Département Simulation Numérique des écoulements et Aéroacoustique

RELEASE REPORT

elsA version V3.3

/ELSA/PVL-09002

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1.DESCRIPTION OF THE COMPLETE ELSA RELEASE

The *elsA*/V3.3 release is first composed of the *elsA* kernel and its companion Python-*elsA* interface. The (CFD) capabilities of the *elsA* kernel may be extended by additional modules. The currently existing modules are the following :

- the `Ael` module devoted to fluid/structure coupling (including the `Lur` sub-module devoted to Euler or Navier-Stokes linearized equations) ;
- the `Opt` module devoted to gradient computation for shape optimization.
- The use of Python-*elsA* interface is described in :
- /ELSA/MU-98057/V3.3 : User's Reference Manual
- /ELSA/MU-05038/V1.0 : User's Reference Manual for the `Ael` module
- /ELSA/STB-09025/V1.0 : MT and MU for elsA Opt shape optimisation module

In the framework of the software configuration management, the *elsA* kernel and the Python-*elsA* interface are identified by the version number V3.3 associated to production version number 3.3.06 and to CVS tag : I3306o.

The *elsA*/V3.3 release also includes the following additional (user-oriented) tools :

- the `merger` tool : tool to merge blocks (useful after computation to concatenate splitted result files) ;
- the `transPrepare` tool : tool to prepare the transition-related additional files ;
- the `adim_lib` tool : tool to help the user to define normalization ;
- the `elsa_io` : tool allowing data processing and used by several of the previous tools.

The use of these tools is described in :

- /ELSA/MU-06023/V1.0 : Additional Tools User's Manual

In the framework of the software configuration management, the versions of all these tools are identified by the same CVS tag : I3306o.

The *elsA*/V3.3 release is also composed of KCore, Converter, Generator, Geom, Post and Transform python modules (which were not present in *elsA*/V3.2)::

- Kcore : common library, required for the other modules Converter, Post, Geom, Generator and Transform.
- No documentation is provided (no python function) ;
- Converter : converts files to arrays, CGNS trees, creates new CGNS trees,...
- The user guide is /ELSA/MU-09020 (Converter Module v1.4 – User Guide)
- Geom : builds some simple geometries.

☐ The user guide is /ELSA/MU-09021 (Geom Module v1.4 – User Guide)

☐Generator : creation of meshes, information on meshes.

☐ The user guide is /ELSA/MU-09022 (Generator Module v1.4 – User Guide).

☐Transform : modification of meshes.

☐ The user guide is /ELSA/MU-09023 (Transform Module v1.4 – User Guide)

☐Post : post-processing tool, dedicated to Chimera computations.

☐ The user guide is /ELSA/MU-09024 (Post Module v1.4 – User Guide)

In the framework of the software configuration management, the version of these external modules (managed by SVN tool) is identified by a specific version number 1.4.

The *elsA*/V3.3 release includes additional tools for dedicated (coupling) applications, such as :

☐the pyHOST tool for coupling *elsA* with HOST for helicopter aeromechanics applications (specific version number V1.0)

The *elsA*/V3.3 release is also composed of the `elsAxdt` Python-CGNS interface used for input and output of in-memory CGNS compliant trees and for coupling with external tools.

The use of this Python-CGNS interface is described in :

☐/ELSA/MU-02052/V2.0 : Python/CGNS interface for *elsA*.

In the framework of the software configuration management, the version of this Python-CGNS interface (managed by SVN tool) is identified by a specific version number 5.30.

The additional tools (`merger`, `transPrepare`, `adim_lib` , `elsa_io`), the `elsAxdt` interface and the python modules `KCore`, `Converter`, `Generator`, `Geom`, `Post` and `Transform` are supported tools and modules.

Finally the elsA/V3.3 release offers some functionnalities that may use and some that require the use of the open source USURP. Surface loads integration is necessary, either for solution post-processing or for aeroelasticity calculations. When using Chimera grids, surface loads integration is not straightforward, and the *elsA* users have to be informed that double definition of walls may lead to wrong values of surface loads if integration is carried out twice in the overlapping regions. Therefore, when surface grids overlap, correct surface loads integration requires either reconstruction of wall surface grids or use of weight for overlapping cells.. The *Zipper* function developed by S. Péron in the *Post* module allows the post-processing of Chimera overlapping solutions. A single unstructured grid is generated from the set of overset structured surface grids. The USURP function of the *Post* module is an alternate capability to do this type of post-processing by using weight for overlapping cells. Aeroelasticity calculations using Chimera overlapping grids (new capability of version V3.3) also rely on the USURP function.

