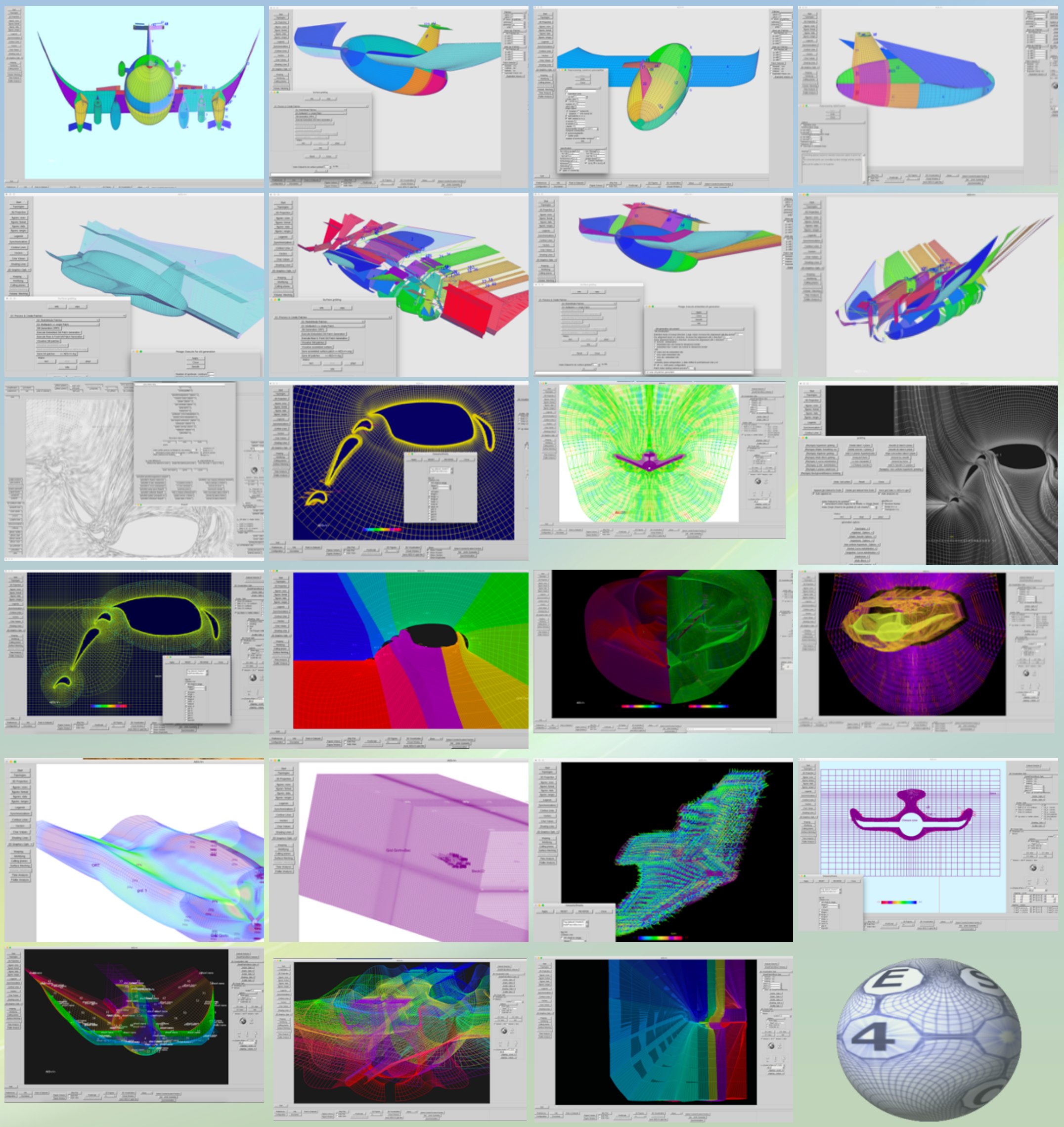
Meshing around with AES=V=

Michael H.L. Hounjet



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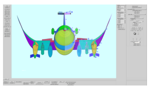


Summary

This report demonstrates the surface mesh design/ generation and volume mesh generation methods embedded in AES=V=. Surface meshes of complete aircraft can be designed/generated easily ab initio with AES=V= and forms the basis of volume mesh generation.

The AES=V= mesh generation methods can deal with arbitrary two-dimensional shapes (aerofoils and arbitrary cross sections) and three-dimensional shapes. The mesh applications are easy to use for engineers, the processes are easily repeatable, robust and fast.

AES=V= incorporates a very flexible surface mesh generation avoiding unacceptably large turn-around times, especially when dealing with design, certification and qualification studies and modifications/installation effects.

AES=V= incorporates a powerful and fast volume mesh generation tool, reckoning with aerodynamic, hydrodynamic and aeroelastic applications and a low level of effort at work-floor level.

AES=V= is a tool directed to the analysis, the pre-processing and postprocessing involved in aerodynamics, hydrodynamics and aeroelasticity. AES=V= is straightforward to use and applies the GLUI user interface library (Version 2.36). It embeds 2D and 3D visualization, warping (representation of mode shapes on aerodynamic meshes from the structural meshes), mollifying (data enhancing/morphing), surface mesh design & generation, volume mesh generation (single block, multiple blocks, tetrahedron/prism and chimera connection), time analysis and modal flutter analysis.

Nomenclature

AES=2=	General two-dimensional unsteady lifting surface method
AES=W=	Subsonic two-dimensional lifting surface method modelling ventilated windtunnel walls.
AES=3=	General three-dimensional unsteady lifting surface aerodynamic method
AES=O=	General three-dimensional steady and unsteady body aerodynamic, hydrodynamic and acoustic method in bounded and unbounded flows
AES=V=	Aeroelastic multipurpose method
CFD	Computational Fluid Dynamics
CHIMERA	Overlapping mesh connector
DEA	Domino Effect Approach
LCO	Lift Carry Over plane
FSI	Fluid Structure Interaction
GLUI	User Interface Library
LE	Leading Edge Patch (front edge, green)
PS	Portside Edge Patch (red)
SS	Starboard Edge Patch(blue)
TE	Trailing Edge Patch (rear edge, yellow)
DIA	Double sided upstream connector patch
WAKE	Double sided downstream connector patch
SLIT	Double sided connector patch
r	Mesh coordinate
s	Patch coordinate
t	Patch coordinate
i	Patch index along s
J	Patch index along t
k	Mesh index along r
nb	Number of blocks
ni	Number of points along s

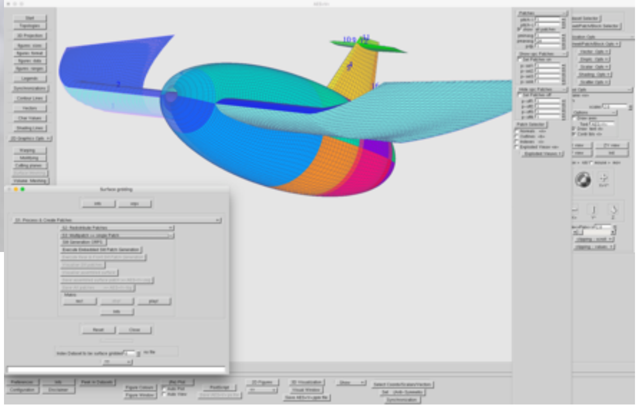
1 Introduction

This report demonstrates the surface mesh design/ generation and volume mesh generation methods embedded in AES=V=. Surface meshes of complete aircraft can be designed/generated easily ab initio with AES=V= and forms the basis of volume mesh generation.

AES=V= is a tool directed to the analysis, the pre-processing and postprocessing involved in aerodynamics, hydrodynamics and aeroelasticity. AES=V= is straightforward to use and applies the GLUI user interface library (Version 2.36). It embeds 2D and 3D visualization, warping (representation of mode shapes on aerodynamic meshes from the structural meshes), mollifying (data enhancing/morphing), surface mesh design & generation, volume mesh generation (single block, multiple blocks, tetrahedron/prism and chimera connection), time analysis and modal flutter analysis.

Mesh generation is of fundamental importance in all CFD simulations but it is especially so in aeroelasticity as the efficient application of computer methods to determine the unsteady flow poses specific requirements to the meshes and the mesh generating procedures. Furthermore, in aerodynamics based on the Navier-Stokes equations the situation is very demanding due to the required smoothness of the mesh in the stream-wise directions and due to the relatively small spacing required in the direction normal to the flow near the wall and in the wake. Also mesh quality affects accuracy and convergence rate of numerical solutions.

AES=V= incorporates a very flexible surface mesh generation avoiding unacceptably large turn-around times, especially when dealing with design, certification and qualification studies and modifications/installation effects. AES=V= keeps the geometrical description of the wetted surface at a flexible level by the use of a network of patches containing discrete sets of coordinates and offers basically two ways which can be combined:

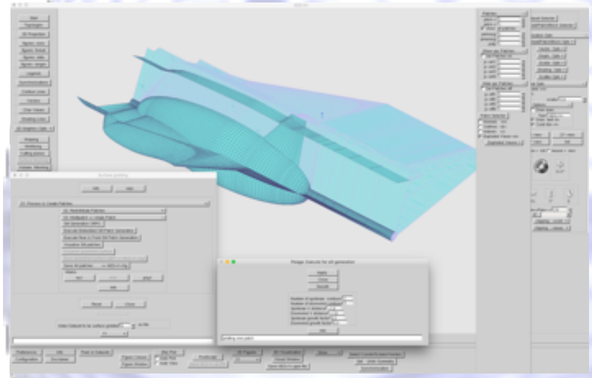


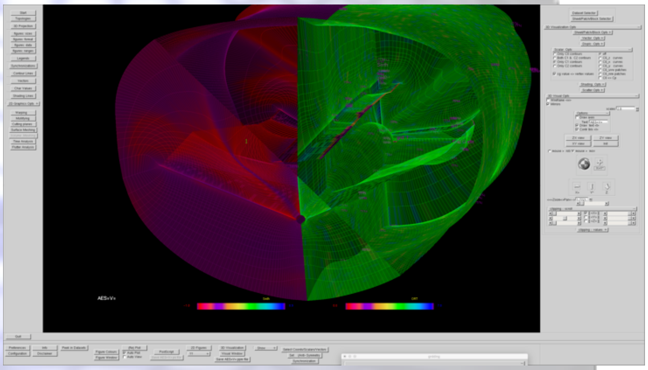
A set of patches is easily created by AES=V= of wings, pylons, fuselages, payloads, effectors, canards, tip stores and combinations thereof. For example, a configuration consisting of a wing with winglet, fuselage and a T tail can be designed and meshed in a few minutes wall clock time (see right figure).
A set of patches can also be imported which can be tuned, tailored, modified and extended. As the CAD/CAM specialists often cannot be secured for these activities it is important that some kind of tooling is applied to cut-out non-aerodynamic relevant parts and redundant parts and to

prescribe missing relevant parts. In particular issues as manipulation, repair (holes and non-abutments), open and close edges have to be dealt with.

Short turn-around wall clock times are further associated with the domino effect approach (DEA). The DEA minimizes input of required spacings and number of cells to very few patches avoiding the nuisance of specifying time consuming balanced inputs for all patches. The distribution on other patches is automatic with smooth transitions along and across edges. For most configurations a multi-patch or mono-patch structured surface description and/or panelling with embedded connector upwind and downwind slit patches (wake surfaces) can be assembled from the individual patches. The connector slits are automatically created.

AES=V= incorporates a powerful and fast volume mesh generation tool, reckoning with aerodynamic, hydrodynamic and aeroelastic applications and a low level of effort at work-floor level. For example, the configuration consisting of a wing with winglet, fuselage and a T tail (see left figure). can be meshed within a few seconds (see right figure). Mono hexahedral meshes, multi non overlapping hexahedral mesh compositions and overlapping hexahedral mesh compositions (Chimera mesh, overset mesh) can be generated. The domain decomposition is performed for the overlapping approach. The volume meshing consists of generating or providing a set of (in)dependent body conforming volume meshes around the surface patches which might overlap (chimera, overset) or share their non-body surface patch boundaries (multi block). The Chimera approach permits the use of high quality nearly orthogonal volume meshes around each individual component by hyperbolic mesh generation thereby naturally adapting to flow and geometry characteristics at the expense of generating connectivity. The Chimera approach is supported with automated background mesh generation adapted to the spacings at the outer and inner boundaries of the component meshes. Similarly, as the robust generation of the connectivity requires some rules not being violated in zones of overlap it is important that some kind of trimming feature are applied in zones of overlap to prevent miss-match of oversets meshes. The hexahedral meshes can also be transformed fully or partly to tetrahedron or prism meshes.





Also important in mesh generation is the fast inspection of the meshes and to minimize the efforts by the applicators. The adequate graphics inspection tools enable the visualization of all mesh related quantities of interest.

The AES=V= mesh generation methods can deal with arbitrary two-dimensional shapes (aerofoils and arbitrary cross sections), simple three-dimensional shapes (wings) to complete fixed wing aircraft. The mesh applications are easy to use for engineers, the processes are easily repeatable, robust and fast.

AES=V= surface mesh tooling features geometry design/ creation (wing, fuselage, pylon, payloads et cetera) and manipulation to design/tailor a surface mesh for volume mesh generation or a panelling for aerodynamic analysis with CFD methods or panel methods (AES=O=, http://www.aes4ac.com/).

The surface mesh module involves design/creation of patches (wings, pylons, payloads, fuselages, effectors, et cetera), editing of imported patches (exports of CAD/CAM programs) and allows tailoring a configuration to specific application needs.
The effort for redistributions is quite low due to the domino effect method (DEA). The DEA warps required mesh spacings specified at a very few selected edges smoothly over all the patches of the configuration. A single surface patch of an A/C configuration by assembling the rectangular network of individual patches, including non-body connector patches (slits, e.g., wake surfaces) might be composed in order to generate the very advantageous single volume block mesh.

AES=V= volume mesh generation features; wing conforming topologies and Cartesian (background); good quality, robust and fast; overset(chimera) connectivity together with hyperbolic hexahedral mesh generation, algebraic hexahedral mesh generation, post elliptic smoothing, post tetrahedron & prism mesh transformation, overset(chimera) connectivity and Visual Quality (& Chimera Connection) Analysis.

2 Running AES=V=

Running AES=V= ab initio will generate automatically the preferences file *.prefs_aes=v =* in your home directory and the configuration file *aes=v=.cnf* in your specified working storage directory. These files might serve as templates for your own applications. The files containing bulky data should be listed on the *aes=v=.cnf* file. First specify the pathname of your working storage directory on the *.prefs_aes=v=* file in your home directory. Next prepare a very simple *aes=v=cnf* file just containing names of the file(s) containing the patch or mesh data. These files should reside in the working storage directory. AES=V= can be executed in any other directory however, resulting analysis and data files are saved in the aforementioned working storage directory. Running AES=V= will present its workbench screen containing the many buttons and rollouts related to its many actions and control (see Figure 1).

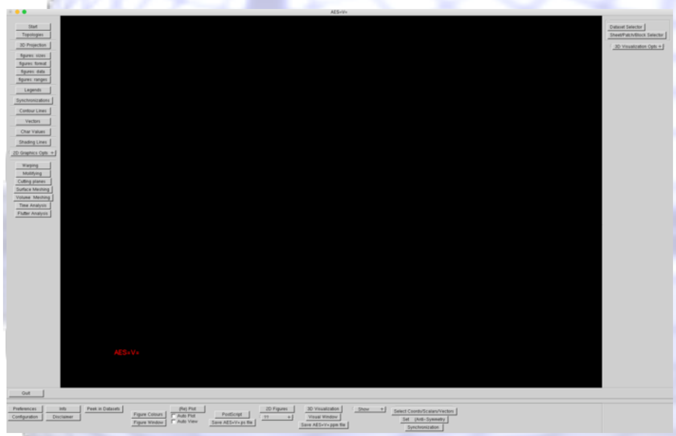


Figure 1 The start-up screen of AES=V=: the AES=V= workbench

3 AES=V='s surface mesh generation

Surface mesh generation forms the basis of volume mesh generation. AES=V= keeps the geometrical description of the body surface at a flexible level by the use of discrete sets of coordinate inputs (patches). It is assumed that an accurate enough discrete surface representation of the actual geometry might be obtained either from AES=V='s patch (re)model/design methods or as imported output from CAD/CAM packages.

The network of quadrilateral patches is organized and linked via an implicit connectivity table based. A patch is a set of relevant sections collocated in space that describes the geometry of a part of the body. The surface mesh generation is performed for all the patches of the network. This results in a set of patches whose edges have either unique connectivity properties or are free. This network-type of architecture allows for a very flexible specification of the mesh spacing in different areas of the configuration geometry. A single-patch structured surface mesh covering the entire geometry might be generated, by assembling the separate patches and filling the gaps with connector patches.
AES=V='s surface mesh module can create(design) surface patches containing discrete data based on typical aerodynamic shapes such as wings, fuselage, payloads et cetera. The design tooling is directed to ease the fast modelling of interference/installation effects of fuselage, payloads, pylons et cetera on wings and tails. It is very easy to model the surface of aircrafts equipped with multiple pylons, winglets, T-tails and payloads ab initio or to add pylons and payloads to existing configurations:

- for a wing-like (pylons, wings, tails, fins) geometry, by combining bi-dimensional sections and prescribing planform, thickness, twist, sweep, dihedral and anhedral angle variations along the wing planform. The latter operation requires usually the input of non-dimensionless cross-sections (aerofoils or using embedded aerofoils).
- For a body-like (fuselage, nacelle, payload, et cetera), by combining bi-dimensional sections prescribing shape (cross-sections et cetera) and front/rear location or using embedded shapes (paraboloid, ellipsoid, et cetera).

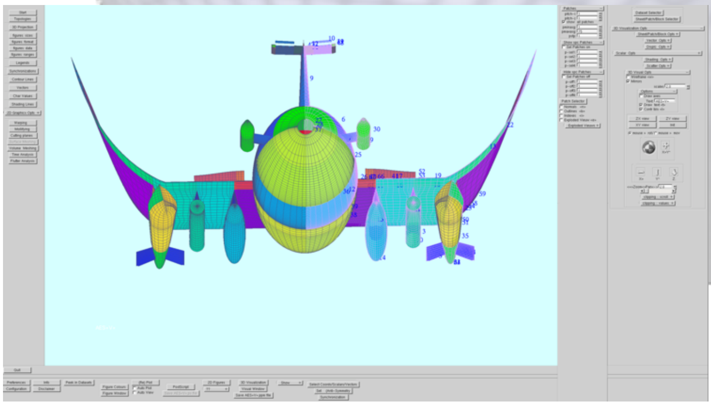


Figure 2 Design possibilities: A/C with pylons, payloads, nacelle, effectors and a spoiler.

The design tools are directed to ease the fast modelling of interference effects of fuselage, payloads, pylons et cetera on wings and tails.
The design possibilities of AES=V= are illustrated in Figure 2, showing an A/C with pylons, payloads, nacelle, effectors and a spoiler which has been generated ab initio.

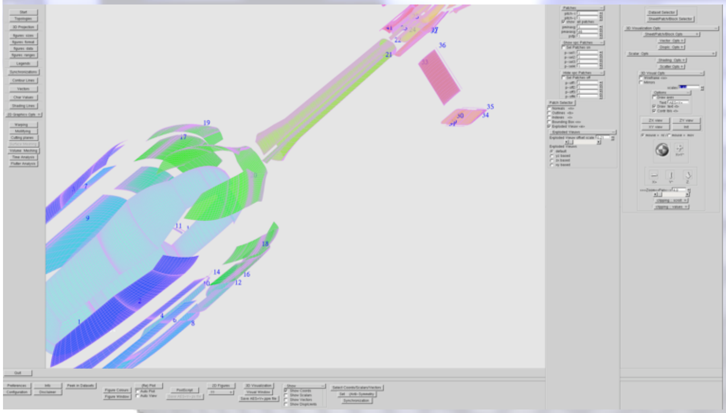
Alternatively, the solid body geometry (a wing or a full air(water)craft) can be imported as a collection of patches by direct extraction from CAD/CAM packages. The imported patches can be tuned to the needs of the aerodynamic or aeroelastic applications. For example, cut out irrelevant parts, change topology of nose, tail and inlet region parts, split some patches and take care with respect to the orientation of the patches such that the normal on patches is pointing outward. With emphasis on aeroelasticity, the idealisation of non-lifting components can be performed. Simplifying parts of the geometry that do not contribute to the generalized forces, because the deformation/ movement of these parts is too small. For aeroelastic purposes only lifting surface parts of the geometry will generate a significant aerodynamic contribution to the generalized forces of interest.

When striving for the advantageous mono block mesh the main task is to manipulate the patches such that a network of patches results, each uniquely connected to neighbouring patches by their vertices. In the ideal situation, the patches already are uniquely connected and the manipulation stage can be skipped. These activities are supported with the graphics inspection tool, revealing normal, edge and index information of the patches. The patches can be redistributed in order to obtain a smooth spacing distribution across connecting edges. The effort for redistributions is quite low due to the domino effect approach (DEA). The DEA warps required mesh spacings specified at a very few selected edges smoothly over all the patches of configuration.
Slit connector patches automatically formed from leading, trailing and side edges of patches completize the network. Finally, the network of patches is assembled to a single patch.

In summary AES=V='s surface mesh tool performs the following:

- Create (ab initio aircraft design) & change patches:
- delete irrelevant parts.
- change patch topology.
- split patches.
- combine patches.
- rapid design/creation of fuselage, wings, pylons, splitters, nacelles, payloads, tip(vane)s and trailing edge extensions and effectors.
- change orientation, modify (sweep, thickness, dihedral, aspect ratio) of patches and clone patches
- Redistribute patches with a good continuous connection at patch edges,
- Assemble the patches network to one single surface patch with H topology including embedded, trailing and leading-edge continuation slits.
- Et cetera

The surface mesh or volumes mesh generation is accessed by pressing the associated button on the left dock. Then the surface meshing window pops up together with a visualization of an imported file (see Figure 3).
The surface meshing requires no file at all or the import of one file containing the coordinates of the patches describing the configuration. The file has the uniform AES=V= format and might be imported from CAD/CAM tools or simply a saved file from a previous surface mesh generation.



The visualization options are selectable in the docks at the right-hand side and also by pressing the visual window button in the bottom dock. Patches can be selected/deselected. Pitch rates can be set. An explosive view can be shown. Normal, outlines, indices et cetera can be inspected.

Figure 3 The Surface Meshing Window showing an exploded view

Three main actions can be performed by opening an associated rollout which gives access to a multitude of patch actions. In each phase the user can record his actions to replay them in a later stage and to save the latest surface mesh. The second phase and the third phase require that the connection of patches is set in phase S1. This will allow for a smooth redistribution in phase S2. Phase S3 will try to define a rectangular network of patches by automatically filling the gaps with connector slit patches. The phases are described shortly in the next sections.

3.1 Phase S1: Design/ edit/ manipulation

Patches can be edited and created to model the surface of A/C components or complete A/C. Patches can be edited/manipulated to satisfy the patch requirements of Phase S3 (mono block) and/or to enable a smooth redistribution in Phase S2. In Phase S2 the redistribution phase, continuity of spacing and number of points at their borders is obtained when patches are connected at their vertices. This might require splitting of patches to avoid orphans and insure connected vertices.

When it is required in Phase S3 to compile the network of patches with connections at their vertices to a single patch the major task is to manipulate the patches such that a set of patches results, each uniquely connected to neighbouring patches by their vertices or lie in the symmetry plane for a semi model. Imported patches hardly ever satisfy the aforementioned property and need the Phase S1 manipulation stage. This in general requires subdivisions of nonaligned patches and modification of patches containing apices and different topology and orientations. For that purpose, segment merging and redistribution tools and a normal direction finder with equalizer and patch constructer are provided. The subdivision and connection process can be run more or less automated, however offsets in the geometrical definition may cause failure and require sometimes the user's intervention (subdivision or modification).

