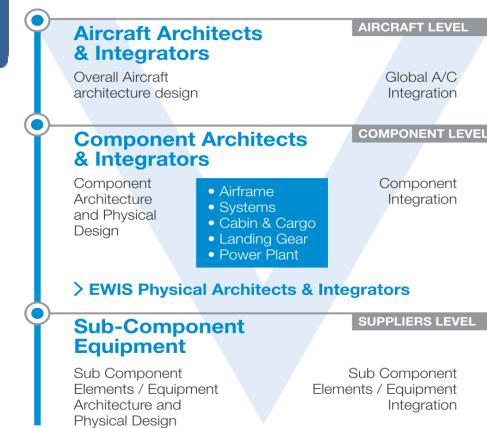
...reflected by an architect organization



E Architect

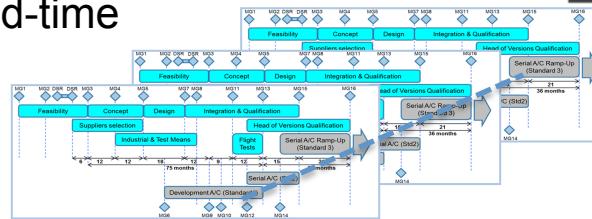


Define the component overall virtual architecture.
Launch, coordinate and drumbeat MDTO studies



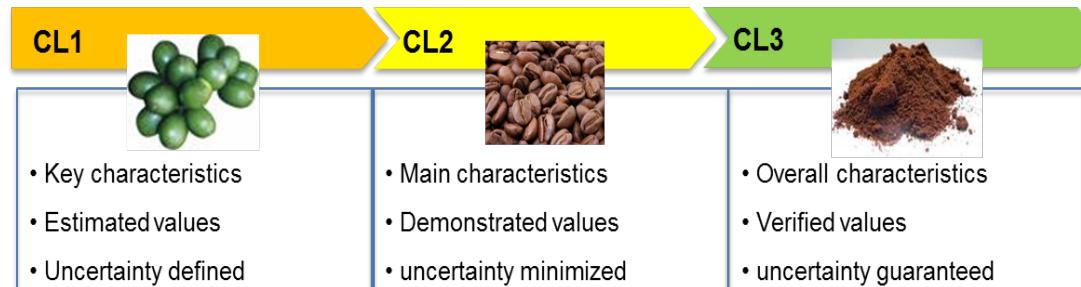
Convergence process

Strategies to reduce the development cycle lead-time require to run activities in parallel



Convergence relies on collecting and consolidating information & data out of these activities

Convergence levels reflects the granularity & maturity of the data



MULTIDISCIPLINARY TRADE-OFF CAPABILITY

The aircraft mechanical system

Interviews of architects in charge of the Flight Physics perimeter



CL1.x



Aero shapes
Flight Control surfaces
Landing Gear
Power Plant
Airframe
Etc.

major parameters of Components + functional propagation of parametric variations

Aerodynamics
Loads

Structure: FEM, stress

Propulsion

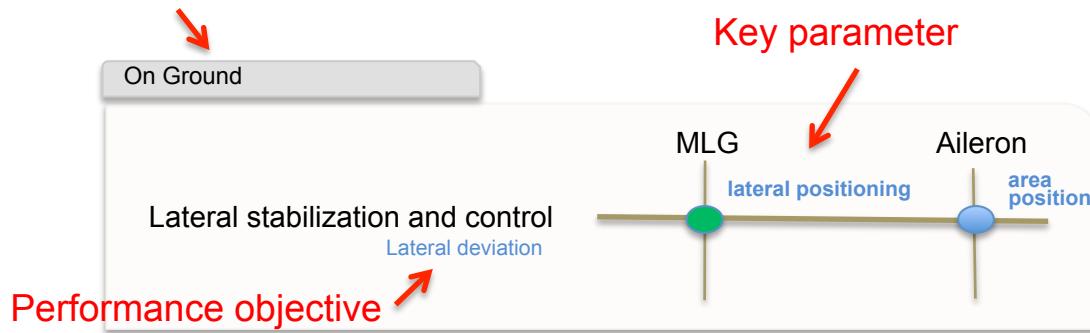
Handling Qualities

Etc.

Disciplines involved in mechanical studies

Simplified example

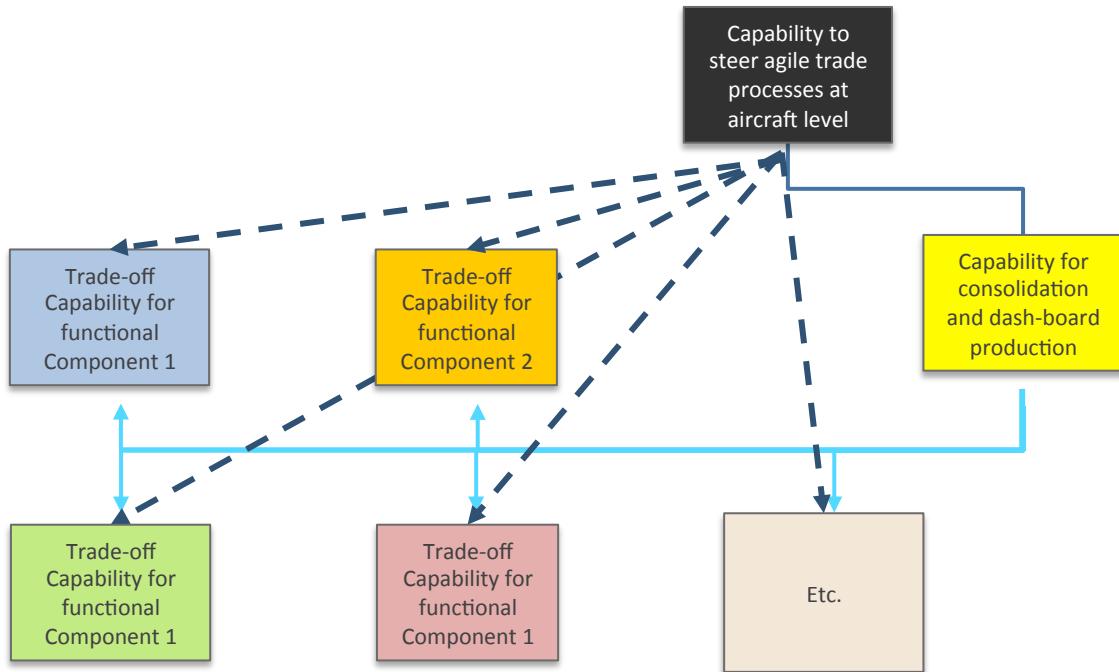
Operational case



For a given performance, a trade can be done between lateral positioning of the main landing gear and ailerons parameters

We call MDTOC the process – operated by a dedicated multidisciplinary engineering team, using dedicated component models and function simulation methods – that can size these components according a tested configuration chosen by the architect

Multi Disciplinary Trade Off Capability

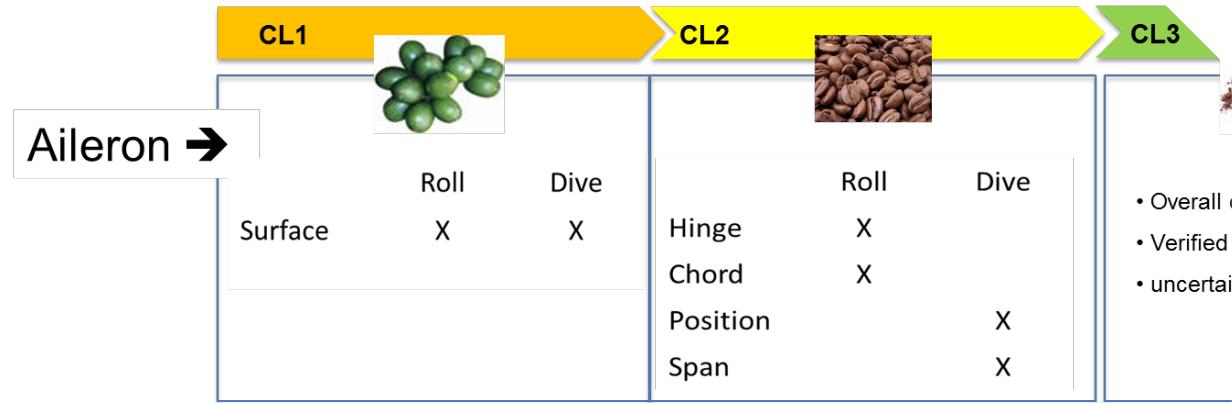


Generalizing the analysis for classical civil aircrafts:

- Describe functions of the Flight Physics System
- Allocate functions to physical components of this Flight Physics System
- Cut out into this allocation map, consistent perimeters of trade-off capabilities, in charge of sizing some components with regards to the functions they were allocated to.