This USURP function is not released by Onera to the *elsA* users, since USURP is an open source licensed by the Pennsylvania State University. The license has to be asked to Mr. David A. Boger (Applied Research Laboratory, The Pennsylvania State University). Note that some slight modifications done by the DADS department to USURP software for aeroelasticity calculations with Chimera grids must also be taken into account.

The Web documentation (http://elsa.onera.fr) includes the following elements, updated for this main release :

- general information on software ;
- the User's Manuals ;
- the Validation Report /ELSA/PTST-98088

If you want paper copies of some of the User's Manuals, please ask us.

2.EVOLUTIONS OF THE ELSA KERNEL

We describe here the main evolutions of the *elsA* kernel between version V3.3 and previous release version V3.2.

2.1.Modelling capabilities

2.1.1.Turbulence modelling for RANS equations

- Explicit algebraic heat flux model based on EARSM k-kl model (L. Dupland/H. Bezard/H. Gaible, DMAE)
- Buoyancy effects in transport equation based on EAHFM/EARSM k-kl model (L. Dupland/H. Bezard/ H. Gaible, DMAE)
- Compressibility and density gradient effects in SST Menter (H. Bezard/H. Gaible, DMAE)
- DRSM associated with multistage BC (R. Houdeville, DMAE)
- DRSM association with motion (R. Houdeville, DMAE)

2.1.2.Calculation of distances

- Allow walldistance extraction before computing loop (A. Couilleaux, DSNA)
- Allow turbulent computation without computing walldistance (A. Couilleaux, DSNA)

2.1.3.Transition

☐Transition criterion for unsteady flows (R. Houdeville, DMAE)

☐Transition criterion taking into account several typical roughness shapes (R. Houdeville, DMAE)

2.1.4.Detached Eddy Simulation (DES)

☐Delayed DES (V. Brunet, DAAP)

2.1.5.Other modeling capabilities

☐First elements of Time Spectral Method for periodic unsteady flows (F. Sicot/G. Puigt, Cerfacs)

☐BAY model for Vortex Generator (V. Brunet, DAAP / B. Michel, DSNA)

☐Equilibrium real gas (limited, in this release, to inviscid and laminar flows, with a limited range of boundary types [sym, insup, outsup, wallslip, walladia, wallisoth]) (C. Marmignon/M. Gazaix, DSNA)

2.2.Boundary conditions

☐Mixing plane BC in absolute formulation (P. Raud, DSNA)

☐Inlet or outlet rotating or translating distortion user map (G. Ngo Boum, LMFA)

☐Blade count reduction stage with multigrid (S. Plot, DSNA)

☐Aeroelastic chorochronicity in absolute variables (A. Dugeai, DADS)

☐Chorochronicity stage condition in absolute variables (S. Plot, DSNA)

2.3.Mesh capabilities

☐Split omega_file (M. Gazaix, DSNA)

☐'nomatch' extended for sliding-mesh for non-axi casing treatment and interface between two rows (M. Montagnac, Cerfacs)

☐Chimera connectivity write/read (F. Blanc/B. Landsmann, Cerfacs)

☐Topologic masks (J. Delbove, Airbus)

☐Extended definition of psi (JC. Boniface, DAAP)

☐Chimera Implicit Hole Cutting preprocessing (F. Blanc/B. Landmann, Cerfacs)

☐Chimera Patch Assembly (F. Blanc/B. Landmann, Cerfacs)

☐Chimera associated with nomatch joins near masked cells (G. Jeanfaivre/P.Raud, DSNA)

☐Chimera and chorochronicity for non axi casing treatment (L. Castillon, DAAP)

2.4.Numerics

☐Ausmp & Van Leer with moving frame and/or deformation (B. Michel, DSNA)

☐DTS/Gear second order restart (only for fixed meshes) (M. Gazaix, DSNA)

☐Ausmp scheme associated with nomatch/nearmatch join (B. Michel, DSNA)

☐3rd order RBC schemes for steady problems and match joins (B. Michel, DSNA)

☐3rd order RBC schemes with rotation terms (B. Michel, DSNA)

☐3rd order RBC schemes for irregular meshes (B. Michel, DSNA)

☐Metrics restriction on coarse grid instead of metrics computation (Airbus)

☐2nd order exact restart for RBC scheme (B. Michel, DSNA)

