Military Aircraft

RCS Simulation

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Overview

- Introduction
- Methods,Tools for mm-wave applications
- Examples
- Further requirements / developments

Introduction

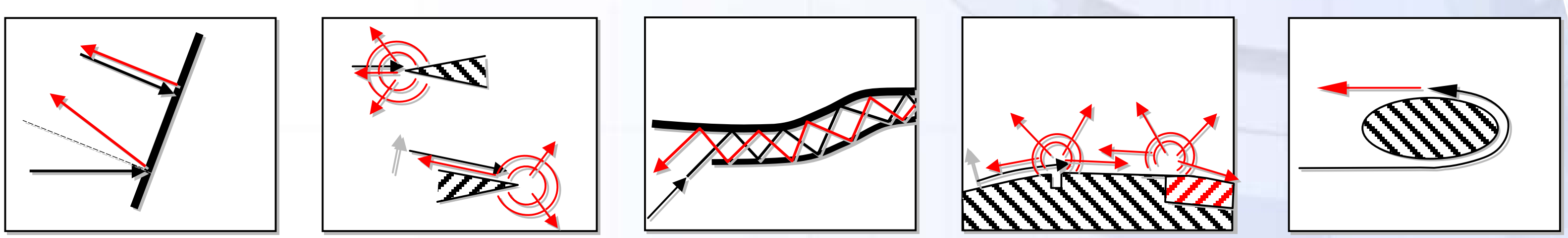
- RCS simulation requirements for Millimeter-Wave applications
  - **Accuracy:** small details (antennas, etc.) important in certain recognition / identification applications
    - Hybridisation of methods
  - **Speed:** algorithms should not scale strongly with frequency
    - Fast algorithms, new Aproaches
    - Geometry representations
  - **Flexibility:** Many configurations (A/C: store config.) to be considered, Moving parts to be considered
    - Flexible handling of Geometry
    - Parametrisation of Geometry

Methods for RCS simulations

- Fundamental subdivision between ***full-wave*** and ***asymptotic*** approach.

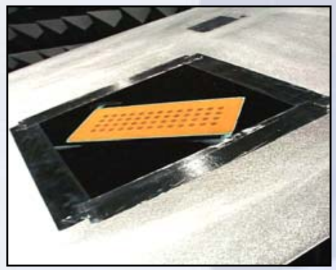
- **Full wave** („low frequency techniques“): Solution of Maxwell‘s equations

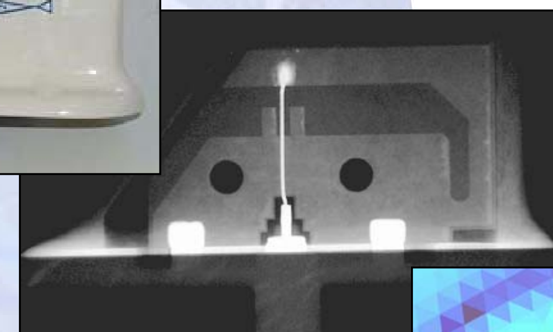
- **Asymptotic** („high frequency techniques“): Approximation of target backscattering by a number of independent effects

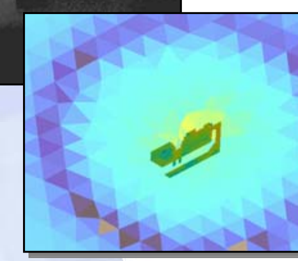


Methods, Hybridisation

- Complex details (Antennas, cavities, etc.) need „full-wave“ treatment. Examples:
  - **Antennas**







  - **Cavities, inlets**

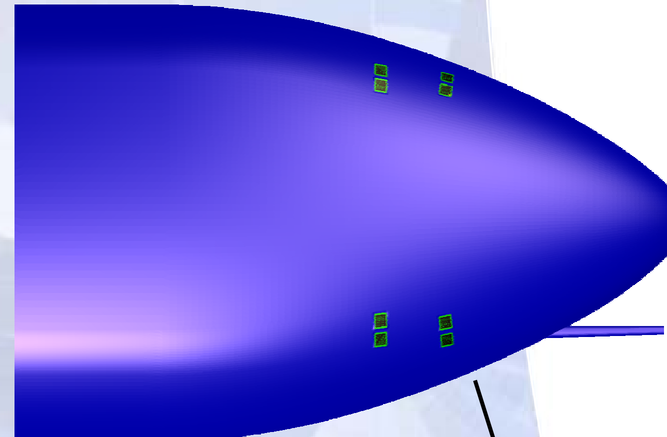
  - **Details of the size of the wavelength**

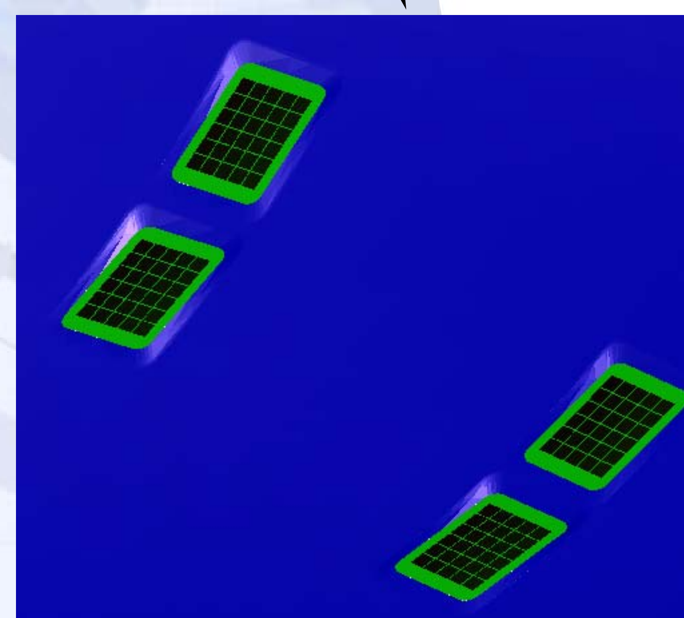
Methods, Hybridisation

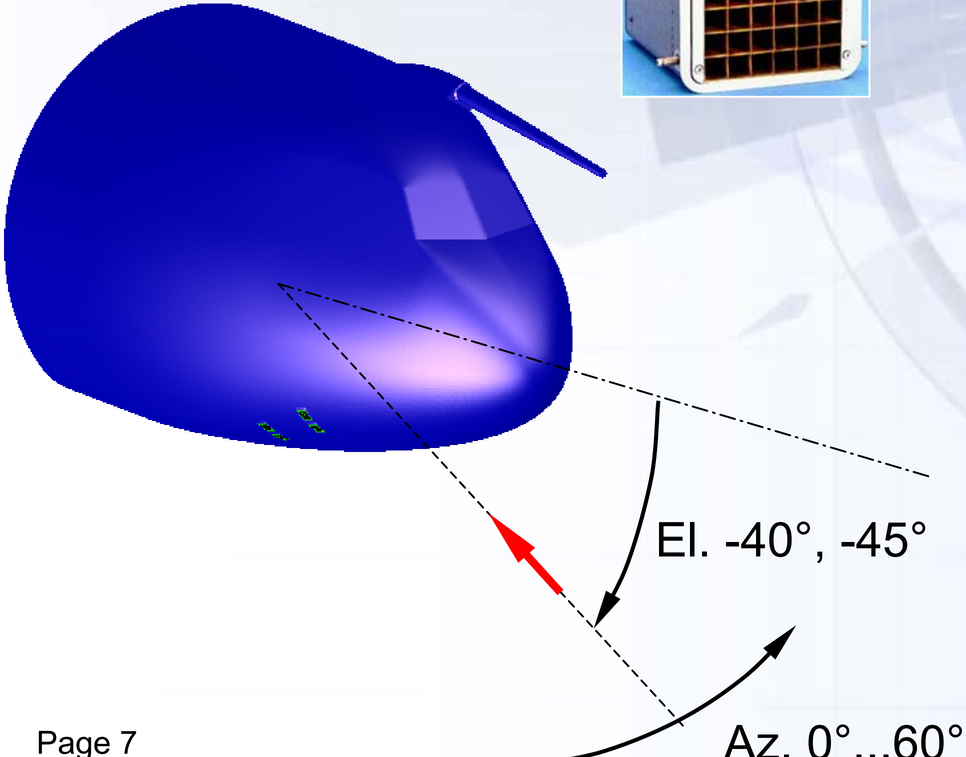
- **Full-Wave methods in use**
  - Multilevel Fast Multipole Algorithm accelerated Method of Moments (MLFMA)
  - Finite Difference (FD) Techniques
  - Modal formulations
- **Hybridisations**
  - Superposition of backscattering (if scatterer is not shadowed)
  - Incident field from asymptotic method
  - Backscattering interacts with the rest of the object
  - Full-wave formulation includes interactions with „exterior“ geometry

Hybridisation example: Dispenser Influence on RCS of transp. A/C

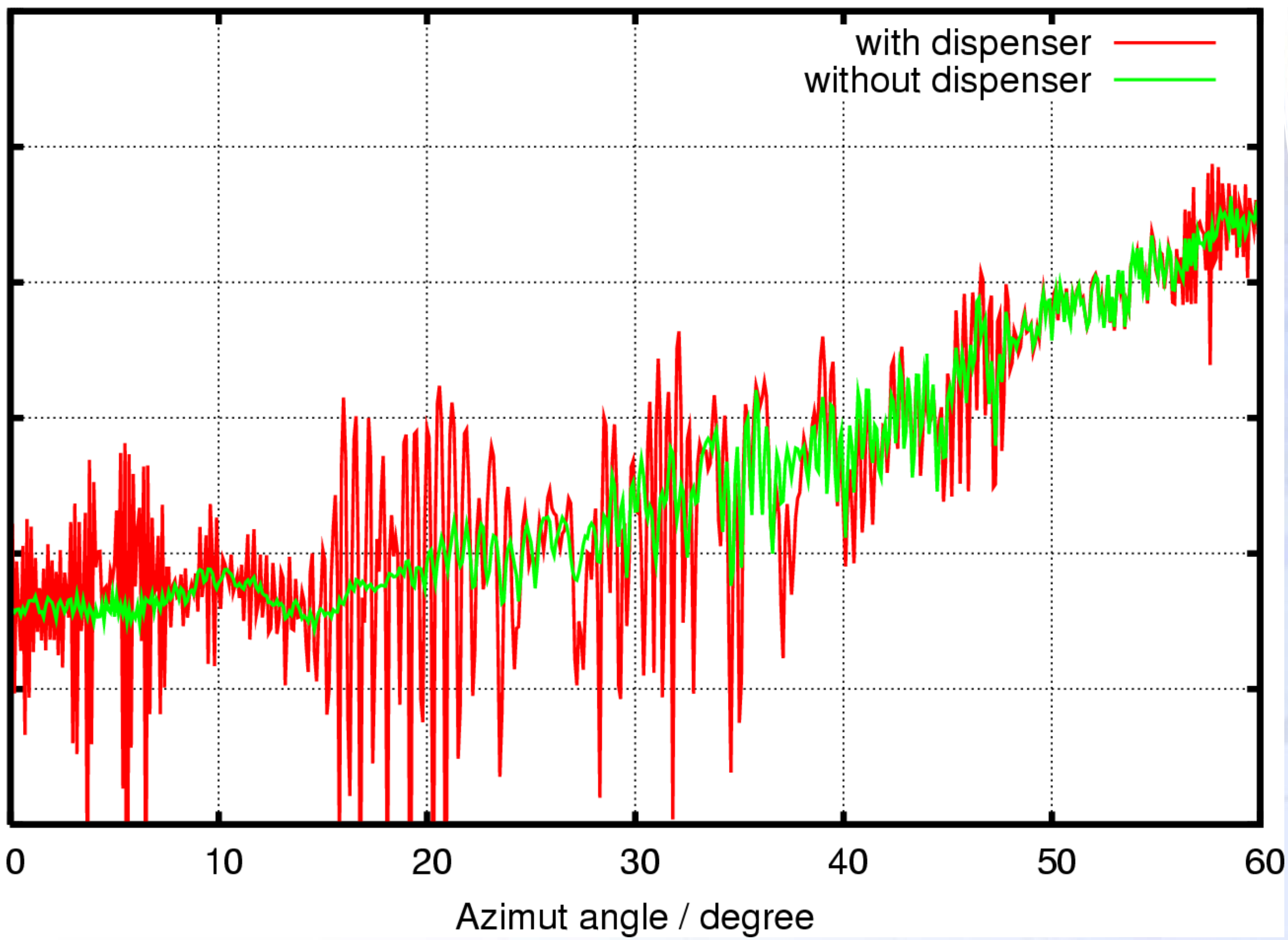
- Test section to evaluate influence of clustered dispenser compared with Fuselage return