Multi Disciplinary Trade Off Capability

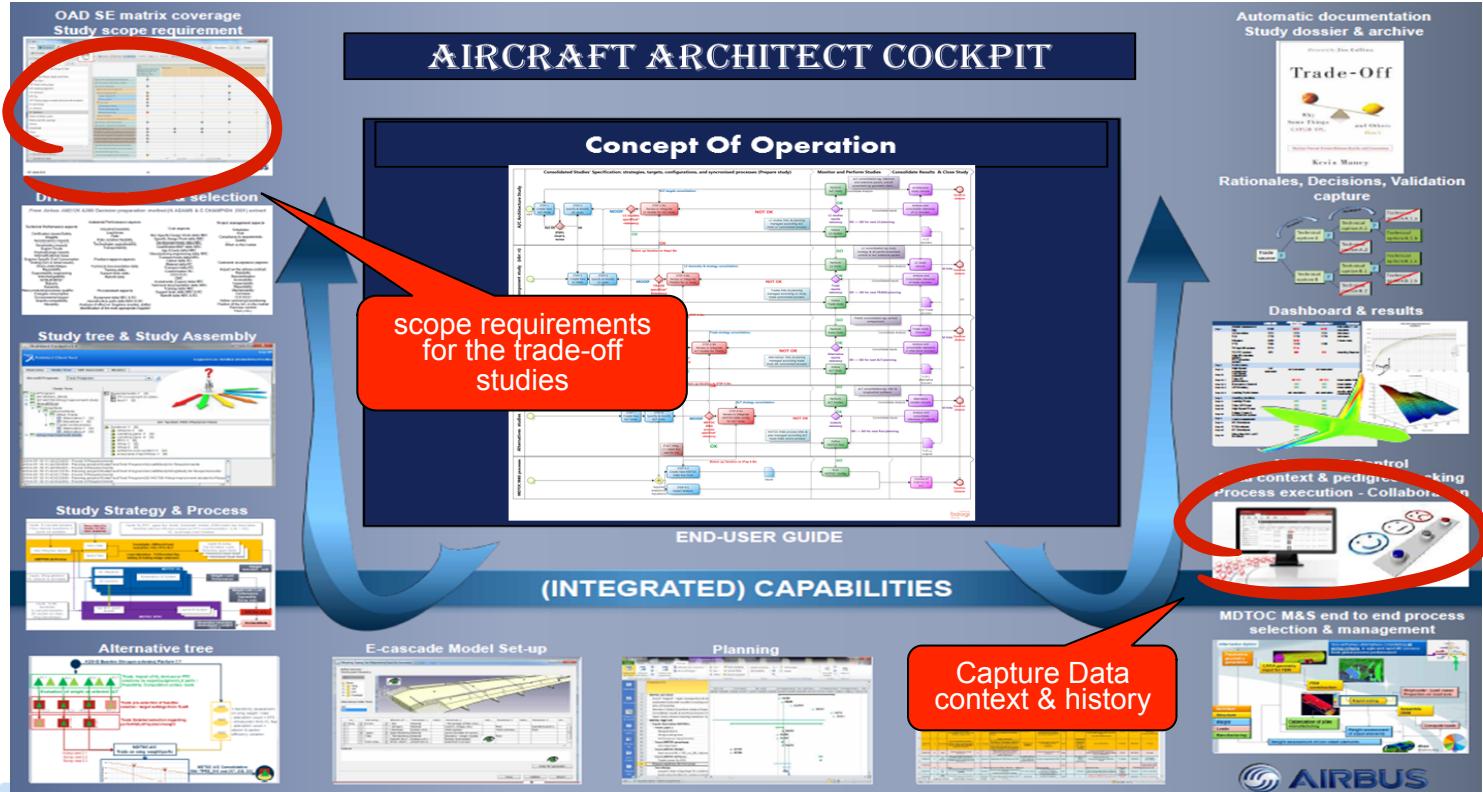
Along the convergence process, sizing methods have growing fidelity level, meaning that different aspects (sub-sets of parameters) of the Component can be evaluated and sized



- from highly integrated and very rapid sizing methods supporting the feasibility phase
- to downstream processes for highly accurate design phase

A DEDICATED WORKBENCH FOR THE ARCHITECTS

A dedicated workbench for the architects



Architecture
Trade off
Management
Capability

P. Gendre "System of MTOCs synthesis".
December 2015

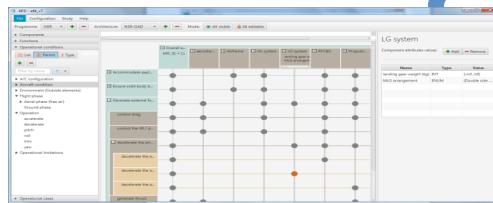
DEFINING AN ARCHITECTURE TRADE OFF MANAGEMENT CAPABILITY

Sketching a process

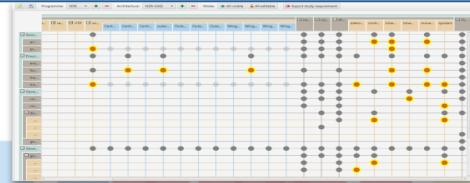


Create architecture alternatives by instantiating components and valuing their attributes

Formalize links between functions and components using an allocation matrix



Export study scope requirement - defined by selecting allocation points

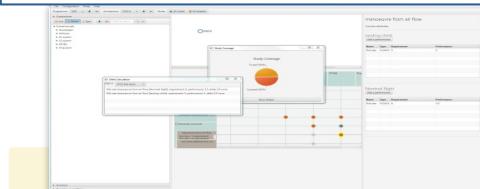


START

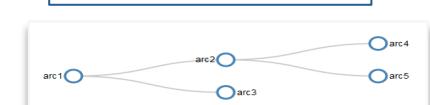
"Ailerons, elevons and rudder are defined to "maneuver from air flow", to "trim and stabilize from air flow" in engine failure cases. These surfaces also contribute to "ensure air lift at low speed" (drooped ailerons) and to "transmit external forces & moments and resist to consequent internal loads" through the Load Alleviation Functions (MLA and GLA) "



Collect & integrate study results
+ verify validity of architecture
(estimated perf vs req, allocation points covered by studies so far...)

