

THESIS PRESENTATION

Development of Code for a Physical Optics Radar Cross Section Prediction and Analysis Application (POFACETS 3.0)



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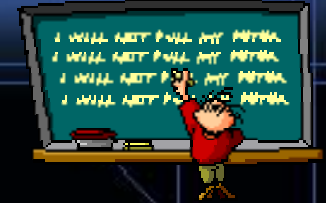
Prof. D. Curtis Schleher

POFACETS 3.0

- **PRESENTATION OVERVIEW**
 - **RADAR CROSS SECTION BASICS**
 - THESIS GOALS
 - POFACETS OVERVIEW
 - NEW FUNCTIONALITIES
 - NEW COMPUTATIONAL CAPABILITIES
 - CONCLUSIONS
 - FURTHER IMPROVEMENTS



POFACETS 3.0



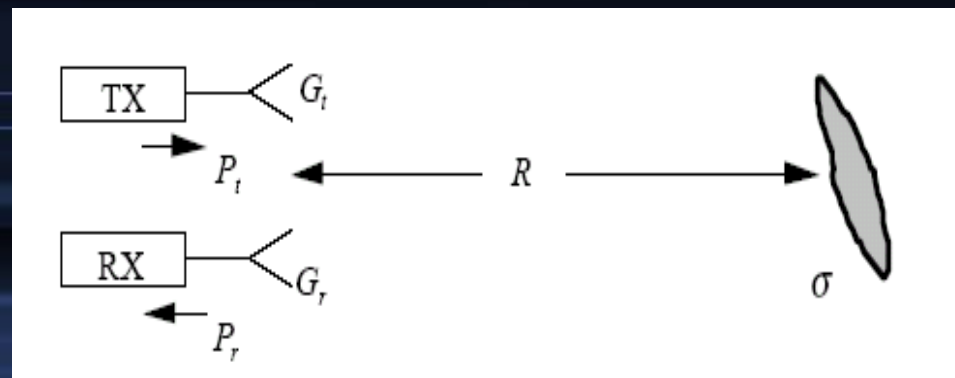
- **RADAR CROSS SECTION BASICS**

- Radar Cross Section (RCS) represents the magnitude of the echo signal returned to a radar by the target

- Formal definition:
$$\sigma \equiv \frac{\text{Power reflected to receiver per unit solid angle}}{\text{Incident power density}/4\pi}$$

- Range Independent. Depends on Frequency, Polarization & Target Aspect

- Units of m^2 and dBsm



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- **RCS BASICS**

- Why is RCS important?
 - Signal received by radar is proportional to RCS of target
 - Required Effective Radiated Power for Self-Protection Jamming also proportional to RCS
- RCS reduction important aspect of signature reduction in military platforms (e.g. F-117, B-2, Visby corvette)



POFACETS 3.0

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POFACETS 3.0



- **THESIS GOALS**

- RCS importance makes necessary to predict RCS of targets and evaluate effects of shaping and materials
- Existing RCS prediction software packages are usually expensive, have high requirements on computer resources and feature long run-times
- Need for an inexpensive software that will run on standard PCs and produce results in seconds or minutes for standard geometrical shapes

POFACETS 3.0

- **THESIS GOALS**

- POFACETS 2.3 developed in 2000 by Prof. D. Jenn and Commander E. Garrido allows user to design a model and evaluate its RCS

- MATLAB compatibility issues

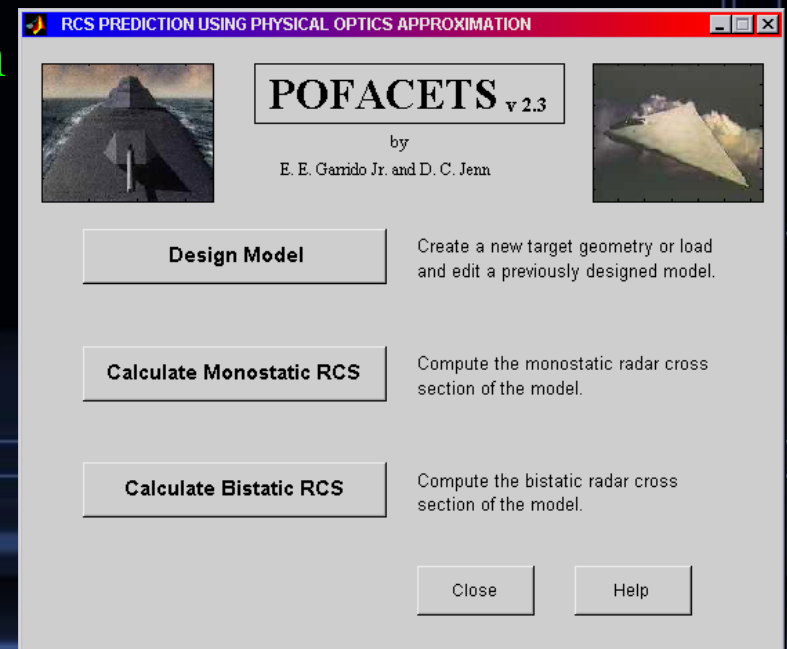
- Limitations in model design

- Thesis Goals:

- Upgrade POFACETS 2.3 version

- Add new functionalities

- Add new computational capabilities



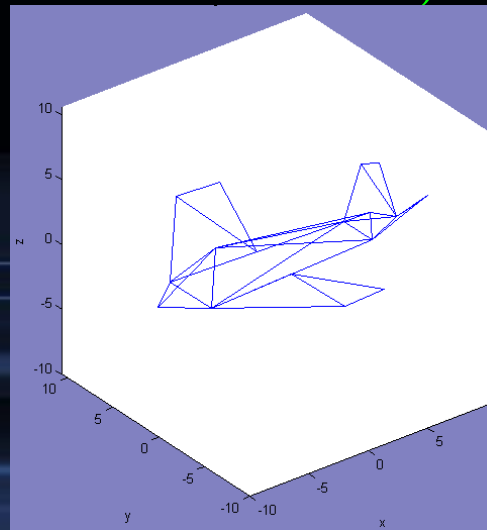
POFACETS 3.0

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POFACETS 3.0

- **POFACETS OVERVIEW**
 - Program implements 2 main tasks:
 - Target Model Design
 - Model surfaces defined by use of triangular facets
 - Nodes defined by their x,y,z coordinates
 - Facets defined by three nodes (right hand rule used to define external facet side)



POFACETS 3.0

- POFACETS OVERVIEW
 - RCS Calculations
 - Monostatic and Bistatic Cases
 - Physical Optics method is used to calculate current on illuminated facets. Current is set to zero in non-illuminated facets
 - Radiation integrals and Taylor series used to compute scattered field from each facet. Total scattered field is sum of fields from each facet.
 - RCS is computed as:
$$\sigma = 4\pi \frac{|\vec{E}_s|^2}{|\vec{E}_i|^2}$$
 - Diffraction, Multiple Reflections, Shadowing, Surface Waves are not included in calculations

POFACETS 3.0

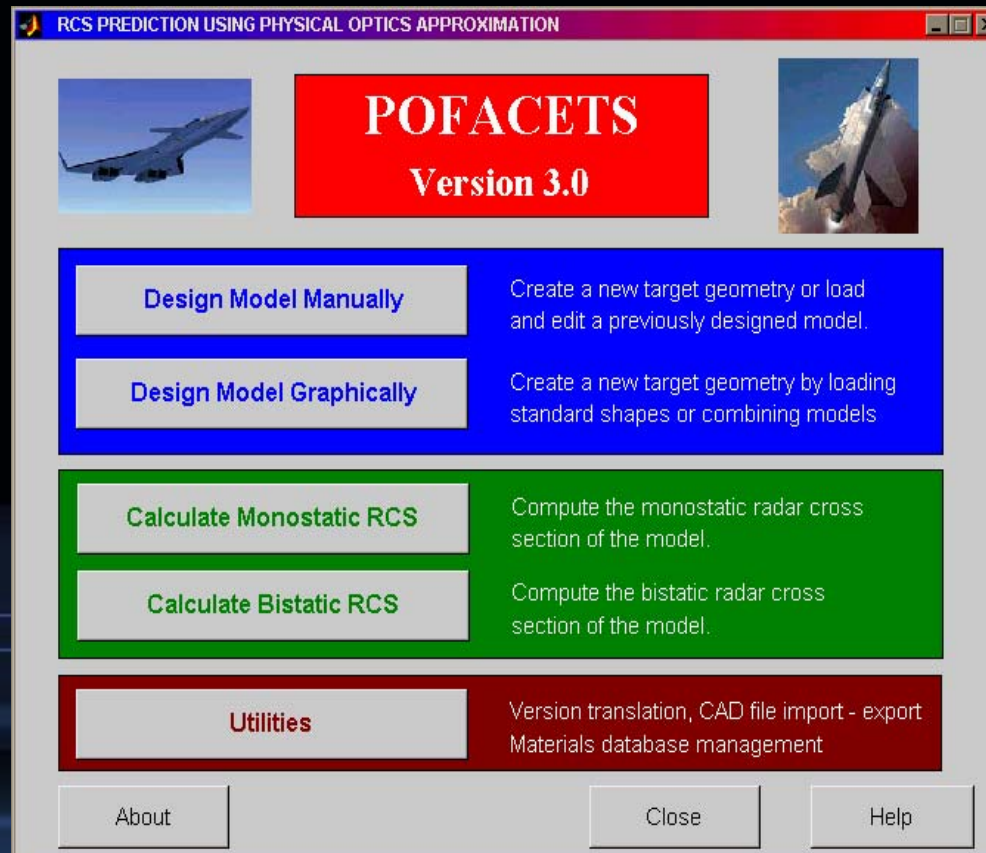
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POFACETS 3.0