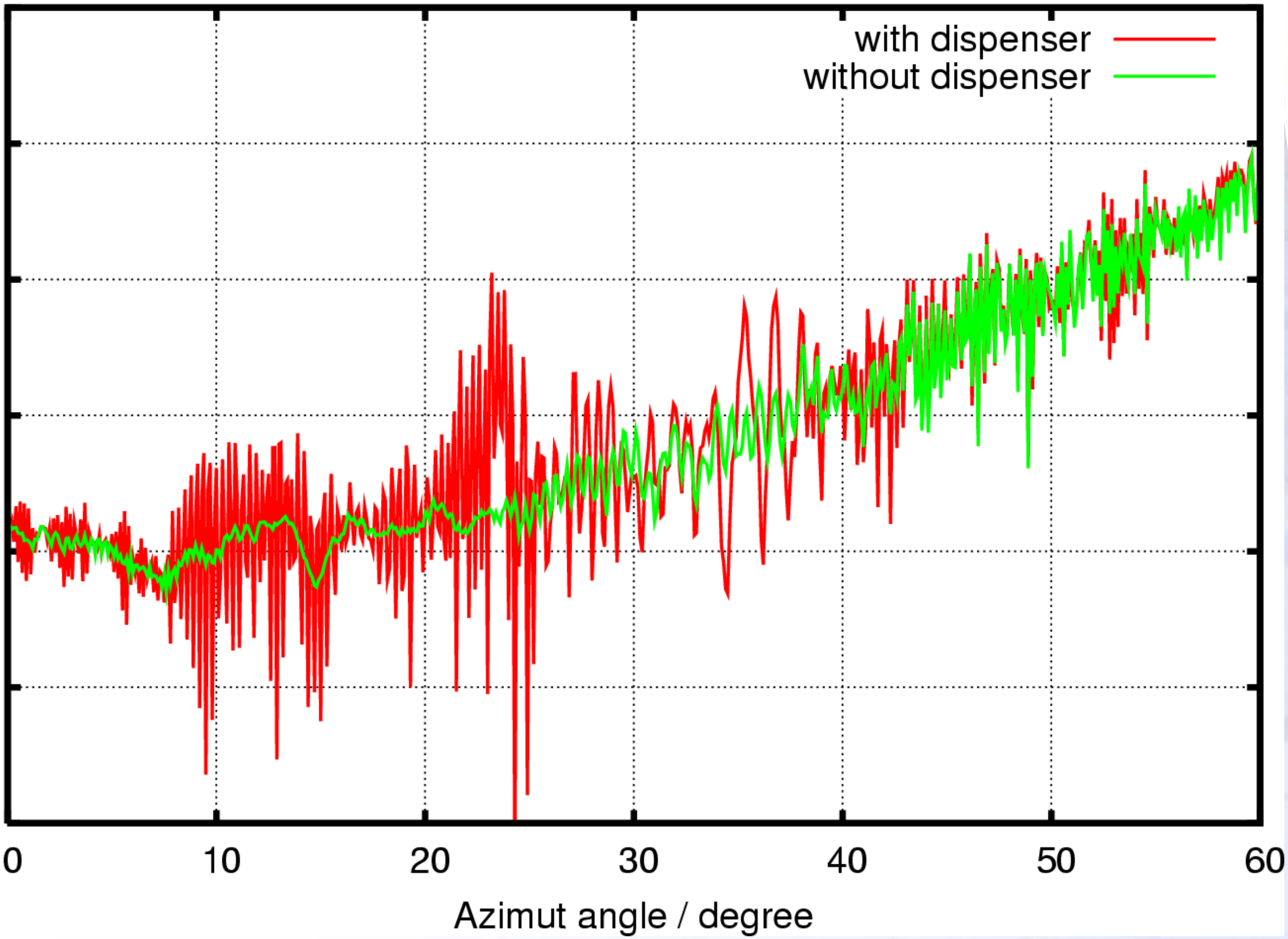




Nose section at 36 GHz - elevation -40.0 degree, vertical polarisation

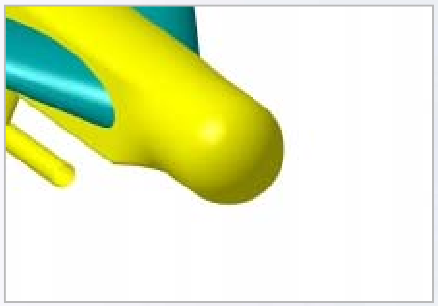


Nose section at 36 GHz - elevation -45.0 degree, vertical polarisation

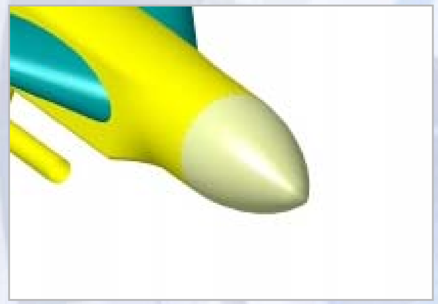


Example for Full-Wave method / component analysis

- Example: bandpass radome (FSS) for radar application



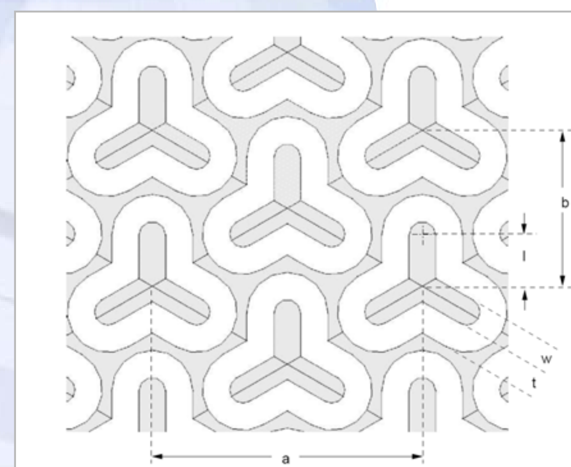
conventional



proposal with bandpass radome

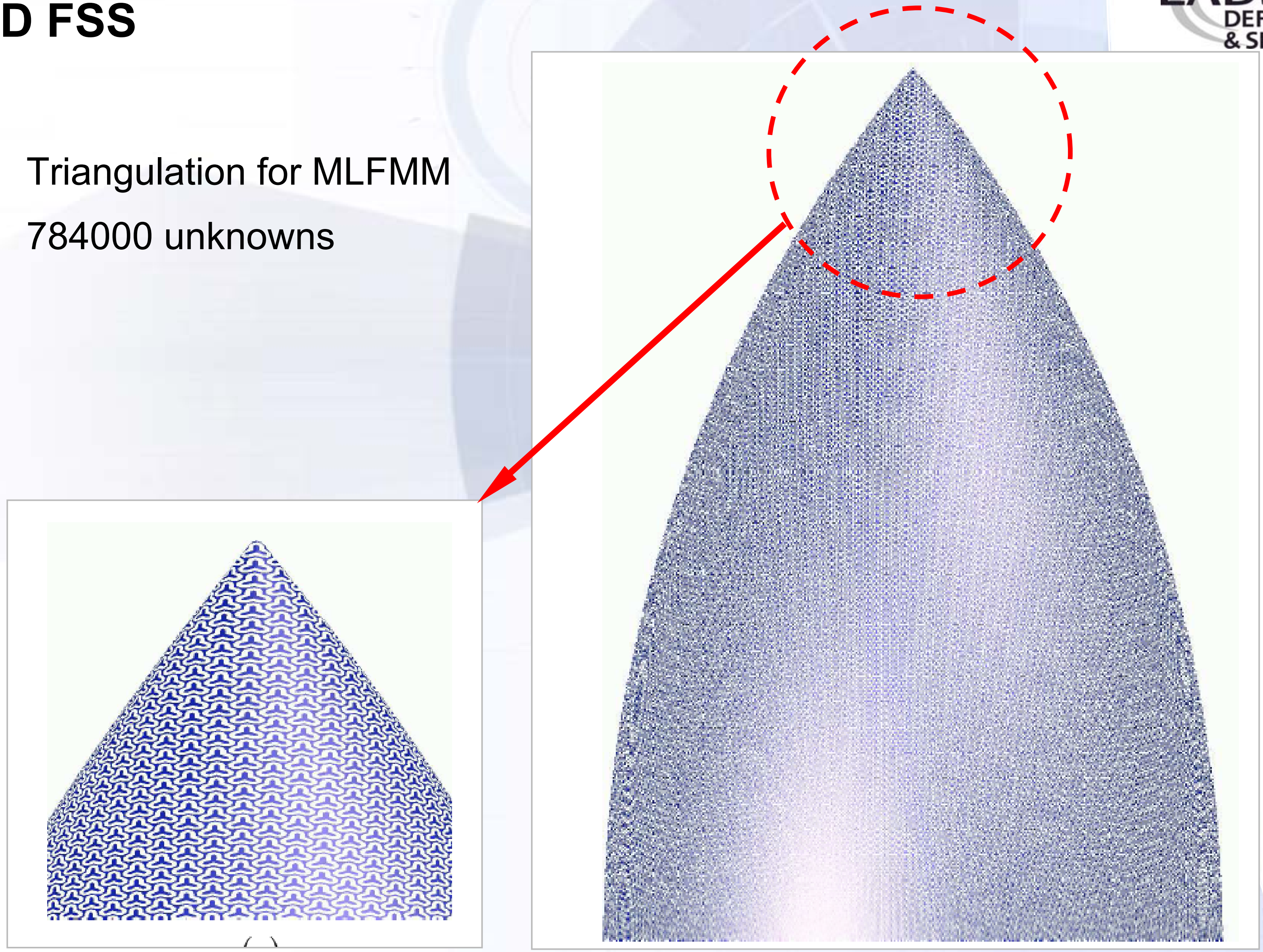
→ Detailed view of Bandpass structure:

→ Verification of 3D curved (ogive) bandpass

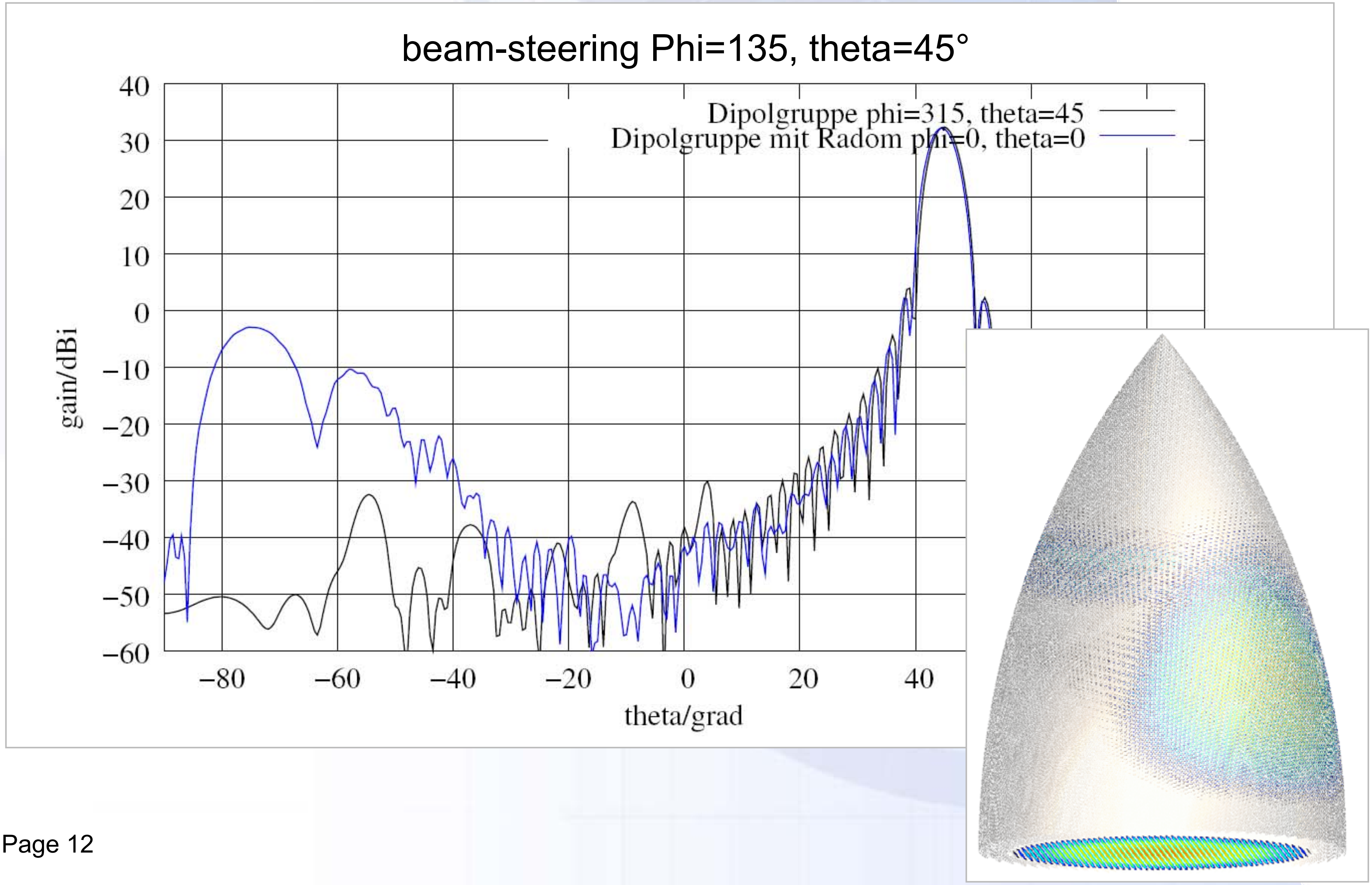


3D FSS

- Triangulation for MLFMM
- 784000 unknowns

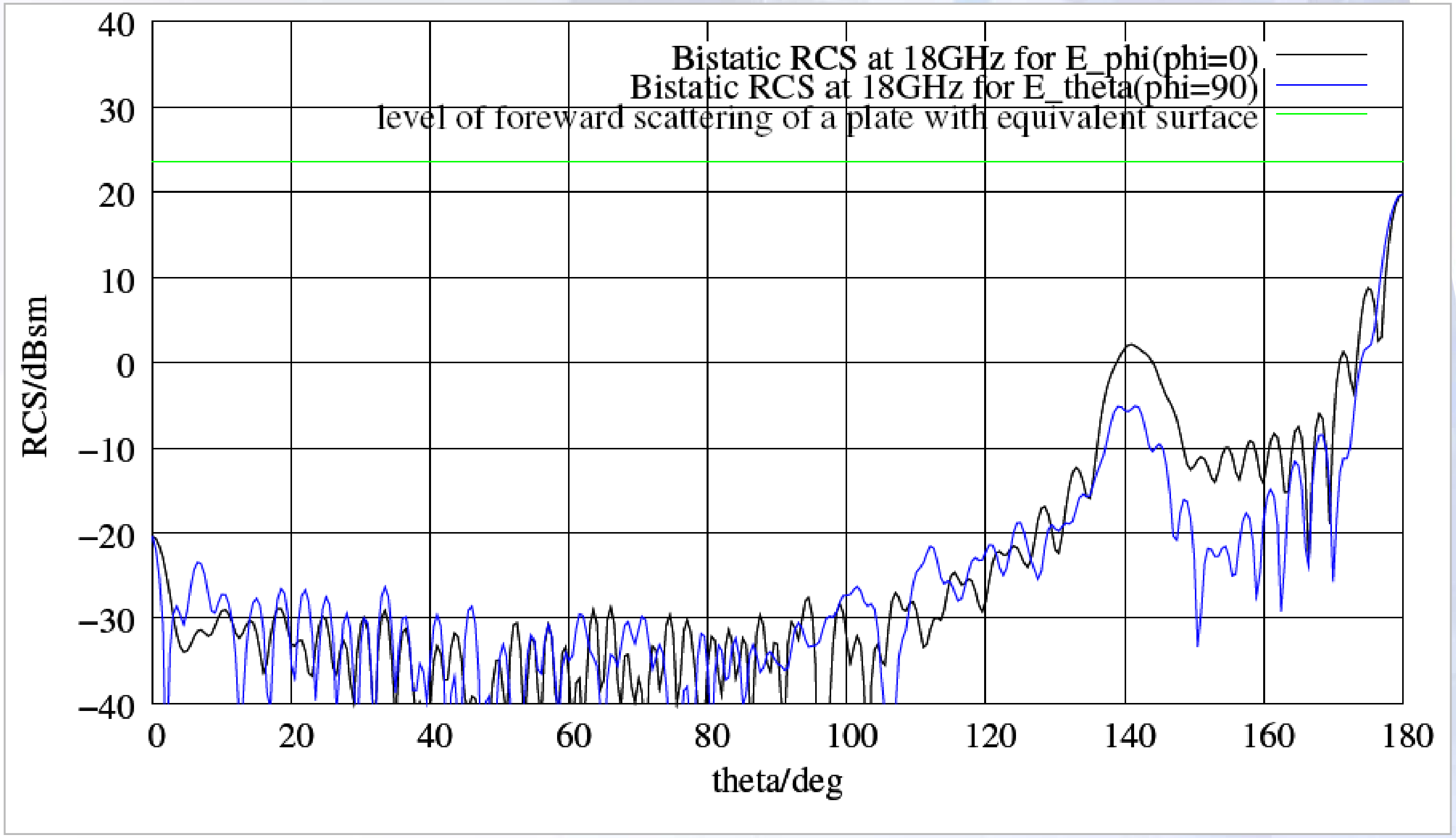


Performance / design verification of the Ogive FSS



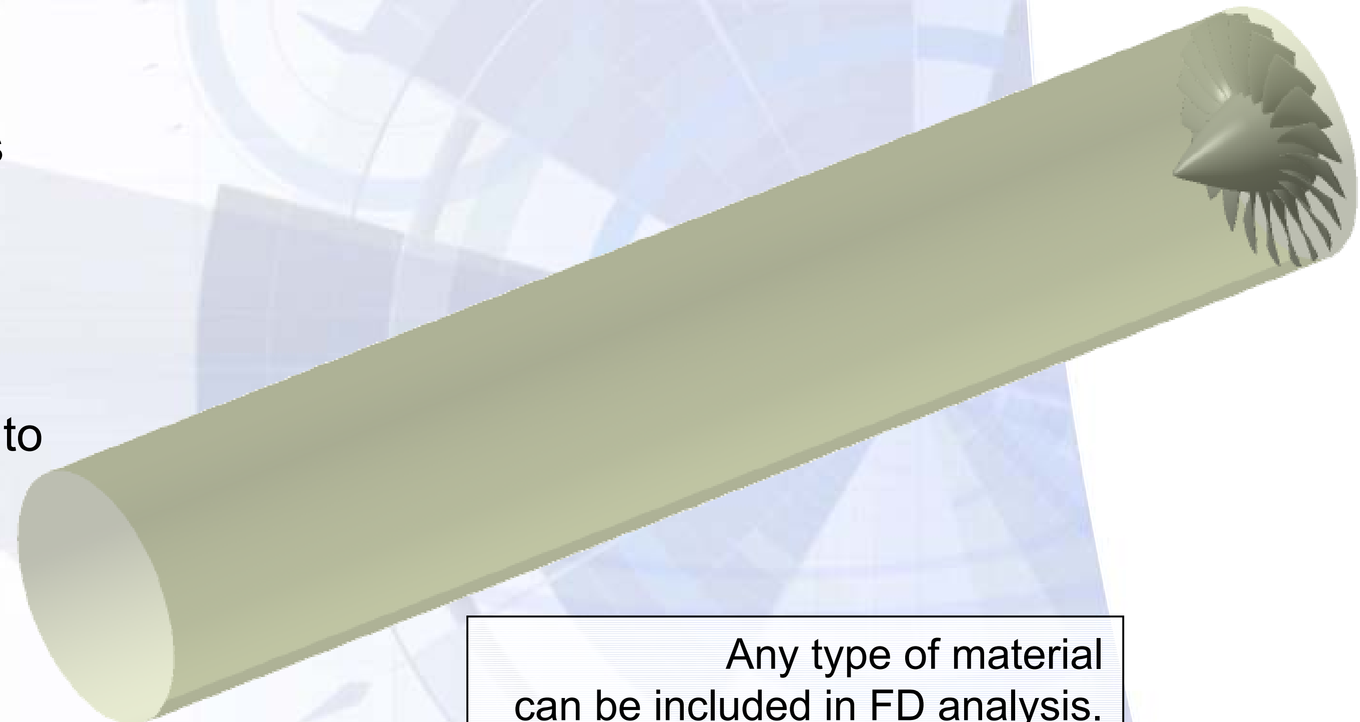
RCS performance

- Bistatic RCS, front aspect



Finite Difference Code for large Engine Inlets

- Typ. application
  up to 400 mio. cells
- parallelized
- example: 4m Inlet,
  pulse-excitation up to
  18GHz



Any type of material
can be included in FD analysis.

Asymptotic Base-Algorithms

- For most A/C applications, 1st and 2nd bounce contributions are important (excluding cavities, inlets, etc.)

- Important: Algorithm should not scale with frequency

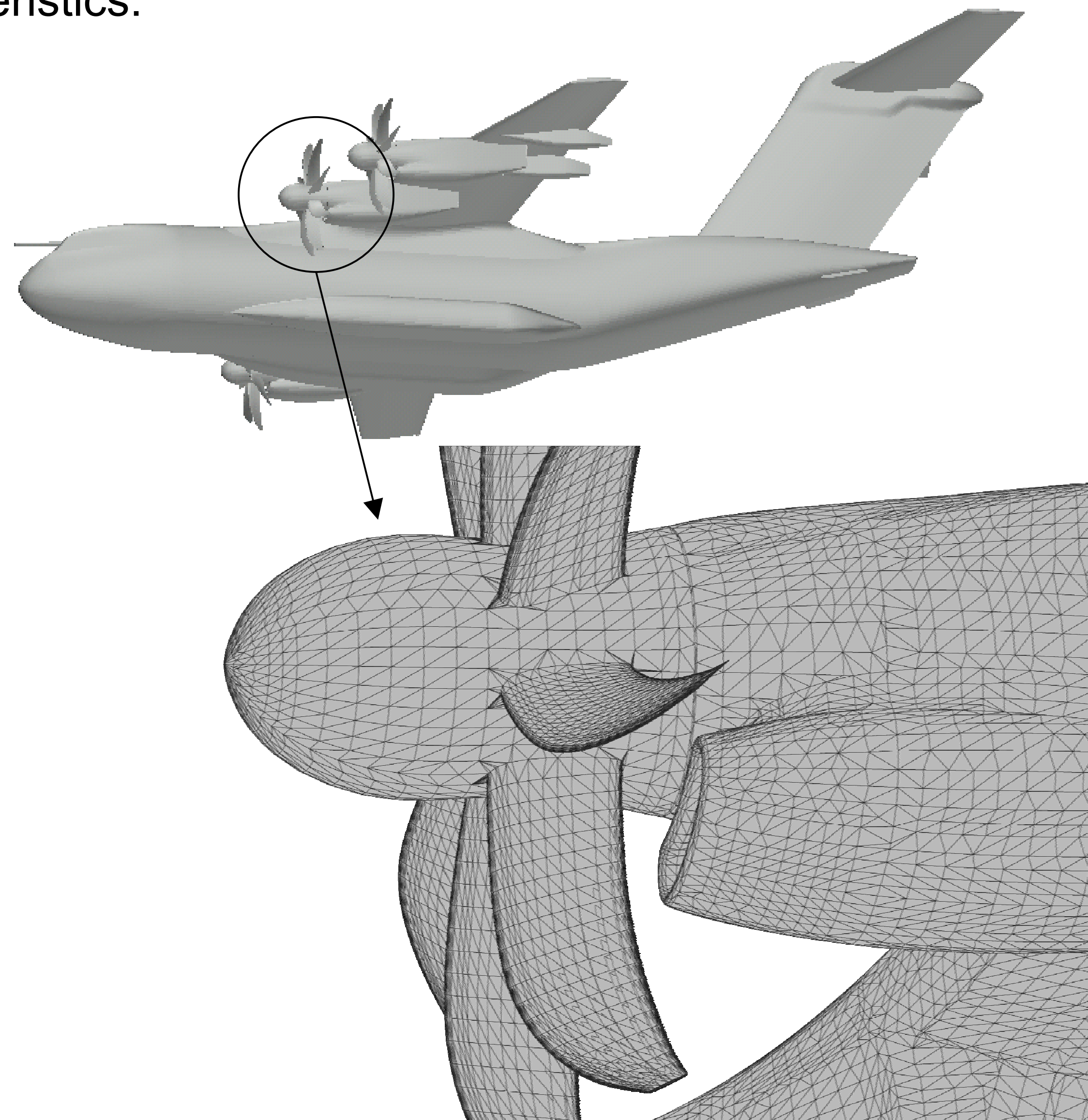
- Usual approach GO/PO for multiple effects.