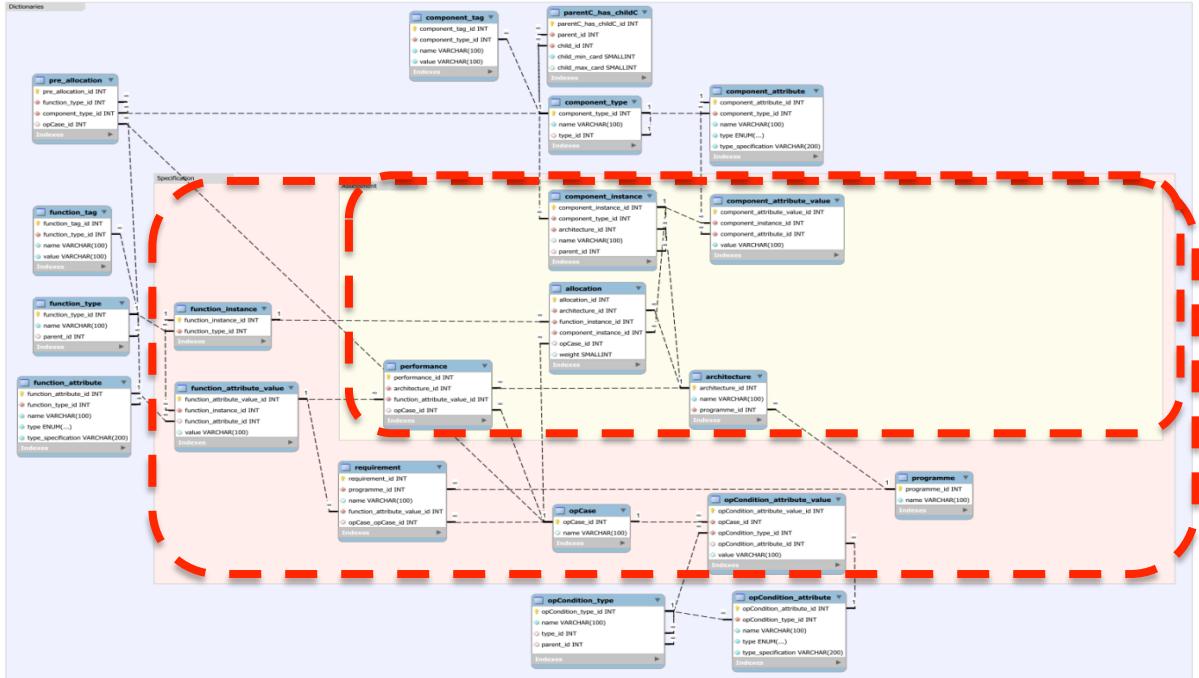


MDTOC
method is ran



Monitor history &
progress of
architecture layers

Core information concepts



Architecture modelling elements

- Functions & attributes
- Operations & attributes
- Components & attributes

Views

- Dictionary
- Specification (Program context)
- Architecture

Extended information concepts

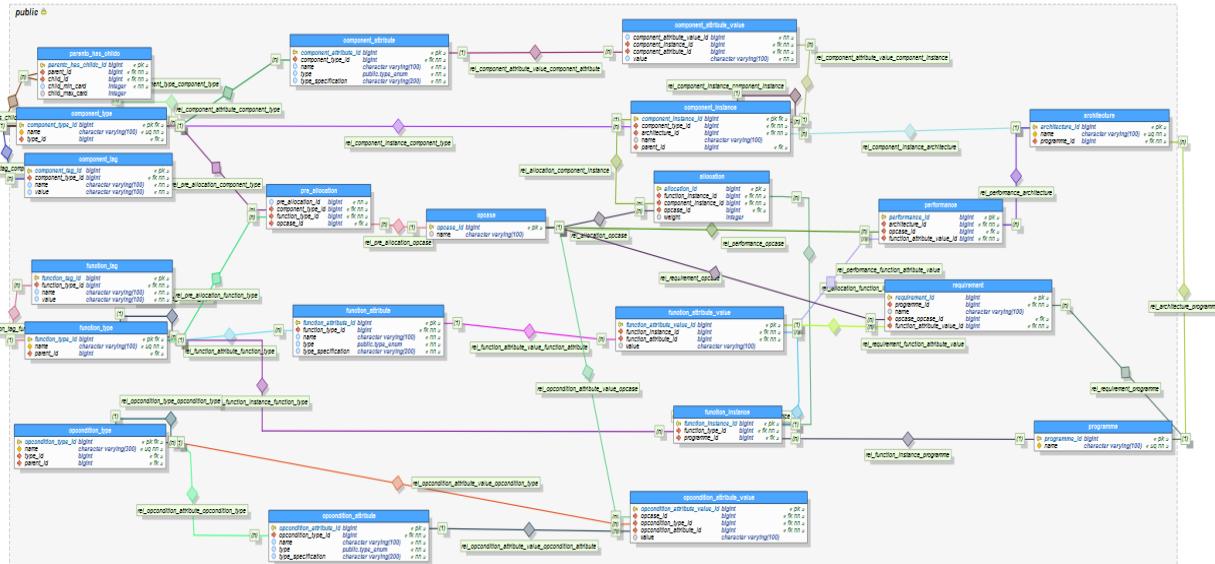


Process modelling elements

- Study
- Convergence Layer

Views

- Architecture refinement
- Value delta



SKETCHING A CASE STUDY

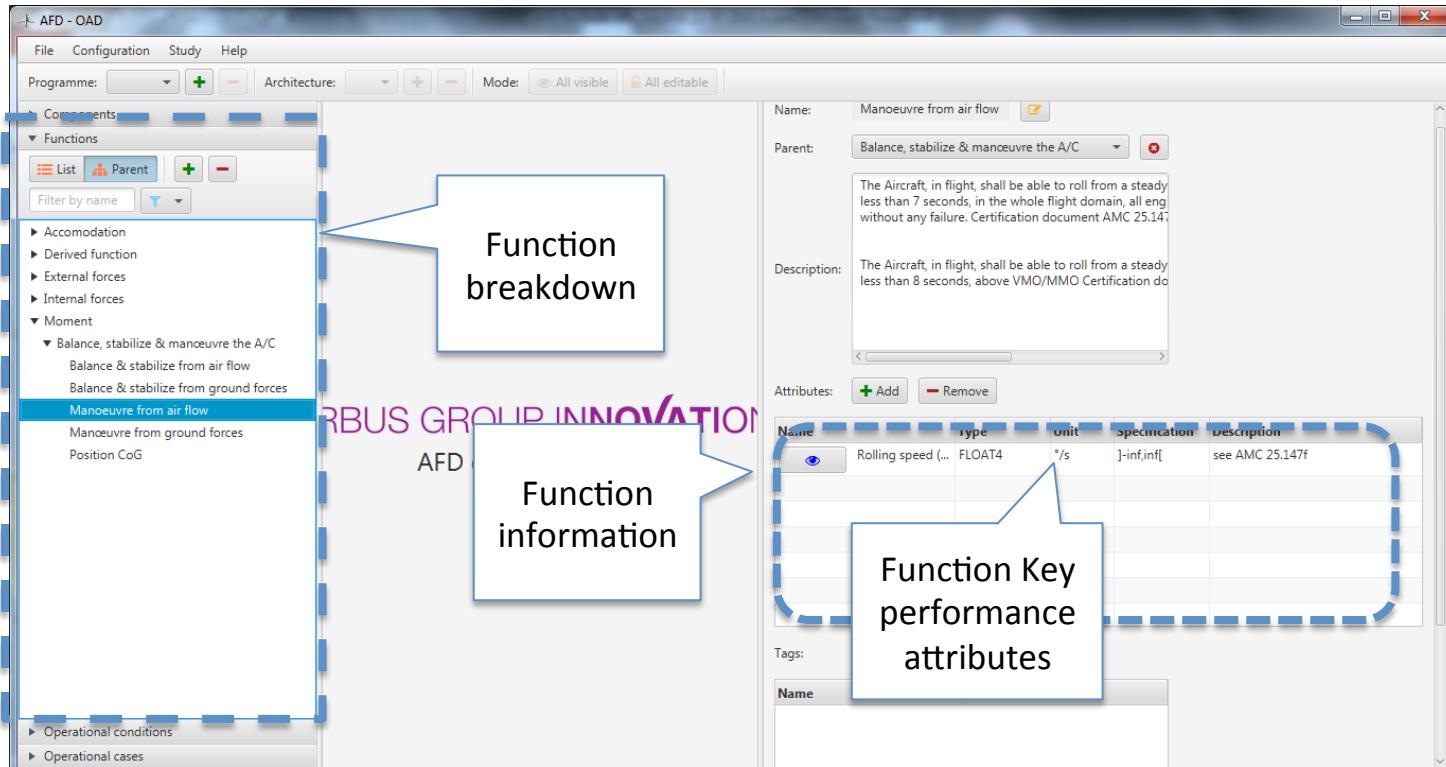
User driven prototyping – agile - to sketch a process and to test our ideas

No fully mature tools but rather ideas to be handed over R&T

Dictionary: Function breakdown



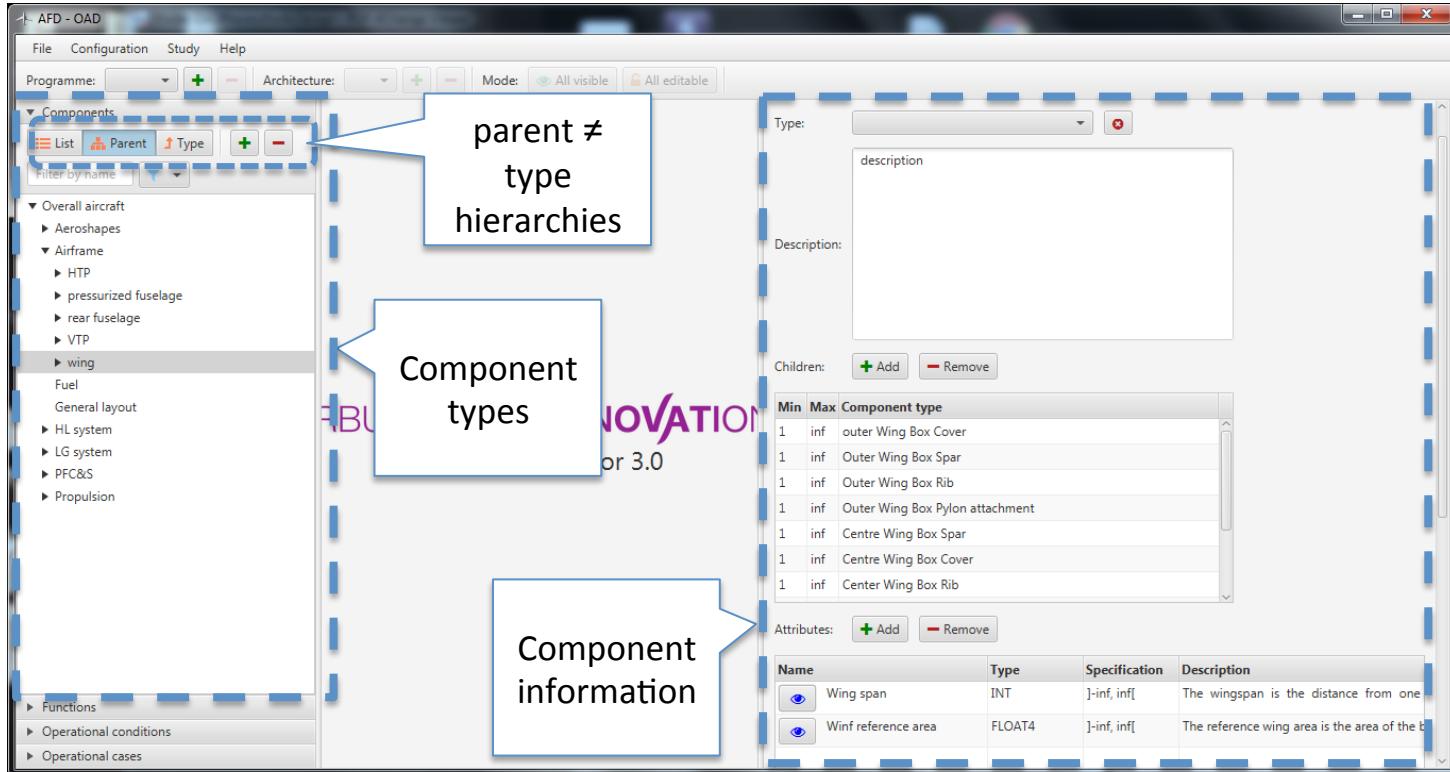
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The screenshot shows the AFD - OAD software interface. On the left, the 'Functions' tree view is expanded, showing categories like 'Accommodation', 'Derived function', 'External forces', 'Internal forces', and 'Moment'. Under 'Moment', 'Balance, stabilize & manoeuvre the A/C' is selected, which further branches into 'Balance & stabilize from air flow' and 'Balance & stabilize from ground forces'. A blue box labeled 'Function breakdown' points to this tree view. The main central area displays a function card for 'Manoeuvre from air flow'. The card includes fields for 'Name' (Manoeuvre from air flow), 'Parent' (Balance, stabilize & manoeuvre the A/C), 'Description' (The Aircraft, in flight, shall be able to roll from a steady less than 7 seconds, in the whole flight domain, all eng without any failure. Certification document AMC 25.147), and 'Attributes' (Rolling speed, FLOAT4, unit °/s, specification J-inf, inf, description see AMC 25.147f). A blue box labeled 'Function information' points to the description and attributes sections. Another blue box labeled 'Function Key performance attributes' points to the attribute table. The interface has a header bar with 'File', 'Configuration', 'Study', 'Help', and various mode buttons. The bottom navigation bar includes 'Programme', 'Architecture', 'Mode', 'All visible', and 'All editable' buttons.