3.2 Phase S2: Semi global redistribution of the patches

Having a set of patches (from Phase S1 or imported from file) the second phase will redistribute the surface mesh according to spacings, number of points along s and t and auxiliary distribution options. To avoid specification of the aforementioned parameters for each patch and in order to obtain smooth transitions the Domino Effect Approach is embedded. The DEA requires the input of the spacings (at edges) and the number of points for a few patches which are interpolated (extrapolated) by a proprietary volume spline method to other surface patches. When patches are connected at their vertices, they will share the same spacings and number of points. The resulting patches can be used in the next Phase S3 or saved for a Chimera volume mesh generation or AES=O= panel method calculations.

3.3 Phase S3: Compilation of network of patches into a single H patch (with artificial connector slit patches)

Having a set of patches (from phase S1 or S2 or imported from file) a single surface patch for the whole configuration is successfully generated when the patch edges of the set are uniquely connected to neighbouring patches by their vertices. Connector slit patches (double valued) will be automatically generated at leading and trailing edges of wing like patches that are free to fill up the gaps in the rectangular network.

4 Demo Surface mesh generation/ processing

Examples of the capabilities of the surface mesh generator are presented in this section. The design tools are directed to ease the fast modelling of interference effects of fuselage, payloads, pylons et cetera on wings and tails.

In aeroelastic practice dealing with pre design and post design (qualification, certification, installation) one usually encounters the following cases for which the surface mesh generation can be easily and in minutes wall clock time done by AES=V= without having to reside to alien datasets:

- A wing
- A wing with a winglet
- A wing with a winglet and a fuselage
- A wing with a winglet, fuselage and T-tail
- A wing with a winglet, fuselage, T-tail and fuselage pylon+ nacelle.
- A wing with a winglet, fuselage, T-tail, fuselage pylon+ nacelle and underwing pylon-payload
- Et cetera

The generation of the wing with winglet, fuselage and T-tail is demonstrated in the next sections. In each case the actions can be stored on macro's and the resulting patches can be saved on files: *AES=V=.esg, AES=V=.dsg, AES=V=.osg* and *AES=V=.fsg*. Figure 4 shows the body patches at the end of Phase S2.

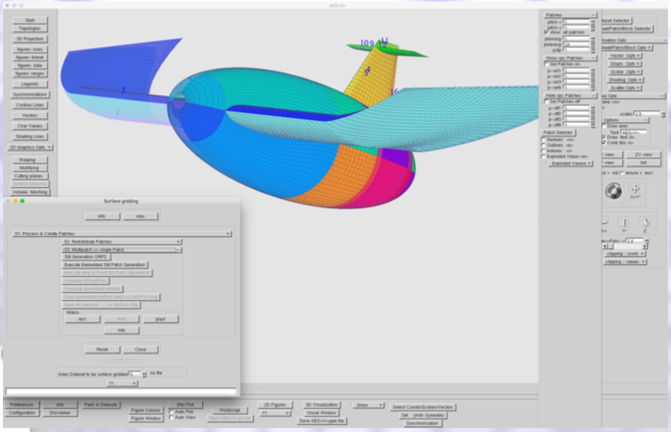


Figure 4 Surface patches of a wing with a winglet, fuselage and T-tail

4.1 Wing surface mesh design

A wing alone analysis requires planform and aerofoil curves. Having started up AES=V= (see section Running AES=V=) in ab initio mode and opening the surface meshing window, a default rectangular XxX surface is automatically generated (see right figure).

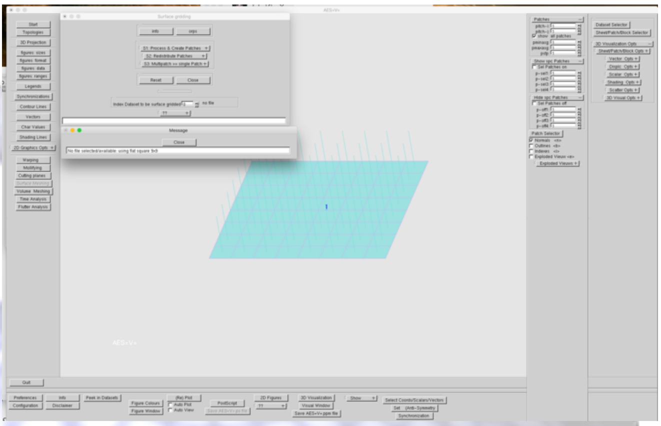
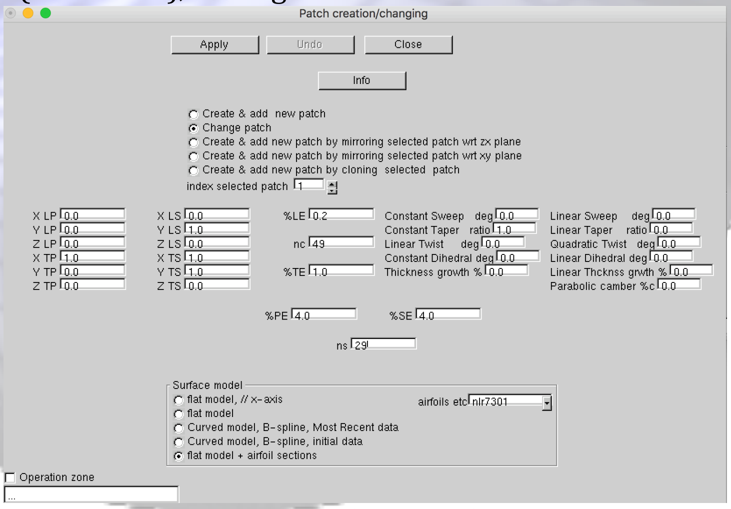


Figure 5 surface mesh of a rectangular wing

This requires the following actions:

- First it is advised to activate the macro recording which can be applied in a future case.
- Open the *S1: Process& Create Patches rollout*.
    - Open the *Patch Design and Remodel rollout*.
        - Open the *Wing Patch creation/remodel window* and change the rectangular surface by setting various parameters defining a wing surface (vertices, spacings, number of points and selection of an aerofoil (NLR 7301), see Figure 6.



○ Create & add new patch
● Change patch
○ Create & add new patch by mirroring selected patch wrt zx plane
○ Create & add new patch by mirroring selected patch wrt xy plane
○ Create & add new patch by cloning selected patch
index selected patch 1

X LP 0.0
Y LP 0.0
Z LP 0.0
X TP 1.0
Y TP 0.0
Z TP 0.0

X LS 0.0
Y LS 1.0
Z LS 0.0
X TS 1.0
Y TS 1.0
Z TS 0.0

%LE 0.2
nc 49
%TE 1.0

Constant Sweep deg 0.0
Constant Taper ratio 1.0
Linear Twist deg 0.0
Constant Dihedral deg 0.0
Thickness growth % 0.0

Linear Sweep deg 0.0
Linear Taper ratio 0.0
Quadratic Twist deg 0.0
Linear Dihedral deg 0.0
Linear Thcknss grwth % 0.0
Parabolic camber %c 0.0

%PE 4.0
%SE 4.0

ns 29

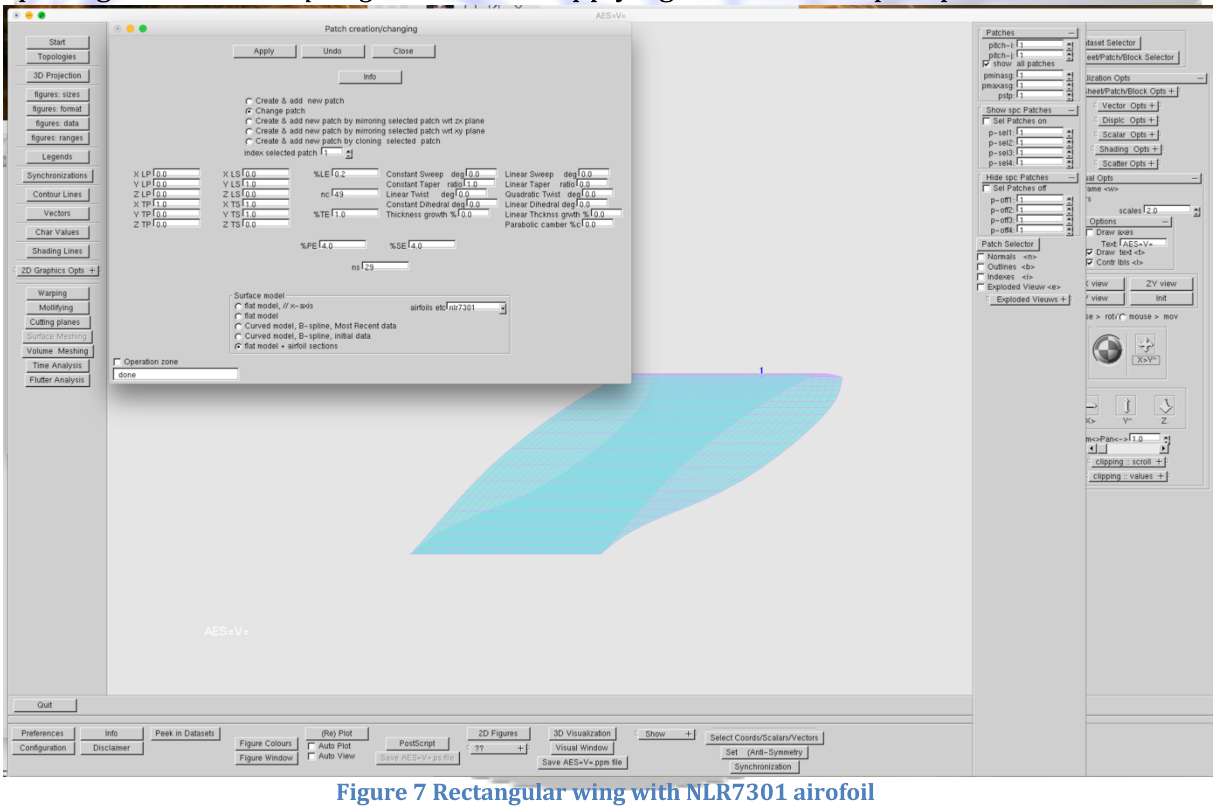
Surface model
○ flat model, // x-axis
○ flat model
○ Curved model, B-spline, Most Recent data
○ Curved model, B-spline, initial data
● flat model + airfoil sections
airfoils etc nlr7301

☐ Operation zone
...

Figure 6 Wing design window

- Apply the generation.

Figure 7 shows a single surface patch representing the surface mesh of a rectangular wing with NLR7301 aerofoil. The mesh runs from trailing edge lower side to trailing edge upper side and from portside to starboard side. The mesh is open at the starboard side and portside. For a semi wing alone case the mesh can be closed at the portside by opening the *remodel tip edge rollout* and applying one of the simple options.



Patch creation/changing

○ Create & add new patch
● Change patch
○ Create & add new patch by mirroring selected patch wrt zx plane
○ Create & add new patch by mirroring selected patch wrt xy plane
○ Create & add new patch by cloning selected patch
index selected patch 1

X LP 0.0
Y LP 0.0
Z LP 0.0
X TP 1.0
Y TP 0.0
Z TP 0.0

X LS 0.0
Y LS 1.0
Z LS 0.0
X TS 1.0
Y TS 1.0
Z TS 0.0

%LE 0.2
nc 49
%TE 1.0

Constant Sweep deg 0.0
Constant Taper ratio 1.0
Linear Twist deg 0.0
Constant Dihedral deg 0.0
Thickness growth % 0.0

Linear Sweep deg 0.0
Linear Taper ratio 0.0
Quadratic Twist deg 0.0
Linear Dihedral deg 0.0
Linear Thcknss grwth % 0.0
Parabolic camber %c 0.0

%PE 4.0
%SE 4.0
ns 29

Surface model
○ flat model, // x-axis
○ flat model
○ Curved model, B-spline, Most Recent data
○ Curved model, B-spline, initial data
● flat model + airfoil sections
airfoils etc nlr7301

☐ Operation zone
done

Figure 7 Rectangular wing with NLR7301 airofoil

For the next Phases S2&S3 it is advised to split the patch in an upper and lower patch both running from leading edge to trailing edge. In Phase S2 this mesh can be redistributed and in Phase S3 the mesh can be extended with forward and downward running slits. These steps are similar as the wing with winglet case (see next section) and will not be discussed here. We will close the mesh with a winglet in the next section.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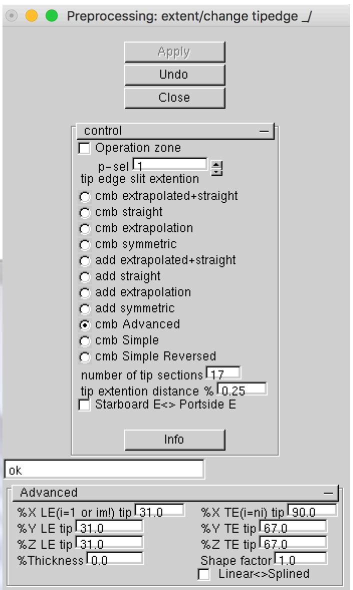
4.2 Designing a wing with a winglet

In the previous section the surface mesh of a simple rectangular wing has been generated.
The mesh is open at the starboard side and portside. The wing at the tip edge is closed with a winglet. This is performed by opening the tip extension window, setting various parameters and its application, see   Figure 8.



Preprocessing: extent/change tipedge _/

control
☐ Operation zone
p-sel 1
tip edge slit extention
○ cmb extrapolated+straight
○ cmb straight
○ cmb extrapolation
○ cmb symmetric
○ add extrapolated+straight
○ add straight
○ add extrapolation
○ add symmetric
● cmb Advanced
○ cmb Simple
○ cmb Simple Reversed
number of tip sections 17
tip extention distance % 0.25
☐ Starboard E<> Portside E

ok

Advanced
%X LE(i=1 or iml) tip 31.0
%Y LE tip 31.0
%Z LE tip 31.0
%Thickness 0.0
%X TE(i=ni) tip 90.0
%Y TE tip 67.0
%Z TE tip 67.0
Shape factor 1.0
☐ Linear<>Splined

Figure 8 tip extension window

Figure 9 shows a single surface patch representing the surface mesh of a rectangular wing with NLR7301 aerofoil and starboard edge closed with a winglet. The shape of the winglet is controlled by various parameters allowing many shapes.
Again, for the next Phases S2&S3 it is advised to split the patch in an upper and lower patch both running from leading edge to trailing edge. This requires opening the patch change rollout and entering the split window et cetera. In Phase S2 this mesh can be redistributed and in Phase S3 the mesh can be extended with forward and downward running slits).

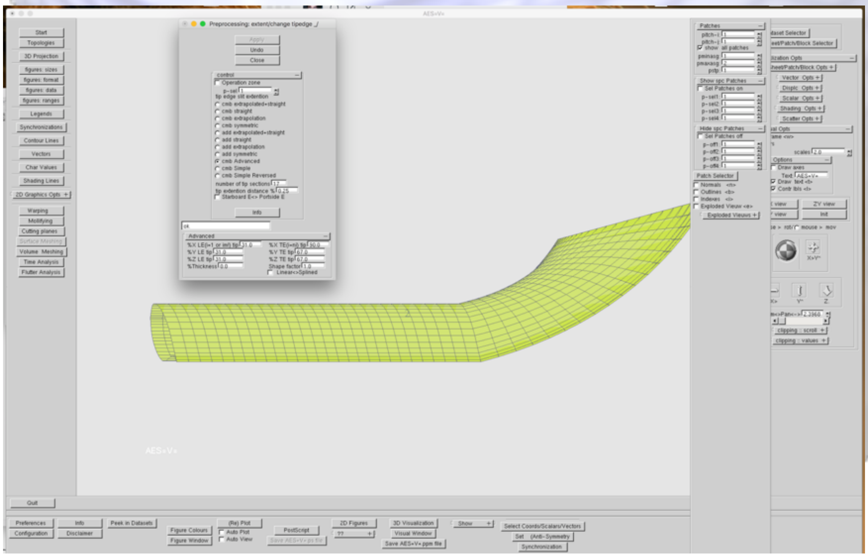
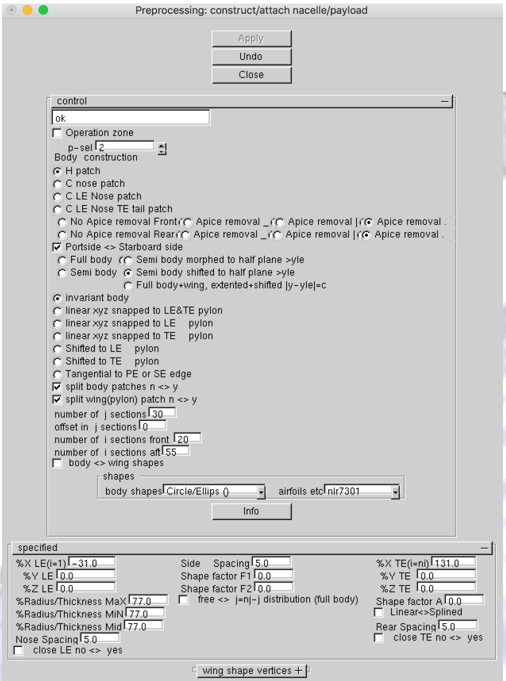


Figure 9 Single patch of a rectangular wing with NLR7301 aerofoil and winglet

4.3 Designing a wing with a winglet and a fuselage



Preprocessing: construct/attach nacelle/payload

ok

☐ Operation zone

p−sel 2

Body construction

● H patch
○ C nose patch
○ C LE Nose patch
○ C LE Nose TE tail patch
○ No Apice removal Front ○ Apice removal _ ○ Apice removal | ● Apice removal .
○ No Apice removal Rear ○ Apice removal _ ○ Apice removal | ● Apice removal .

☑ Portside <> Starboard side
○ Full body ○ Semi body morphed to half plane >yle
○ Semi body ● Semi body shifted to half plane >yle
○ Full body+wing, extented+shifted |y−yle|=c

● invariant body
○ linear xyz snapped to LE&TE pylon
○ linear xyz snapped to LE pylon
○ linear xyz snapped to TE pylon
○ Shifted to LE pylon
○ Shifted to TE pylon
○ Tangential to PE or SE edge

☑ split body patches n <> y
☑ split wing(pylon) patch n <> y

number of j sections 30
offset in j sections 0
number of i sections front 20
number of i sections aft 55

☐ body <> wing shapes

shapes
body shapes Circle/Ellips () airfoils etc nlr7301

%X LE(i=1) −31.0
%Y LE 0.0
%Z LE 0.0
%Radius/Thickness MaX 77.0
%Radius/Thickness MiN 77.0
%Radius/Thickness Mid 77.0
Nose Spacing 5.0
☐ close LE no <> yes

Side Spacing 5.0
Shape factor F1 0.0
Shape factor F2 0.0
☐ free <> j=nj−j distribution (full body)

%X TE(i=ni) 131.0
%Y TE 0.0
%Z TE 0.0
Shape factor A 0.0
☐ Linear<>Splined
Rear Spacing 5.0
☐ close TE no <> yes

Figure 10 The body design window

In the previous sections the surface mesh of a simple rectangular wing with a winglet was presented. We will start at the point the winglet was created by continuing or running earlier stored and recorded macros on file. We will add a semi fuselage at the portside side. This is performed by opening the body design window and setting various parameters and its application, see

Figure 10. Many possibilities can be accessed in the window. We select an ellipsoidal shape, H patch, delete the apices, specify number of points in front and aft, activate the splitting of body and wing in patches.

Figure 11 shows the network of patches modelling the configuration. Note that the intersection of the wing with the ellipsoid is taken care off. The parts of the wing inside the ellipsoid are not deleted but transformed outside the first intersecting wing strip! Alternatively, we could have used a C patch for the front and/or rear.

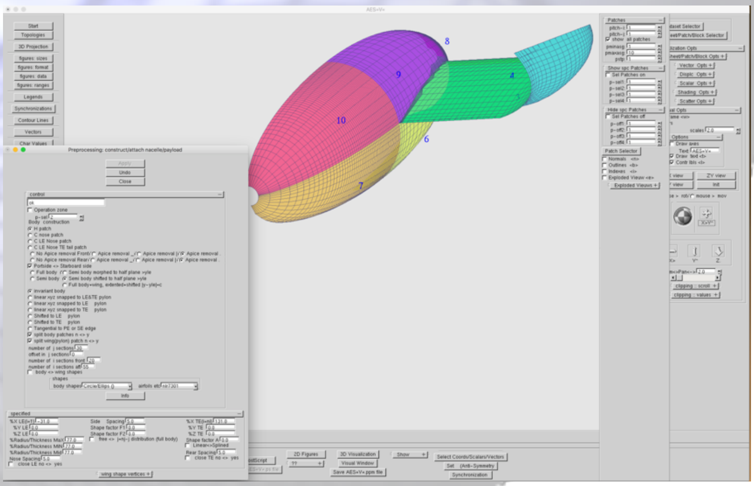
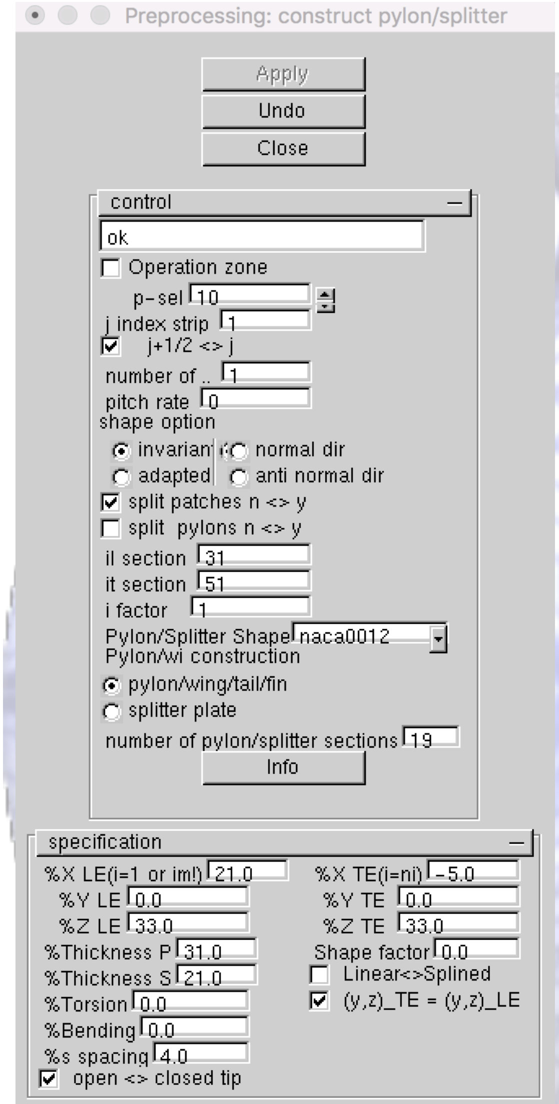


Figure 11 Surface patches of a wing with NLR7301 aerofoil and winglet & ellipsoidal body

For the next Phases S2&S3 it is necessary to split the wing& winglet patch in an upper and lower patch both running from leading edge to trailing edge. This is automatically performed. The ellipsoid is split in 6 parts and the wing in 2. In Phase S2 this mesh can be easily redistributed and in Phase S3 the mesh is extended with forward and downward running slits.

