EM-ISAE
Test case No. 1 : Antenna coupling

Chairperson: T. Abboud (abboud@imacs.polytechnique.fr)

Co-chairperson: Q. Carayol (quentin.carayol@dassault-aviation.com)

Co-chairperson: G. Sylvand (guillaume.sylvand@airbus.com)

Use Case prepared with: B. Chaigne, E. Després & L. Rakotondrainibe (IMACS)

Time-harmonic convention

- In this test case, input and output data are in the frequency domain
- Computations may be done by the means of a time-domain or a frequency domain solver
- The time dependency convention is $e^{+j\omega t}$, *i.e.* the inverse Fourier transform is defined as

$$u(t) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} \hat{u}(\omega) e^{+j\omega t} \, d\omega$$

General description

- The aim of the test case is to compute the coupling between two antennas installed on a large like an aircraft supposed to be a Perfect Electric Conductor (PEC)
- Antennas are identical and are represented by the values of electric and magnetic fields on a Huygens surface surrounding the antenna for each frequency
- 4 possible antenna positions are provided via 4 solid transformation matrices are provided allowing to install Huygens boxes on the aircraft
- We consider 4 different configurations with only 2 antennas: (A & B), (A & C), (A & D) and (B & C)
- Expected results: 2x2 S matrix as function of the frequency for the 4 configurations (from 200MHz to 300MHz with a step of 5MHz). Reference impedance is $Z_{\mathrm{ref}} = 50\,\Omega$.

Reference solution

- Participants may create their own reference solution with a direct calculation including the meshed antennas on the aircraft
  - Monopole antenna :
    - PEC wire of length L=30cm and radius r=1mm, normal to the surface (along z axis)
    - Voltage = $1\,V$ (at the junction with the ground/aircraft), internal impedance $Z_g = 50\,\Omega$
  - Antenna positions on the aircraft

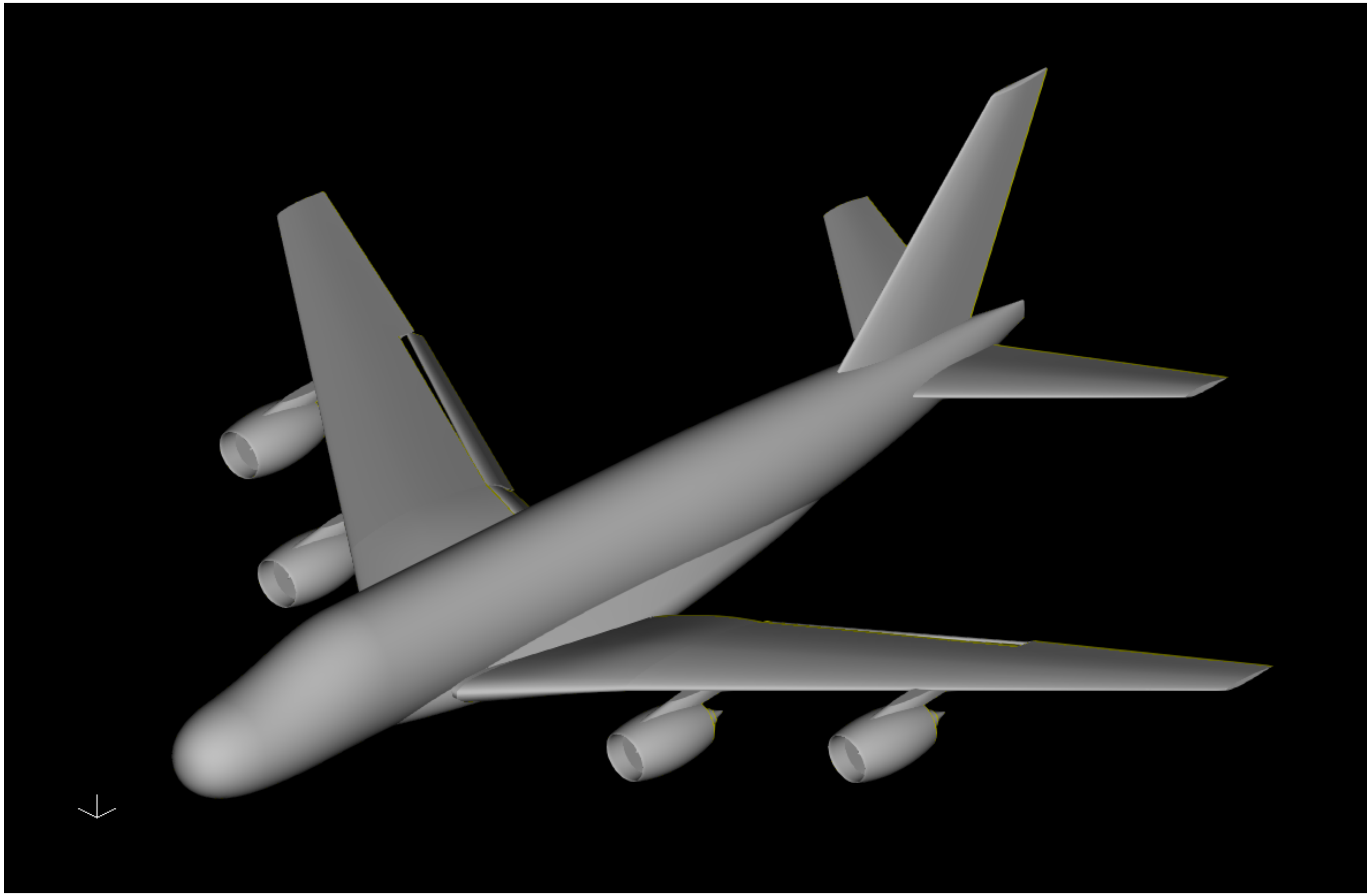
$$\mathtt{A} = (23.000,\quad 0.000,\ -2.950)\,\mathtt{m}$$