Integration definition (IDEF)
for Function modeling
framework

Dictionary: Components



parent ≠ type hierarchies

Component types

Component information

AFD - OAD

File Configuration Study Help

Programme: + - Architecture: + - Mode: All visible All editable

Components

Overall aircraft

- ▶ Aeroshapes
- ▶ Airframe
 - ▶ HTP
 - ▶ pressurized fuselage
 - ▶ rear fuselage
 - ▶ VTP
- ▶ wing

Fuel

General layout

- ▶ HL system
- ▶ LG system
- ▶ PFC&S
- ▶ Propulsion

Functions

Operational conditions

Operational cases

Type: description

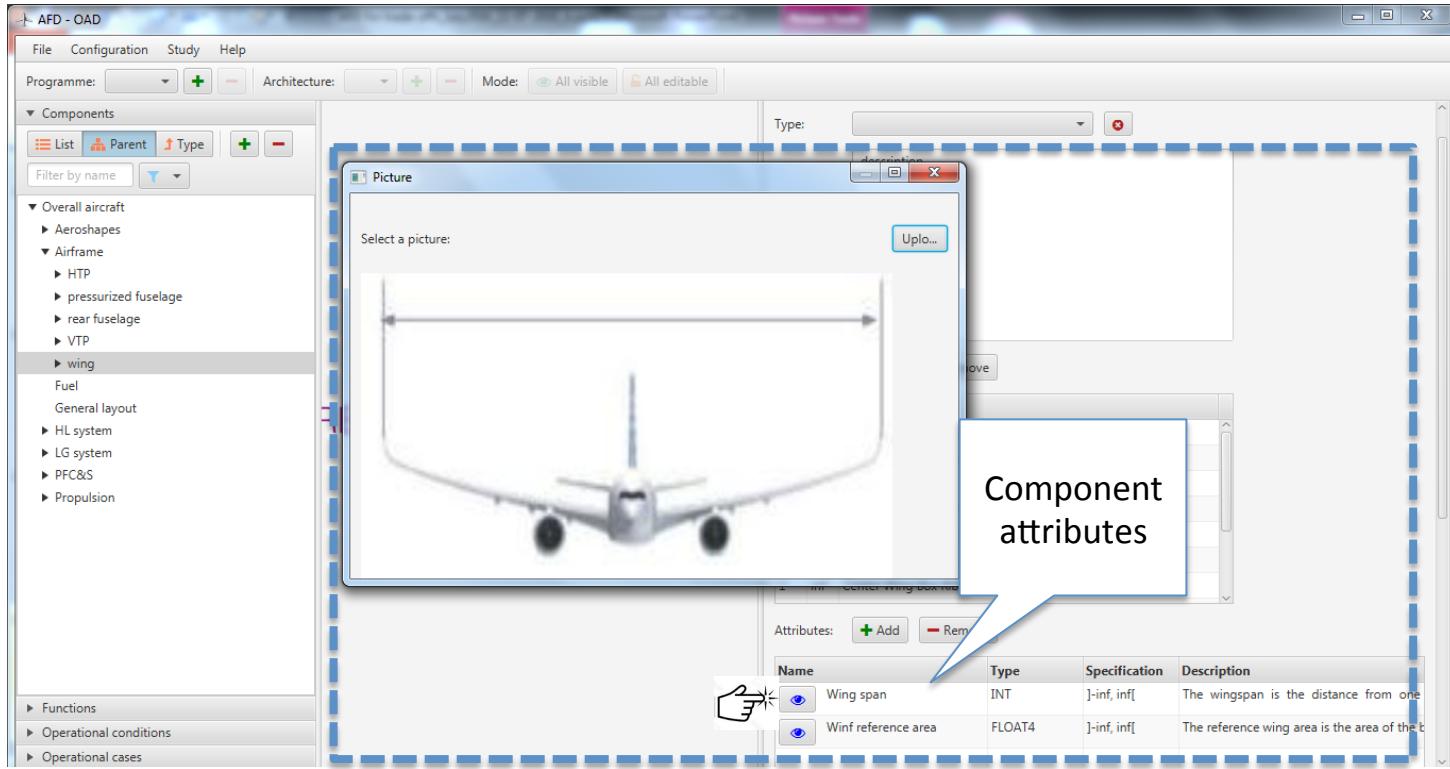
Children: + Add - Remove

Min	Max	Component type
1	inf	outer Wing Box Cover
1	inf	Outer Wing Box Spar
1	inf	Outer Wing Box Rib
1	inf	Outer Wing Box Pylon attachment
1	inf	Centre Wing Box Spar
1	inf	Centre Wing Box Cover
1	inf	Center Wing Box Rib

Attributes: + Add - Remove

Name	Type	Specification	Description
Wing span	INT	J-inf, inf[The wingspan is the distance from one
Winf reference area	FLOAT4	J-inf, inf[The reference wing area is the area of the b

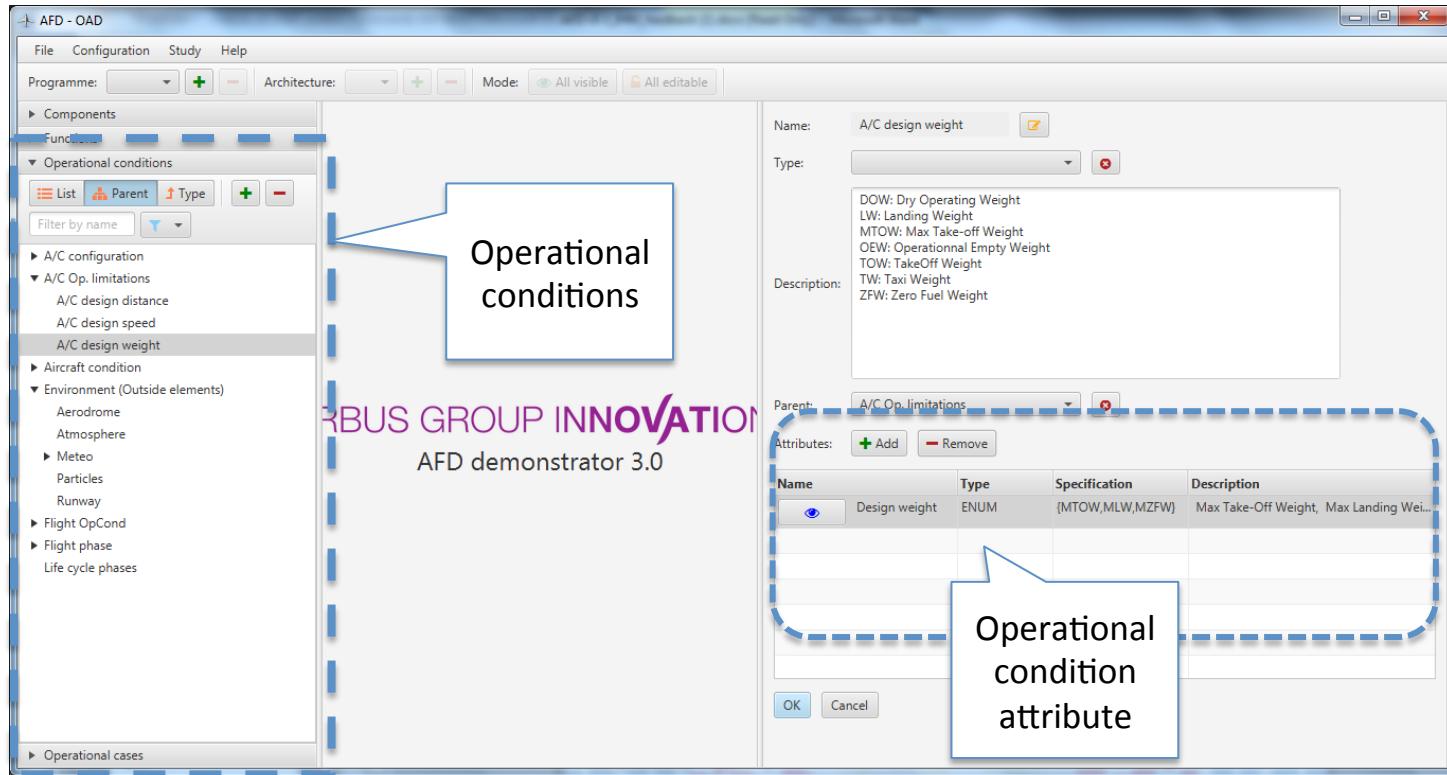
Dictionary: Component key characteristics



Component attributes

Name	Type	Specification	Description
Wing span	INT]-inf, inf[The wingspan is the distance from one wing tip to the other
Wing reference area	FLOAT4]-inf, inf[The reference wing area is the area of the b...