4.4 Designing a wing with a winglet a fuselage and a vertical tail

In the previous sections the surface mesh of a simple rectangular wing with a winglet and an ellipsoidal body was presented. We will start at the point the ellipsoid was created by continuing or running earlier stored and recorded macros. We will add a vertical tail at the rear fuselage. This is performed by opening the *pylon (wing)design window* and setting various parameters and its application, see . Many possibilities can be accessed in the window. We select a naca0012 aerofoil, single patch, activate the splitting of the fuselage and close the tip.



control

ok

☐ Operation zone

p-sel 10

j index strip 1

☑ j+1/2 <> j

number of .. 1

pitch rate 0

shape option

● invariant ○ normal dir

○ adapted ○ anti normal dir

☑ split patches n <> y

☐ split pylons n <> y

il section 31

it section 51

i factor 1

Pylon/Splitter Shape naca0012

Pylon/wi construction

● pylon/wing/tail/fin

○ splitter plate

number of pylon/splitter sections 19

specification

%X LE(i=1 or im!) 21.0

%Y LE 0.0

%Z LE 33.0

%Thickness P 31.0

%Thickness S 21.0

%Torsion 0.0

%Bending 0.0

%s spacing 4.0

☑ open <> closed tip

%X TE(i=ni) -5.0

%Y TE 0.0

%Z TE 33.0

Shape factor 0.0

☐ Linear<>Splined

☑ (y,z)_TE = (y,z)_LE

Figure 12 The Pylon design window

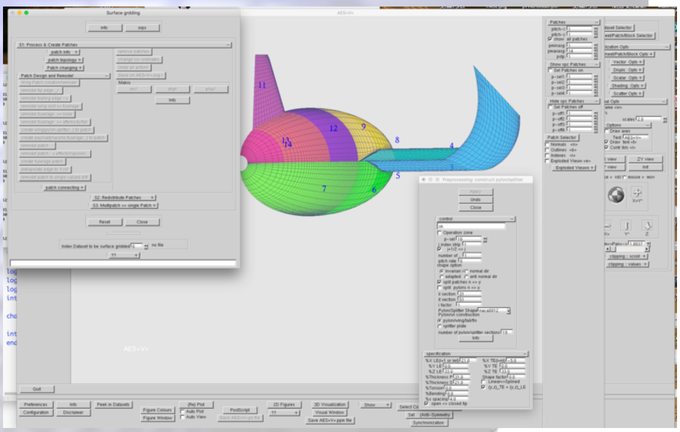
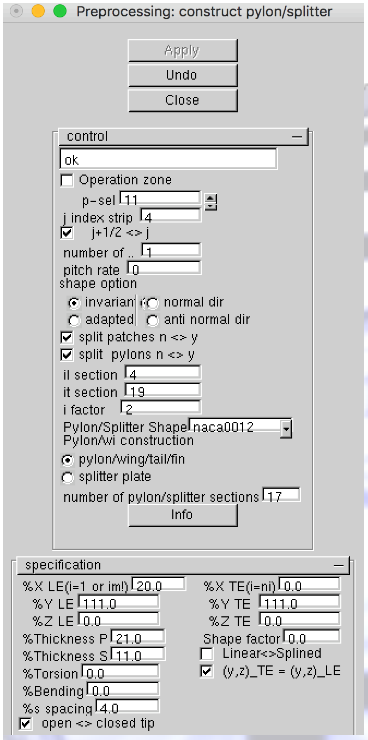


Figure 13 Surface patches of a wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail

w Figure 13 shows a network of patches modelling the configuration. Note that the intersection of the tail with the ellipsoid is taken care off. For the next Phases S2&S3 it is necessary to split the tail fuselage patch. This is automatically performed. The rear top ellipsoid is split in 3 parts. In Phase S2 this mesh can be easily redistributed and in Phase S3 the mesh is extended with forward and downward running slits.

4.5 Designing a wing with a winglet a fuselage a vertical tail and a horizontal tail

In the previous sections the surface mesh of a simple rectangular wing with a winglet an ellipsoidal body and a vertical tail was presented. We will start at the point the vertical tail was created by continuing or running earlier stored and recorded macros. We will add a horizontal tail at the vertical tail. This is again performed by opening the pylon (wing) design window and setting various parameters and its application, see Figure 14. Many possibilities can be accessed in the window. We select a naca0012 aerofoil, single patch, activate the splitting of the tail and close the tip.



Preprocessing: construct pylon/splitter

control
ok
☐ Operation zone
p-sel 11
j index strip 4
☑ j+1/2 <> j
number of .. 1
pitch rate 0
shape option
● invariant ○ normal dir
○ adapted ○ anti normal dir
☑ split patches n <> y
☑ split pylons n <> y
il section 4
it section 19
i factor 2
Pylon/Splitter Shape naca0012
Pylon/wi construction
● pylon/wing/tail/fin
○ splitter plate
number of pylon/splitter sections 17

specification
%X LE(i=1 or iml) 20.0
%X TE(i=ni) 0.0
%Y LE 111.0
%Y TE 111.0
%Z LE 0.0
%Z TE 0.0
%Thickness P 21.0
Shape factor 0.0
%Thickness S 11.0
☐ Linear<>Splined
%Torsion 0.0
☑ (y,z)_TE = (y,z)_LE
%Bending 0.0
%s spacing 4.0
☑ open <> closed tip

Figure 14 The Pylon design window

Figure 15 and Figure 16 show a network of patches modelling the configuration. Note that the intersection of the horizontal tail with the vertical tail is taken care off.
For the next Phases S2&S3 it is necessary to split the tail and fuselage patches. This is automatically performed here for the tails. The vertical fin is split in 6 parts and the horizontal tail in 2 parts.

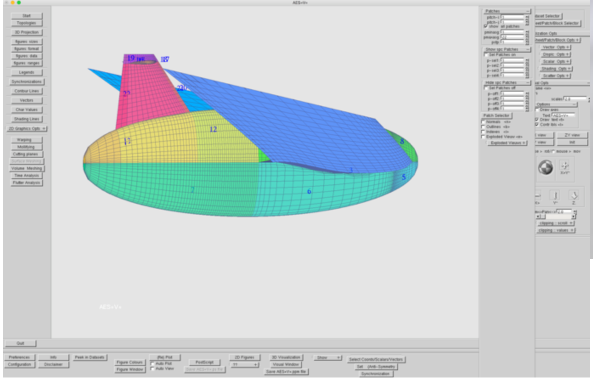


Figure 15 Surface patches of a wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail

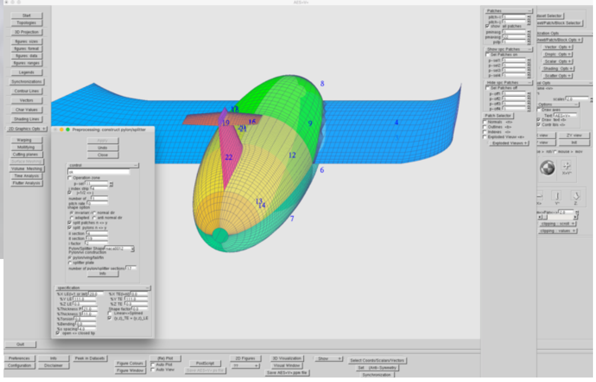
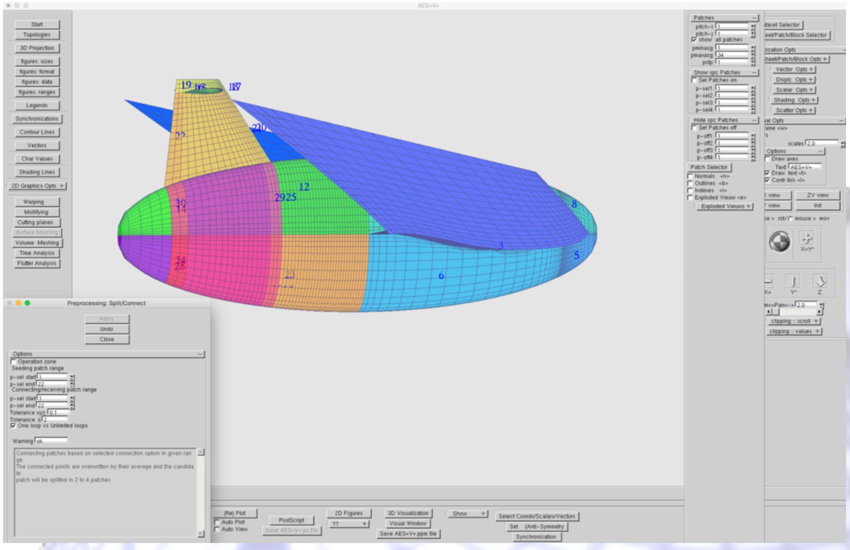


Figure 16 Surface patches of a wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail before automatic split

To connect all the patches the *connection window* is opened and applied, see Figure 17. The fuselage is then further split. In Phase S2 this mesh will be easily redistributed (see next section) and in Phase S3 the mesh is extended with forward and downward running slits (see section 4.7).



Options
☐ Operation zone
Seeding patch range
p-sel start 1
p-sel end 22
Connecting/receiving patch range
p-sel start 1
p-sel end 22
Tolerance xyz 0.1
Tolerance: ij 2
☑ One loop vs Unlimited loops
Warning ok

Connecting patches based on selected connection option in given range.
The connected points are overwritten by their average and the candidate
patch will be splitted in 2 to 4 patches

Figure 17 Surface patches of a wing with NLR7301 airfoil and winglet

& ellipsoidal body& vertical tail& horizontal tail after auto split

4.6 Redistribution of patches of wing with a winglet a fuselage a vertical tail and a horizontal tail

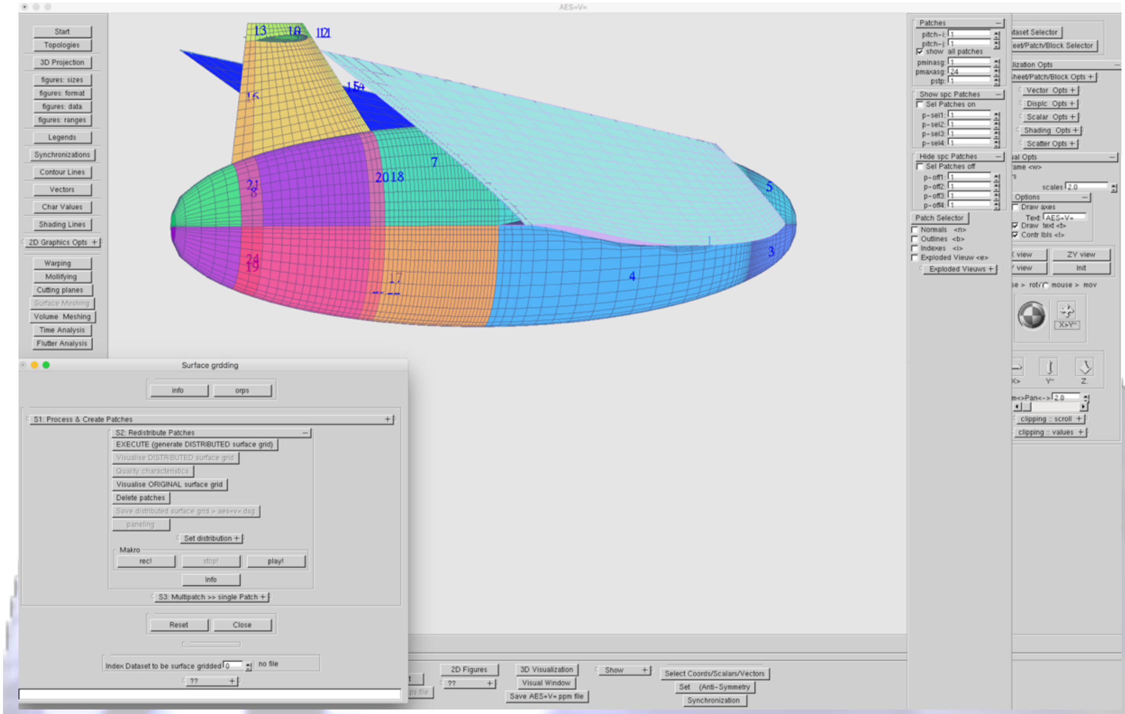
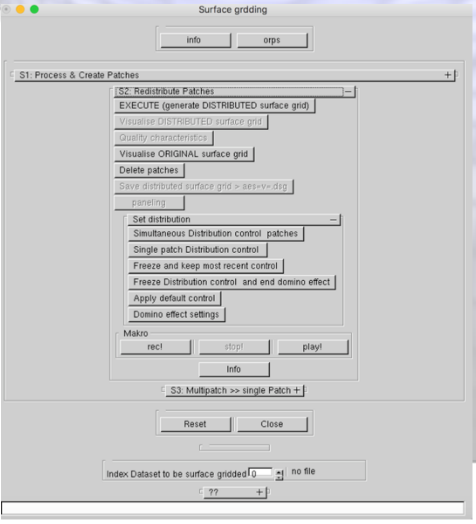


Figure 18 Surface patches of a wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal before redistribution



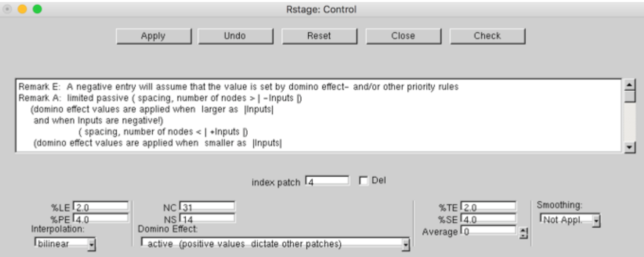
In the previous section the configuration has been designed in the form of a set of patches (see Figure 18). These patches will be easily redistributed resulting in a continuous distribution along and across patch borders. The redistribution is accessed by opening the rollout S3: (see

Figure 19) and opening the *set distribution rollout.*

Figure 19 The surface mesh window with opened

S2: redistribute patches and set distribution rollout.

We will only set a required distribution for the single patch 4 and activate the DEA algorithm (see Figure 20) and Execute the redistribution resulting in the patches depicted in Figure 21 showing a continuous distribution along and across patch borders. It also possible to specify the required distribution for all patches (see Figure 22).

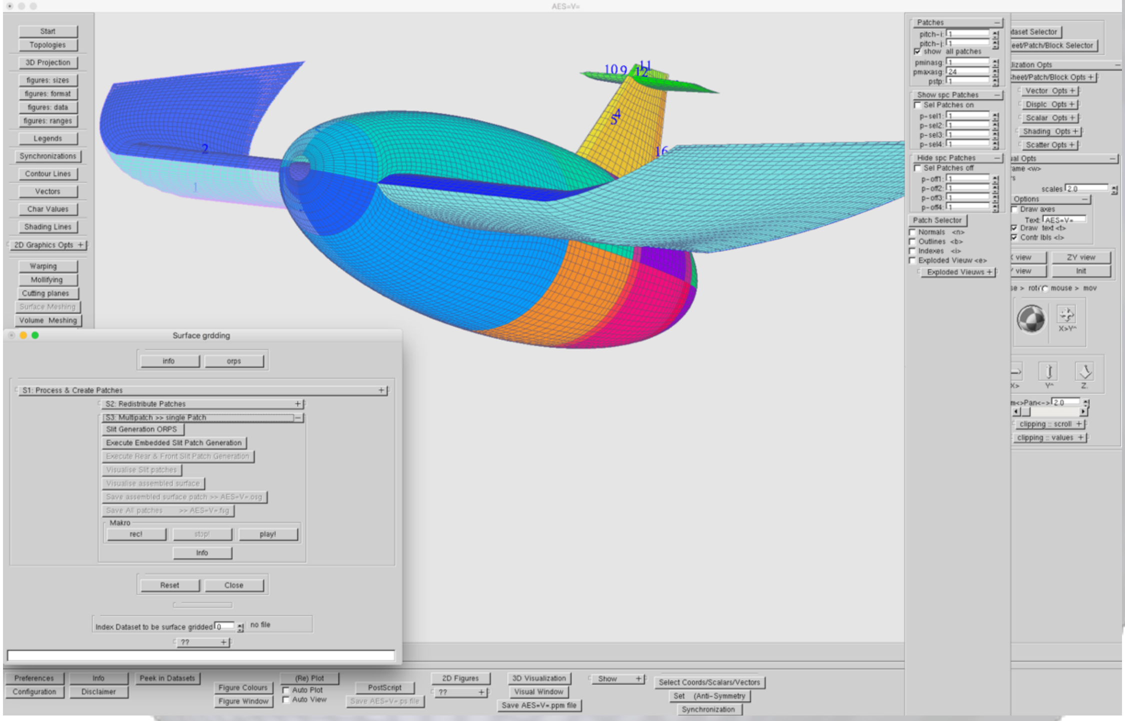


Remark E: A negative entry will assume that the value is set by domino effect- and/or other priority rules
Remark A: limited passive (spacing, number of nodes > | -Inputs |)
(domino effect values are applied when larger as |Inputs|
and when Inputs are negative!)
(spacing, number of nodes < | +Inputs |)
(domino effect values are applied when smaller as |Inputs|

index patch 4 ☐ Del

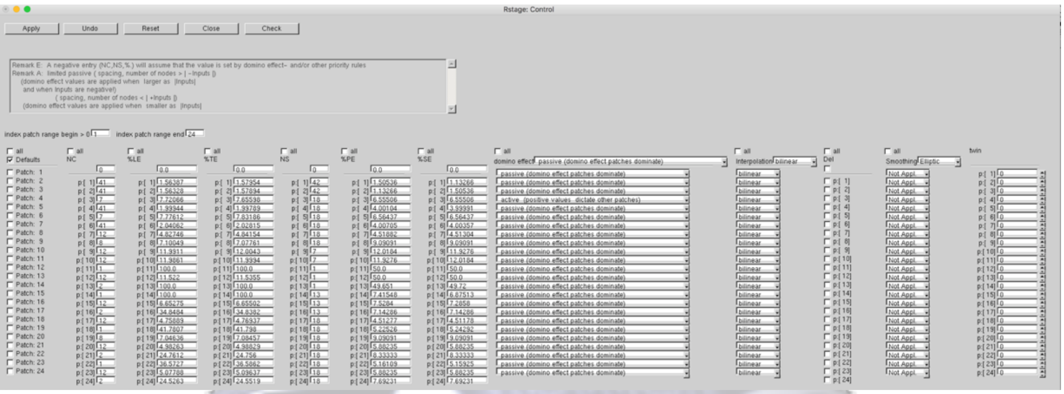
%LE 2.0
%PE 4.0
Interpolation: bilinear
NC 31
NS 14
Domino Effect: active (positive values dictate other patches)
%TE 2.0
%SE 4.0
Average 0
Smoothing: Not Appl.

Figure 20 The single patch distribution control window



Index Dataset to be surface gridded 0 no file

Figure 21 The redistributed patches of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail



Remark E: A negative entry (NC,NS,%.) will assume that the value is set by domino effect– and/or other priority rules
Remark A: limited passive (spacing, number of nodes > | –Inputs |)
(domino effect values are applied when larger as |Inputs|
and when Inputs are negative!)
(spacing, number of nodes < | +Inputs |)
(domino effect values are applied when smaller as |Inputs|

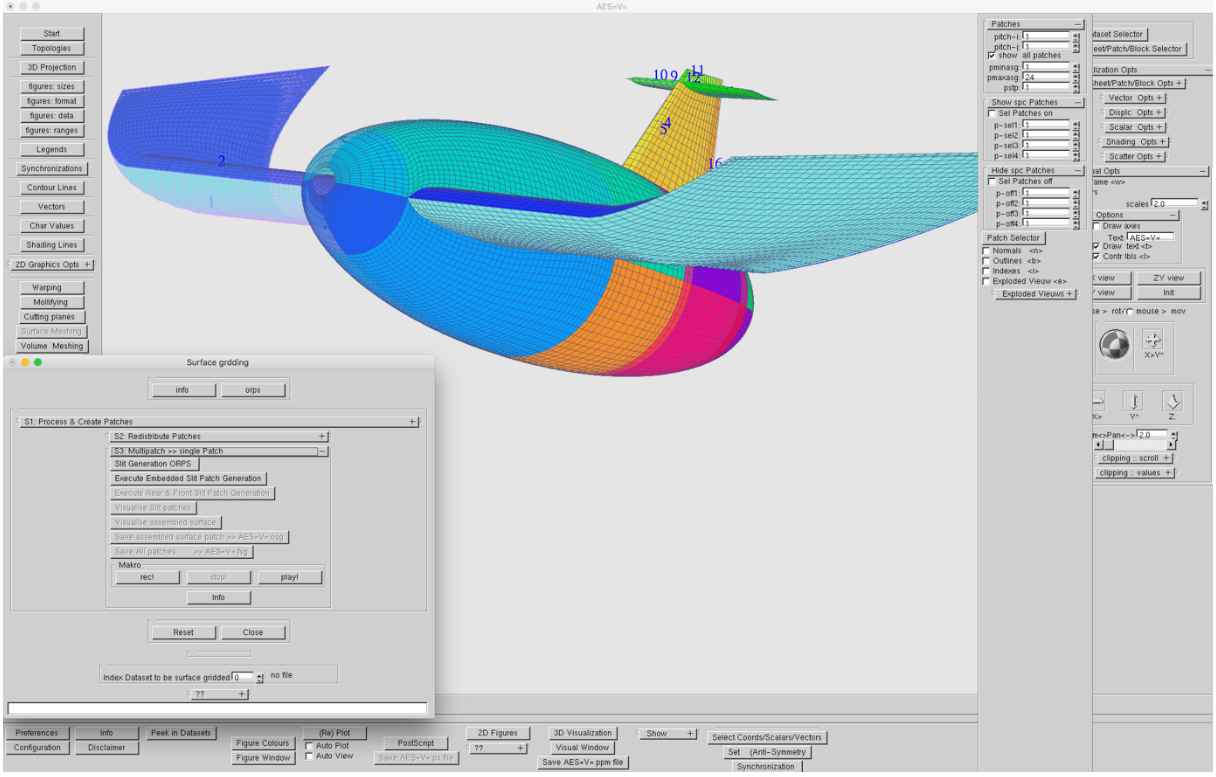
index patch range begin > 0 1 index patch range end 24