$$\mathtt{B} = (25.400,\quad 0.000,\ -2.950)\,\mathtt{m}$$

$$\mathtt{C} = (23.000,\quad 0.000,\quad 5.600)\,\mathtt{m}$$

$$\mathtt{D} = (25.400,\quad 0.000,\quad 5.600)\,\mathtt{m}$$

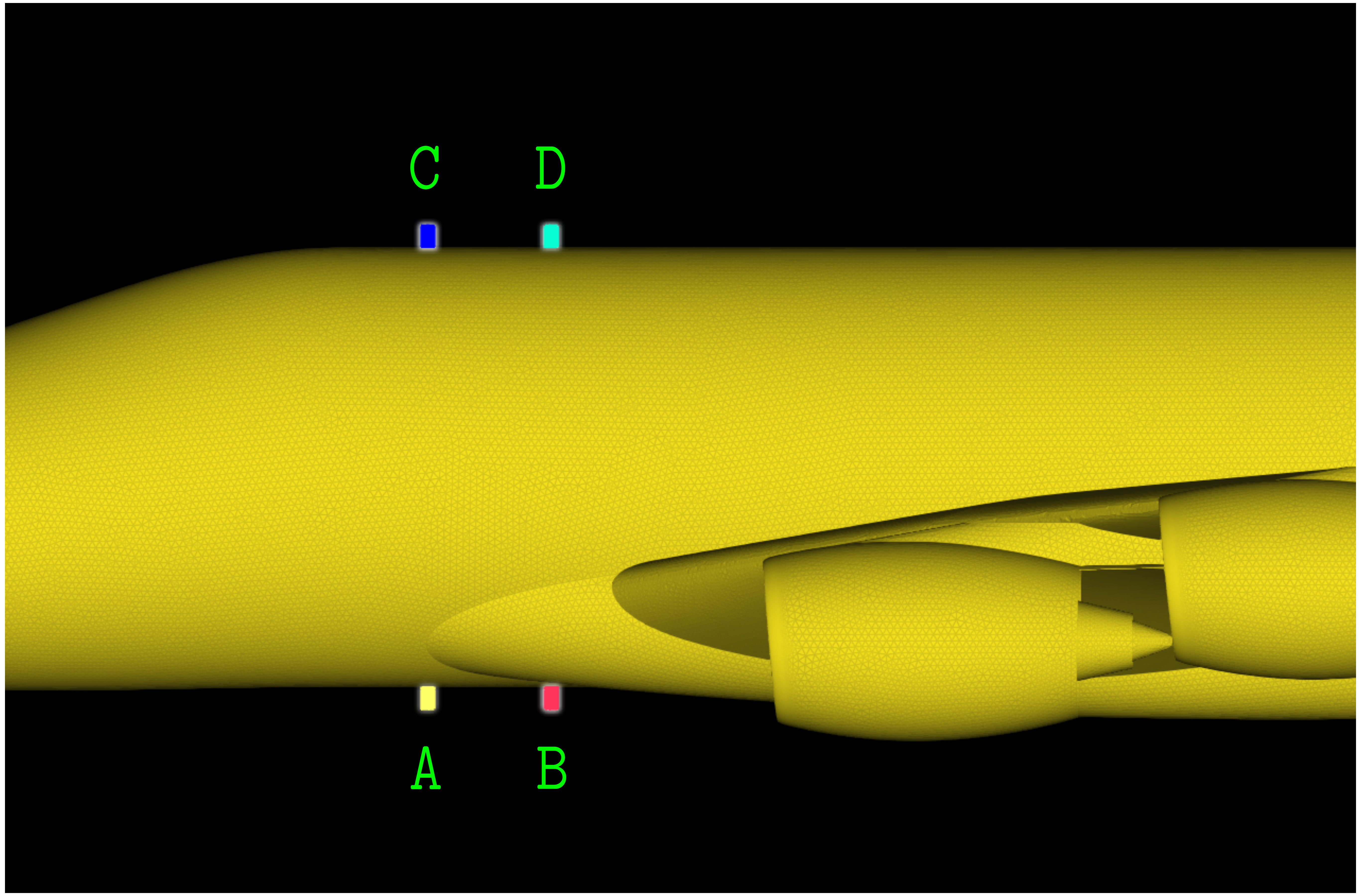
PEC Aircraft Model



Model in STEP format cleaned and ready to mesh.

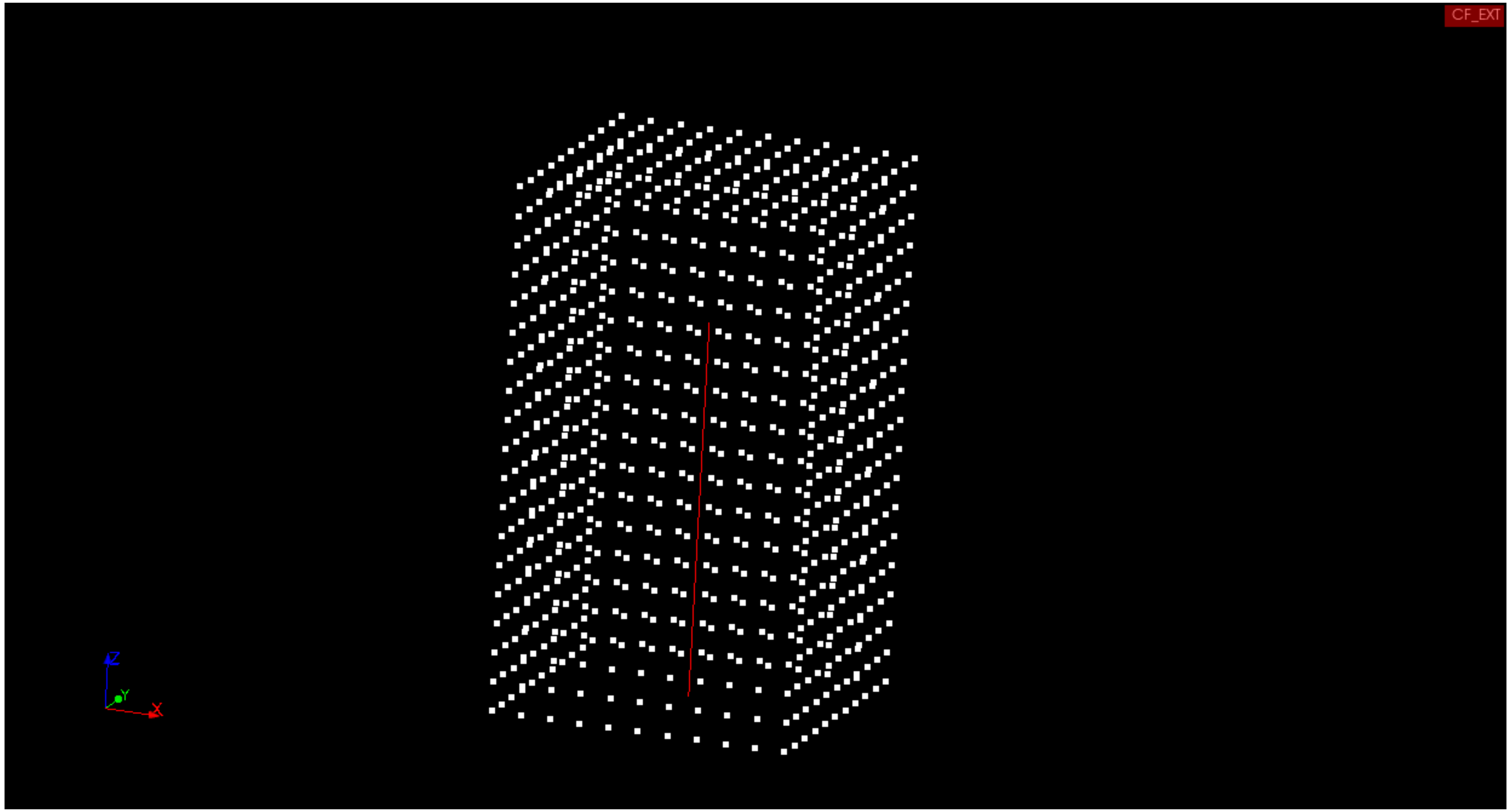
Bounding box dimension: 72.47m x 79.67m x 22.91m