Dictionary: Operational conditions

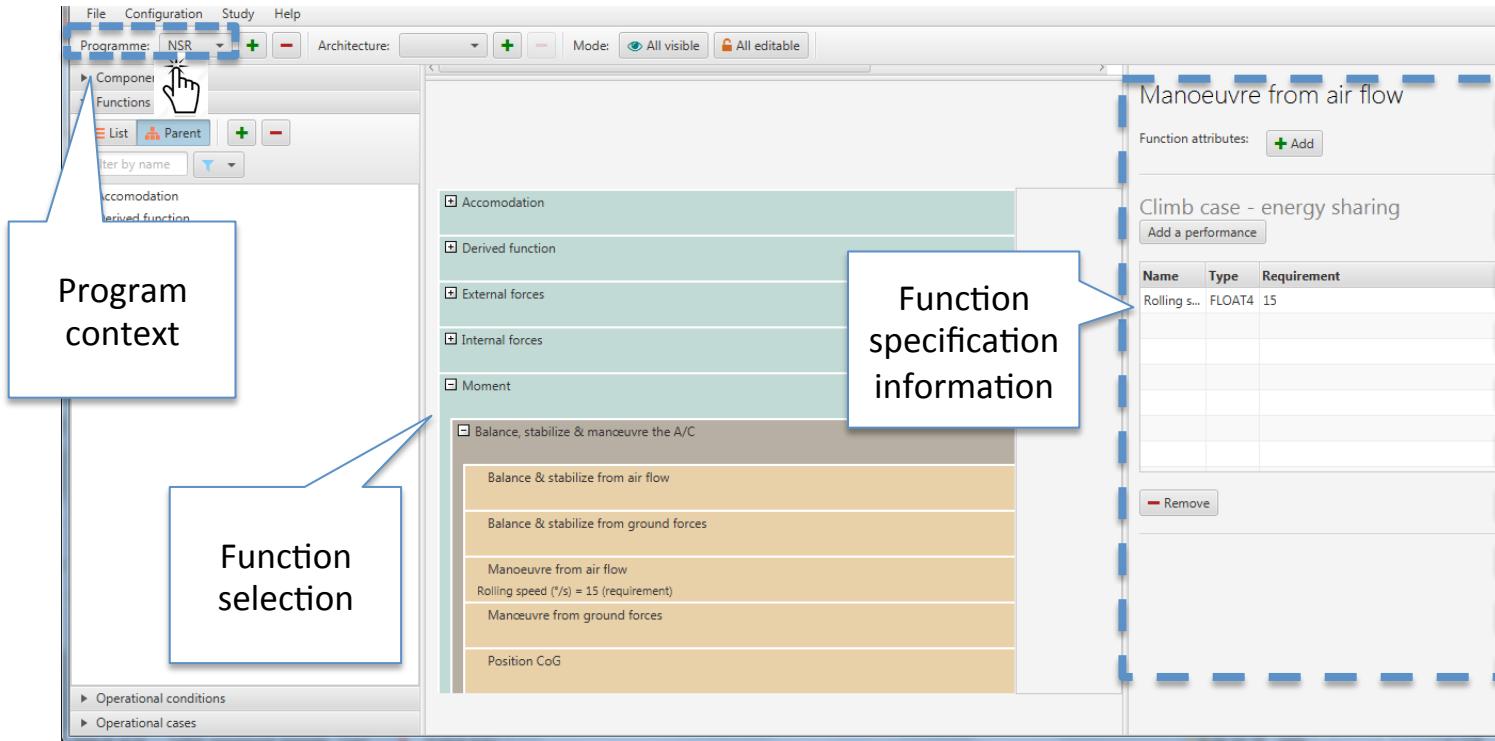


The screenshot shows the AFD - OAD software interface. The left sidebar lists various categories: Components, Functions, Operational conditions, A/C configuration, A/C Op. limitations, A/C design distance, A/C design speed, A/C design weight, Aircraft condition, Environment (Outside elements), Meteo, Flight OpCond, Flight phase, and Life cycle phases. The 'Operational conditions' category is expanded, and 'A/C design weight' is selected. The main panel displays a detailed view of 'A/C design weight' with the following information:

- Name: A/C design weight
- Type: (dropdown menu)
- Description: DOW: Dry Operating Weight
LW: Landing Weight
MTOW: Max Take-off Weight
OEW: Operational Empty Weight
TOW: TakeOff Weight
TW: Taxi Weight
ZFW: Zero Fuel Weight
- Parent: A/C Op. limitations
- Attributes: (button to add or remove)
- Table: A table showing the attribute 'Design weight' with values: Name (Design weight), Type (ENUM), Specification (MTOW,MLW,MZFW), and Description (Max Take-Off Weight, Max Landing Weight).

A callout box labeled 'Operational conditions' points to the 'Operational conditions' category in the sidebar. Another callout box labeled 'Operational condition attribute' points to the table in the main panel.

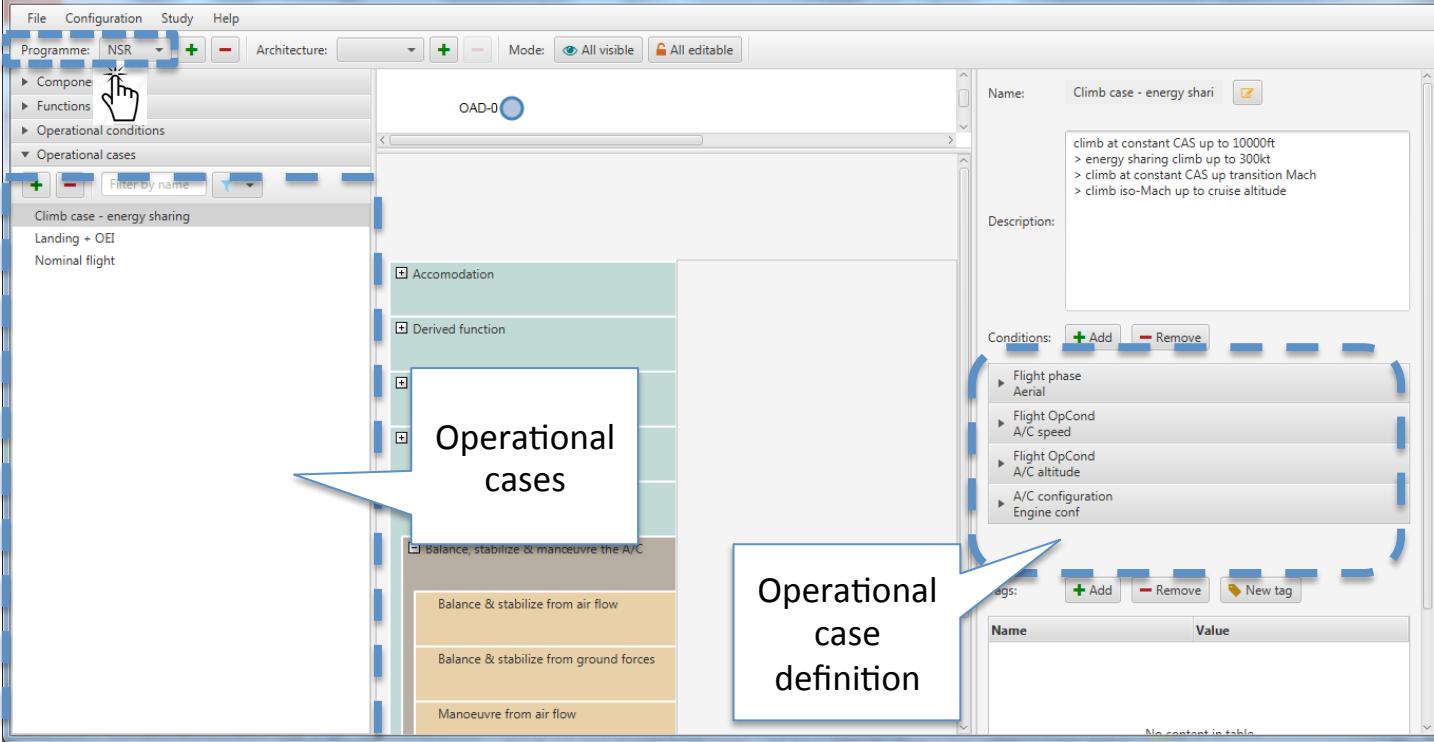
Specification: Functional requirements



From requirements

Performance values dependent on OpCases

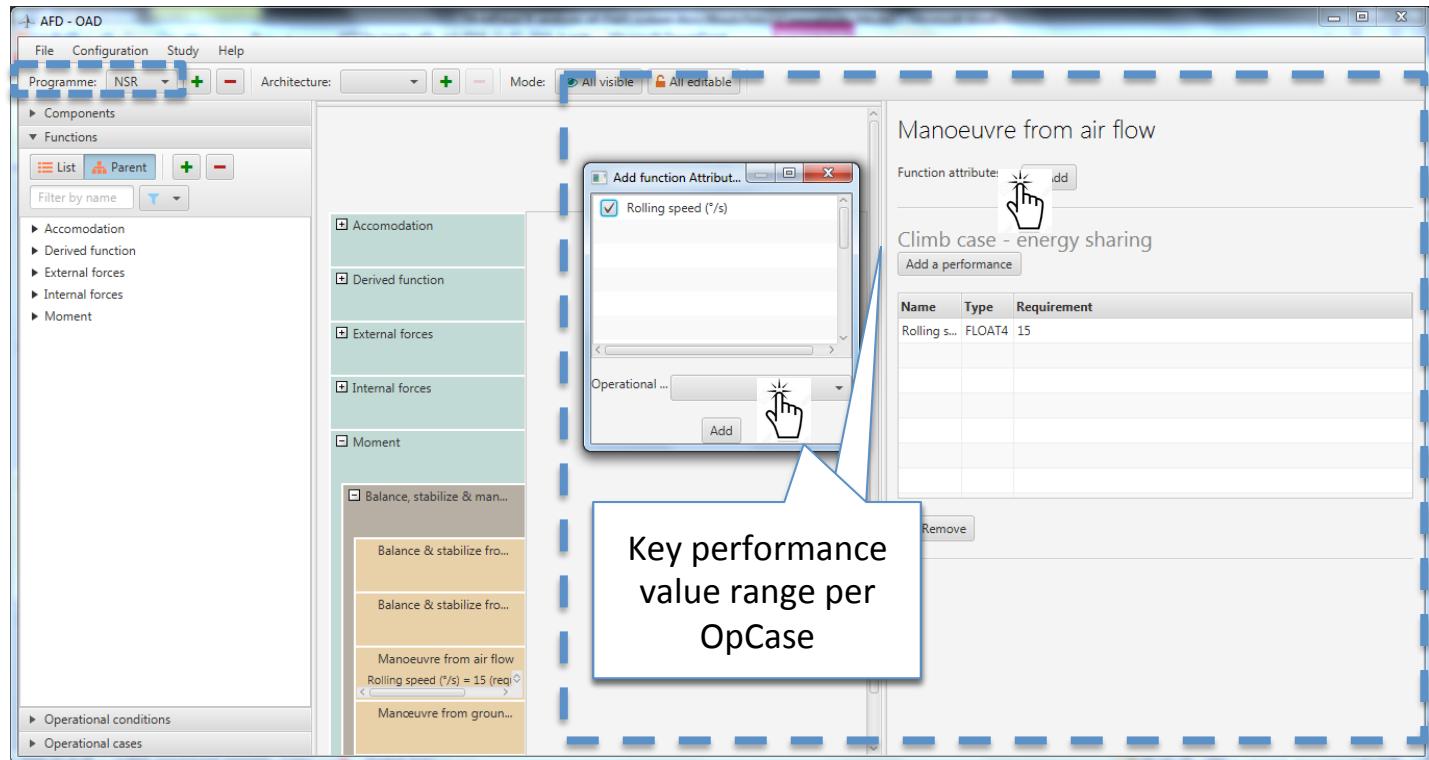
Specification : Sizing operational cases



The screenshot shows the INCOSE Configuration Management software interface. The top menu bar includes File, Configuration, Study, and Help. The left sidebar shows a tree structure with 'Programme: NSR' selected, and categories like Components, Functions, Operational conditions, and Operational cases. The main workspace displays an OAD-0 diagram with a central 'Accommodation' block and several 'Operational cases' blocks. One 'Operational cases' block is highlighted with a blue border and contains sub-blocks: 'Balance, stabilize & manoeuvre the A/C', 'Balance & stabilize from air flow', 'Balance & stabilize from ground forces', and 'Manoeuvre from air flow'. A callout box labeled 'Operational cases' points to this block. Another callout box labeled 'Operational case definition' points to the right-hand panel, which shows a detailed view of a selected operational case: 'Climb case - energy sharing'. The panel includes fields for Name (Climb case - energy sharing), Description (climb at constant CAS up to 10000ft > energy sharing climb up to 300ft > climb at constant CAS up transition Mach > climb iso-Mach up to cruise altitude), Conditions (Flight phase Aerial, Flight OpCond A/C speed, Flight OpCond A/C altitude, A/C configuration Engine conf), and Tags (Name, Value). Buttons for Add, Remove, and New tag are also present.