2.5.Fluid/structure capabilities

☐Lur compatibility with NS, backward-euler and lussor (J. Delbove, Airbus)

☐Lur with skew-symetric fluxes (J. Delbove, Airbus)

☐Additional terms for Lur Navier-Stokes (E. Canonne, DADS)

☐Ael chorochronicity with LUSSOR (A. Dugeai, DADS)

☐Lur improvements : linearized mass flow condition, CPU optimisation, 5p_cor option for viscous_fluxes, directional option for timestep_type

☐Chimera and static fluid-structure coupling (Ph. Girodroux-Lavigne, DADS)

☐Lur + nomatch (E. Canonne, DADS)

2.6.Shape optimization capabilities

☐Complements Opt k-eps (F. Renac, DSNA)

☐Linearization of Michel model (CT. Pham, DSNA)

☐Derivative of an aerodynamic quantity J with respect to mesh X (J. Peter, DSNA)

☐Adjoint for helicopter applications (A. Dumont, DAAP)

2.7.Extractions

☐Mach and turVar Hessian extractions (X. de Saint Victor, DMAE)

☐Cellfict extractions in absolute frame (A. Couilleaux, DSNA)

☐Intermittency extraction in 3D field (R. Houdeville, DMAE)

☐Cell number in boundary layers extraction (R. Houdeville, DMAE)

- ☐Extractions at a given iteration (A. Couilleaux, DSNA)
- ☐Local fluxes or local residuals available with an extractor (M. Gazaix, DSNA)
- ☐Extractions for analysis of Chimera calculations (F. Blanc, Cerfacs)
- ☐Soundspeed extract (S. Dhifi, DSNA)

2.8.New associations

2.9.Parallelization of CFD capabilities

- ☐Transition criteria in parallel MPI (R. Houdeville)

2.10.Python-elsA interface

The following items (with no explicit attribution) are by M. Lazareff (DSNA).

- ☐Python user-defined callback function (M. Gazaix, DSNA)
- ☐Improved grouping of related attributes in Python-elsA interface and documentation (URM)
- ☐Augmented contextual rules (for checking and default value)
- ☐User-side filtering of attributes/values (removal of some possibly "dangerous" choices when using `--filter` command-line argument)
- ☐"user-horizon" for management of automatically set default values
- ☐User-side wrapping of the `register_py_callback()` kernel function, providing table-driven definition of smooth parameter variations (see URM p. 93-94)
- ☐`provide()` method for coherent management of automatically built objects in application-specific classes
- ☐machine type dependent default value for `NOLOG` parameter (involved in logfiles and stantard output messages), and associated `ELSA_NOLOG` environment variable
- ☐improved management of script databases (for traceability and parametric variations)
- ☐improved parametric variations (`variator` class, `--user_config` and `--case_dir` command-line arguments ...)
- ☐improved "target lift" computations (`target_lift` class)

Please refer to /ELSA/MU-98057 v3.3 ("URM v3.3") for details, and specifically to "Important changes in elsA version 3.3" in the Introduction, p. 12.

Some attribute names and values are now obsolete since v3.2 (lookup `--allow_obsolete` in the URM for management).

The output of the `man('elsA')` call may be useful to compare elsA interface versions, see URM v3.3 p. 74.

2.11.Operational features

2.11.1.Performances

☐Flux calculation on nomatch joins without ghost grids (M. Montagnac, Cerfacs)

☐Memory reduction for nomatch (M. Montagnac, Cerfacs)

☐Message scheduling for nearmatch joins (C-S)

☐CPU reduction for high number of blocks (M. Gazaix, DSNA)

2.11.2.Portability

☐IBM Blue Gene (M. Montagnac, Cerfacs)

2.12.Validation

The validation base corresponding to the elsA/V3.3 contains about 195 cases. The validation has been performed on the NEC-SX8 in sequential mode (nec production) and on Galibier (bull_mpi production, between 2 and 32 processors) in parallel mode.

24 cases have been added to the validation data base. 4 cases have been splitted into configuration depending on new fonctionnalities, these sub-cases have been compared to each others.

An abstract of these additions is described on the table below but a complete description of the Validation concerning the release V3.3 is available on the Validation report.