  - PO scaling frequency independent;
    in practice: scaling by frequency dependent discretisation up to certain level.

  - GO (SBR) scaling due to ray grid density dependence from wavelength

Asymptotic Base-Algorithms – Physical Optics

- PROTHEUS / *RCSPO* characteristics:
  - Analytical integration of the PO-currents on plane triangles, typical object sizes: $10^5 \ldots 10^6$ triangles
  - Geometry: triangulation, triangle size depends on surface curvature. Deviations expressed in wavelengths (!)
  - *N* log *N* Algorithms for shadowing (plane wave, spherical wave sources)
  - Edge diffraction



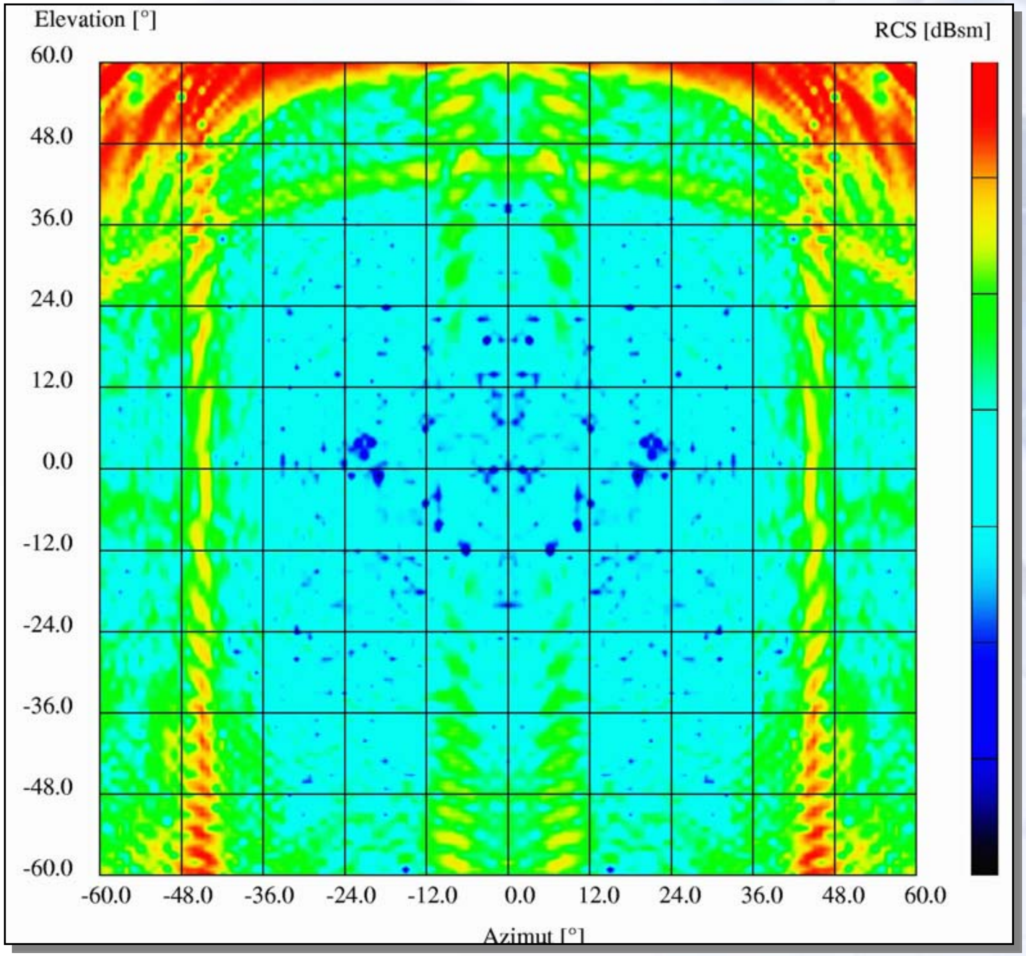
Asymptotic Base-Algorithms – Physical Optics

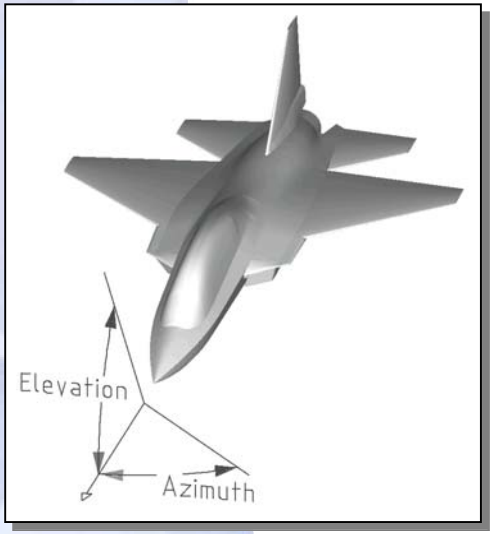
- PROTHEUS/ *RCSPO* characteristics:
  - **Efficient treatment of double reflections**.

    1. Frequency and incidence-angle independent pre-processing:
       - Generation of an interaction list (for domains on the surface)
       - Within the interacting domains, test for shadowing between triangles in the domains
       - Final determination of the coupling domains by various criteria.
    2. Within the frequency/angle loops: computation of the coupling between the pre-selected triangles.
       (N_d^2 process for N_d coupling triangles, but usually $N_d << N$)

Asymptotic methods for RCS evaluations

- Fast multi-aspect analysis using asymptotic techniques

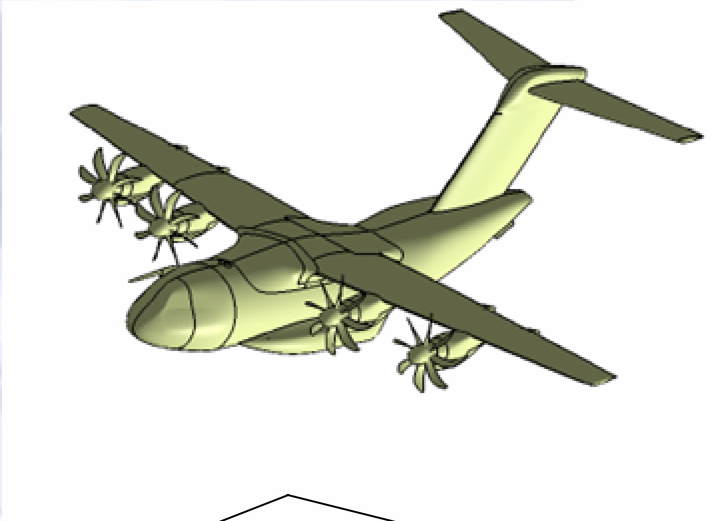




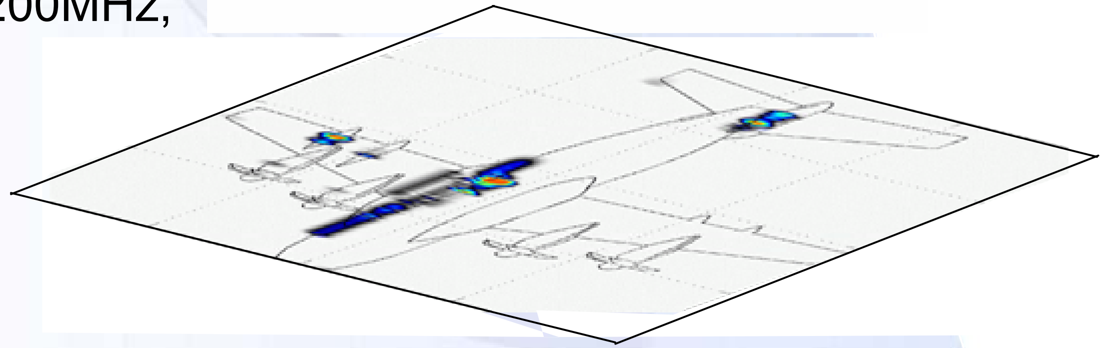
- This example: X-band, direct reflection, edge diffraction: less than 2s/angle 120*120 angles@20PCs: 20min

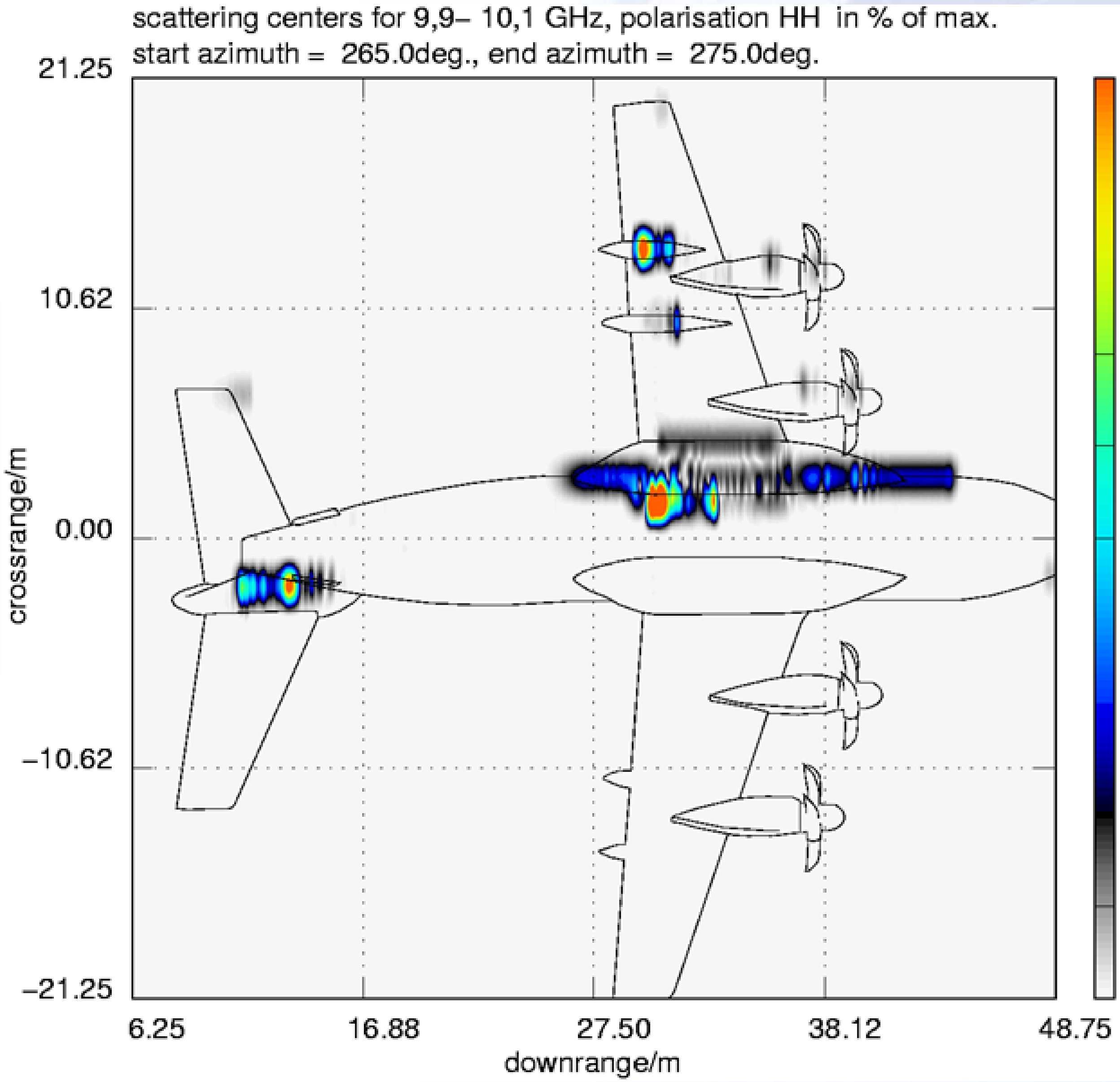
ISAR imaging

- Use of in-house developed imaging software (for RCS measurement post-processing)