OpCase = set of selected OpCond attributes (possibly valued)

Specification: Functional requirements



Key performance value range per OpCase

Manoeuvre from air flow

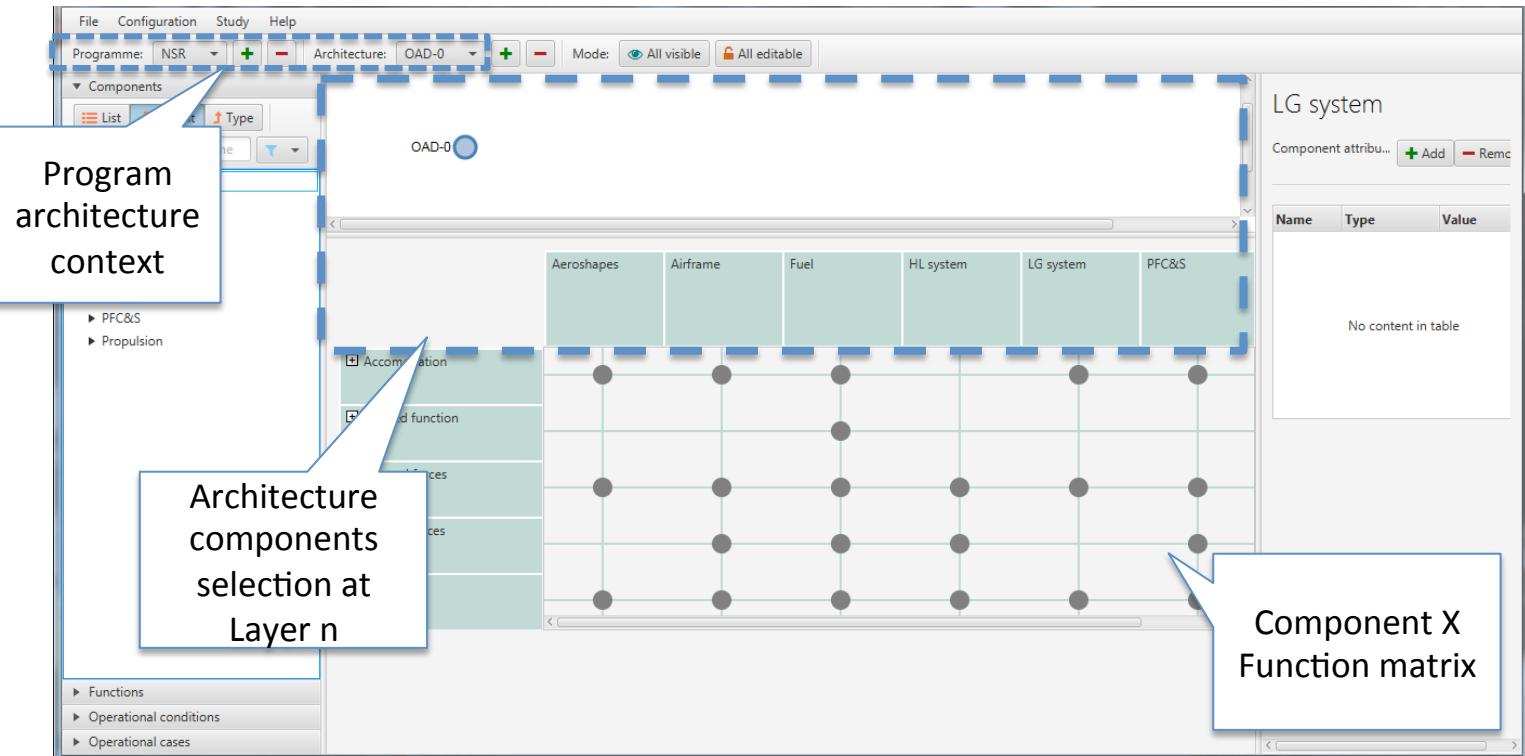
Function attribute: Rolling speed (*/s)

Climb case - energy sharing

Add a performance

Name	Type	Requirement
Rolling s...	FLOAT4	15

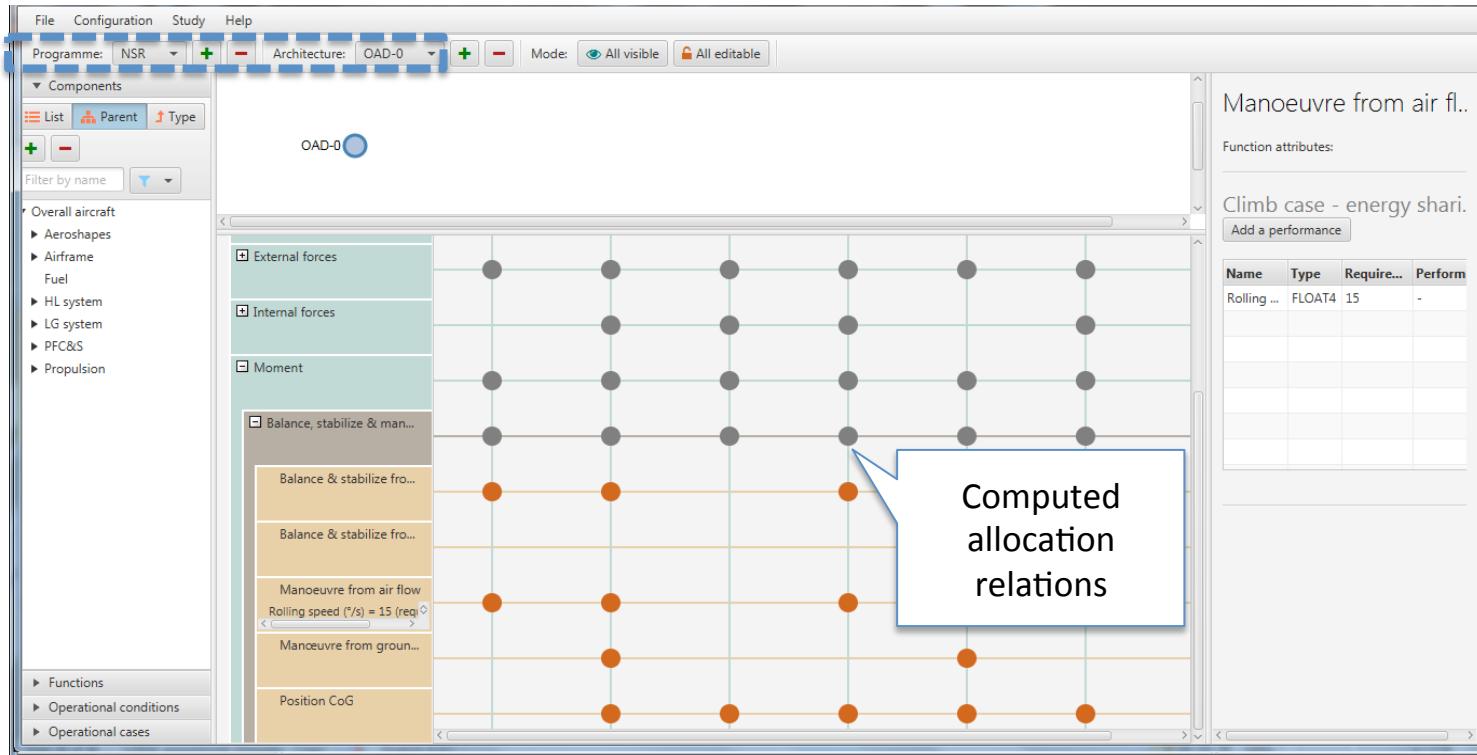
Architecture: Component X Function matrix



That architecture Component is sized for...

That architecture Component contributes to...