Name		Specific capabilities	Configuration
Blunt3D-RealGas		Steady real gas flow	Blunt Cylinder 3D
CASING-NM		Channel with simulated casing: Axisymmetric - Nomatch - unsteady - Wilcox model	Channel with simulated casing. Steady subsonic turbulent viscous flow.
Plate-Keps-v2f		K-epsilon v2f turbulent model	2D flat plate
naca_underwall	Config 1	Cartesian elements and infinite plane masks	Shockless inviscid flow on a NACA0012 under a wall - 2 domains (two dimensional configuration)
	Config 2	Parallelepiped and infinite plane masks	
	Config 3	Implicit Hole Cutting algorithm	

	Config 4	Patch Assembly algorithm	
IHT-MULTIMODEL	Config 1	Smagorinsky model with selective function	Homogeneous isotropic turbulence (HIT) with free decaying. Periodicity applied on all the boundaries of the cubic box
	Config 2	Smagorinsky model without selective function	
	Config 3	Structure function model	
	Config 4	Filtered structure function model	
RAE-KO-LU-SST-SCHEME	Config 1	AUSMP flux	transonic turbulent flow around a 2-D profile - NS + (k-omega) Kok version model with SST correction
	Config 2	Jameson flux	
	Config 3	RBC scheme order 2	
	Config 4	RBC scheme order 3	
	Config 5	RBC scheme irregular	
S3CH-MS-01		Fan inlet massflow	S3Ch configuration : Swept wing section between two walls + pylon and powered nacelle
WingM6-KO-SST-SCHEME	Config 1	AUSMP flux	M6 wing. Steady transonic turbulent viscous flow
	Config 2	Jameson flux	
	Config 3	RBC scheme order 2	
	Config 4	RBC scheme order 3	
	Config 5	RBC scheme irregular	
WingM6-Michel-Lin		Linearization of Michel \& al. turbulent model	M6 Wing 1972 - 3D config Steady transonic turbulent viscous flow Gradient computation: linearized method
WingDefRoeAdj		14 design variables. Computed on 32 processors	M6 wing Steady transonic turbulent viscous flow Gradient computation: Adjoint method

2.13. Corrections / limitations

The list of the « Problem Reports » fully treated since the release of version V3.2 and having induced modifications of source or documentation may be read on the *elsA* Web site in the Problem Report data base.

3.ADDITIONAL (USER-ORIENTED) TOOLS

3.1.Evolution of the tools

The capability to partition blocks in parallel MPI including block splitting (`Split` additional module) has been improved in version V3.3 . More precisely, the new capabilities are the following :

☐Split capability : splitter can be used with MPI executable on 1 processor (M. Gazaix, DSNA)

☐split chimera mask (M. Gazaix, DSNA)

☐split DES information (M. Gazaix, DSNA)

☐extension for nomatch and nearmatch (M. Gazaix, DSNA)

☐memory reduction (M. Gazaix, DSNA)

☐high number of splitted blocks (M. Gazaix, DSNA)

☐split actuator and force files (M. Gazaix, DSNA)

4.ELSAXDT PYTHON-CGNS INTERFACE AND ADDITIONAL TOOLS FOR DEDICATED COUPLING APPLICATIONS

4.1.Evolution

The module elsA`xdt` developed by M. Poinot (DSNA) has been further extended since *elsA*/V3.2 release. This module allows input and output of in-memory CGNS compliant trees, and is used for coupling with external tools.

The main evolutions in v5.30 are the Multi-Base capabilities and and extended use of the families. The Chimera is managed now using these two features, it makes it possible to define a complete multi-base Chimera computation in a full CGNS file.

4.2.Validation

The listing of tests of the specific validation base of `elsAxdt` module is included in the User's Manual /ELSA/MU-02052/V2.0.

5. KCORE, CONVERTER, GENERATOR, GEOM, TRANSFORM AND POST

These modules are new modules which were not present in *elsA*/V3.2.

6.CAPABILITIES OF ELSA/V3.3 SOFTWARE

6.1.List of capabilities

The main capabilities available in version V3.3 of *elsA* are described in the table below, using the following abbreviations.