☐ all ☑ Defaults	☐ all NC	☐ all %LE	☐ all %TE	☐ all NS	☐ all %PE	☐ all %SE	☐ all domino effect passive (domino effect patches dominate)	☐ all Interpolation bilinear	☐ all Del	☐ all Smoothing Elliptic	twin
	0	0.0	0.0	0	0.0	0.0			☐		
☐ Patch: 1	p:[1] 41	p:[1] 1.56387	p:[1] 1.57954	p:[1] 42	p:[1] 1.50536	p:[1] 1.13266	passive (domino effect patches dominate)	bilinear	☐ p:[1]	Not Appl.	p:[1] 0
☐ Patch: 2	p:[2] 41	p:[2] 1.56328	p:[2] 1.57894	p:[2] 42	p:[2] 1.13266	p:[2] 1.50536	passive (domino effect patches dominate)	bilinear	☐ p:[2]	Not Appl.	p:[2] 0
☐ Patch: 3	p:[3] 7	p:[3] 7.72066	p:[3] 7.65598	p:[3] 18	p:[3] 6.55506	p:[3] 6.55506	passive (domino effect patches dominate)	bilinear	☐ p:[3]	Not Appl.	p:[3] 0
☐ Patch: 4	p:[4] 41	p:[4] 1.99944	p:[4] 1.99789	p:[4] 18	p:[4] 4.00104	p:[4] 3.99991	active (positive values dictate other patches)	bilinear	☐ p:[4]	Not Appl.	p:[4] 0
☐ Patch: 5	p:[5] 7	p:[5] 7.77612	p:[5] 7.83186	p:[5] 18	p:[5] 6.56437	p:[5] 6.56437	passive (domino effect patches dominate)	bilinear	☐ p:[5]	Not Appl.	p:[5] 0
☐ Patch: 6	p:[6] 41	p:[6] 2.04062	p:[6] 2.02815	p:[6] 18	p:[6] 4.00705	p:[6] 4.00357	passive (domino effect patches dominate)	bilinear	☐ p:[6]	Not Appl.	p:[6] 0
☐ Patch: 7	p:[7] 12	p:[7] 4.82746	p:[7] 4.84154	p:[7] 18	p:[7] 4.51882	p:[7] 4.51304	passive (domino effect patches dominate)	bilinear	☐ p:[7]	Not Appl.	p:[7] 0
☐ Patch: 8	p:[8] 8	p:[8] 7.10049	p:[8] 7.07761	p:[8] 18	p:[8] 9.09091	p:[8] 9.09091	passive (domino effect patches dominate)	bilinear	☐ p:[8]	Not Appl.	p:[8] 0
☐ Patch: 9	p:[9] 12	p:[9] 11.9911	p:[9] 12.0043	p:[9] 7	p:[9] 12.0184	p:[9] 11.9276	passive (domino effect patches dominate)	bilinear	☐ p:[9]	Not Appl.	p:[9] 0
☐ Patch: 10	p:[10] 12	p:[10] 11.9861	p:[10] 11.9994	p:[10] 7	p:[10] 11.9276	p:[10] 12.0184	passive (domino effect patches dominate)	bilinear	☐ p:[10]	Not Appl.	p:[10] 0
☐ Patch: 11	p:[11] 1	p:[11] 100.0	p:[11] 100.0	p:[11] 1	p:[11] 50.0	p:[11] 50.0	passive (domino effect patches dominate)	bilinear	☐ p:[11]	Not Appl.	p:[11] 0
☐ Patch: 12	p:[12] 12	p:[12] 11.522	p:[12] 11.5355	p:[12] 1	p:[12] 50.0	p:[12] 50.0	passive (domino effect patches dominate)	bilinear	☐ p:[12]	Not Appl.	p:[12] 0
☐ Patch: 13	p:[13] 2	p:[13] 100.0	p:[13] 100.0	p:[13] 1	p:[13] 49.651	p:[13] 49.72	passive (domino effect patches dominate)	bilinear	☐ p:[13]	Not Appl.	p:[13] 0
☐ Patch: 14	p:[14] 1	p:[14] 100.0	p:[14] 100.0	p:[14] 13	p:[14] 7.41548	p:[14] 6.87513	passive (domino effect patches dominate)	bilinear	☐ p:[14]	Not Appl.	p:[14] 0
☐ Patch: 15	p:[15] 12	p:[15] 6.65275	p:[15] 6.65502	p:[15] 13	p:[15] 7.5284	p:[15] 7.2858	passive (domino effect patches dominate)	bilinear	☐ p:[15]	Not Appl.	p:[15] 0
☐ Patch: 16	p:[16] 2	p:[16] 34.8484	p:[16] 34.8382	p:[16] 13	p:[16] 7.14286	p:[16] 7.14286	passive (domino effect patches dominate)	bilinear	☐ p:[16]	Not Appl.	p:[16] 0
☐ Patch: 17	p:[17] 12	p:[17] 4.75889	p:[17] 4.76937	p:[17] 18	p:[17] 4.51277	p:[17] 4.51178	passive (domino effect patches dominate)	bilinear	☐ p:[17]	Not Appl.	p:[17] 0
☐ Patch: 18	p:[18] 1	p:[18] 41.7807	p:[18] 41.798	p:[18] 18	p:[18] 5.22526	p:[18] 5.24292	passive (domino effect patches dominate)	bilinear	☐ p:[18]	Not Appl.	p:[18] 0
☐ Patch: 19	p:[19] 8	p:[19] 7.04636	p:[19] 7.08457	p:[19] 18	p:[19] 9.09091	p:[19] 9.09091	passive (domino effect patches dominate)	bilinear	☐ p:[19]	Not Appl.	p:[19] 0
☐ Patch: 20	p:[20] 12	p:[20] 4.98263	p:[20] 4.98829	p:[20] 18	p:[20] 5.88235	p:[20] 5.88235	passive (domino effect patches dominate)	bilinear	☐ p:[20]	Not Appl.	p:[20] 0
☐ Patch: 21	p:[21] 2	p:[21] 24.7612	p:[21] 24.756	p:[21] 18	p:[21] 8.33333	p:[21] 8.33333	passive (domino effect patches dominate)	bilinear	☐ p:[21]	Not Appl.	p:[21] 0
☐ Patch: 22	p:[22] 1	p:[22] 36.5727	p:[22] 36.5862	p:[22] 18	p:[22] 5.16109	p:[22] 5.15925	passive (domino effect patches dominate)	bilinear	☐ p:[22]	Not Appl.	p:[22] 0
☐ Patch: 23	p:[23] 12	p:[23] 5.07788	p:[23] 5.09637	p:[23] 18	p:[23] 5.88235	p:[23] 5.88235	passive (domino effect patches dominate)	bilinear	☐ p:[23]	Not Appl.	p:[23] 0
☐ Patch: 24	p:[24] 2	p:[24] 24.5263	p:[24] 24.5519	p:[24] 18	p:[24] 7.69231	p:[24] 7.69231	passive (domino effect patches dominate)	bilinear	☐ p:[24]	Not Appl.	p:[24] 0

Figure 22 The multiple patch distribution control window

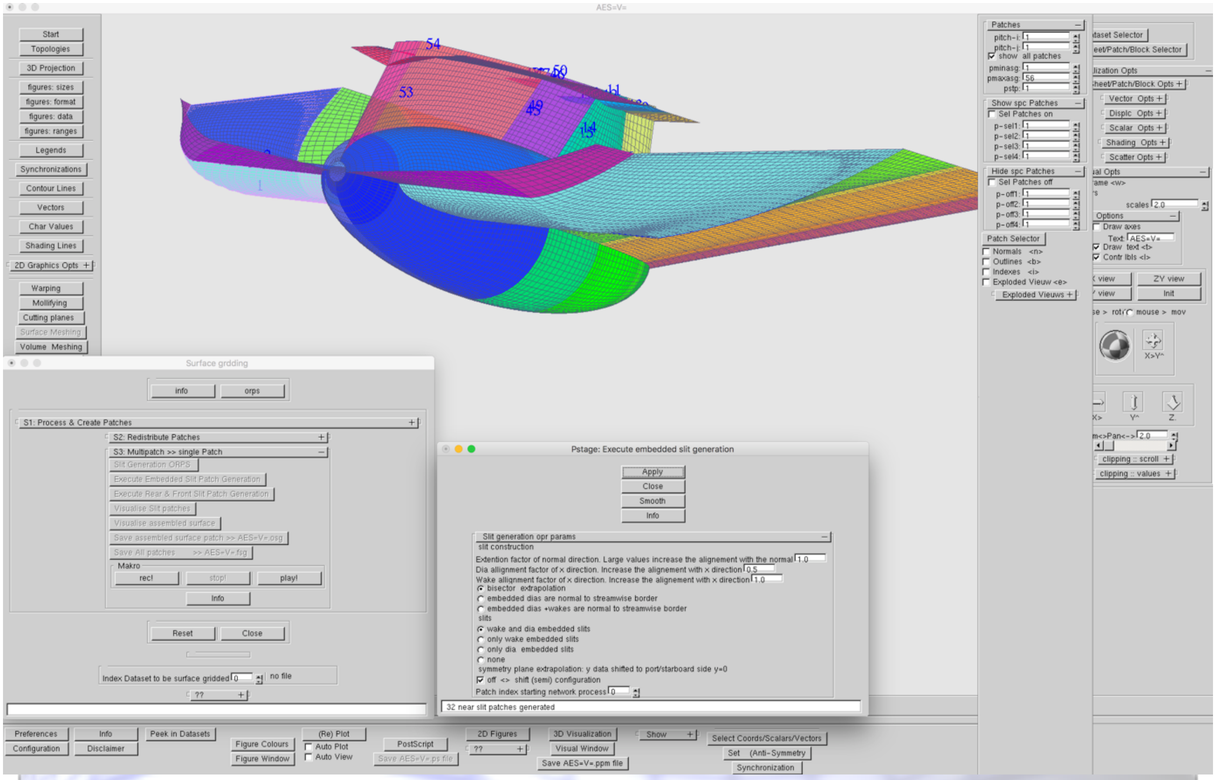
4.7 Assembling patches of wing with a winglet a fuselage a vertical tail and a horizontal tail to a mono patch

In the previous section the configuration has been redistributed in the form of a set of patches (see Figure 21) with a continuous distribution along and across patch borders. The assembling is accessed by opening the rollout *S3: multipatch >>single patch* (see Figure 23). We will open the embedded slit generation window and execute the generation of embedded slits with default parameters resulting automatically in the patches depicted in Figure 24 and Figure 25. Figure 26 shows an explosive view of all the patches. Next, we completize the patches with far upwind and far downwind slit surfaces by opening the associated window, set the number of strips and growth ratio and apply it. Figure 27 and Figure 29 show the resulting mono patch and Figure 30 and Figure 28 show the patch network. In section 6.3 a volume mesh will be generated around this mono patch.



Index Dataset to be surface gridded 0 no file

Figure 23 Surface mesh window with open S3: rollout and redistributed patches of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail



Pstage: Execute embedded slit generation

Slit generation opr params

slit construction

Extention factor of normal direction. Large values increase the alignement with the normal 1.0

Dia allignment factor of x direction. Increase the alignement with x direction 0.5

Wake allignment factor of x direction. Increase the alignement with x direction 1.0

● bisector extrapolation
○ embedded dias are normal to streamwise border
○ embedded dias +wakes are normal to streamwise border

slits

● wake and dia embedded slits
○ only wake embedded slits
○ only dia embedded slits
○ none

symmetry plane extrapolation: y data shifted to port/starboard side y=0

☑ off <> shift (semi) configuration

Patch index starting network process 0

32 near slit patches generated

Figure 24 Embedded slit generation window and redistributed patches of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail completized with embedded slit patches

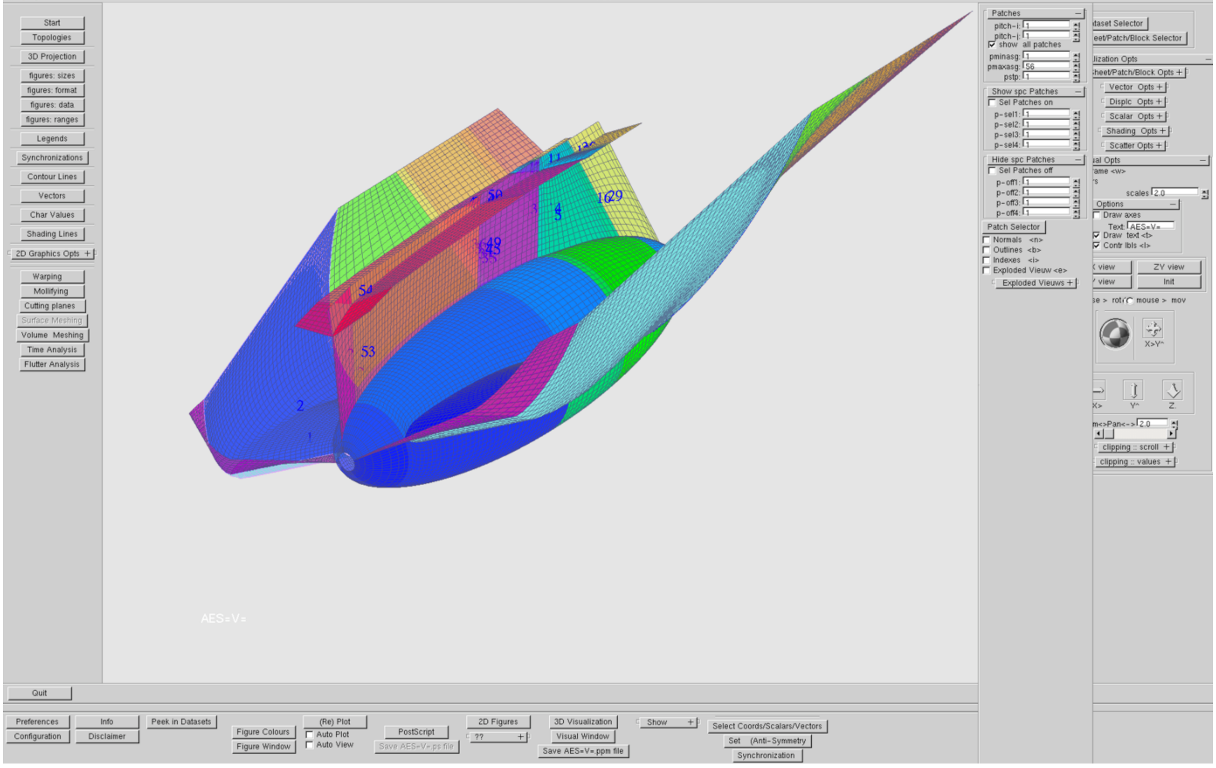


Figure 25 Embedded slit generation window and redistributed patches of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail completized with embedded slit patches

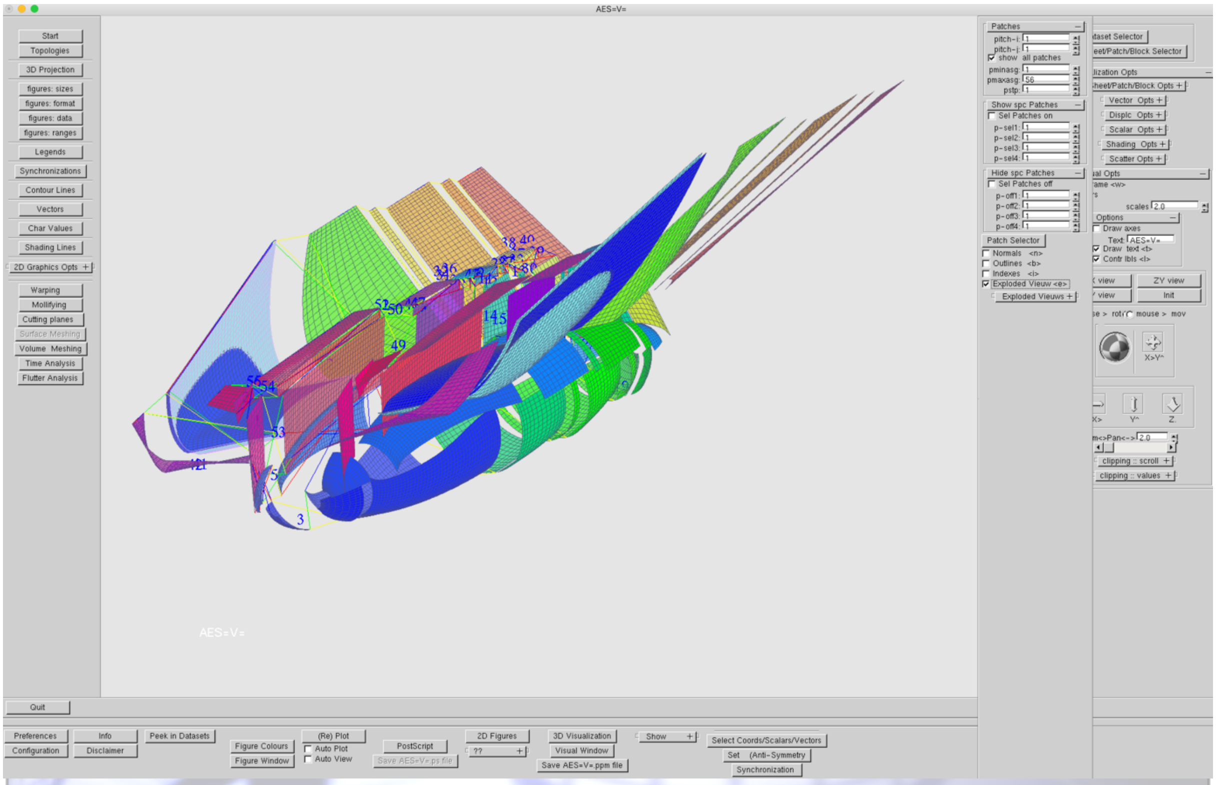
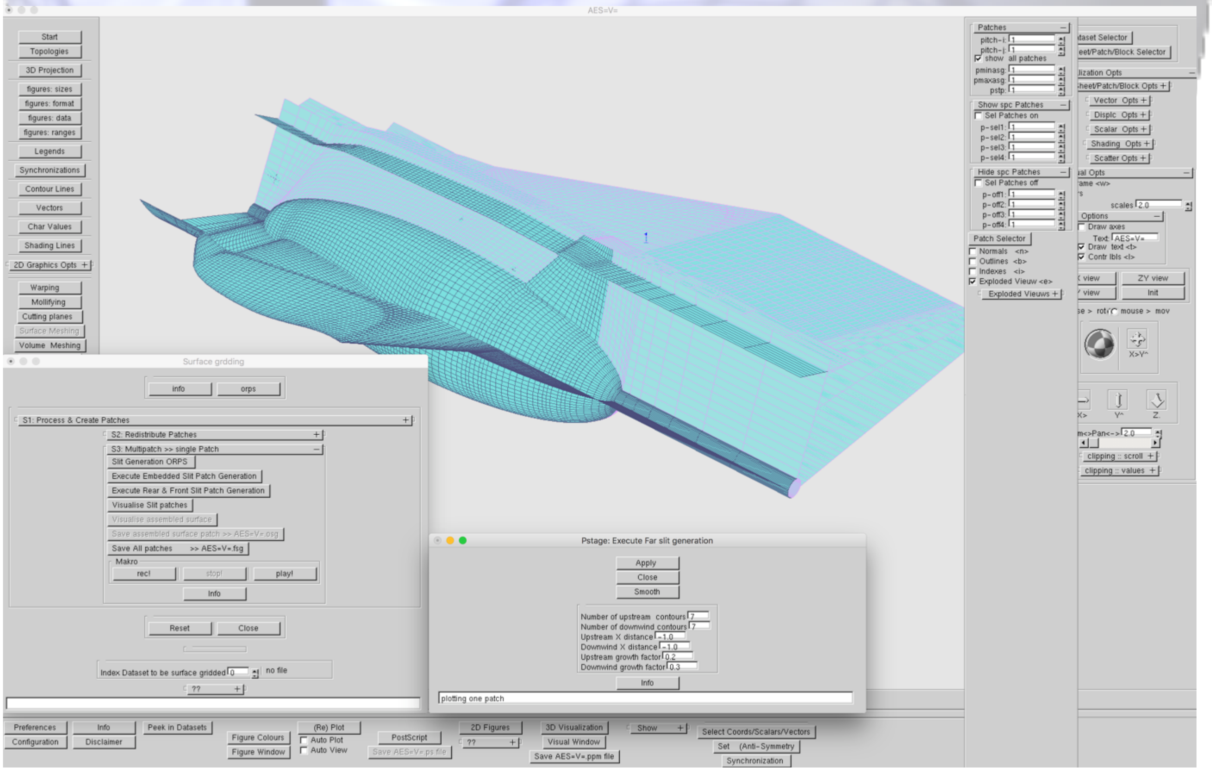


Figure 26 Explosive view of redistributed patches of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail completized with embedded slit patches



Pstage: Execute Far slit generation

Number of upstream contours 7
Number of downwind contours 7
Upstream X distance -1.0
Downwind X distance -1.0
Upstream growth factor 0.2
Downwind growth factor 0.3

plotting one patch

Figure 27 Mono patch of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail completized with embedded slit patches and front and rear far slit patches

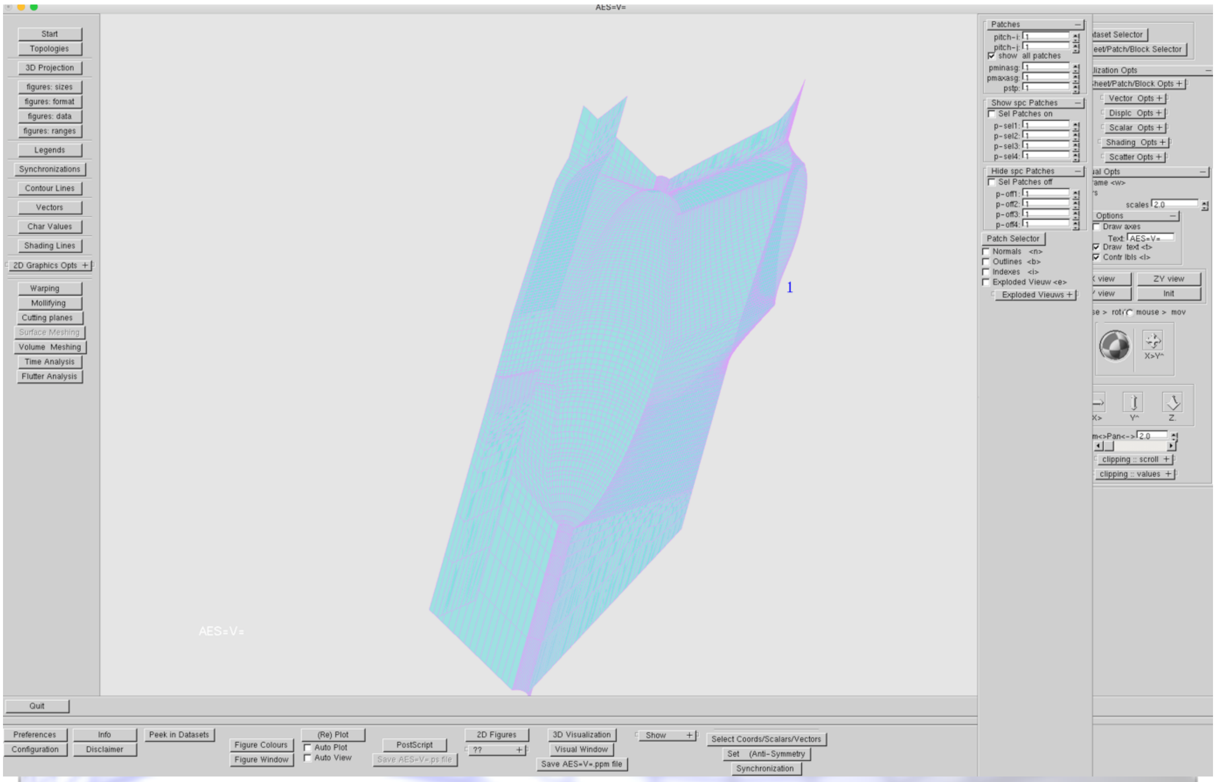


Figure 28 Mono patch of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail completized with embedded slit patches and front and rear far slit patches