Architecture: Component X Function matrix



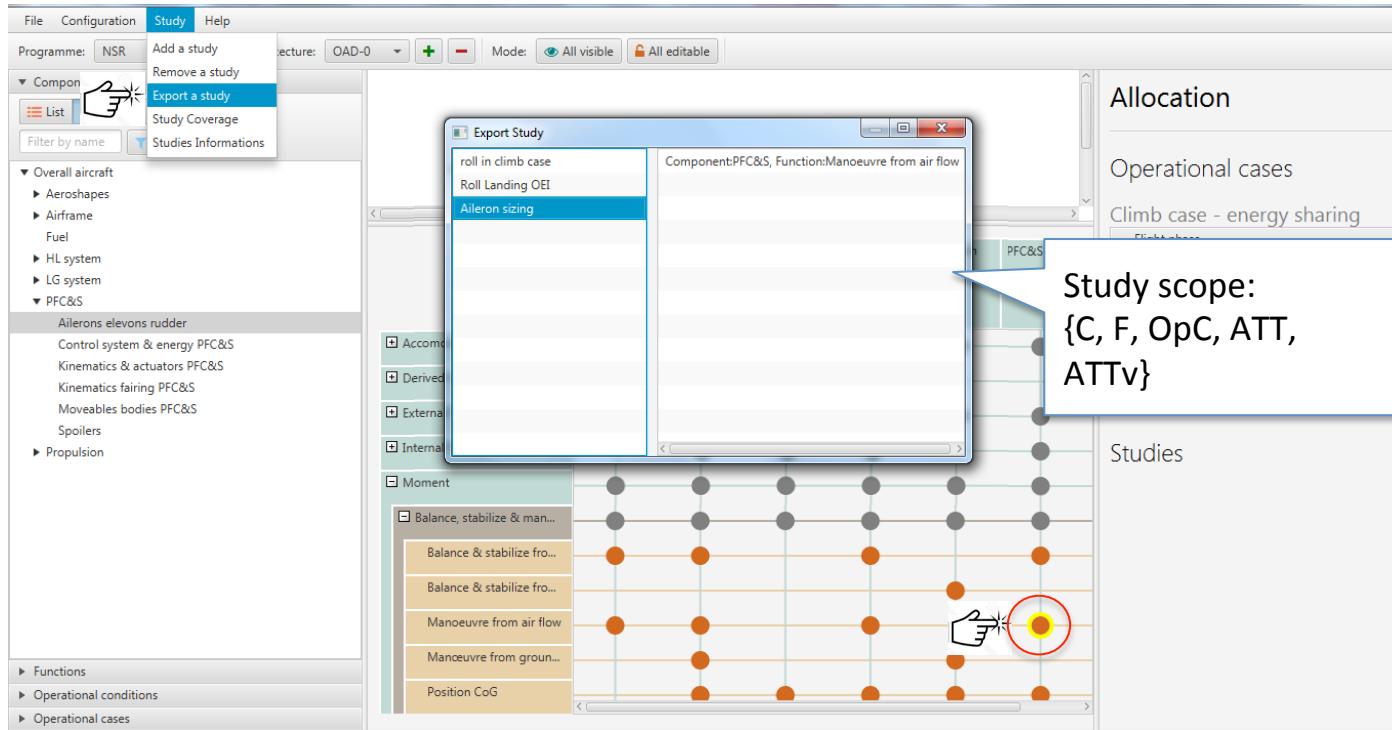
That architecture Component is sized for...

That architecture Component contributes to...

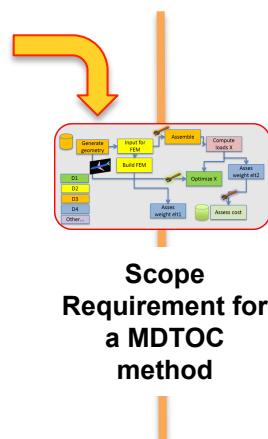
Export Study scope requirements



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Study scope: {C, F, OpC, ATT, ATTv}

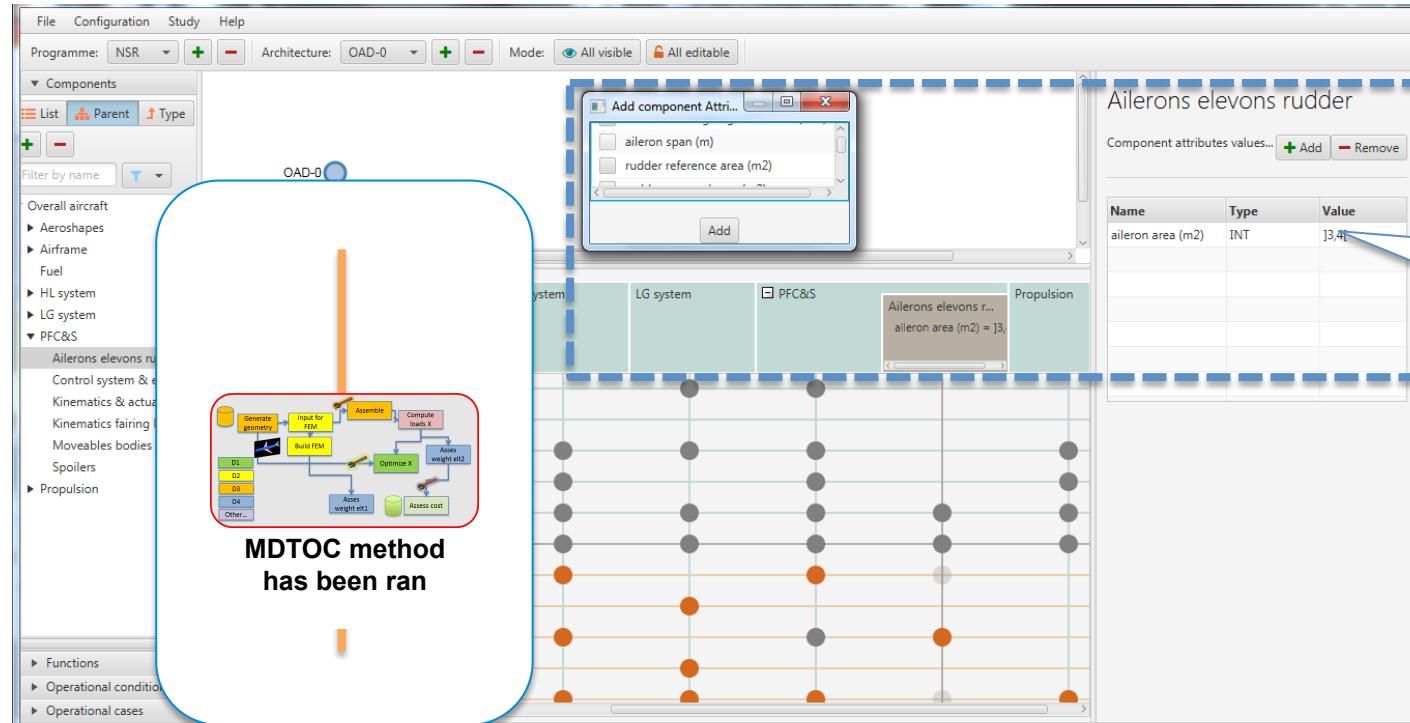


Import attribute estimated values

(Static, discrete as in DBD)
Links to figures, models...



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File Configuration Study Help

Programme: NSR + - Architecture: OAD-0 + - Mode: All visible All editable

Components

OAD-0

Overall aircraft

- Aeroshapes
- Airframe
- Fuel
- HL system
- LG system
- PFC&S
 - Ailerons elevons r...
 - Control system & e...
 - Kinematics & actu...
 - Kinematics fairing
 - Moveables bodies
 - Spoilers
- Propulsion

Functions

Operational conditions

Operational cases

MDTOC method has been ran

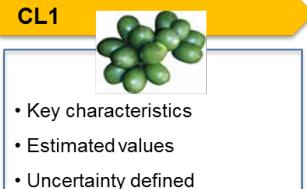
Add component Attr... aileron span (m) rudder reference area (m2) Add

Ailerons elevons rudder

Component attributes values + Add - Remove

Name	Type	Value
aileron area (m2)	INT	13.41

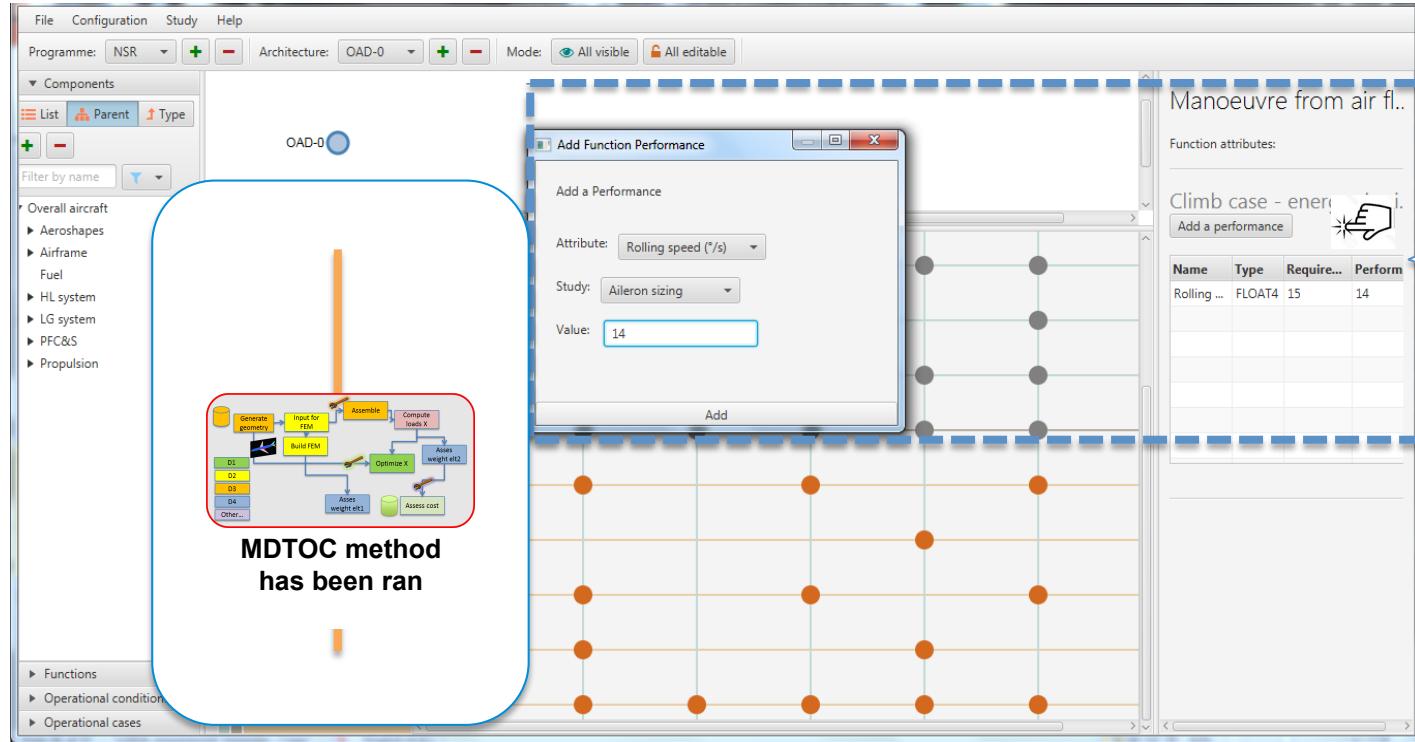
Component CL1
Key characteristic
sized in Study