Aircraft mesh + antennas



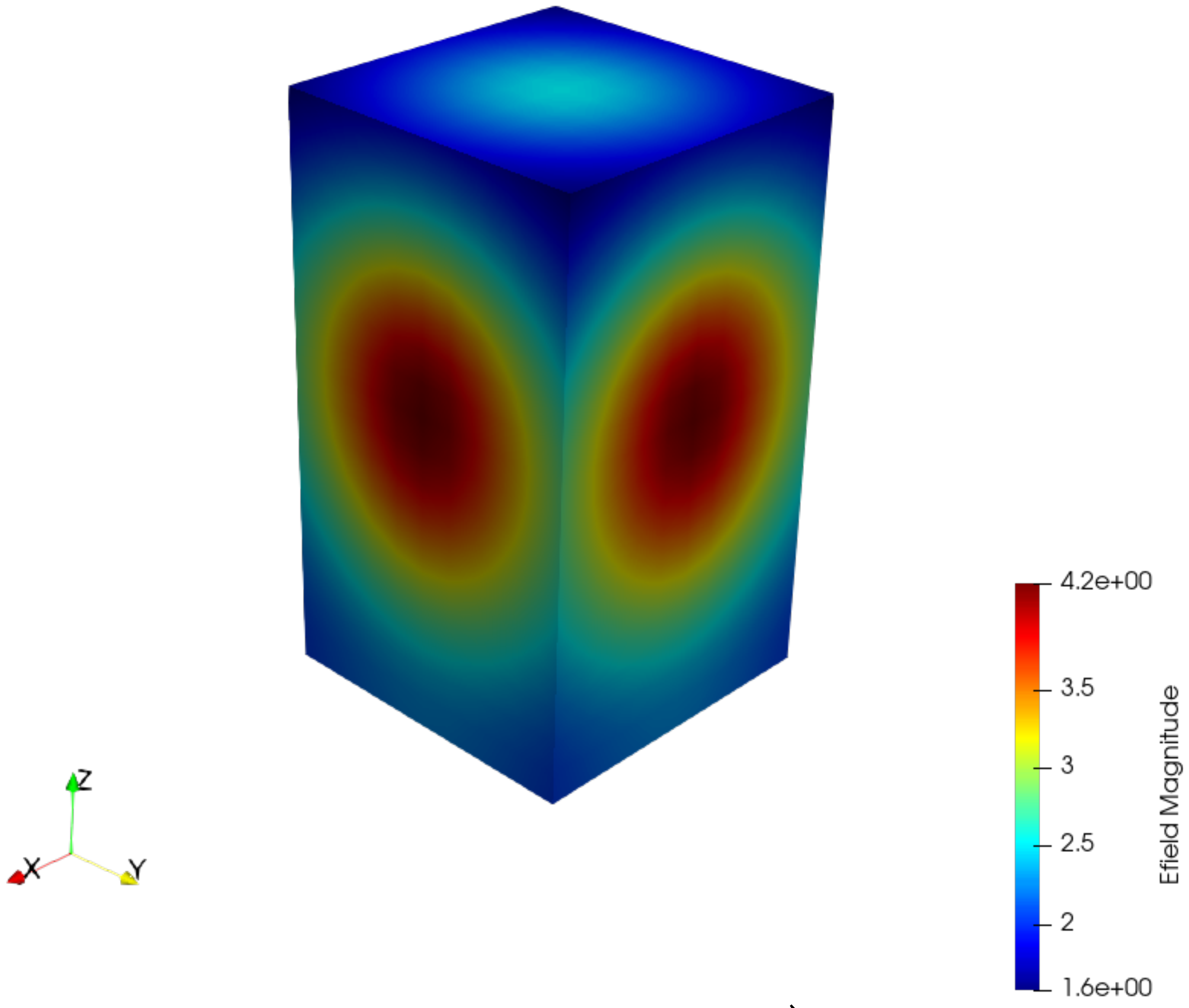
Example of triangular surface mesh: 692 624 triangles with a mesh step $h \sim \lambda/7$ at $300\,\mathrm{MHz}$