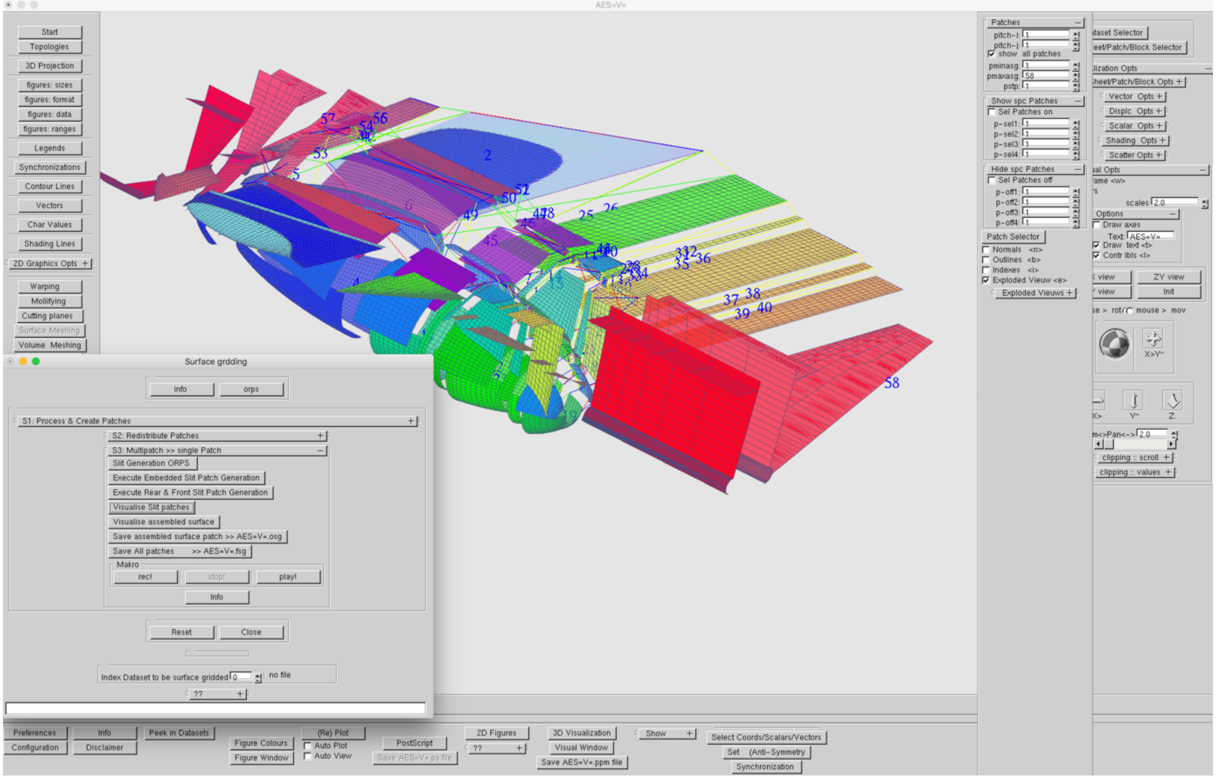
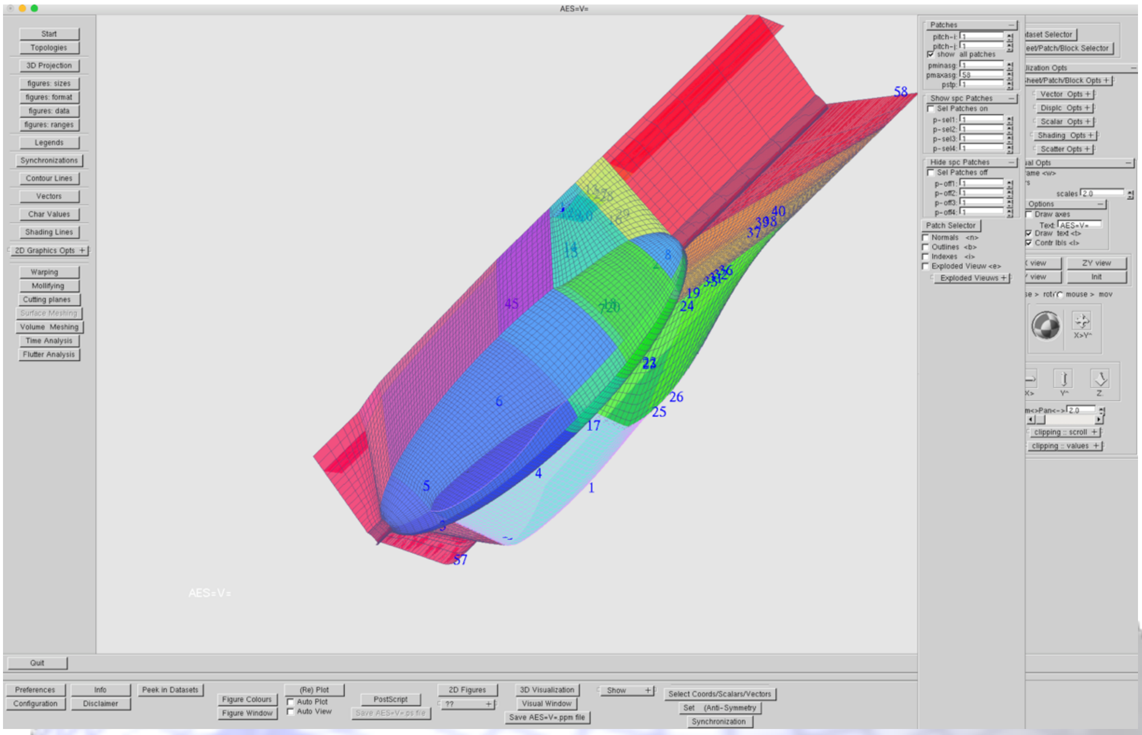


Figure 29 Explosive view of redistributed patches of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail completized with embedded slit patches and far rear and front slits



pitch-i: 1
pitch-j: 1
☑ show all patches
pminasg: 1
pmaxasg: 58
pstp: 1
☐ Sel Patches on
p-sel1: 1
p-sel2: 1
p-sel3: 1
p-sel4: 1
☐ Sel Patches off
p-off1: 1
p-off2: 1
p-off3: 1
p-off4: 1
☐ Normals <n>
☐ Outlines <b>
☐ Indexes <i>
☐ Exploded Vieuw <e>
ame <w>
scales 2.0
☐ Draw axes
Text: AES=V=
☑ Draw text <t>
☑ Contr lbls <l>
se > rot ○ mouse > mov
m<>Pan<–> 2.0
☐ Auto Plot
☐ Auto View

Figure 30 Redistributed patches of the wing with NLR7301 aerofoil and winglet & ellipsoidal body& vertical tail& horizontal tail completized with embedded slit patches and far rear and front slits

4.8 Dealing with imported surface patches

This section presents how to deal with an imported dataset with some features which takes the following steps to arrive at the ultimate single patch surface grid:

Obtain the geometry as a set of discrete patches from a CAD/CAM package in AES=V= format. Put the file in a working directory.

- Define the working directory on *.prefs.aes=v=.*
- Create *aes=v=.cnf* and define the file on *aes=v=.cnf.*
- Apply AES=V=.
- Press the Surface Meshing button which opens the *Surface Meshing Window* and shows the dataset.
- Open the *Phase S1: Edit rollout*. It is advised to use macro recording here.
- Make sure and take action that the patch normal is pointing outward.
- Make sure and take action that patches run from Leading edge to Trailing edge.
- Eliminate apices by redistribution.
- Add/create your own patches.
- Make sure and take action that all vertices are connected, except for those at the front and rear and in the symmetry plane (semi configurations). Vertex mismatching is in most cases due to wrong normal orientation or due to tolerances in imported patches.
- Et cetera.
- Close the *Phase S1: rollout.*
- Open the *Phase S2: surface redistribution rollout.*
- Set for the upper or lower wing segments the DEA on and specify the spacing at the edges and number of required nodes.
- Generate the surface mesh. Inspect distribution.
- Close the *Phase S2: redistribution rollout.*
- Open the *Phase S3: slit generation rollout* and generate embedded slits.
- Generate far upstream and downstream slits.
- Write the surface mesh to the output file.
- Close *Phase S3*: *slit generation rollout.*
- Et cetera.


E
S
4

5 AES=V=volume mesh generation

The volume mesh generation is carried out for each patch separately resulting in a set of individual volume meshes. The input data consists of surface patches which may represent either a part or better the whole of an A/C configuration, depending on the required topology. Only structured surface patches can be meshed. Existing hexahedral meshes can be refined, extended and/or smoothed.

The volume meshing consists of generating or providing:

- Single Block: A single block patch conforming volume mesh around/from a single surface patch ultimately representing the complete A/C. There is hardly any restriction in topology.
- Multiple Blocks: a set of dependent patch conforming volume meshes sharing/matching their non-body surface patch boundaries.
- Overset Blocks: A set of dependent patch conforming volume meshes around the surface patches which do not have to match exactly but rather overlap each other (chimera, overset). The three main components of the overset mesh system methodology are the single block structured mesh generator, the background mesh generator and the mesh connection algorithm. The Chimera approach reduces geometric complexities. Generally, the patch conforming meshes are embedded within a background mesh of simple structure covering the whole domain.
- Transformation of parts (or full) of the hexahedral meshes to triangular (2D), tetrahedron and prism meshes. The prism is oriented along the streamline axis.

AES=V= volume mesh generation is based on hyperbolic, algebraic mesh generation fortified with elliptical smoothing and requires minimal user interference. Speed, robustness and range of applicability are key items.
The outer boundaries are defined according to the selected mesh topology for each patch and method or prescribed. The volume mesh nodes are distributed from the surface patches towards far field boundaries which depend on the associated topologies.

Hyperbolic mesh generation generates reasonably good hexahedral meshes for geometries with moderate concave zones with respect to: orthogonality, stretching and aspect ratio of cells and have free outer boundaries.

Algebraic mesh generation generates hexahedral meshes for geometries with relatively small concave zones and have defined outer boundaries.

Elliptic smoothing improves mesh quality, unravel and smoothes transition zones between generations. Eliminates cross-over and negative cell volumes, increases smoothness and uniformity of cells.

Chimera tagging connects overlapping meshes. The latter approach permits the use of high quality nearly orthogonal volume meshes around each individual component by hyperbolic mesh generation thereby naturally adapting to local flow and geometry characteristics at the expense and risks of generating connectivity. The overlapping regions require information to be transferred between the different sets of meshes by

interpolation and for which the connectivity has to be derived. For Chimera meshes the patch conforming O-type topology mesh is preferred because it allows for a significant reduction of the overlap zones as well as enabling a uniform spacing in the overlap zones. The tagging algorithm categorizes the centroids (cell centroid stencil) or vertices (cell vertex stencil) of each component mesh as: **Normal;** adheres to the governing equation, **Fringe;** handled by warping from Normal and/or Fringes, and **Hole;** is excluded. The tagging algorithm supports cell centroid and cell vertex stencils. Allows 1 to 4 connection (fringe) layers; The value of any quantity at a fringe point is obtained from its nearest points or tri-linear hexahedral or Laplacian physical or hexahedral mapped or biharmonic physical or hexahedral mapped interpolation. The support points of the interpolation might be 1 to 8 points, might be explicit (the support of each fringe point does not contain other fringe points, just normal points) or implicit (the support of fringe point might contain other fringe points, besides normal points) and moreover external support points outside the overlap zone might be allowed (radiation).
Generally sufficient overlap of the component meshes is required and moreover the mesh spacing of the interfering meshes should be compliant in the fringe zones which is not easy to satisfy as this involves in general the region close to the component inner surface and the region close to the component outer surface. The construction of the overall Chimera mesh from the component meshes can be a time-consuming operation. Alternating Direction Trees are applied to reduce the run time. The tagging strategy can be default (maximum overlap) or weighted (mesh index, mesh value, et cetera).

With AES=V= volume mesh generation method the effort to generate mono-block HO meshes about the single patch surface description of the complete aircraft with embedded upwind slits and downwind slits (wake surfaces) with mild concavities is quite small. The meshes have good quality about concave areas such as aerofoil noses and wing-fuselage junctions. The accuracy of the mono-block mesh approach to more complex configurations is considered acceptable for aeroelastic applications rather than for performance design.

In the latter situation AES=V= ‘s multi-block mesh generation is an alternative. The individual meshes are generated about each patch with a hybrid hyperbolic/algebraic method. The corner vertices of the outer top boundary of each patch might be prescribed or free. The connecting side boundaries are averaged.

Background mesh generation. The Chimera approach is supported with Cartesian as well as cylindrical background mesh generation adapted to the spacing at the outer and inner boundaries of the component meshes.

Triangular, prism or tetrahedron mesh transformation. The hexahedral meshes are simply split in regular zones. In negative volume zones or zones of reduced mesh quality a Delaunay method is used. A hybrid mesh composed of body conforming hexahedral cells near the body and prism or tetrahedron cells towards the far field boundaries is easily generated. Therefore, the hexahedral mesh generation is a pretty good baseline for a structured unstructured mesh generation. Moreover, the transformation zone can be specified thus leaving hexahedral cells near the inner (boundary layer) and/or far field boundaries.

Non-uniform hexahedral hyperbolic generation which reduces the number of hexahedra's in concave zones[1].

The individual meshes can be tuned with the following:

- Elliptic smoothing
- Normal curve redistribution and subdivision to improve spacing in concave zones and/or to correct excessive elliptic smoothing
- Tangential curve redistribution to improve spacing in oversets zones and in concave zones
- H topology transformation to C topology to account for curved noses
- H topology edge transformation to H topology to account for curved noses.
- Plane deletion
- Smoothing of the latest generated k planes
- Unravelling by smooth and by force
- Wipe concavities
- Mesh Characteristics analysis

The individual meshes, their characteristics and Chimera connections can be visualised in many ways. Embedded mesh characteristics are: i) orthogonality (skewness); ii) smoothness, iii) stretching et cetera.

---

[1] still under development

6 Demo volume mesh generation

The objective of the section is to demonstrate the volume mesh generation module of AES=V= for several characteristic geometries from complex 2-D objects to a complete 3-D A/C type configurations. AES=V= has provided single meshes from complex 2-D objects to complete 3-D A/C configurations.

The volumes mesh generation is accessed by pressing the associated button on the left dock. Then the volume meshing window pops up together with a visualization of the selected imported file. The volume meshing requires basically the import of one file containing the coordinates of the patches describing the surface of the A/C. The file has the AES=V= format which has to be specified on the *aes=v=.cnf* file. The visualization options are selectable in the dock at the right-hand side and also by pressing the visual window button in the bottom dock. Moreover, blocks and planes can be selected/deselected. Pitch rates can be set. In Chimera mode holes, fringes, donors and interpolation coefficients can be inspected.

Having started up AES=V= (see section Running AES=V=) and opening the volume meshing window (see Figure 31), the input patches are visualized. You can perform the actions by pressing associated buttons in the volume meshing window. You can control the actions with the associated rollouts. The actions and control can be applied to all patches or to selected patches.

6.1 Mesh generation procedure in general

- Select the patch file
- Select/set the topologies
- Apply the hyperbolic or algebraic mesh generation. When problems (negative volumes and mesh overlap) occur in the hyperbolic generation (often caused by a non-smooth surface mesh description at tip edges and non-smooth transitions at relatively small body components (e.g. nose of fuselage) to the slits and in very strong concave zones) increase pitch rates and/or the alpha and/or 4 th order smoothing and/or reduce growth.
- Smooth the meshes
- Extend the meshes by the hyperbolic method or algebraically to the distance needed by the application.
- Smooth the meshes
- For viscous applications refine the meshes algebraically close to the body by prescribing an adequate viscous spacing.
- Smooth the meshes
- Check by analysing the mesh by the embedded options and smooth until the meshes are good.
- Save the meshes.

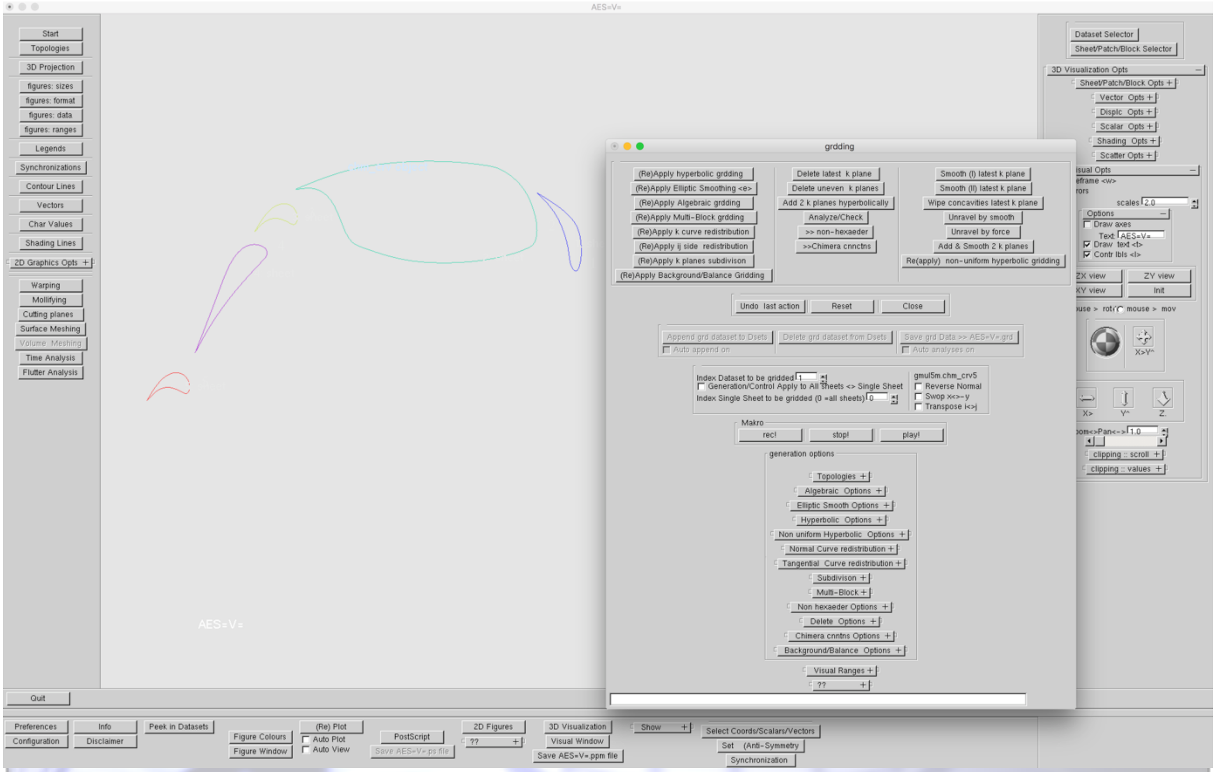


Figure 31 The volume meshing window and the multi element aerofoil

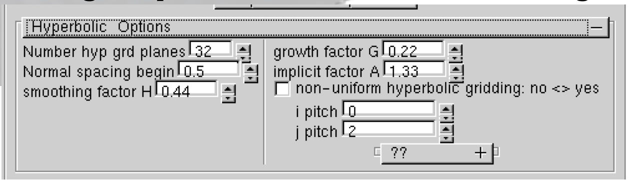
6.2 2D volume mesh applications

This section demonstrates the 2D mesh applications about a multi element aerofoil as follows:

6.2.1 Single block hexahedral mesh

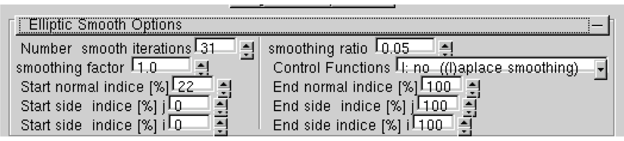
The elements are connected from their trailing edges to the nearest point on the noses as a single rectilinear patch and a mono block mesh is generated (see Figure 34).

The generation takes a few seconds effort wall clock time. The figure shows the mesh and a typical output of the mesh characteristic, its orthogonality. Many other characteristics can be visualised. The mesh is generated with the hyperbolic method using default control with pitch value 3. Setting the pitch value is advised for strong concave or discontinuous geometries and for speed. A few elliptic smoothing's are applied in the outer region (Figure 33).


Hyperbolic Options

Number hyp grd planes 32
Normal spacing begin 0.5
smoothing factor H 0.44
growth factor G 0.22
implicit factor A 1.33
☐ non-uniform hyperbolic gridding: no <> yes
i pitch 0
j pitch 2

Figure 32 Hyperbolic generation control



Elliptic Smooth Options

Number smooth iterations 31
smoothing ratio 0.05
smoothing factor 1.0
Control Functions l: no ((l)aplace smoothing)
Start normal indice [%] 22
End normal indice [%] 100
Start side indice [%] j 0
End side indice [%] j 100
Start side indice [%] i 0
End side indice [%] i 100

Figure 33 Elliptic smoothing control

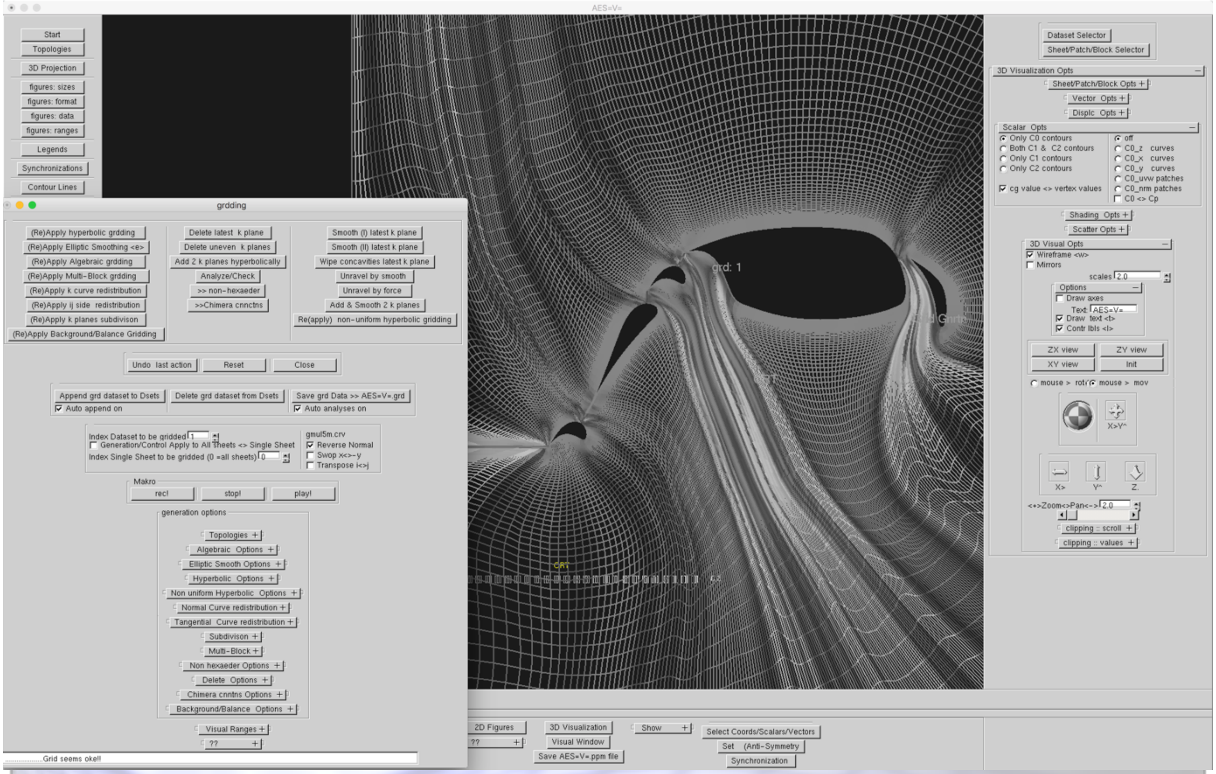
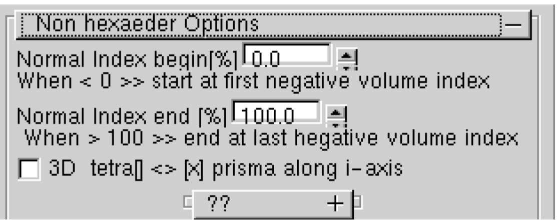


Figure 34 The volume meshing window and the generated mesh about the multi element aerofoil. The grey level shading shows the orthogonality.

6.2.2 Triangular mesh

The afore generated mono block mesh is simply transformed into a triangular mesh (Figure 36). Again, this takes a few seconds wall clock time. In regular zones this is straightforward. In zones with negative volumes (not in this example) a Delaunay approach is applied. It is believed that this approach forms a very good baseline for unstructured simulations. All cells are transformed in this example. By specifying the normal begin index and or end index only a zone is transformed which might be advantageous for viscous simulations.