- Generation of a 2D Image
  Example:
  Azimuth 90 +/- 5°, Elevation= -15°,
  Image-resolution 50cm:
  - Simulation bandwidth: 200MHz, step width 1MHz
  - Angular step = 0.0154°
  - 129600 simulations



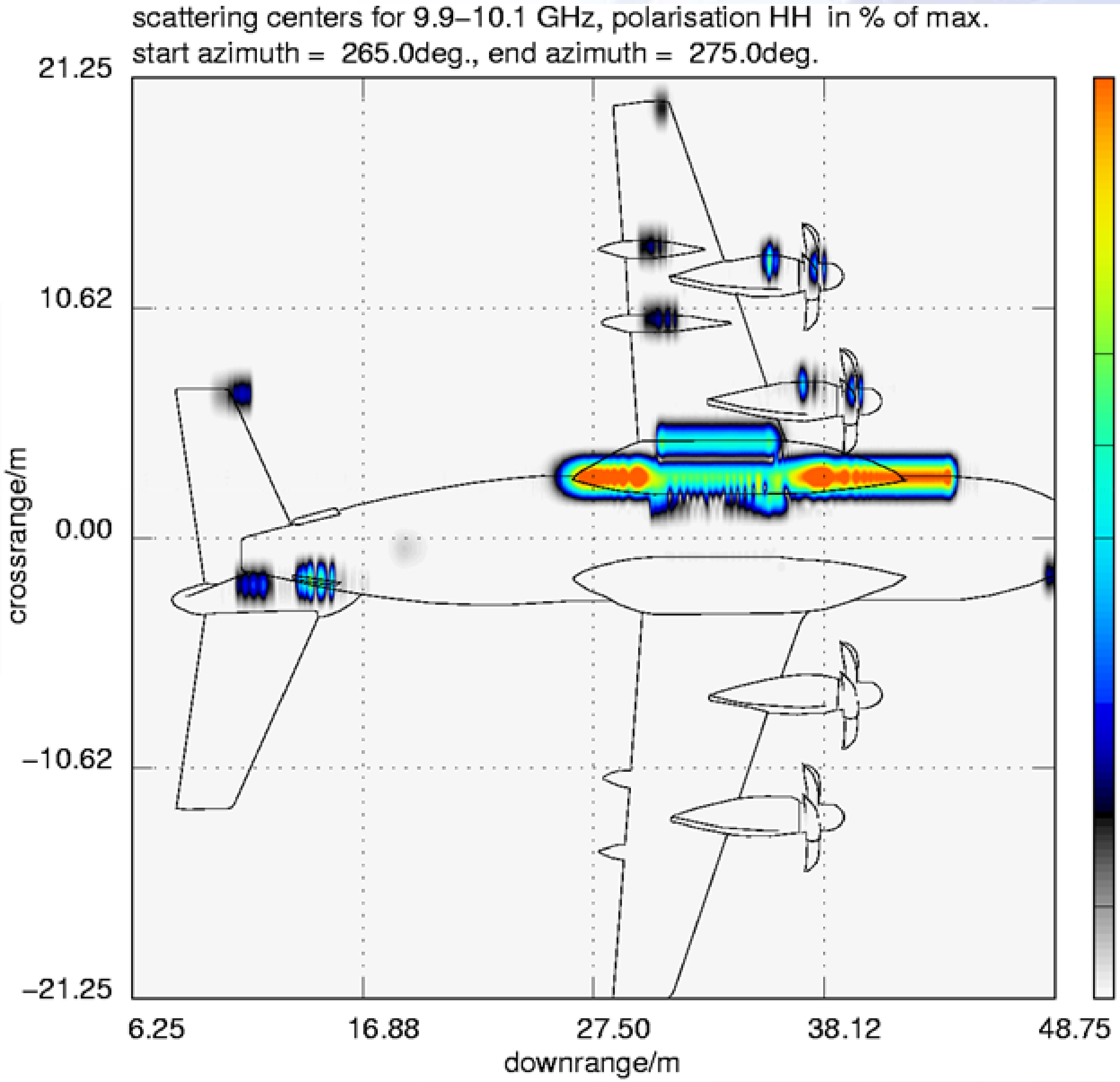


ISAR image

Elevation –15°

Azimut 85°-95°

All effects



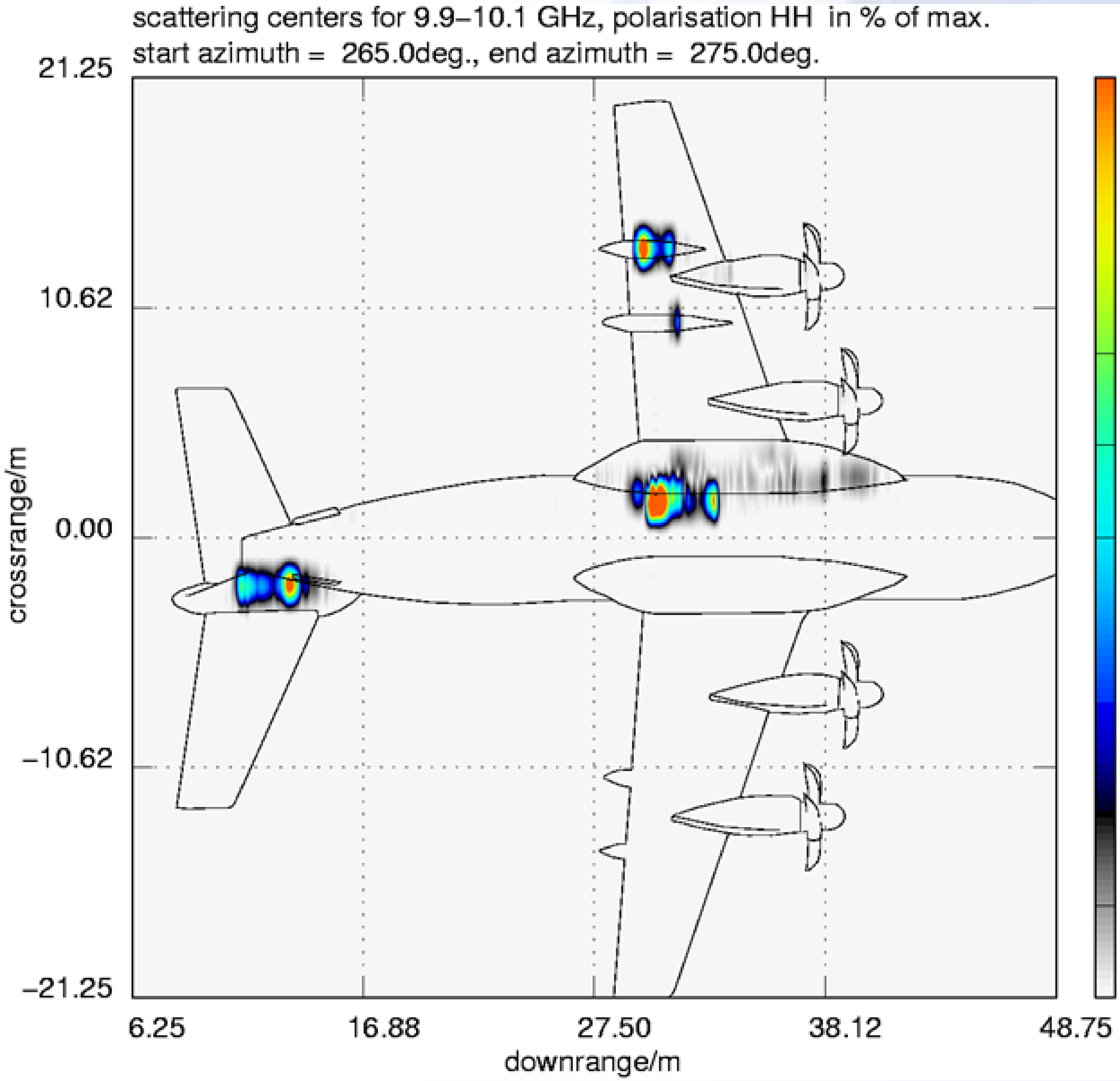
ISAR image

Elevation –15°

Azimut 85°-95°

Contribution:

Direct reflections



ISAR image

Elevation –15°

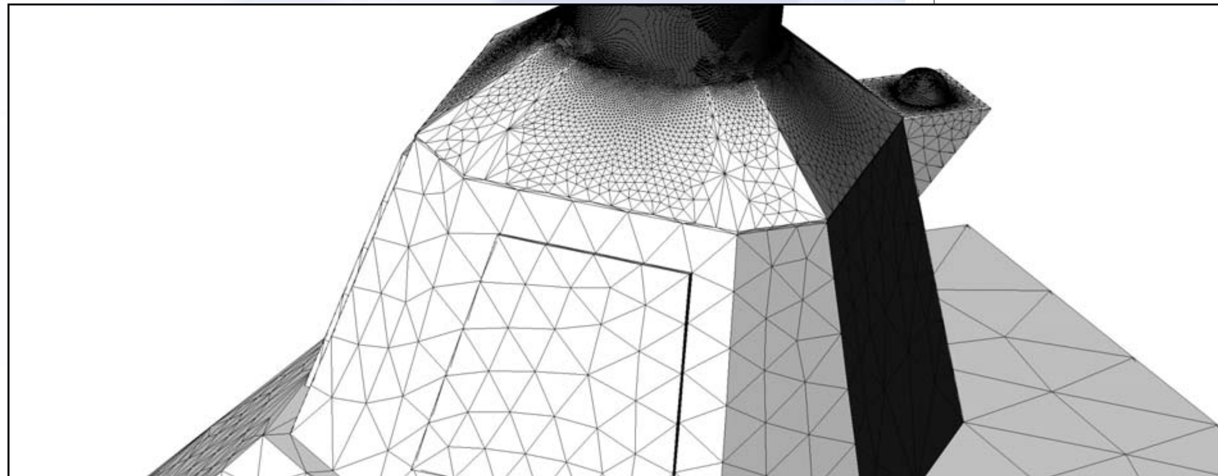
Azimut 85°-95°

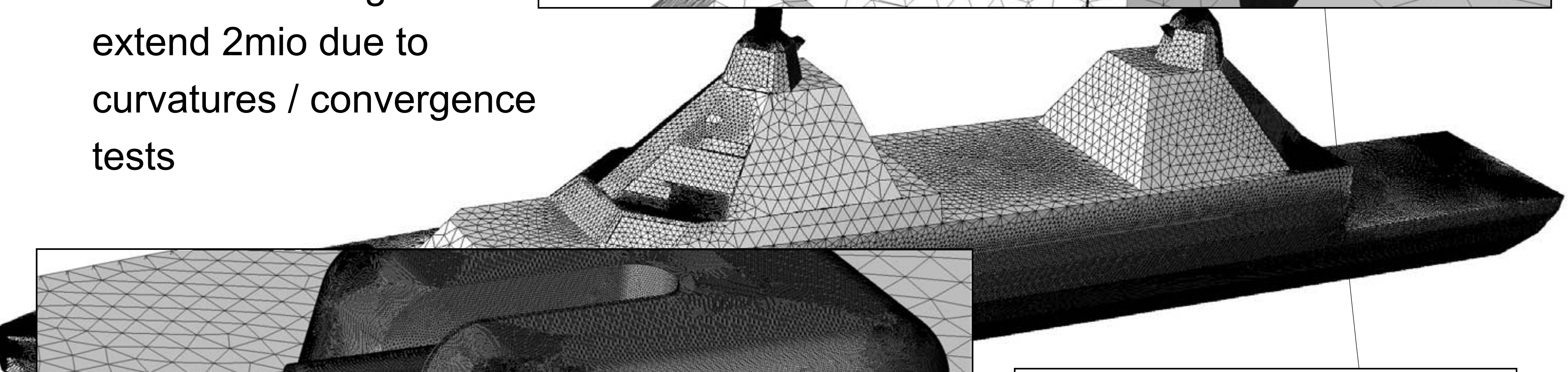
Contributions:

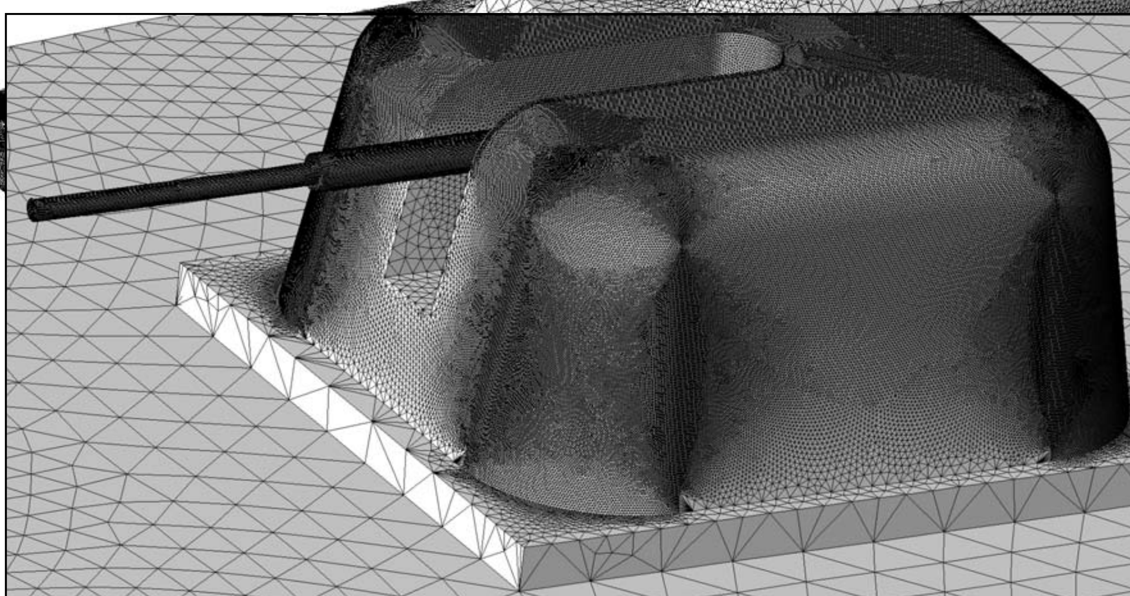
Double reflections

Current extensions

- Example: mesh of a ship config.
- Number of triangles extend 2mio due to curvatures / convergence tests







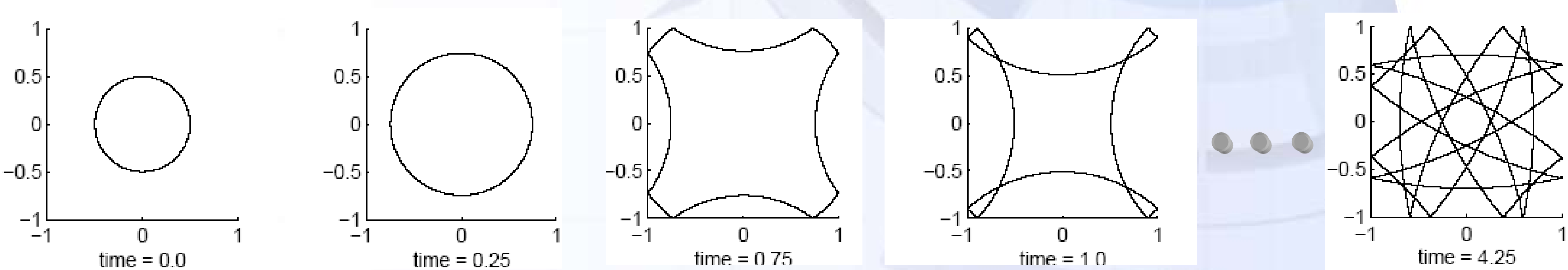
Extension to curved surfaces:

• NURBS handling to complex

• use curved triangles

Extension, Current Work

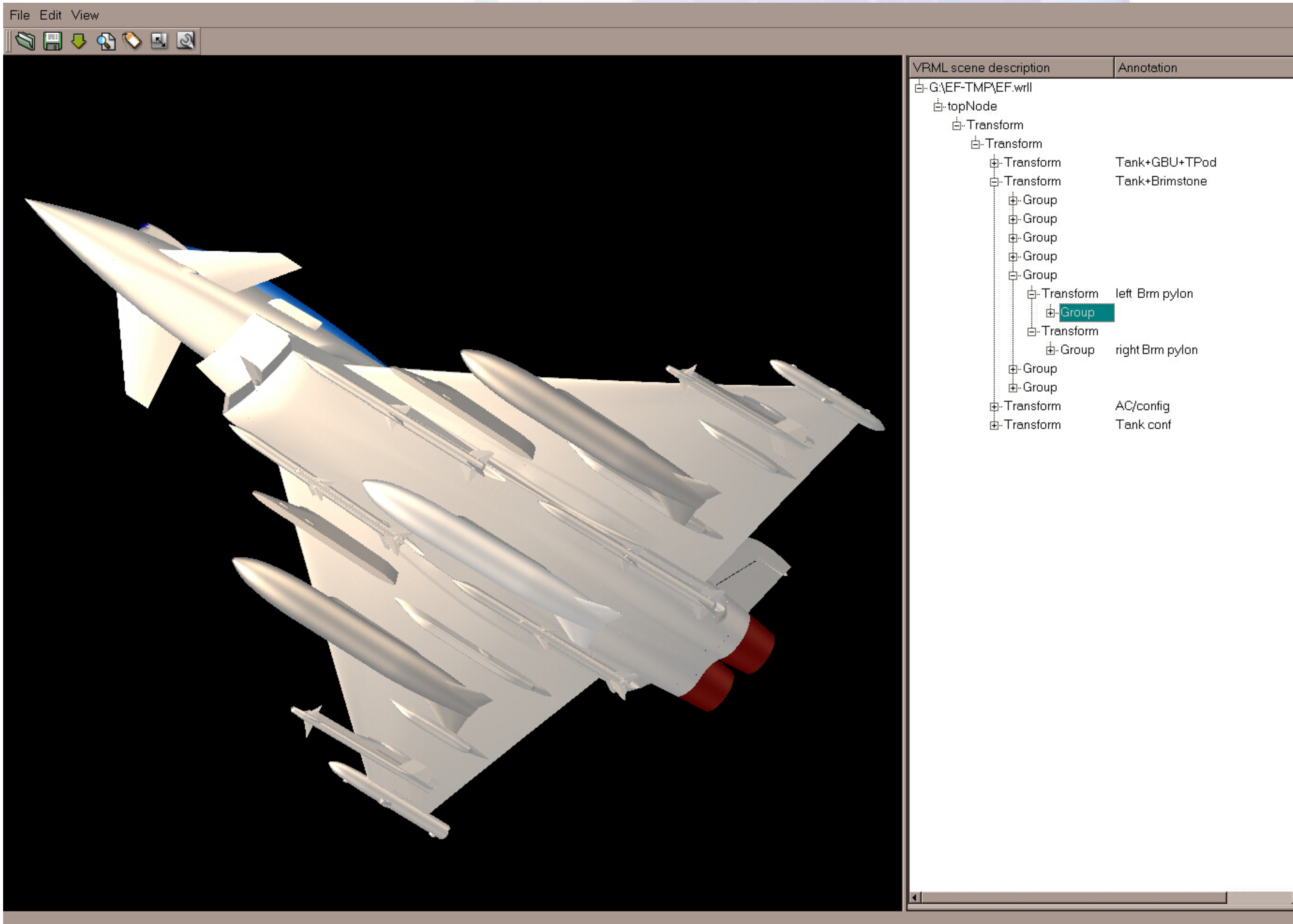
- Extension to curved triangles (polynomial up to 2.deg. in u,v)
  - Good compromise between number of elements, complexity of computation
  - Generation easy / wide spread available (used in visualisation)
- Totally frequency independent approach:
  - Investigation of the Wave-front (WF) evolution method



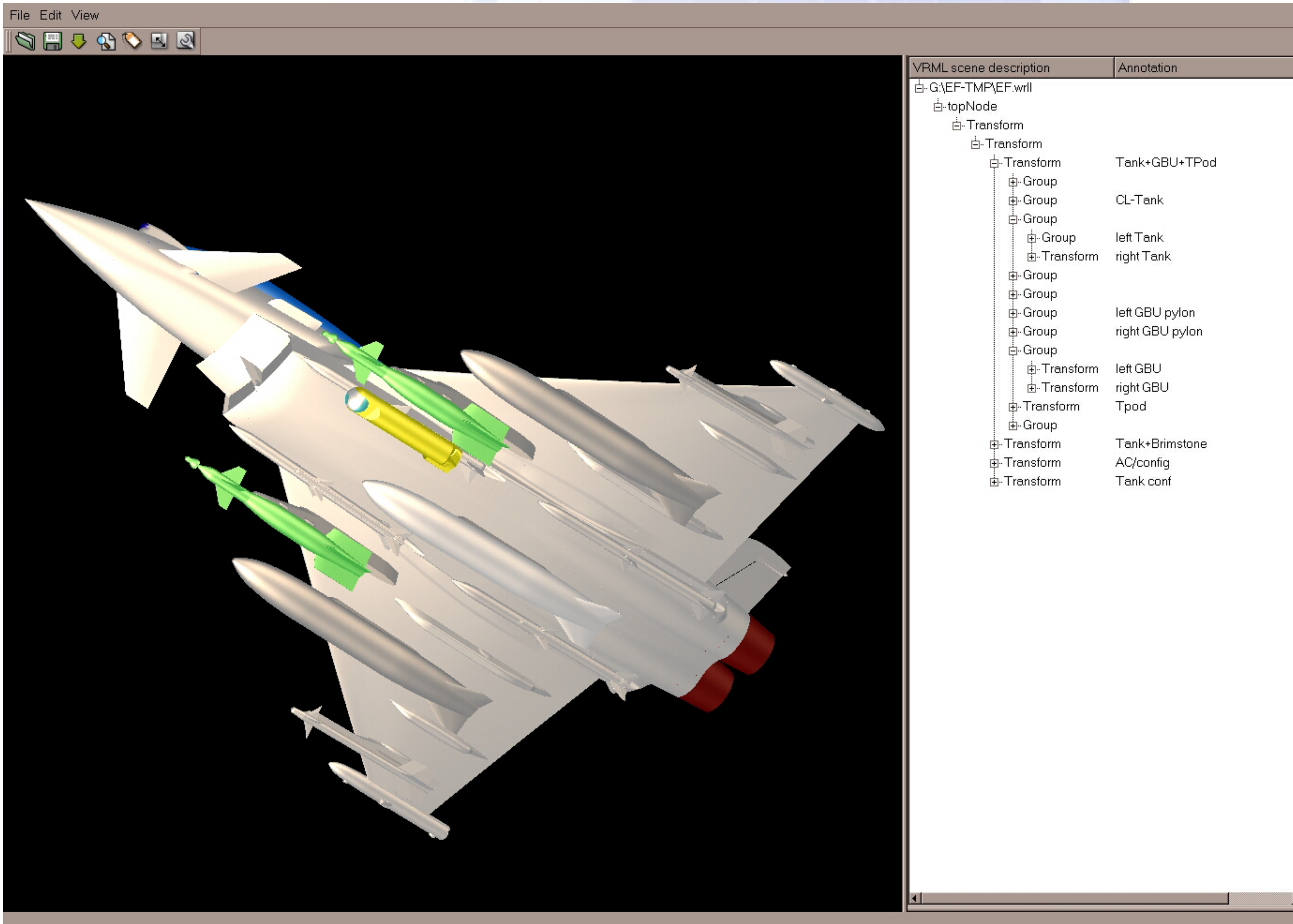
The CAD issue

- Requirements:
  - analysis of different vehicle-configurations (loads, stores, etc.)
  - Analysis of configuration in different states (moving parts)
- Modifications of the geometry in CAD is often time consuming
- We use VRML based geometry description
  - Meshed geometry, supporting also curved triangles
  - Widely available / incorporated in CAD systems,
  - Capable of keeping geometry data structure:
    - Enable / disable parts of the geometry
    - Parameterisation of transforms (moving parts) outside CAD