Huygens Box



HB: cloud of vertices

Example of field on the Huygens Box



Electric field $|\vec{E}|$

Huygens box: vertices and fields

1 file per frequency: `MonopoleVertexFields_{Frequency}Hz.txt`

It will be used to model all antennas

It contains

- a header with the time convention, the frequency (in Hz) and a reminder of the format
- the coordinates of each vertex and the associated EM field

in the following format (1st ligne of the header recalls the time convention $e^{+j\omega t}$):

```
# Time convention +1
# Frequency          270000000
# Px Py Pz Re{Ex} Im{Ex} Re{Ey} Im{Ey} Re{Ez} Im{Ez} Re{Hx} Im{Hx} Re{Hy} Im{Hy} Re{Hz} Im{Hz}
P1x P1y P1z Re(E1x) Im(E1x) Re(E1y) Im(E1y) Re(E1z) Im(E1z) Re(H1x) Im(H1x) Re(H1y) Im(H1y) Re(H1z)
Im(H1z)
P2x P2y P2z Re(E2x) Im(E2x) Re(E2y) Im(E2y) Re(E2z) Im(E2z) Re(H2x) Im(H2x) Re(H2y) Im(H2y) Re(H2z)
Im(H2z)
.
.
.
PNx PNy PNz Re(ENx) Im(ENx) Re(ENy) Im(ENy) Re(ENz) Im(ENz) Re(HNx) Im(HNx) Re(HNy) Im(HNy) Re(HNz)
Im(HNz)
```

Huygens box: S11

The S11 parameter of the antenna is given in the file `Monopole_S11.s1p` in the following format:

```
! Time convention +1
# Hz S RI R 5.0000000000e+01
freq Re(S11) Im(S11)
.
.
.
```

Solid transformation matrix

A solid transformation is applied to the Huygens box `MonopoleVertexFields_{Frequency}Hz.txt` in order to position it on the aircraft. 1 transformation file is provided for each antenna: `Antenna{id}_transformation.txt` which contains a 3x4 matrix:

```
Rxx Rxy Rxz Tx
Ryx Ryy Ryz Ty
Rzx Rzy Rzz Tz
```

where R is the rotation matrix and T is the translation vector (in meters) :

$$X \mapsto X' = RX + T$$

{id} takes the values:

{id}= ‘A’, ‘B’, ‘C’ or ‘D’

Output file format

- Coupling will be computed for 3 configurations :
  - config1: coupling of Antenna A and Antenna B
  - config2: coupling of Antenna A and Antenna C
  - config3: coupling of Antenna A and Antenna D
  - config4: coupling of Antenna B and Antenna C
- The 2x2 S matrix results will be given in 4 different 9-column files: config1.s2p, config2.s2p, config3.s2p and config4.s2p in the following format

```
! Time convention +1
# Hz S RI R 5.0000000000e+01
freq Re(S11) Im(S11) Re(S21) Im(S21) Re(S12) Im(S12) Real(S22) Imag(S22)
.
.
.
```

Additional informations

- Numerical method and solver with a brief description if needed
- Mesh properties: min/max/average element diameters, number of degrees of freedom
- Computer used for the simulation: type of CPU/GPU, number of cores per node, number of nodes, memory…
- Elapsed time