Non hexaeder Options

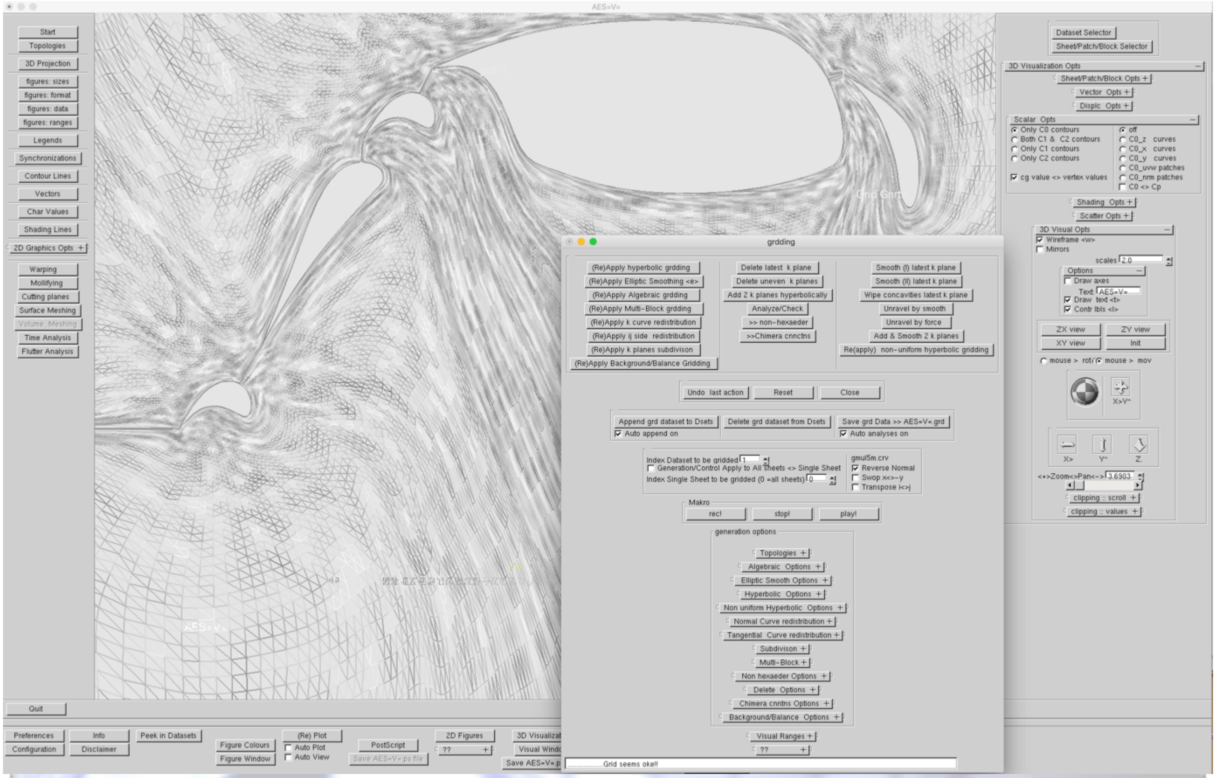
Normal Index begin[%] 0.0
When < 0 >> start at first negative volume index

Normal Index end [%] 100.0
When > 100 >> end at last negative volume index

☐ 3D tetra[] <> [x] prisma along i-axis

?? +

Figure 35 Non hexahedral control



Grid seems oke!!

Figure 36 The volume meshing window and a triangular mesh about the multi element aerofoil. The grey level shading shows the smoothness

6.2.3 Multi-block mesh

Next a multi-block mesh is generated about the elements (Figure 37). This requires to split the single patch surface in multiple patches. We chose simple for the demonstration to split the patch in 12 patches at the trailing edges and about their quarter chords. There are of course much better splits and blocks possible! We select the outer boundary in the form of a default normal extension of the vertices at the edges of the patches. H topology blocks are generated with the hyperbolic method with default control. These can be simply transformed to C topology which are continuously connected to their predecessors or changed with the Hturn method to improve the mesh near element noses. The many possibilities to construct multi-block meshes are presented in Figure 38. The generation can take much more efforts (minutes in this case) at the work floor with respect to patch selection, outer boundaries setting, smoothing's and redistributions. In this case the mesh is generated for the first few mesh layers with the hyperbolic method for each patch to take care of the concave areas (especially the yellow zone between slat and aerofoil), the following layers are a blend with hyperbolic generated layers and algebraically generated layers. The side boundaries of connecting meshes are automatically averaged and smoothed. Also, redistributions along k are applied to account for excessive smoothing.

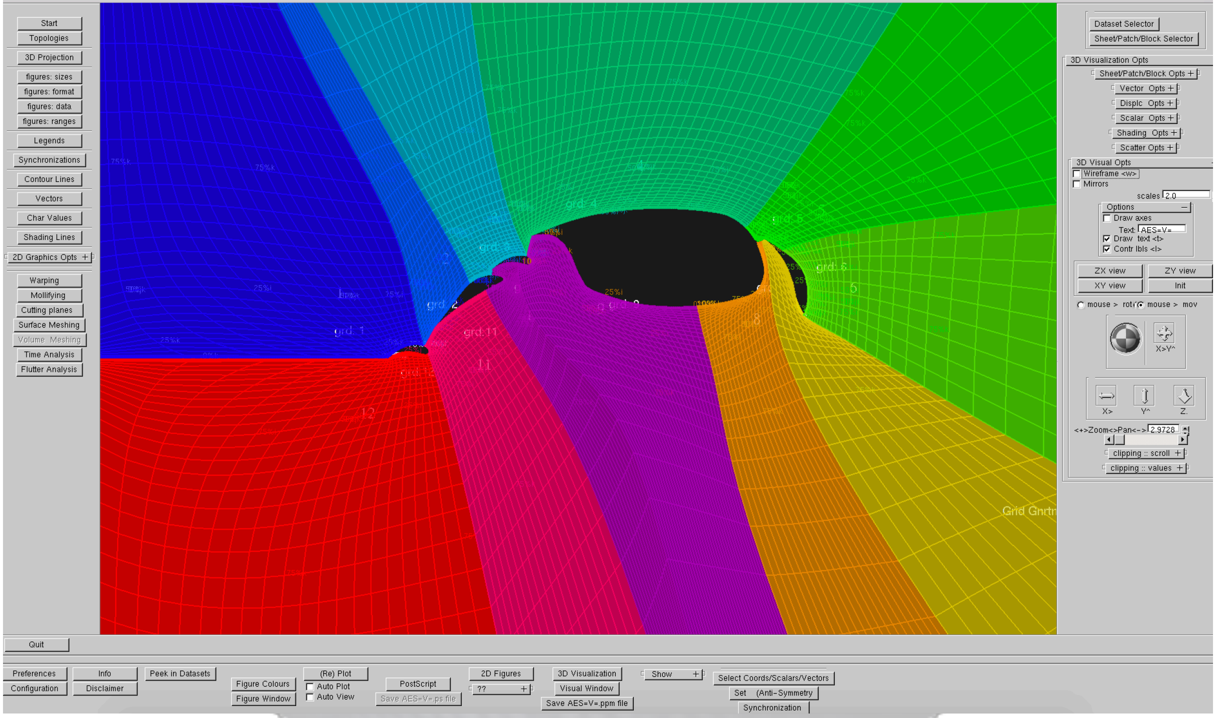
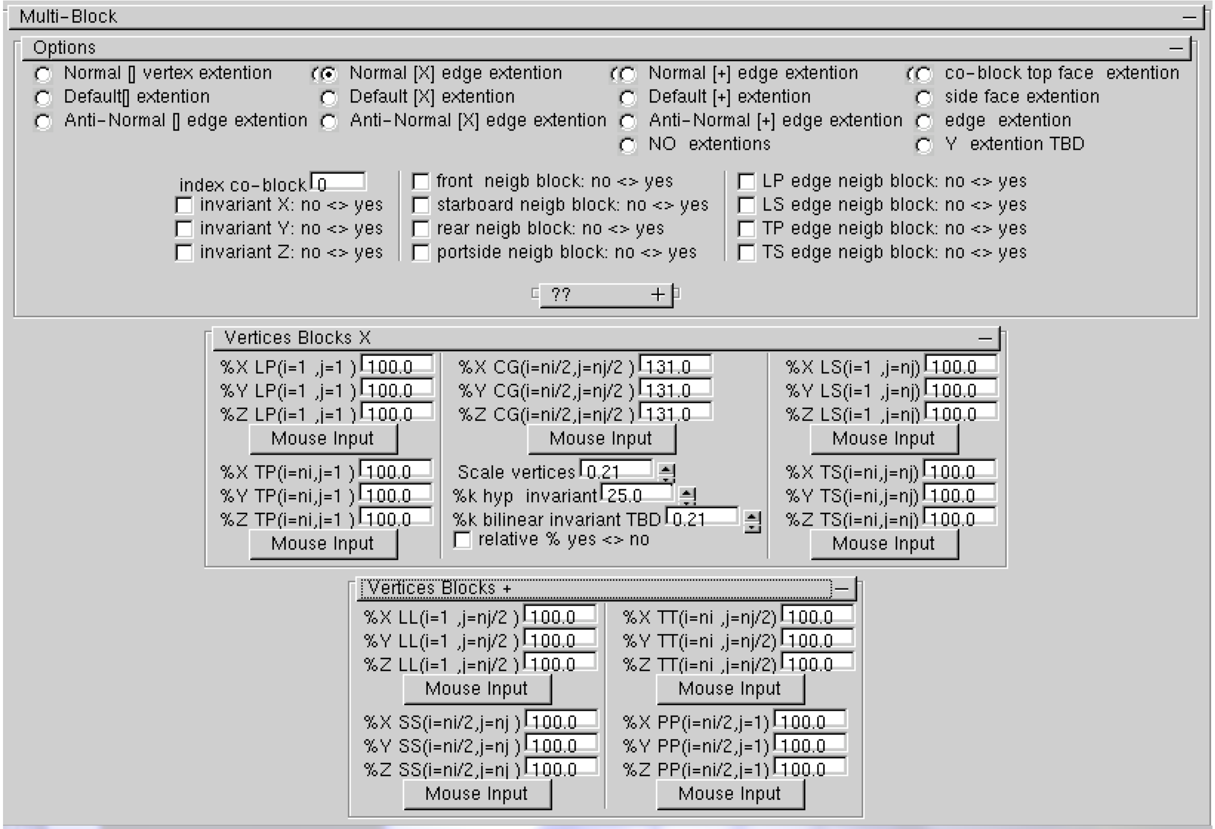


Figure 37 A multi block mesh about the multi element aerofoil



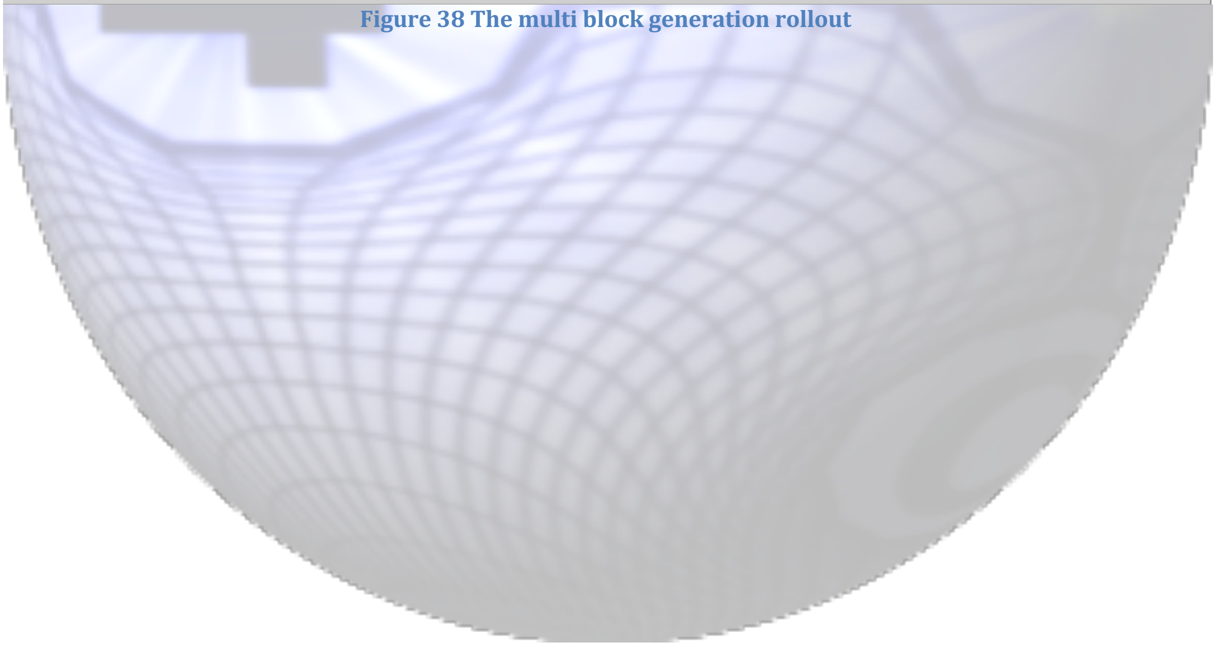
○ Normal [] vertex extention
○ Default[] extention
○ Anti-Normal [] edge extention
● Normal [X] edge extention
○ Default [X] extention
○ Anti-Normal [X] edge extention
○ Normal [+] edge extention
○ Default [+] extention
○ Anti-Normal [+] edge extention
○ NO extentions
○ co-block top face extention
○ side face extention
○ edge extention
○ Y extention TBD

index co-block 0
☐ invariant X: no <> yes
☐ invariant Y: no <> yes
☐ invariant Z: no <> yes
☐ front neigb block: no <> yes
☐ starboard neigb block: no <> yes
☐ rear neigb block: no <> yes
☐ portside neigb block: no <> yes
☐ LP edge neigb block: no <> yes
☐ LS edge neigb block: no <> yes
☐ TP edge neigb block: no <> yes
☐ TS edge neigb block: no <> yes

%X LP(i=1 ,j=1) 100.0
%Y LP(i=1 ,j=1) 100.0
%Z LP(i=1 ,j=1) 100.0
%X TP(i=ni,j=1) 100.0
%Y TP(i=ni,j=1) 100.0
%Z TP(i=ni,j=1) 100.0
%X CG(i=ni/2,j=nj/2) 131.0
%Y CG(i=ni/2,j=nj/2) 131.0
%Z CG(i=ni/2,j=nj/2) 131.0
Scale vertices 0.21
%k hyp invariant 25.0
%k bilinear invariant TBD 0.21
☐ relative % yes <> no
%X LS(i=1 ,j=nj) 100.0
%Y LS(i=1 ,j=nj) 100.0
%Z LS(i=1 ,j=nj) 100.0
%X TS(i=ni,j=nj) 100.0
%Y TS(i=ni,j=nj) 100.0
%Z TS(i=ni,j=nj) 100.0

%X LL(i=1 ,j=nj/2) 100.0
%Y LL(i=1 ,j=nj/2) 100.0
%Z LL(i=1 ,j=nj/2) 100.0
%X SS(i=ni/2,j=nj) 100.0
%Y SS(i=ni/2,j=nj) 100.0
%Z SS(i=ni/2,j=nj) 100.0
%X TT(i=ni ,j=nj/2) 100.0
%Y TT(i=ni ,j=nj/2) 100.0
%Z TT(i=ni ,j=nj/2) 100.0
%X PP(i=ni/2,j=1) 100.0
%Y PP(i=ni/2,j=1) 100.0
%Z PP(i=ni/2,j=1) 100.0

Figure 38 The multi block generation rollout



6.2.4 Chimera composition

A chimera composition is generated about the elements which is a rather complex scenery. We will generate periodic meshes about the elements with the hyperbolic method. First, we set the geometric periodicity for all five elements, and specify solid boundary and free outer boundaries. We apply next the hyperbolic mesh generation once with default control. Selecting the wing element as the balance we specify the far field boundary for its mesh and run a few times the hyperbolic mesh generation only for this element until it overlaps all others (Figure 39)

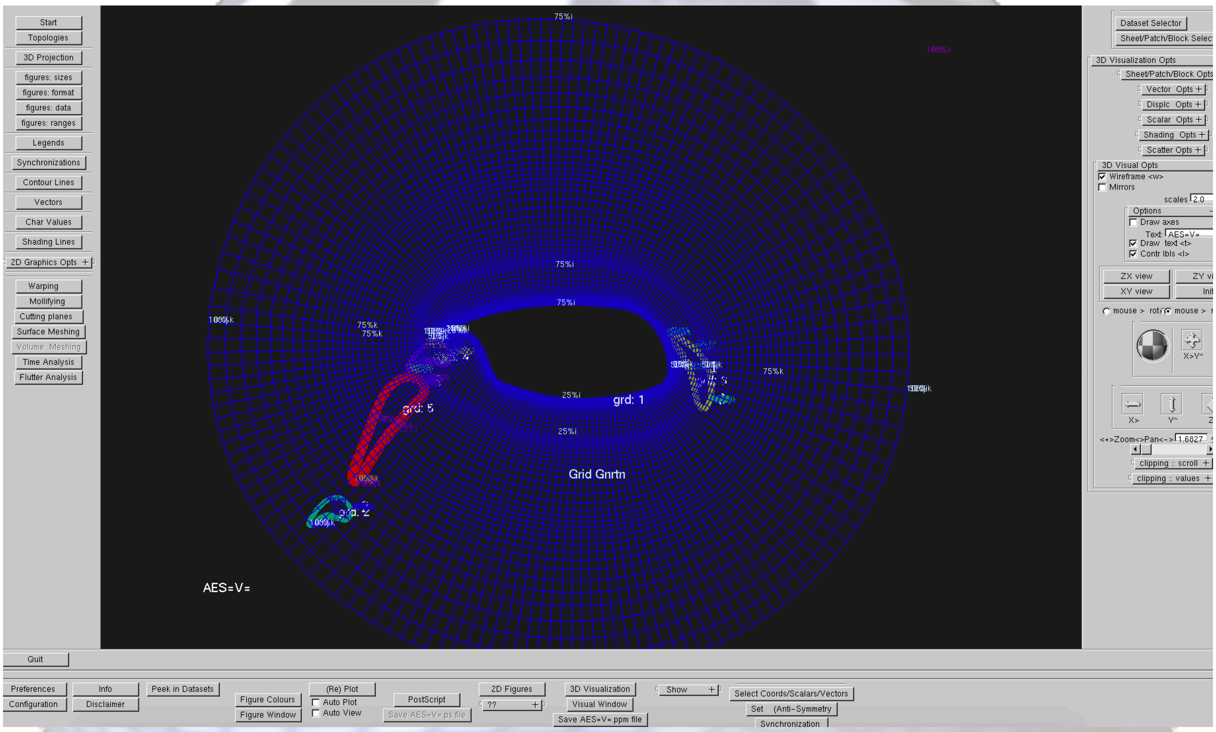
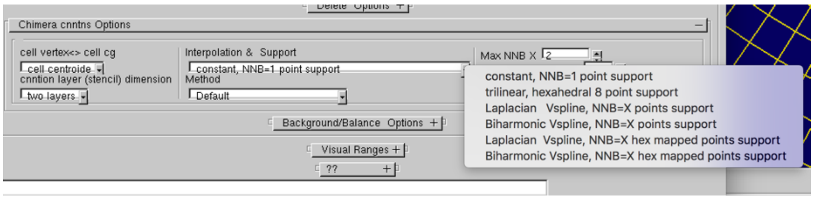


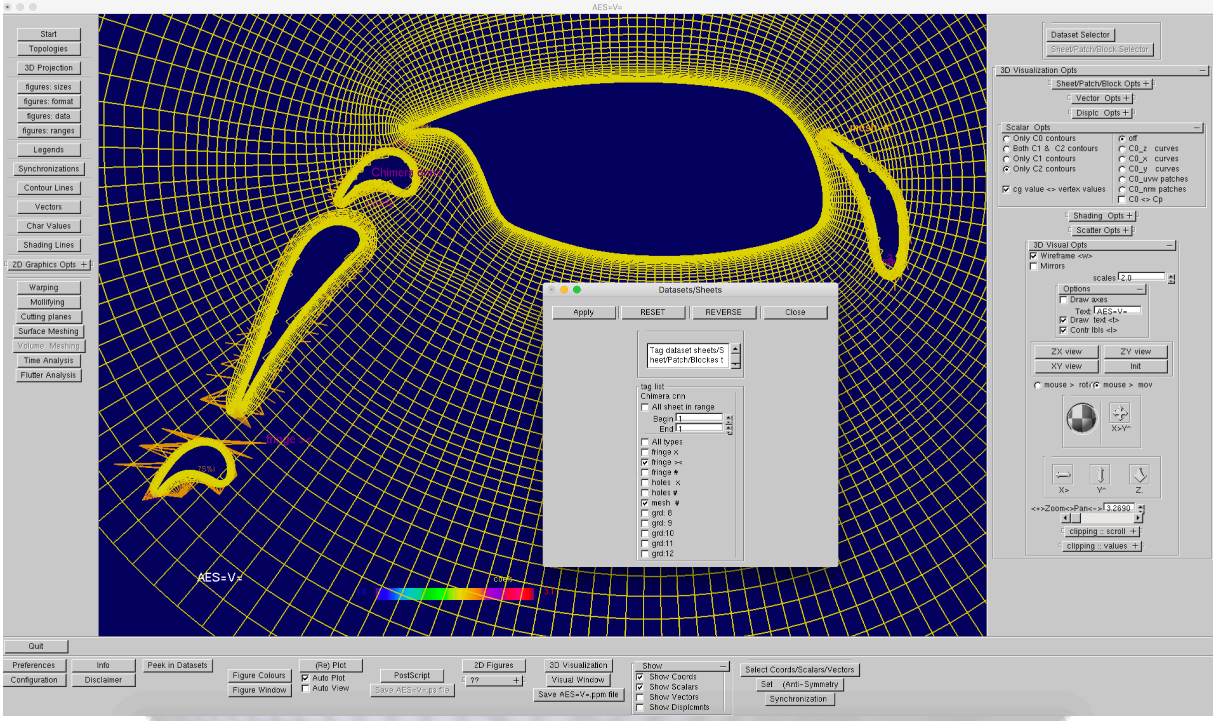
Figure 39 A multiple mesh about the multi element aerofoil



cell vertex<> cell cg: cell centroide
cnntion layer (stencil) dimension: two layers
Interpolation & Support: constant, NNB=1 point support
Method: Default
Max NNB X: 2

Next, we apply the Chimera method using the default control as shown right in the Chimera Rollout and present the the resulting composition (Figure 40). The figure shows the mesh, the fringes and the donor-fringe connection with coefficient value. One can improve the composition by adapting the balance mesh spacing in the overlapping zones.
Constant, Trilinear 8 supp,

The value of any quantity at a fringe point is obtained from a simple tri- linear interpolation of the values of the support points.



Datasets/Sheets: Tag dataset sheets/Sheet/Patch/Blockes t
tag list: Chimera cnn
☐ All sheet in range
Begin 1
End 1
☐ All types
☐ fringe ×
☑ fringe >‹
☐ fringe #
☐ holes ×
☐ holes #
☑ mesh #
☐ grd: 8
☐ grd: 9
☐ grd:10
☐ grd:11
☐ grd:12

Scalar Opts: ● Only C2 contours; ● off; ☑ cg value <> vertex values
3D Visual Opts: ☑ Wireframe <w>; ☐ Mirrors; scales 2.0
Options: ☐ Draw axes; Text AES=V=; ☑ Draw text <t>; ☑ Contr lbls <l>
<+>Zoom<>Pan<-> 3.2690
Show: ☑ Show Coords; ☑ Show Scalars; ☐ Show Vectors; ☐ Show Displcmnts
☑ Auto Plot; ☐ Auto View

Figure 40 The composed mesh with fringe coefficients and donors about the multi element aerofoil

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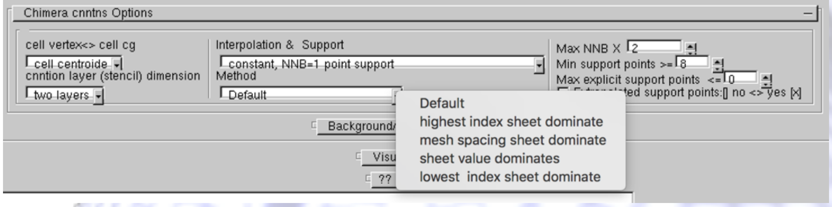
6.2.5 Chimera composition with a background cartesian grid

Finally, we will use a background adapted cartesian mesh as the balance. Again, we start with hyperbolic generation of periodic meshes around each element. The cartesian mesh is generated which automatically adapts to the elements. Next, we apply the Chimera method using the default control as shown left and present the resulting composition (Figure 41). The figure shows the mesh, the holes, the fringes and the donor-fringe connection with coefficient value. One can improve the composition by adapting the mesh spacings in the overlapping zones.