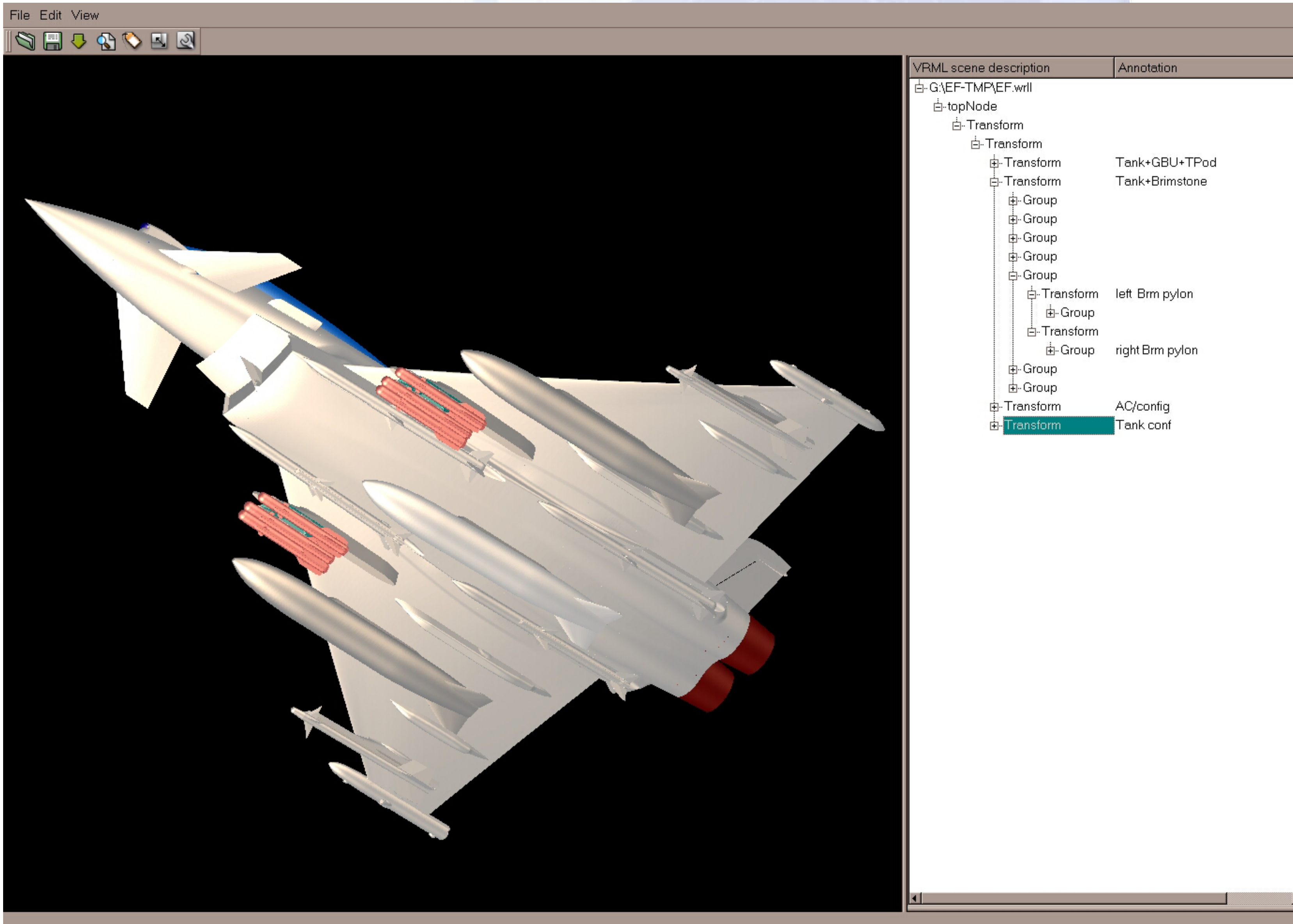
VRML based Geometry description



VRML based Geometry description



VRML based Geometry description



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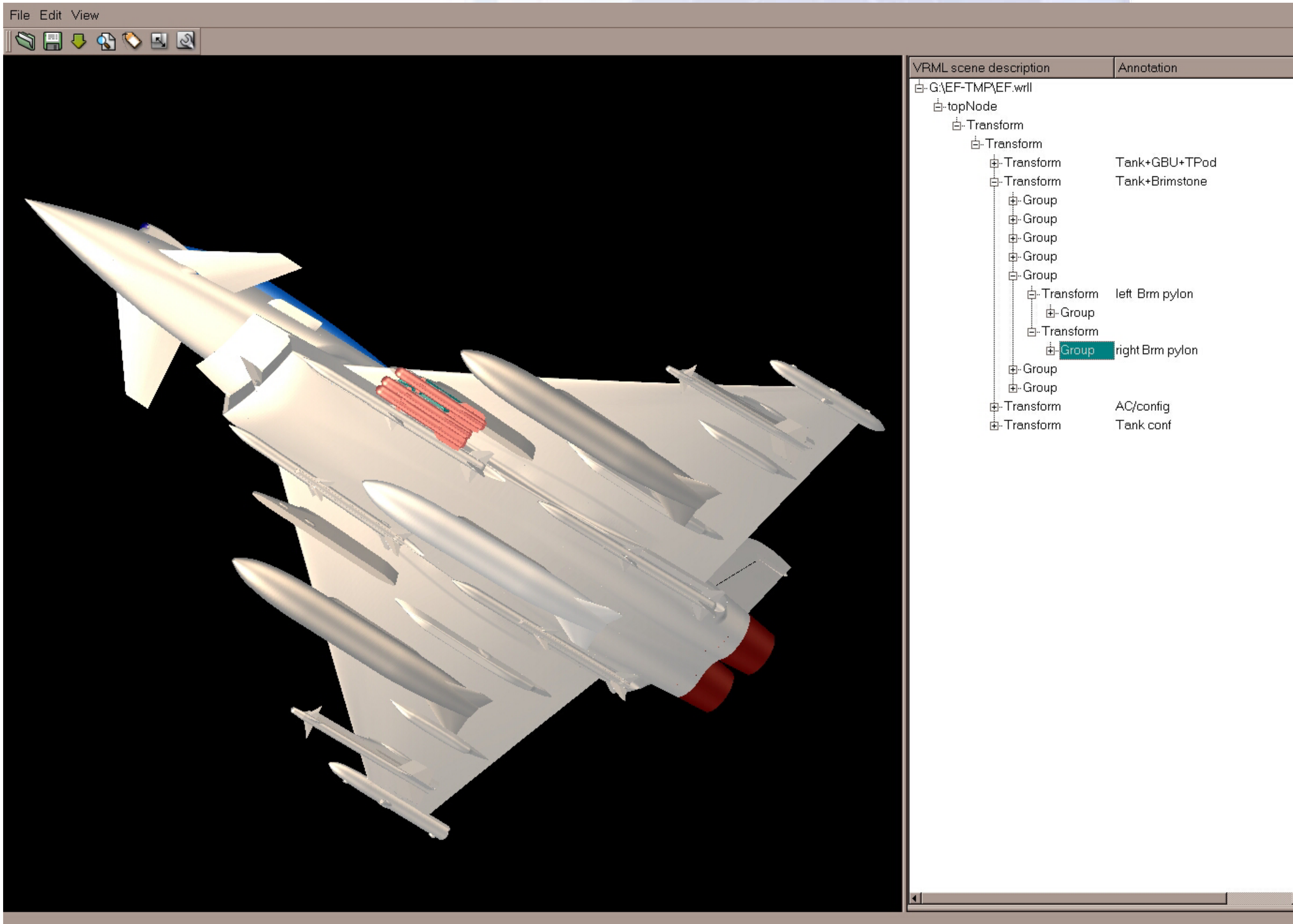