Topics abbreviation	Meaning	State abbreviation	Meaning
MOD.	Modelling capabilities	V	Validation tests
B.C.	Boundary Conditions	VNB	Validation tests (not in validation bases)
MESH	Mesh capabilities	P	Preliminary tests
NUM.	Numerics	F	First tests (preliminary implementation)
RUN	Calculation run	NT	Not tested
		NA	Not available in this version

Table 5 – Meaning of abbreviations

Topics	Capability	State
MOD.	Michel et al. turbulence model (adaptations to turbomachinery and helicopter rotor configurations)	V
MOD.	Baldwin-Lomax turbulence model	V
MOD.	Spalart-Allmaras 1-equation model (basic model, rotation and curvature effects, roughness effects)	V
MOD.	k-ε 2-equation model (Jones-Launder, Launder-Sharma, Chien, high Reynolds formulation, SST correction, two-layer formulation with a 1-equation model)	V
MOD.	Smith k-l 2-equation model (basic model, roughness effects)	V
MOD.	k-ω 2-equation model (Wilcox, Zheng limiter, Menter, SST correction, cross-diffusion term, roughness effects)	V
MOD.	k-φ 2-equation model	P
MOD.	k-kl 2-equation model	V
MOD.	k-ν 2-equation model	V
MOD.	Durbin v2f turbulence model	V
MOD.	Multi-scale (MKFLC2) 4-equation model	V
MOD.	ASM model (formulations : one-layer and two-layer with a 1-equation model)	V
MOD.	EARSM models : Wallin-Johansson model and DMAE model	VNB
MOD	EAHFM/EARSM k-kl model	
MOD.	DRSM-SSG model	VNB

Topics	Capability	State
MOD.	Initialization options of turbulence variables from laminar flow, from eddy viscosity field, from other transport equation model, from "1 point over 2" mesh	V
MOD.	Transition : intermittency file, local criterion or non-local criterion	V
MOD.	Several options for wall distance calculation	V
MOD.	Wall laws options	V
MOD.	Detached Eddy Simulation (DES97, ZDES, DDES)	VNB
MOD.	Large Eddy Simulation (LES) subgrid models : Smagorinsky, Wale, filtered structure function	V
MOD.	Moving frame ("absolute velocity" and "relative velocity" formulations)	V
MOD.	1D, 2D plane, 2D axisymmetric (without or with source terms)	V
MOD.	Unsteady flow	V
MOD.	ALE method (including soft blade capabilities)	V
MOD.	Gravity term	V
MOD.	Scully vortex	NT
MOD	BAY model for vortex generator	V
MOD/NUM	Low velocity preconditioning	V
MOD.	Aeroelastic capabilities : Harmonic forced motion, static and dynamic fluid-structure static coupling	V
MOD.	Linearized Euler equations	V
MOD.	Linearized Navier-Stokes equations	F
MOD.	Shape optimization : calculation of the gradient of the objective, either by the direct differentiation method or by the adjoint state vector	V
B.C.	Wall conditions : several slip options, non-slip conditions (adiabatic, isotherm, prescribed heat flux)	V
B.C.	Subsonic/supersonic inlet/outlet conditions (including inlet local massflow condition and outlet local/global conditions)	V
B.C.	Improved non-reflexion condition for aeroacoustics	VNB
B.C.	Synthetic jet condition	VNB
B.C.	Far-field condition, with or without Froude velocities, with flight or wind-tunnel conditions	V
B.C.	Vorticity condition (2-D calculations)	V
B.C.	Radial equilibrium and winnow conditions for turbomachinery flows	V
B.C.	Aeroelastic wall B.C.	V
B.C.	Porosity and "full cooling" conditions	VNB
B.C.	Conditions describing the effect of a gridding or a honeycomb	VNB

Topics	Capability	State
B.C.	"Generalized" boundary conditions : wall, inlet, non-reflexion	V
B.C.	"Collect" boundary (collection of unstructured sub-boundaries)	V
B.C./MESH	Actuator disc conditions for helicopter rotor and for aircraft propeller	V
B.C./ MESH	Multi-stage steady or unsteady, (blade count reduction and chorochronicity), for turbomachinery flows	V
B.C./ MESH	Chimera and chorochronicity for non axi casing treatment	VNB
B.C./ MESH	Non matching sliding-mesh for non-axi casing treatment and interface between two rows	VNB
MESH	Structured multi-block : coincident match, partially coincident match, quasi-conservative non-coincident match	V
MESH	Structured multi-block : non-coincident match with coincident lines	V
MESH	Periodicity condition (translation or rotation)	V
MESH	Chimera technique	V
NUM.	Centered (divergence or skew-symmetric form) or Upwind (van Leer, Roe, Coquel-Liou, AUSM) fluxes	V
NUM.	Scalar or matrix artificial dissipations for centered schemes (including damping capabilities inside boundary layers)	V
NUM.	Limiters for upwind schemes : minmod, van Albada, van Leer, superbee, 3rd order	V
NUM.	SLIP and CUSP schemes	NT
NUM.	First-order or second-order (Roe-type artificial viscosity) centered fluxes for turbulence transport equations	V
NUM.	Calculation of gradients for dissipative terms : calculation on cell centers without or with corrections on interfaces, calculation on interfaces	V
NUM.	Time integration : Runge-Kutta, backward Euler, Gear, dual time stepping	V
NUM	3rd order RBC schemes for steady problems and match joins	V
NUM	3rd order RBC schemes with rotation terms	VNB
NUM	3rd order RBC schemes for irregular meshes	V
NUM.	Implicit Residual Smoothing with ADI, scalar or matrix implicit methods with LU-RELAX or LU-SSOR inversion	V
NUM.	Multigrid acceleration method	V
NUM.	Local multigrid for Hierarchical Mesh Refinement	V
RUN	Target lift	VNB
RUN	Parallel calculations (MPI library)	V
RUN	Split and merge capabilities	VNB
RUN	Module for data extraction/exchange of CGNS compliant trees	V