Chimera cnntns Options

cell vertex<> cell cg: cell centroide
cnntion layer (stencil) dimension: two layers
Interpolation & Support: constant, NNB=1 point support
Method: Default
Max NNB X 2
Min support points >= 8
Max explicit support points <= 0
Extrapolated support points:[] no <> yes [X]

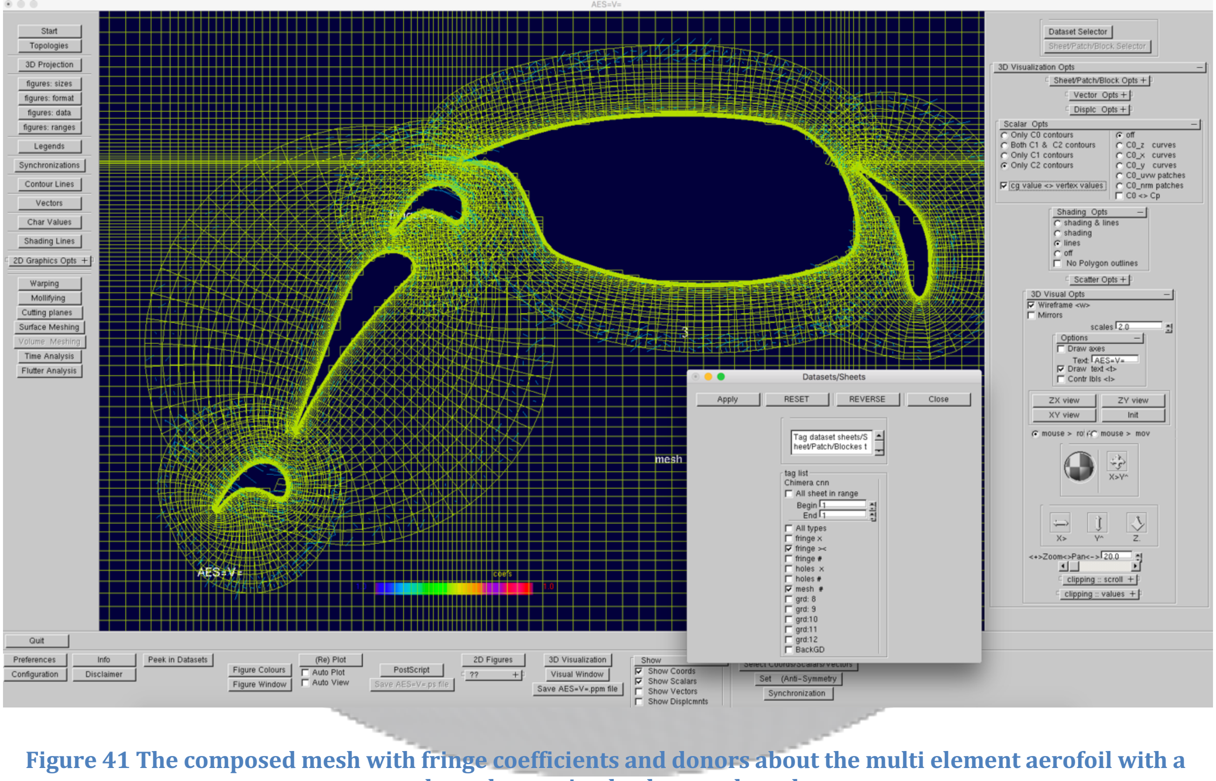


Figure 41 The composed mesh with fringe coefficients and donors about the multi element aerofoil with a adapted cartesian background mesh

6.3 3D volume mesh applications

This section demonstrates the 3D mesh generation about the configuration designed in section 4.5, redistributed in section 4.6 and transformed to a single patch in section 4.7. The configuration consists of a wing with a winglet, a fuselage, a vertical tail and a horizontal tail. Having started up AES=V= (see section
Running AES=V=) and opening the volume meshing window (see Figure 31), the single input patch is visualized. You can perform the actions by pressing associated buttons in the volume meshing window. You can control the actions with the associated rollouts.

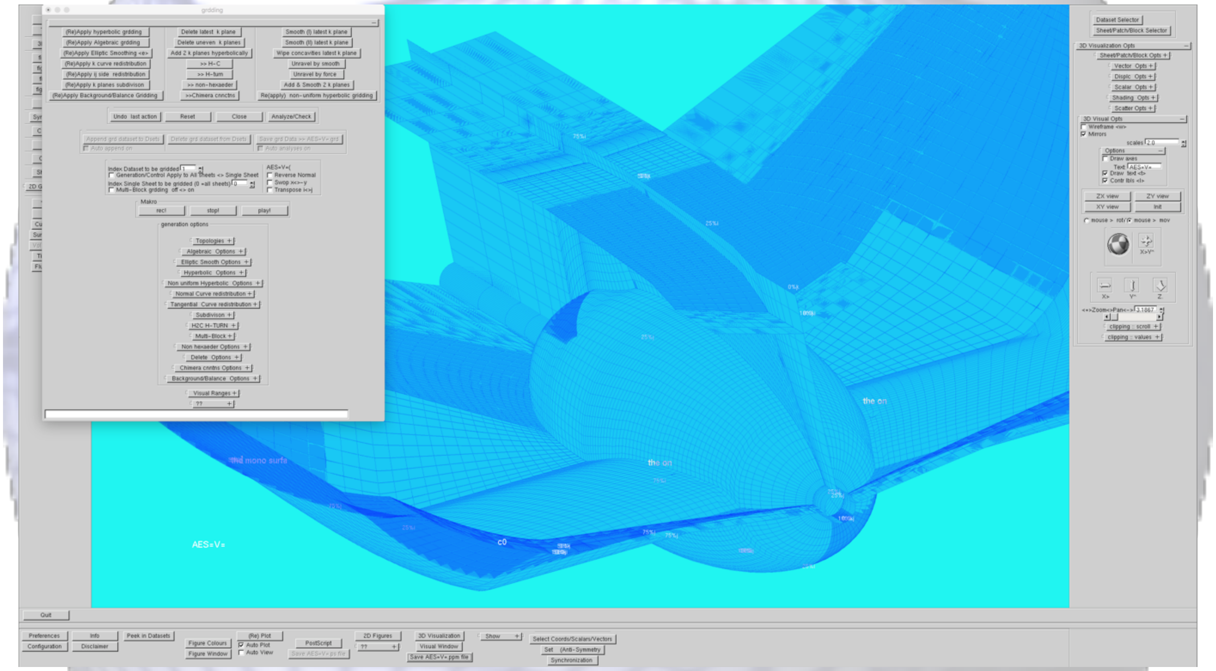
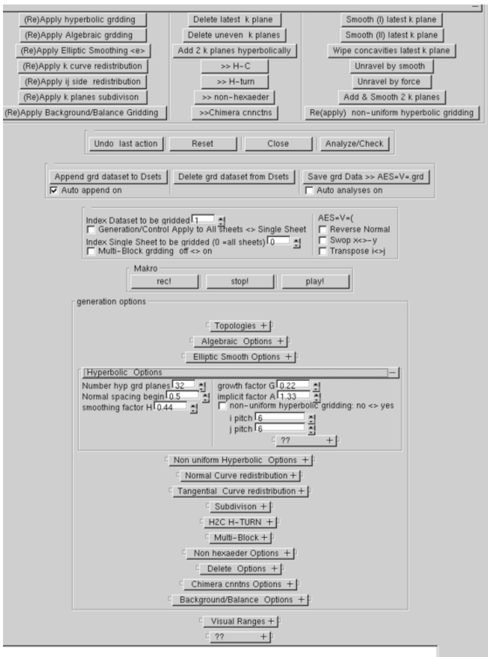


Figure 42 The volume meshing window and the surface mesh of the A/C

6.3.1 Single block hexahedral mesh

We generate a single block **OH** mesh around this fairly complex shape with concavities and some non-smooth transitions.



☑ Auto append on
☐ Auto analyses on

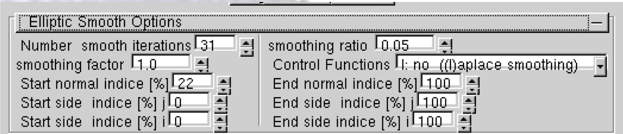
Index Dataset to be gridded 1
☐ Generation/Control Apply to All sheets <> Single Sheet
Index Single Sheet to be gridded (0 =all sheets) 0
☐ Multi-Block grdding off <> on

AES=V=(
☐ Reverse Normal
☐ Swop x<>-y
☐ Transpose i<>j

Number hyp grd planes 32
Normal spacing begin 0.5
smoothing factor H 0.44
growth factor G 0.22
implicit factor A 1.33
☐ non-uniform hyperbolic gridding: no <> yes
i pitch 6
j pitch 6

Figure 43 The volume meshing window

The single block 105x159*33 mesh is generated with the hyperbolic method using default control with pitch values 6 in i and j direction.



Number smooth iterations 31
smoothing factor 1.0
Start normal indice [%] 22
Start side indice [%] j 0
Start side indice [%] i 0
smoothing ratio 0.05
Control Functions l: no ((l)aplace smoothing)
End normal indice [%] 100
End side indice [%] j 100
End side indice [%] i 100

Using pitch values is advised for strong concave or non-smooth geometries and also for speed. A few elliptic smoothing's are applied in the outer region (Figure 33). The generation takes one second effort wall clock time. The figure shows characteristic mesh planes and typical output of the mesh characteristic, its orthogonality (starboard side) and smoothness (port side). Many other characteristics and planes can be visualised. The mesh can be easily changed/improved by smoothing and redistributions and extended.

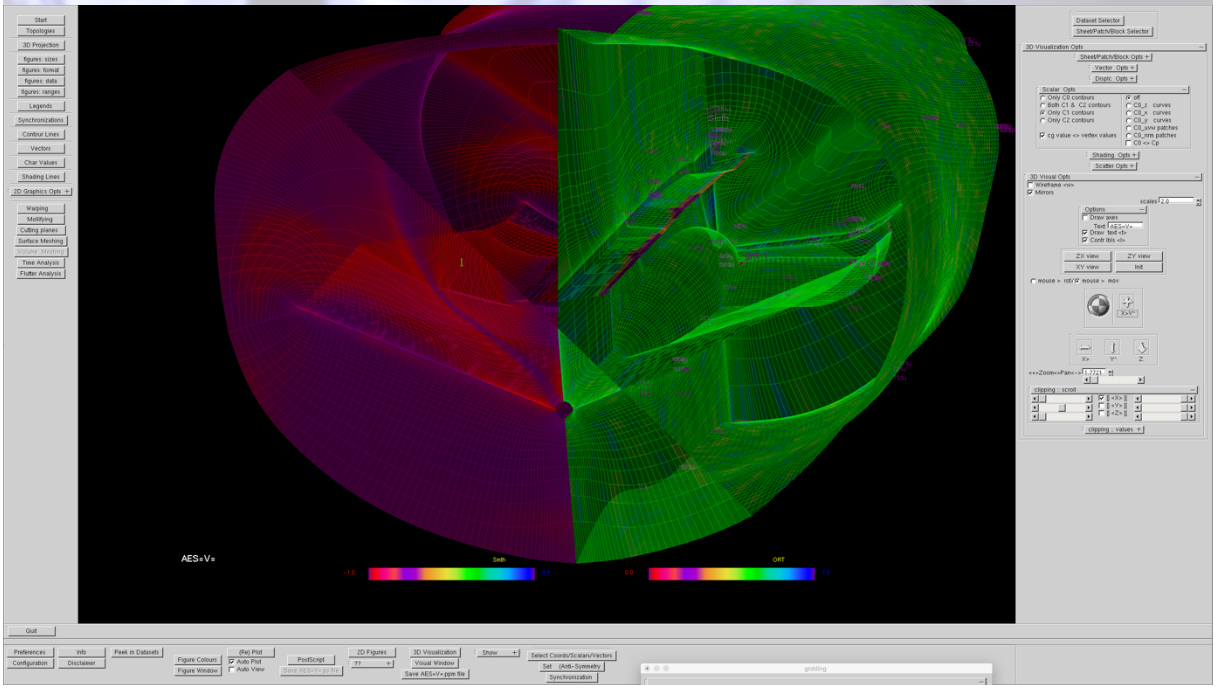


Figure 44 Characteristic mesh planes and mesh characteristics: orthogonality (starboard side) and smoothness (port side) of the mesh around the A/C

6.3.2 Mixed hexahedral-tetrahedra mesh

The hexahedral mesh is simply transformed into a mixed hexahedral-tetrahedra mesh (Figure 36). Again, this takes a few seconds wall clock time. In regular zones this is straightforward. In zones with negative volumes (not in this example) a Delaunay approach is applied. It is believed that this approach forms a very good baseline for unstructured mesh generations. The range 31%-100% normal wise cells are transformed in this example. By specifying the normal begin index and or end index zones are not transformed which might be advantageous for viscous zones and the far field.

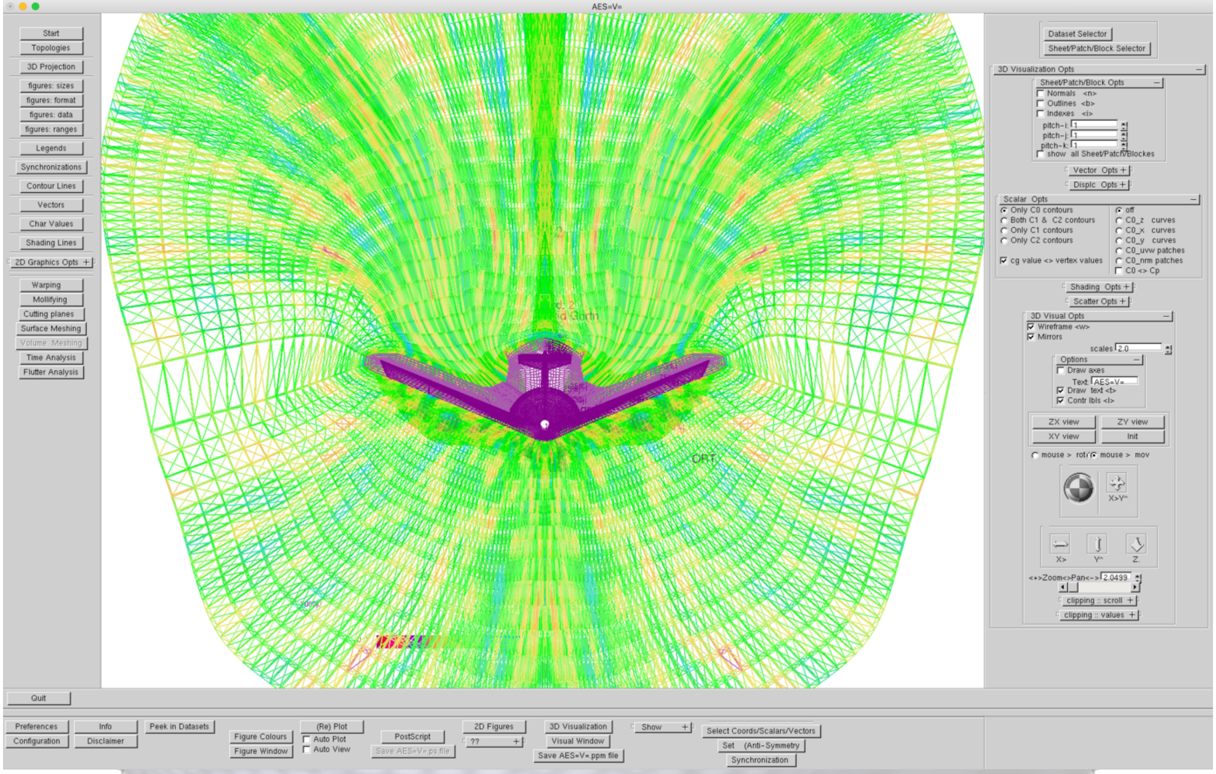
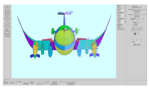


Figure 45 Characteristic mesh planes and mesh smoothing of the mixed hexahedral/tetrahedra mesh around the A/C

6.3.3 Mixed hexahedral-prism mesh

Also, the hexahedral mesh is simply transformed into a mixed hexahedral prism mesh which is more suited for flows with relatively small variations in streamwise directions. Again, this takes a few seconds wall clock time. In regular zones this is straightforward. In zones with negative volumes (not in this example) a Delaunay approach is applied. This approach forms a very good baseline for viscous simulations. Not all cells are transformed in this example. The normal begin index is set to 21% so that a boundary layer zone is not transformed.



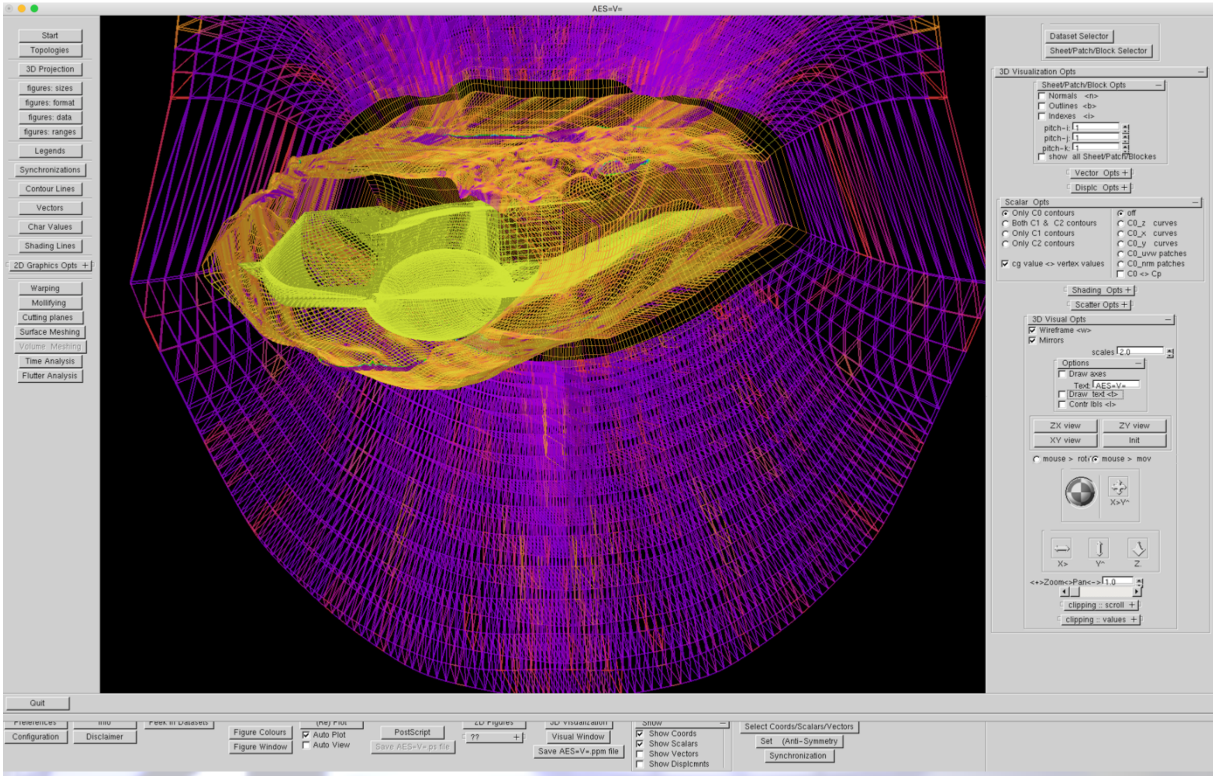
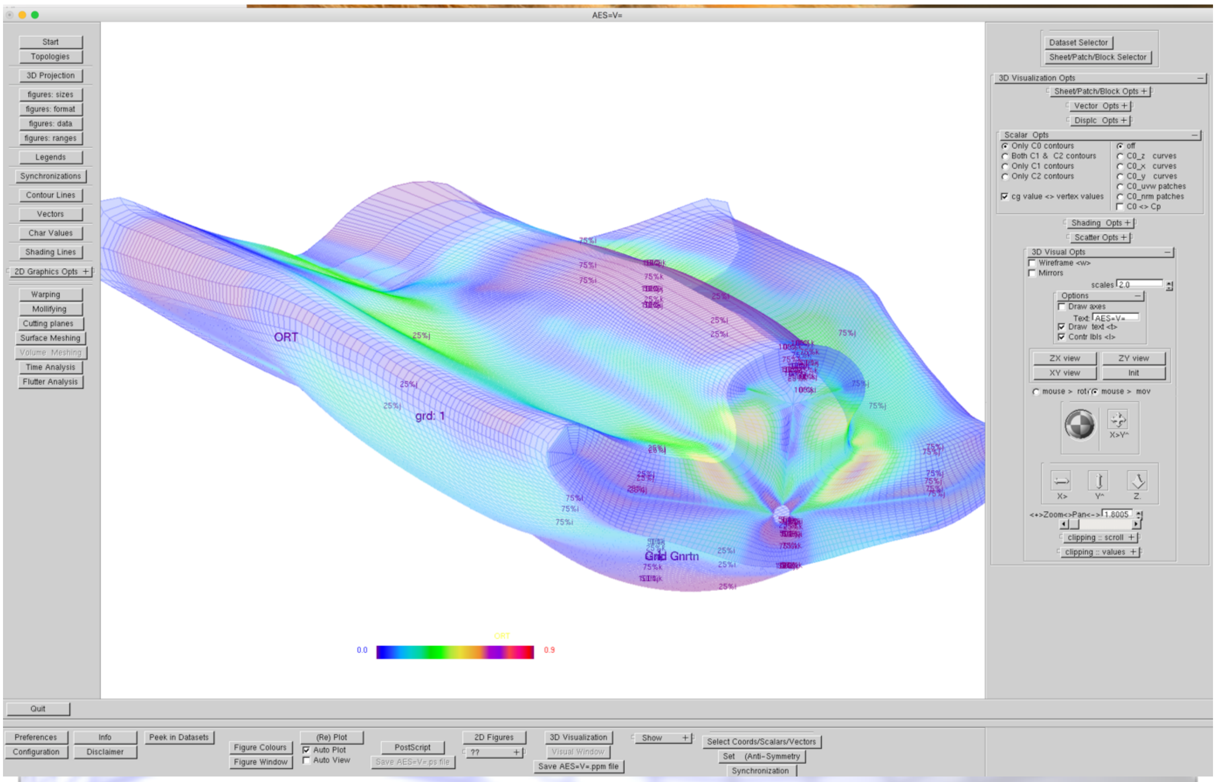


Figure 46 Characteristic mesh planes and mesh smoothing of the mixed hexahedral/prism mesh around the A/C

6.3.4 Chimera composition with a background Cartesian grid

A chimera composition is generated about the A/C only for demonstration purposes. Again, we start with hyperbolic generation of a periodic mesh around the A/C. We generate a single block **OH** mesh around this fairly complex shape with concavities and some non-smooth transitions. The single block 105x319*16 mesh is generated with the hyperbolic method using default control with pitch values 6 in i and j direction, assuming periodicity in j. A few elliptic smoothing's are applied. The generation takes one second effort wall clock time. The figures show characteristic mesh planes and typical output of the mesh characteristic, its orthogonality (Figure 47) and stretching (Figure 48). Many other characteristics and planes can be visualised. The mesh can be easily changed/improved by smoothing and redistributions and extended.