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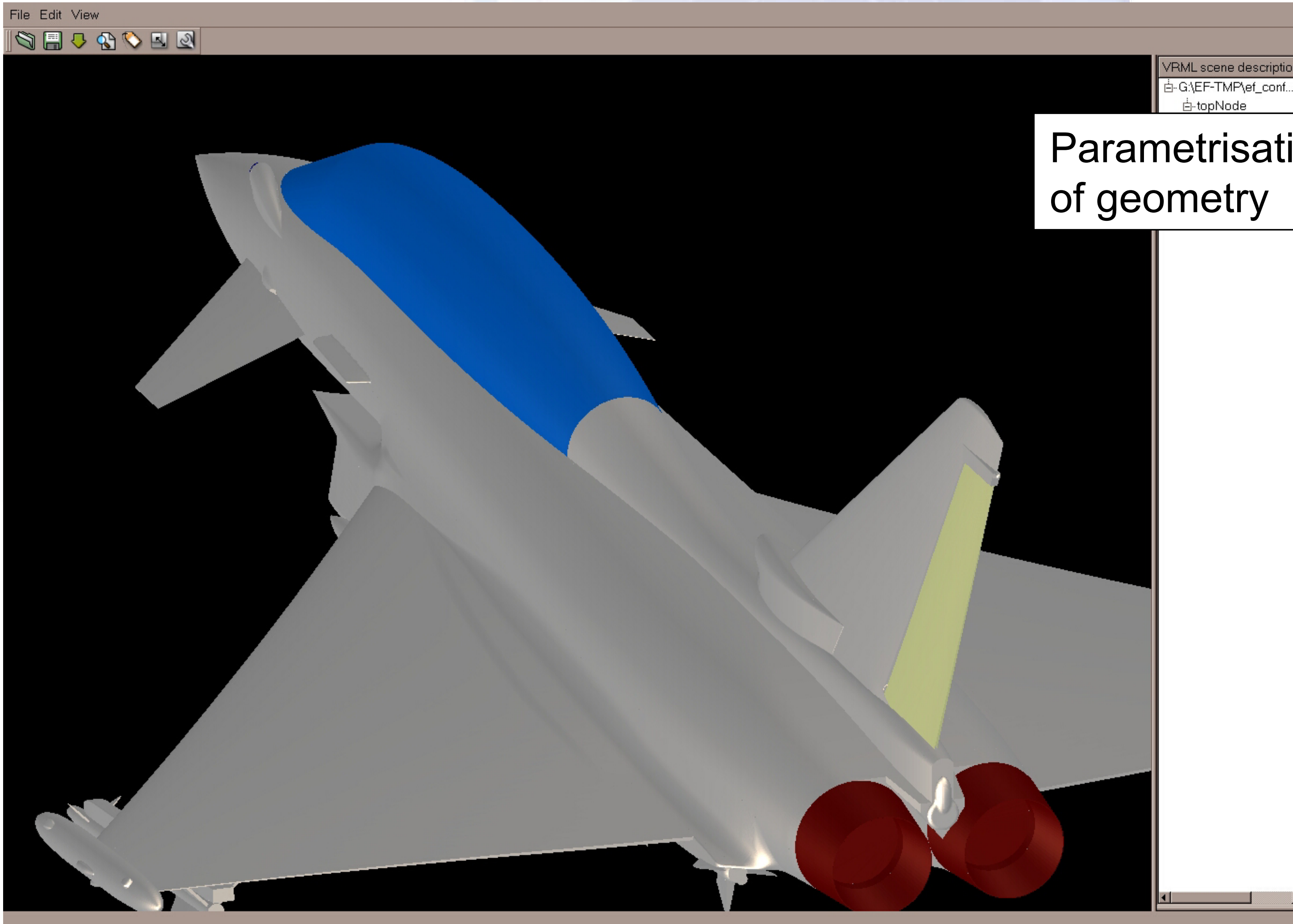
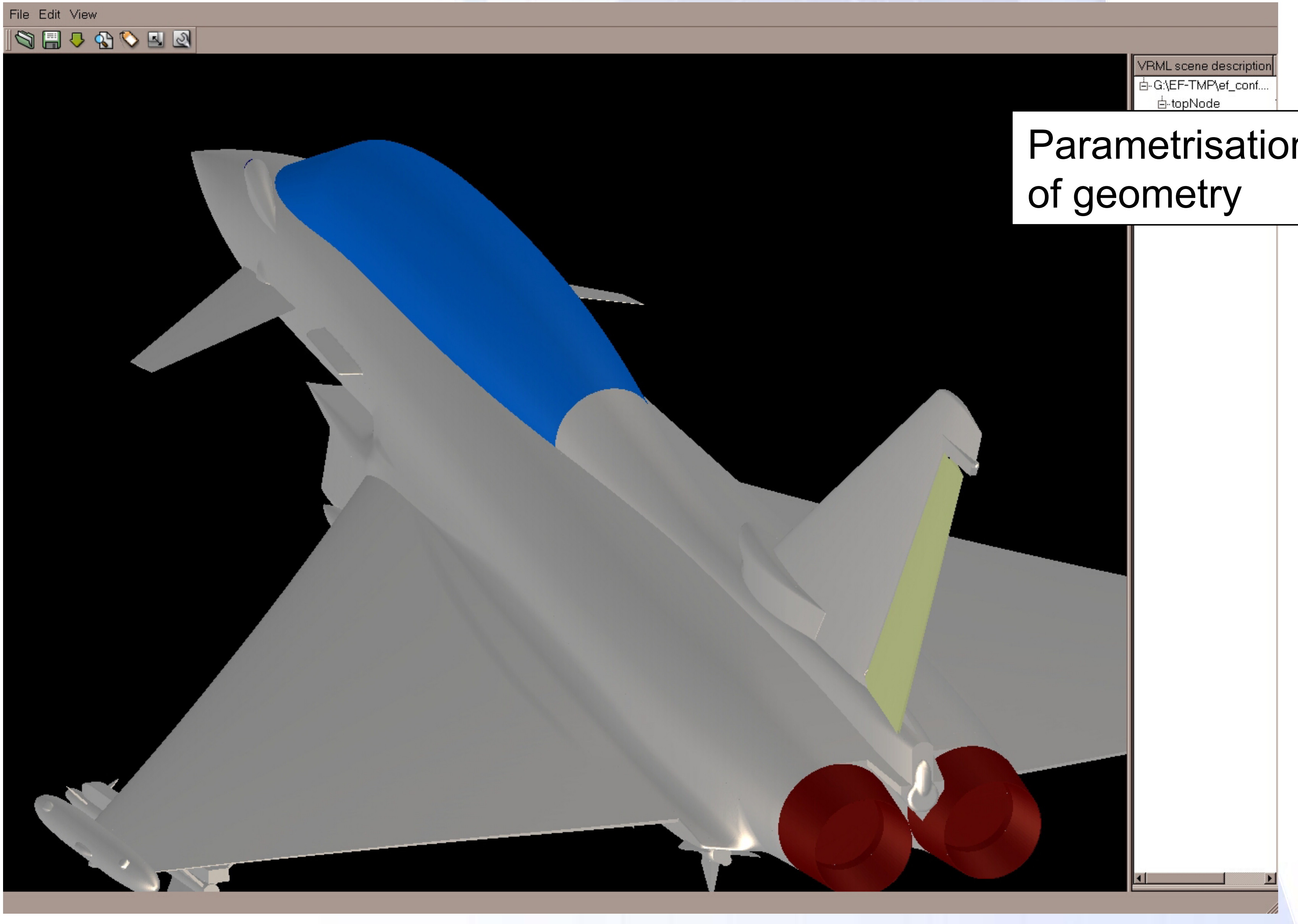


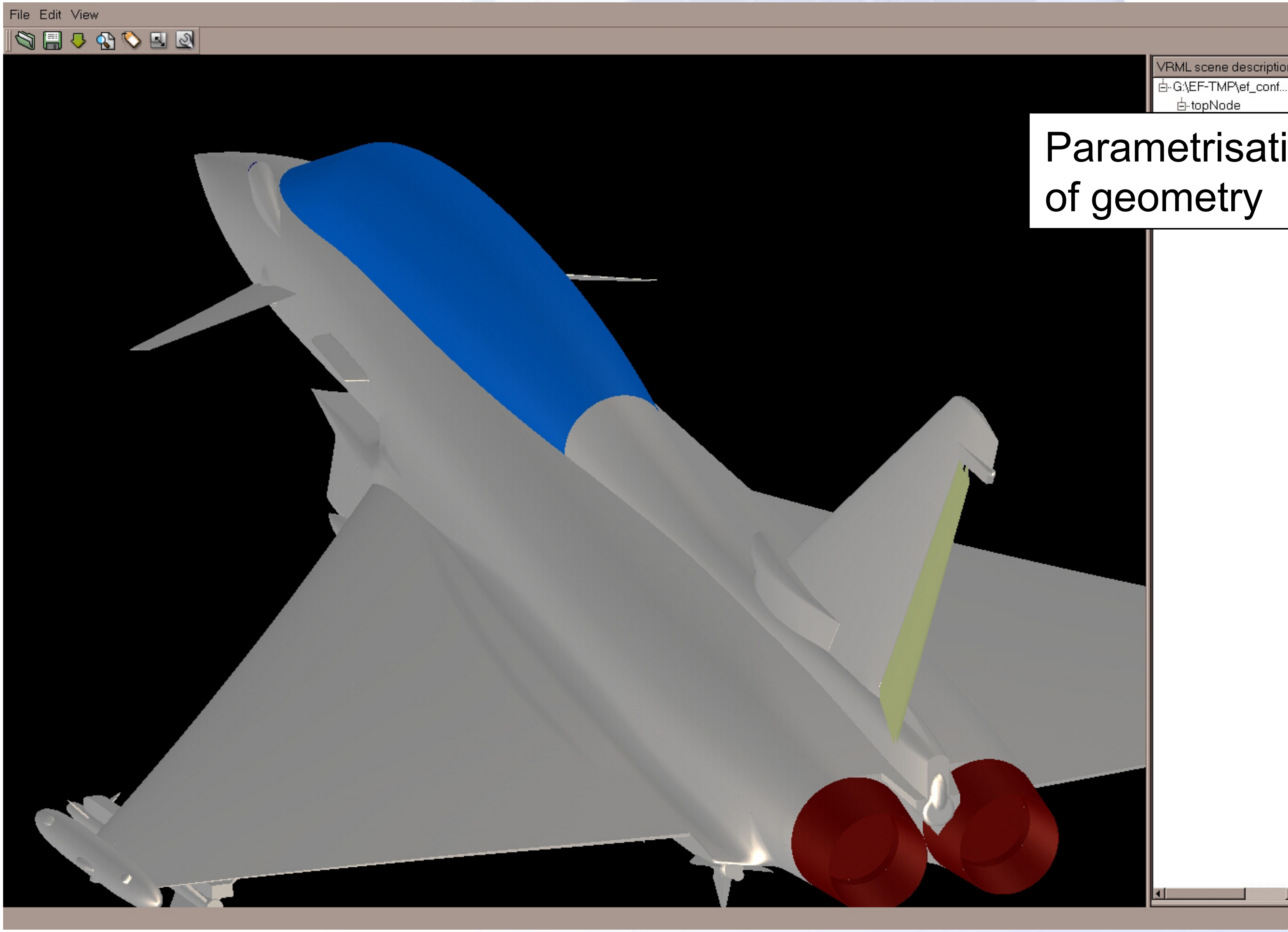
Parametrisation of geometry

VRML based Geometry description



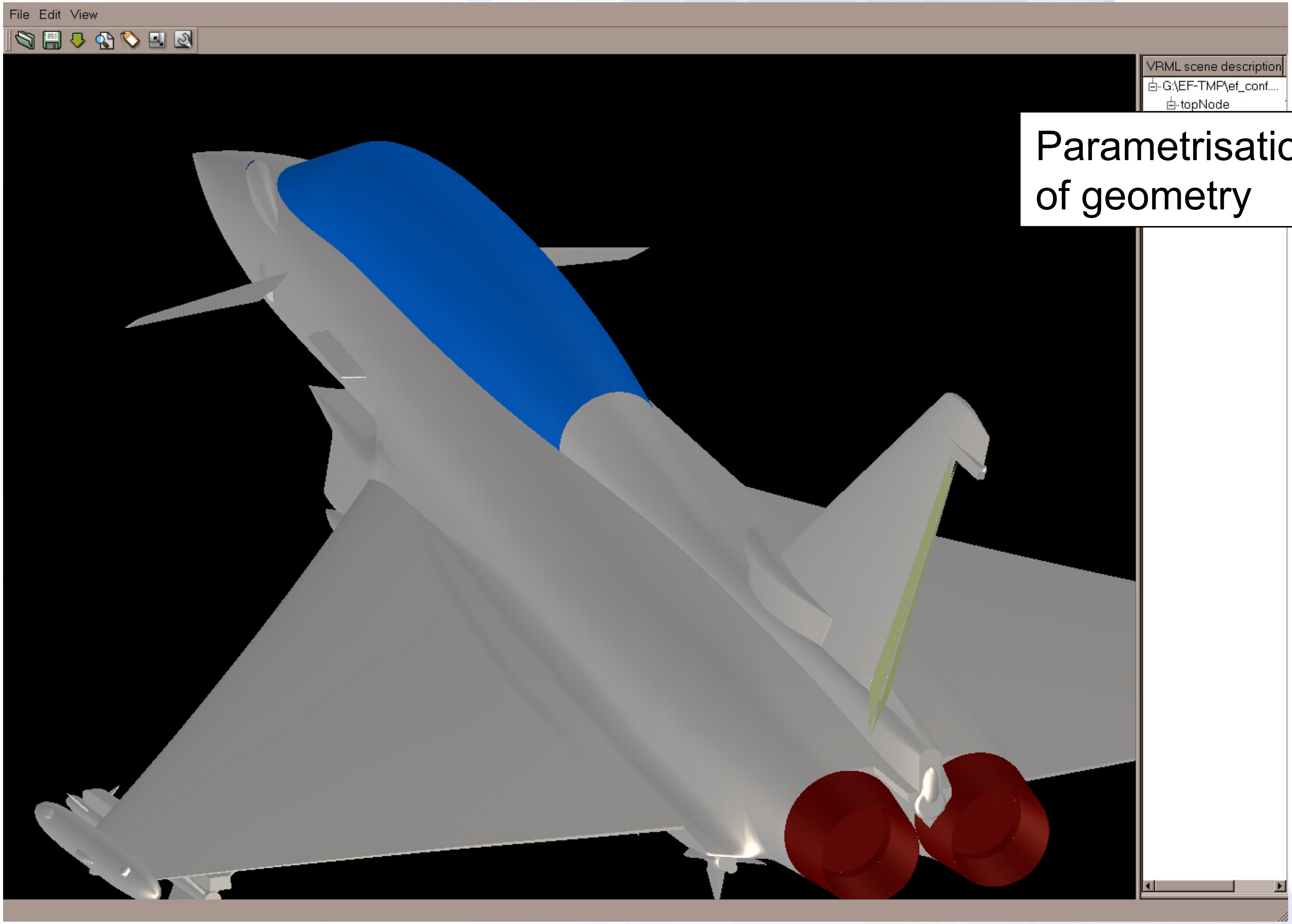
Parametrisation of geometry

VRML based Geometry description



Parametrisation of geometry

VRML based Geometry description



Parametrisation of geometry

Conclusion

- Most of the realistic radar targets require hybrid method for simulation
- Even in mmw-applications, high performance full-wave tools are required for analysis of details
- Examples
- New developments, CAD issues, geometry handling

RCS Simulation

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