Import attribute estimated values



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MDTOC method has been ran

Function attributes:

Name	Type	Require...	Perform...
Rolling ...	FLOAT4	15	14

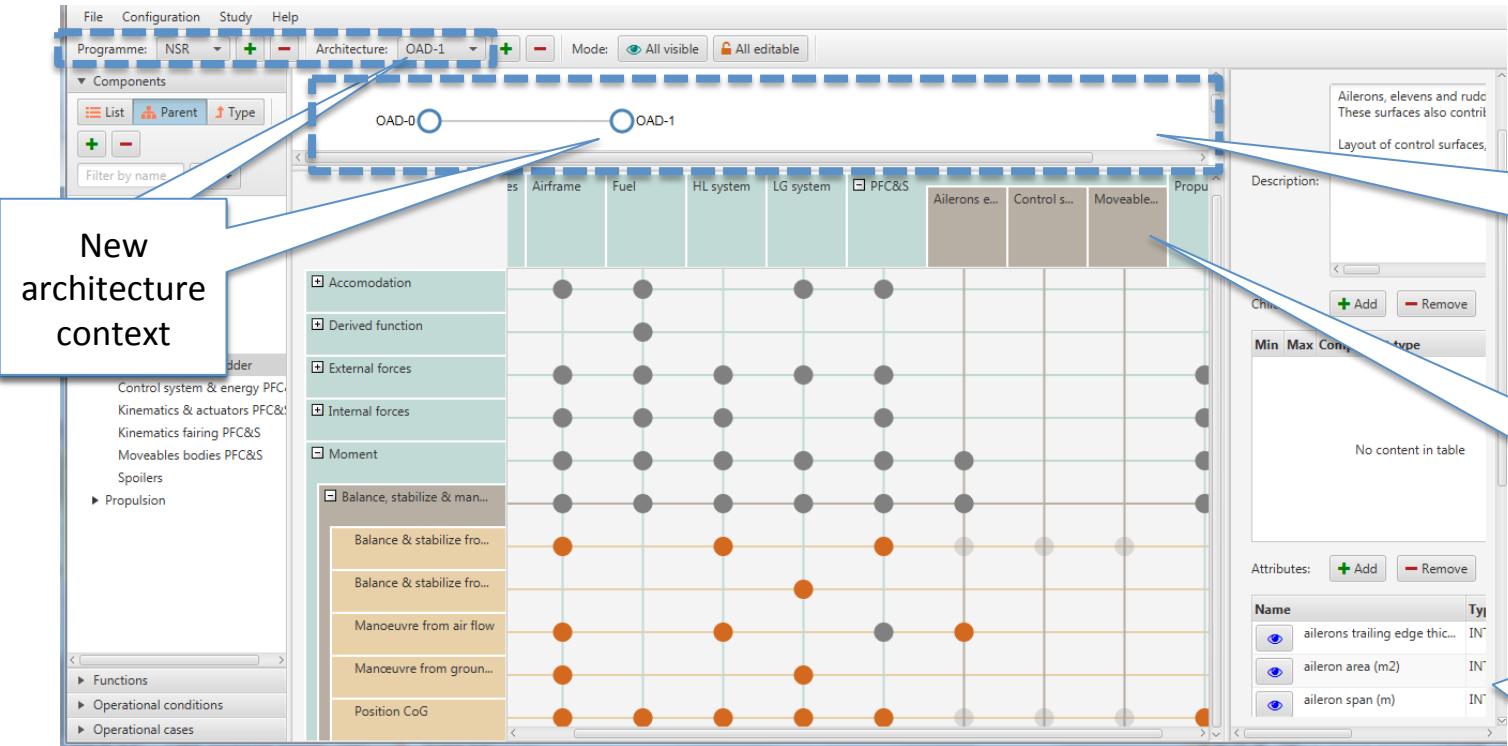
Function Key performance per OpCase estimated values in Study

CL1

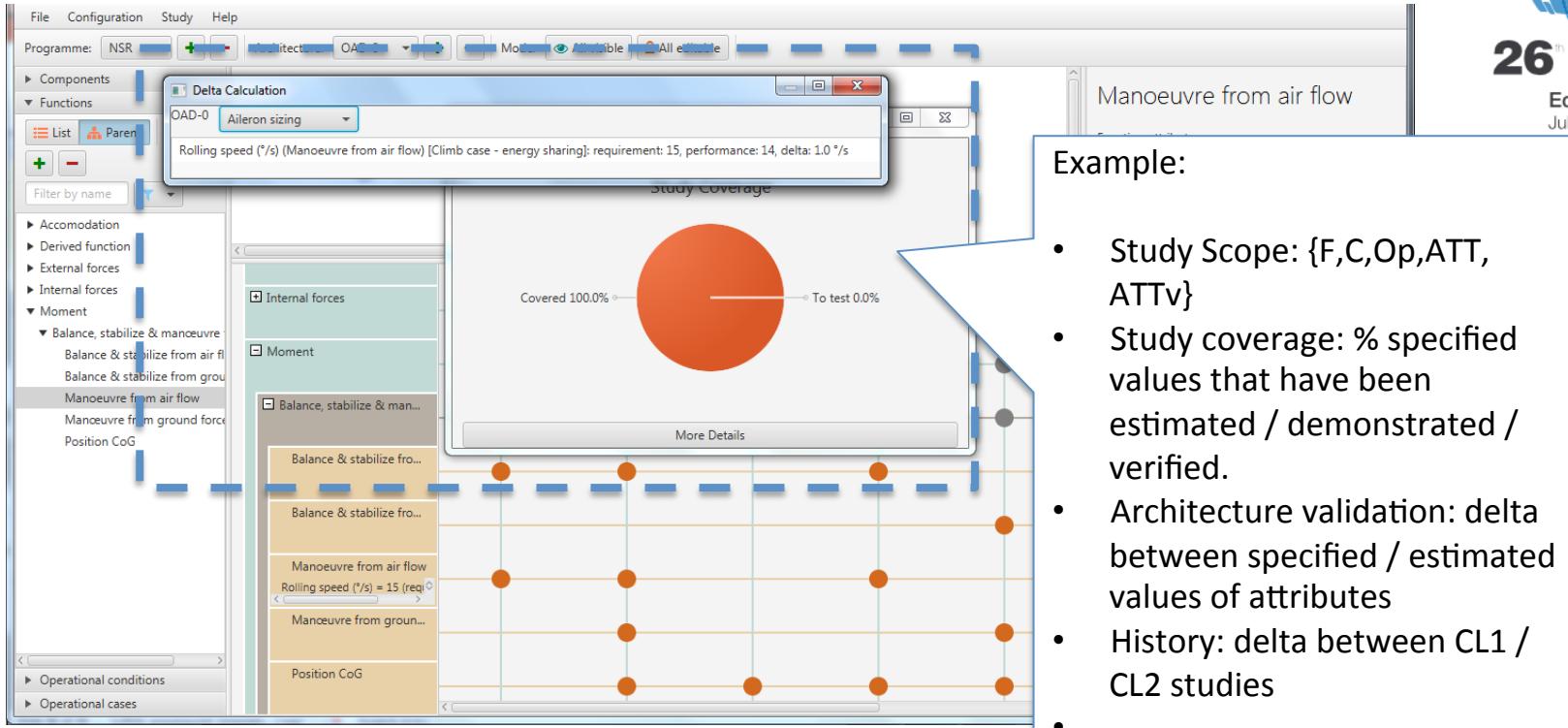


- Key characteristics
- Estimated values
- Uncertainty defined

Refine architecture at next CL n+1



History, progress possible KPIs



The screenshot shows the INCOSE Architecture Analysis tool interface. On the left, a tree view of system components and functions is displayed. In the center, a 'Study Coverage' diagram features a large orange circle representing the study scope, with text indicating 'Covered 100.0%' and 'To test 0.0%'. Below the diagram is a 'More Details' button. On the right, a 'Delta Calculation' dialog box is open, showing a table for 'Manoeuvre from air flow' with columns for 'Requirement', 'Performance', and 'Delta'. The table includes rows for 'Climb case - energy sharing' and 'Manoeuvre from air flow' (with a note 'Rolling speed (°/s) = 15 (req)'). A blue callout box points from the 'Delta Calculation' dialog to the 'Manoeuvre from air flow' row in the table. The bottom of the slide features a decorative footer with colored squares.

Example:

- Study Scope: {F,C,Op,ATT, ATTv}
- Study coverage: % specified values that have been estimated / demonstrated / verified.
- Architecture validation: delta between specified / estimated values of attributes
- History: delta between CL1 / CL2 studies
- ...

SUMMARY

Parting thoughts

Reusable knowledge, reproducible processes...

- product development layer / architect organization
- MDTOC methods (~automatize)
- Function breakdown
- Component libraries
- ...



Flexibility

- New technology == new Component subtypes, with new characteristics
- Key attributes list open
- OpCases definitions

Potential

- A rich Attribute model for architecture convergence
- Opportunity for applying data analytics method / relevant dash-board, monitoring views for the architects
- Information integration with requirements as a potential

Parting thoughts



 ICT	Provide the IT infrastructure
 Methods	Manage consistent dictionaries, architecture knowledge....
 Architect	Define the component overall virtual architecture. Launch, coordinate and drumbeat MDTO studies
 MDTOC leader, M&S	Define the component trade-off capability, M&S means and granularity of the demonstrated values
 Designers	Run studies and give back information on parts impacted by the change (replaced and introduced)