● Only C0 contours

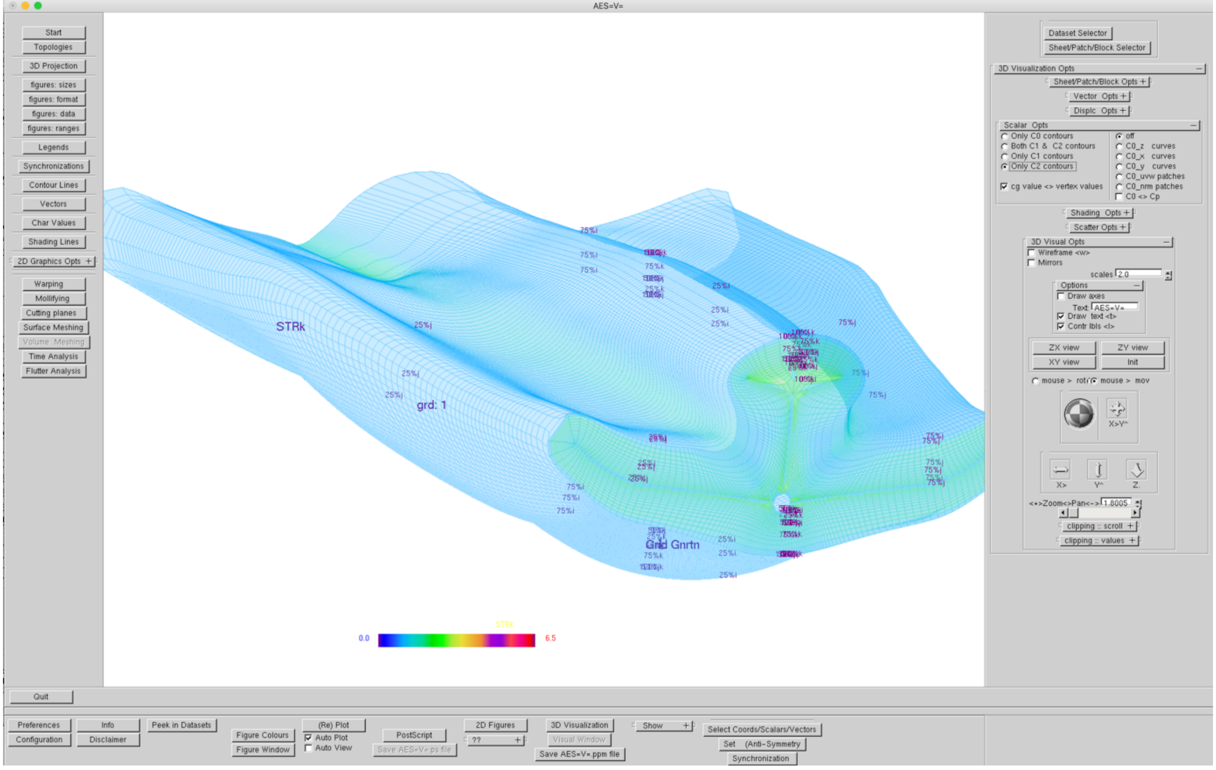
☑ cg value <-> vertex values

● off

scales 2.0

<->Zoom<>Pan<-> 1.8005

Figure 47 Characteristic mesh planes and mesh orthogonality of the hexahedral 105x319x16 mesh around the A/C



● Only C2 contours

☑ cg value <-> vertex values

● off

scales 2.0

<->Zoom<>Pan<-> 1.8005

Figure 48 Characteristic mesh planes and mesh stretching in normal direction of the hexahedral 105x319x16 mesh around the A/C

In this case we apply a background adapted cartesian 120x120x120 mesh as the balance.

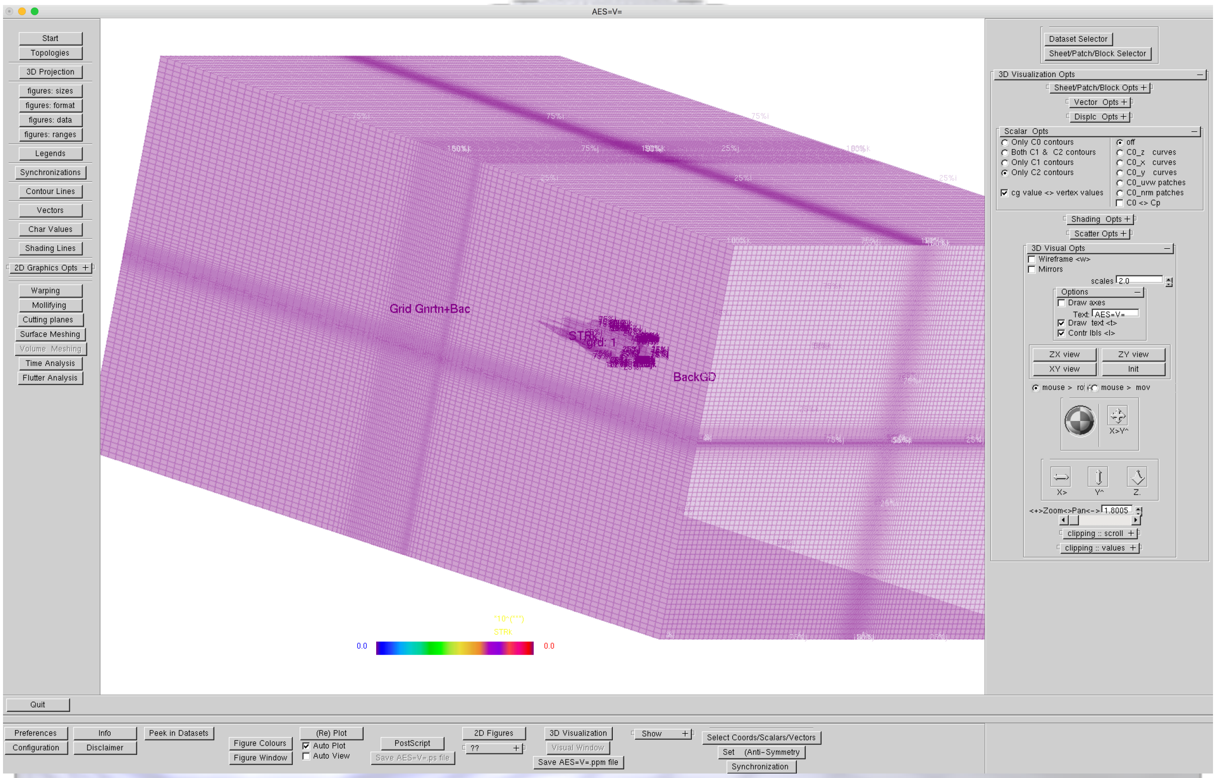
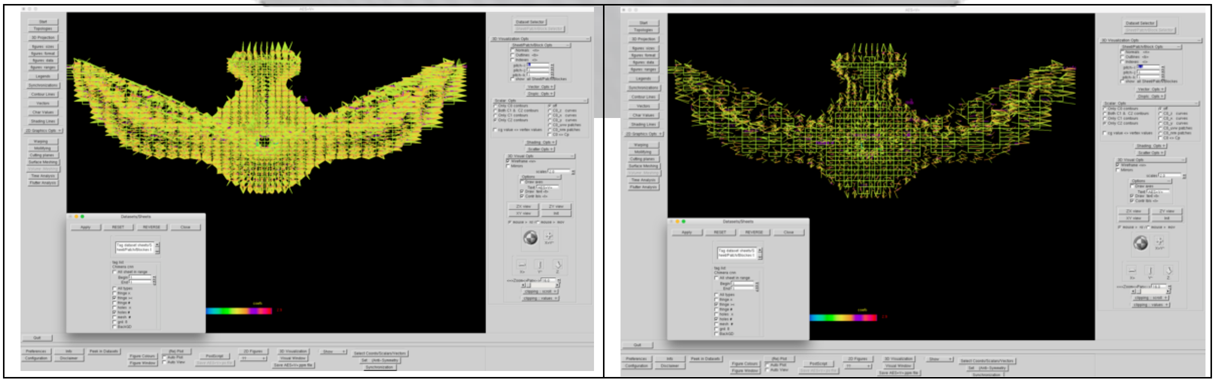


Figure 49 Cartesian 120x120x120mesh with embedded hexahedral 105x319x16 mesh around the A/C

Next, we apply the Chimera method using the default control and present the resulting composition in Figure 50. The connection takes a few seconds. On the other hand it is not easy to analyse in 3D the composition. The figures in Figure 50 a-g shows the holes and the donor-fringe connection with coefficient value. In in Figure 50 h the mesh is depicted in a cross section. In this case we end up with 1,487,483 normal mesh points, 8640 holes (in background mesh) and 87121 fringes.



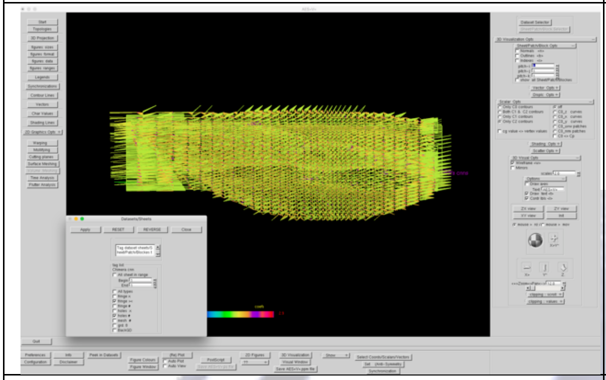
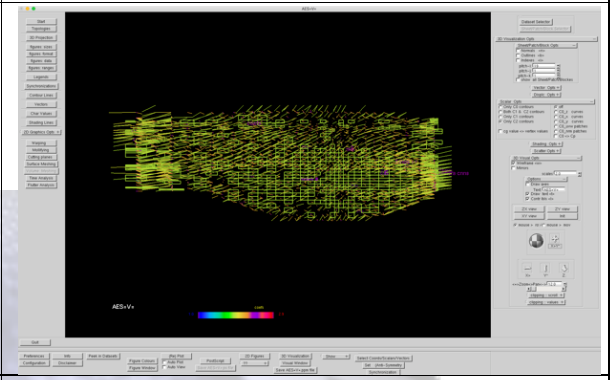
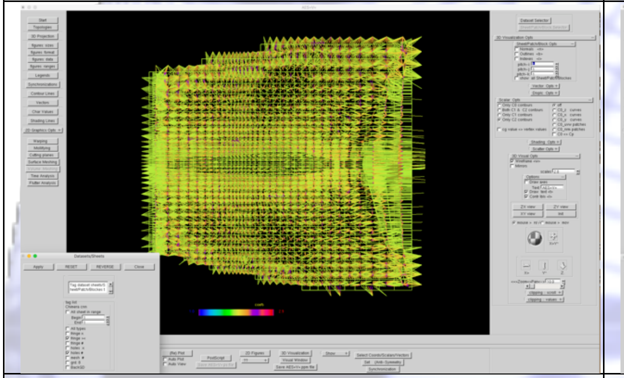
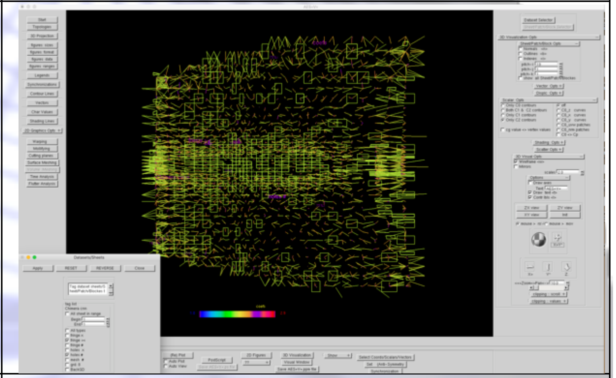
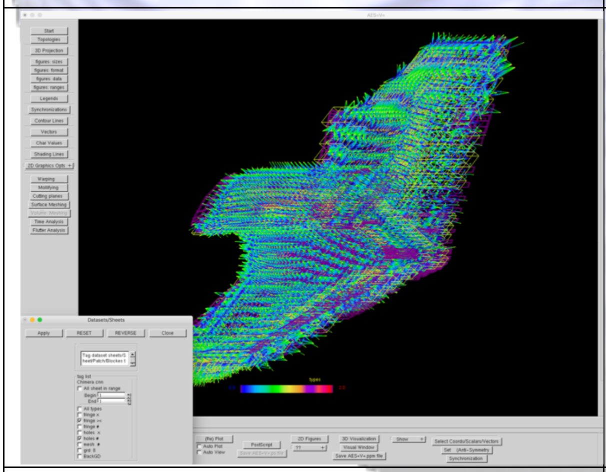
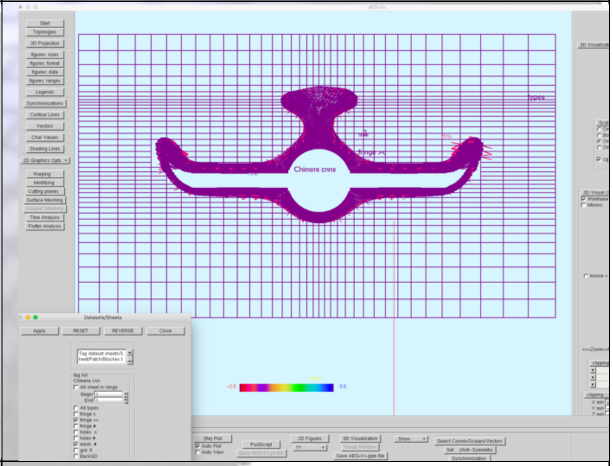
a) *yz projection of holes and donor-fringe connections showing all points*	b) *yz projection of holes and donor-fringe connections showing points with pitch 19*
	
c) *zx projection of holes and donor-fringe connections showing all points*	d) *zx projection of holes and donor-fringe connections showing points with pitch 19*
	
e) *xy projection of holes and donor-fringe connections showing all points*	f) *xy projection of holes and donor-fringe connections showing points with pitch 19*
	
g) *view of holes and donor-fringe connections showing all points*	h) *yz projection of mesh and donor-fringe connections showing points clipped near wing root leading edge*

Figure 50 Characteristics of the chimera composition

6.3.5 Multi block mesh

Finally, a multi-block mesh is generated. This requires to split the single patch surface in multiple patches. We chose simply for the demonstration to split the patch in 4x12 uniform patches (Figure 51). There are of course much better splits and blocks possible! In this case the mesh is algebraically. The side boundaries of connecting meshes are automatically averaged and smoothed.

We start using block top boundaries in normal direction requiring only the default distance at input (Figure 53). We need to smooth the resulting meshes especially with respect to the concave and convex zones(tips) and continue the generation with a prescribed specification at the outer boundaries (Figure 52). Again, we use a uniform specification and made no attempt to improve. Blocks can be simply transformed to C topology which are continuously connected to their predecessors or changed with the Hturn method to improve the mesh near element noses. The many possibilities to construct multi-block meshes are presented in Figure 38. The generation can take much more efforts (minutes in this case) at the work floor with respect to patch selection, outer boundaries setting, smoothing's, redistributions and checks.

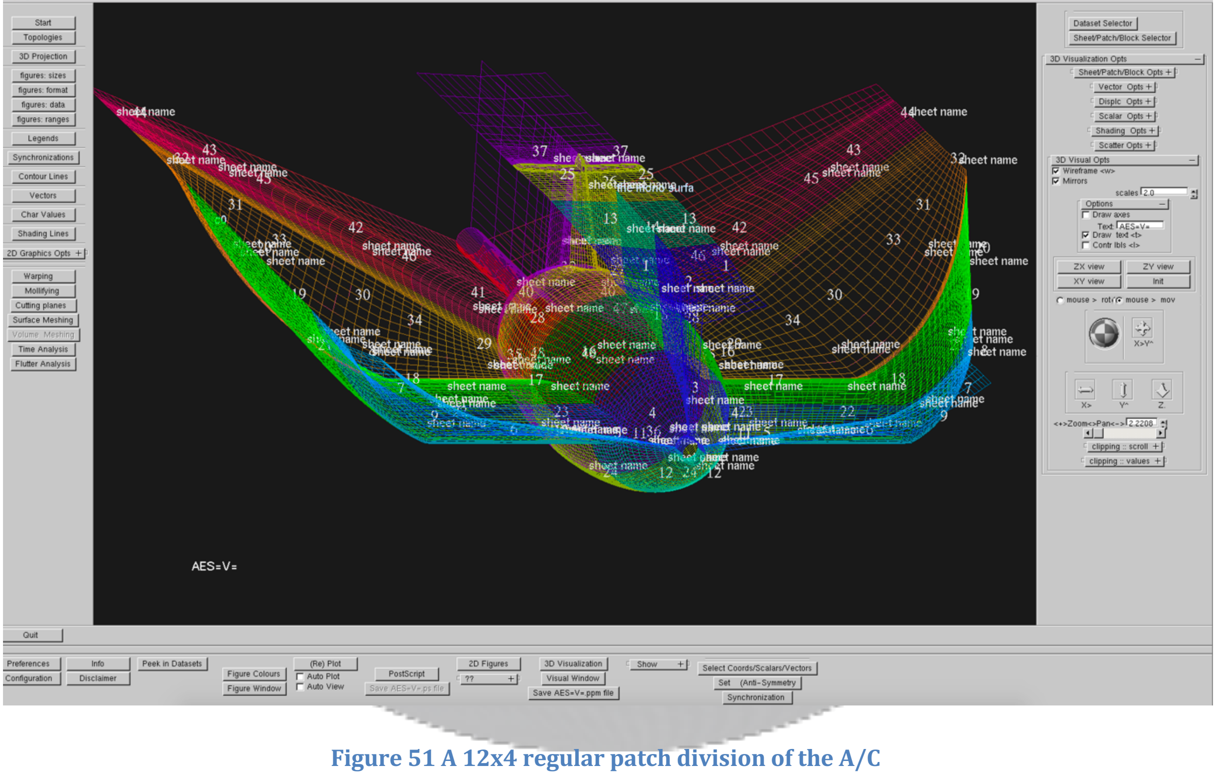


Figure 51 A 12x4 regular patch division of the A/C

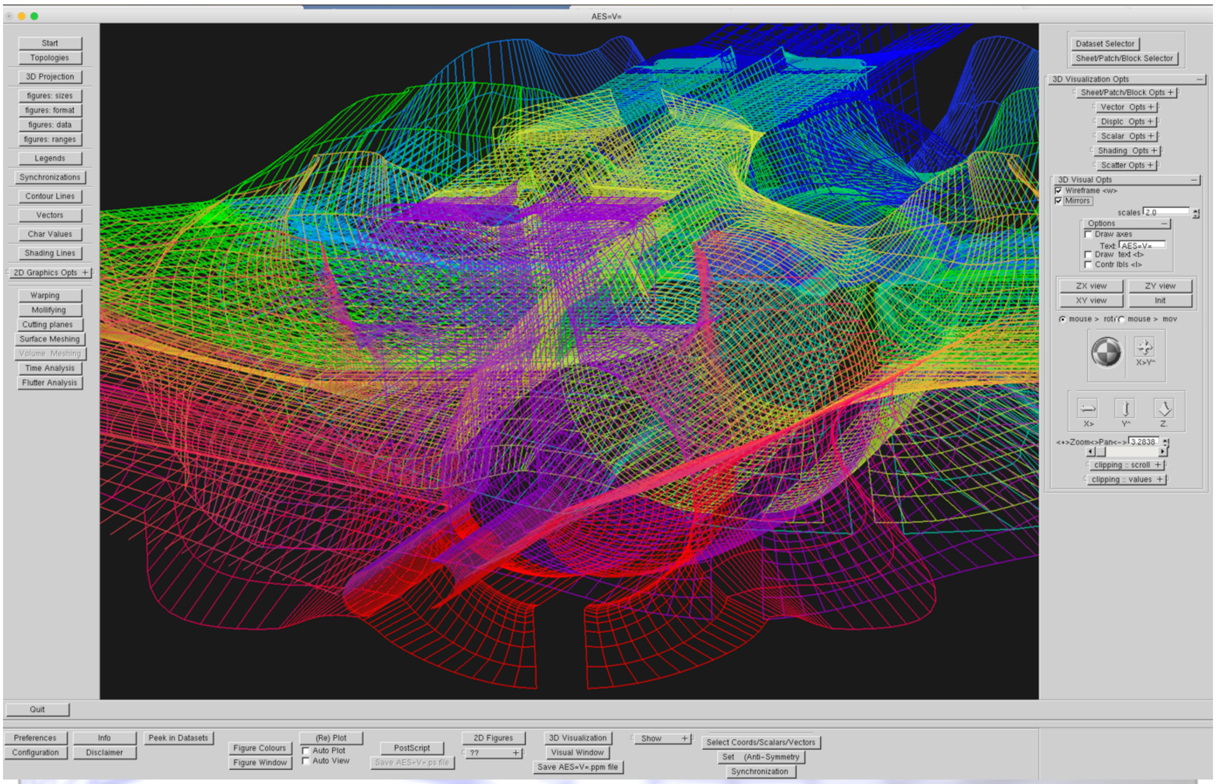


Figure 52 Block faces of a 12x4 blocked near mesh of the A/C

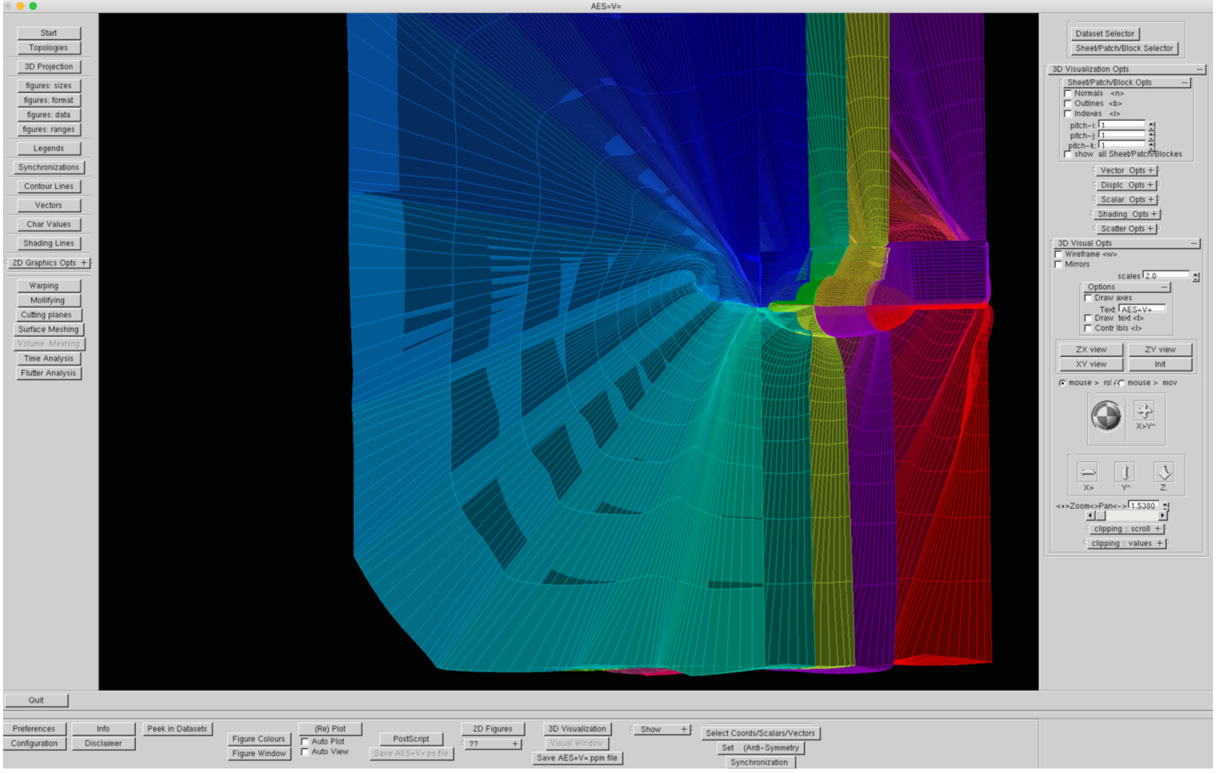


Figure 53 Block faces of a 12x4 blocked mesh of the A/C

7 Conclusions

This report has demonstrated the surface mesh design/ generation and volume mesh generation methods embedded in AES=V=. Surface meshes of complete aircraft can be designed/generated easily ab initio with AES=V= and forms the basis of volume mesh generation.

AES=V= incorporates a very flexible surface mesh generation avoiding unacceptably large turn-around times, especially when dealing with design, certification and qualification studies and modifications/installation effects.

AES=V= incorporates a powerful and fast volume mesh generation tool, reckoning with aerodynamic, hydrodynamic and aeroelastic applications and a low level of effort at work-floor level.

The AES=V= mesh generation methods can deal with arbitrary two-dimensional shapes (aerofoils and arbitrary cross sections), simple three-dimensional shapes (wings) to complete fixed wing aircraft. The mesh applications are easy to use for engineers, the processes are easily repeatable, robust and fast.

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