Table 6 - List of capabilities

6.2.Association of capabilities

The following table gives some indications on available or not-available association of capabilities. It is not an exhaustive list.

Association of capabilities	State	Comment
Transition + moving frames	Yes	
Wall laws + moving frames	Yes	
Wall laws + deforming meshes	Yes	

Turbulent computation without computing walldistance	Yes	Only with :
		– k-epsilon (Jones Launder or Launder Sharma)
		– k-omega wilcox model :
		  – without SST correction
		  – with SST correction without using walldistance
		  – pseudo roughness for omega wall boundary condition.
		Without transition.

BAY model for vortex generator on several mesh blocks	No	
DRSM + blade count reduction stage condition	Yes	
DRSM + chorochronicity stage condition	Yes	
DRSM + Chimera and chorochronicity for non axi casing treatment	Yes	
Low velocity preconditioning + actuator-disc	Yes	Actuator disc match treatment is mandatory.
Low velocity preconditioning + inlet conditions	Yes	
Low velocity preconditioning + moving frames	Yes	Some robustness problems may appear.
Low velocity preconditioning + upwind schemes	Yes	Only with Roe scheme.
Blade count reduction stage condition + absolute formulation in moving frame	No	
Chimera and chorochronicity for non axi casing treatment + absolute formulation in moving frame	No	
Chimera and chorochronicity for non axi casing treatment + Masks	No	

Association of capabilities	State	Comment
Chimera and chorochronicity for non axi casing treatment + additional Chimera blocks (elsewhere than in the casing)	No	
Chimera and chorochronicity for non axi casing treatment + turbulence modelling using wall distance	No	
Chimera and chorochronicity for non axi casing treatment + 1 interpolation cell layer	Yes	
Time Spectral Method + chorochronicity condition	No	
LU-RELAX or LU-SSOR + moving frames with/without deformation	Yes	
LU-RELAX or LU-SSOR + low velocity preconditioning	Yes	Limited to LU-scalar methods.
LU-Relax or LU-SSOR + Dual Time Stepping or Gear	Yes	
ALE + Dual Time Stepping	Yes	
ALE + Chimera	Yes	
Chimera + multigrid	Yes	Advice : "extrapolation without blanking"
Chimera + DRSM	Yes	Limited to double rank of interpolation
Chimera + periodicity	Yes	Some limitations in parallel mode.
Multigrid + `stage_mxpl` condition	Yes	
Multigrid + blade count reduction stage condition	Yes	
Multigrid + chorochronicity	Yes	Loss of accuracy when restart.
Parallel + turbulence modeling	Yes	Except Michel et al. model adapted to specific configurations
Parallel + transition	Yes	
Parallel + wall laws	Yes	
Parallel + Froude condition	Yes	
Parallel + actuator-disc	Yes	Actuator disc match treatment is mandatory.
Parallel + mass-flow boundary conditions	Yes	
Parallel + match/nearmatch/nomatch	Yes	
Parallel + Chimera technique	Yes	Limitation for “multiple wall definition” has been removed in version V3.2
Parallel + radial equilibrium condition	No	
Parallel + `stage_mxpl` condition	Yes	Limitation on bloc distribution when associated with multigrid technique.

Association of capabilities	State	Comment
Parallel + Chimera and chorochronicity for non axi casing treatment	No	
Parallel + blade count reduction stage condition	No	
Parallel + chorochronicity stage condition	No	

Table 7 - Association of capabilities