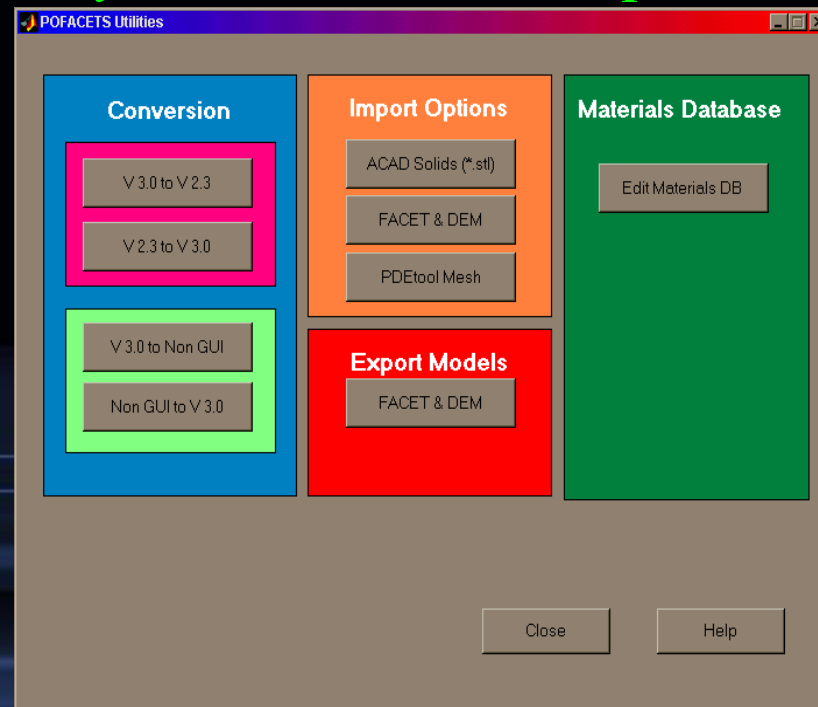


- **NEW FUNCTIONALITIES**
 - Upgrade of existing GUIs to MATLAB 6.5
 - Only standard Windows components used



POFACETS 3.0

- **NEW FUNCTIONALITIES**
 - Upgrade of existing model file database
 - Only one file per model used (previous POFACETS versions used two files for each model)
 - Capability to convert from/to previous versions files



POFACETS 3.0

- **NEW FUNCTIONALITIES**
 - Upgrade of Manual Model Design
 - Unlimited numbers of vertices and facets

Array Editor: coord

File Edit View Web Window Help

Numeric format: shortG Size: 4 by 3

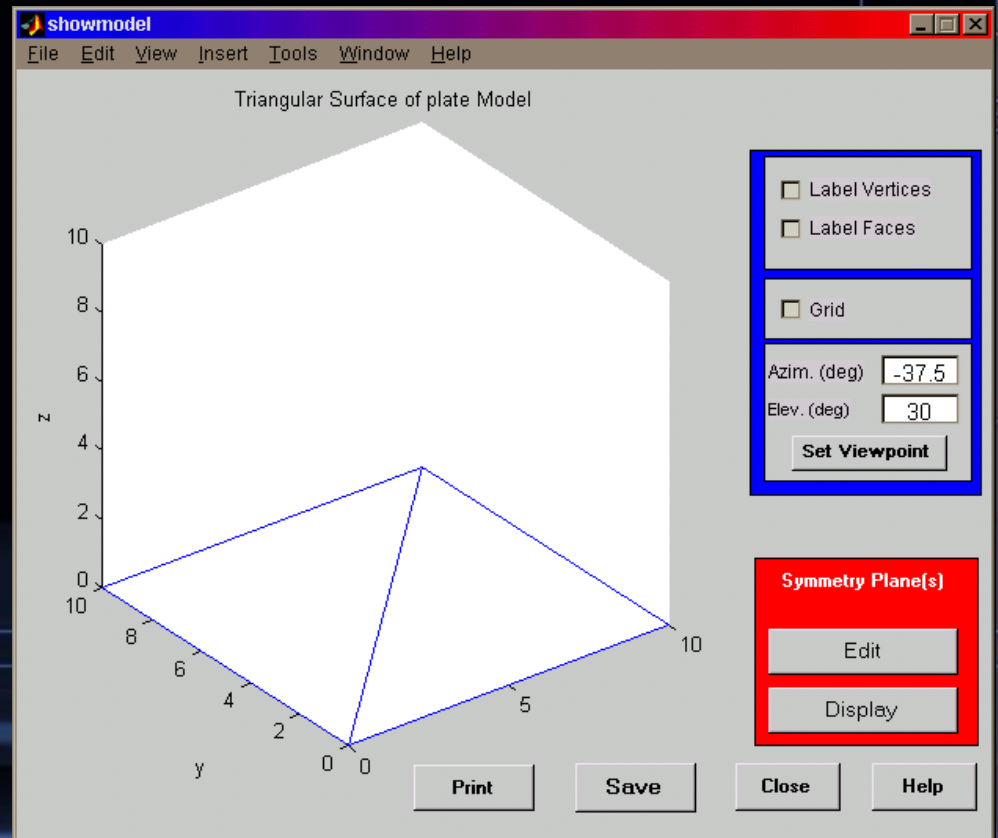
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1	10	10	0
2	0	10	0
3	0	0	0
4	10	0	0

Array Editor: facet

File Edit View Web Window Help

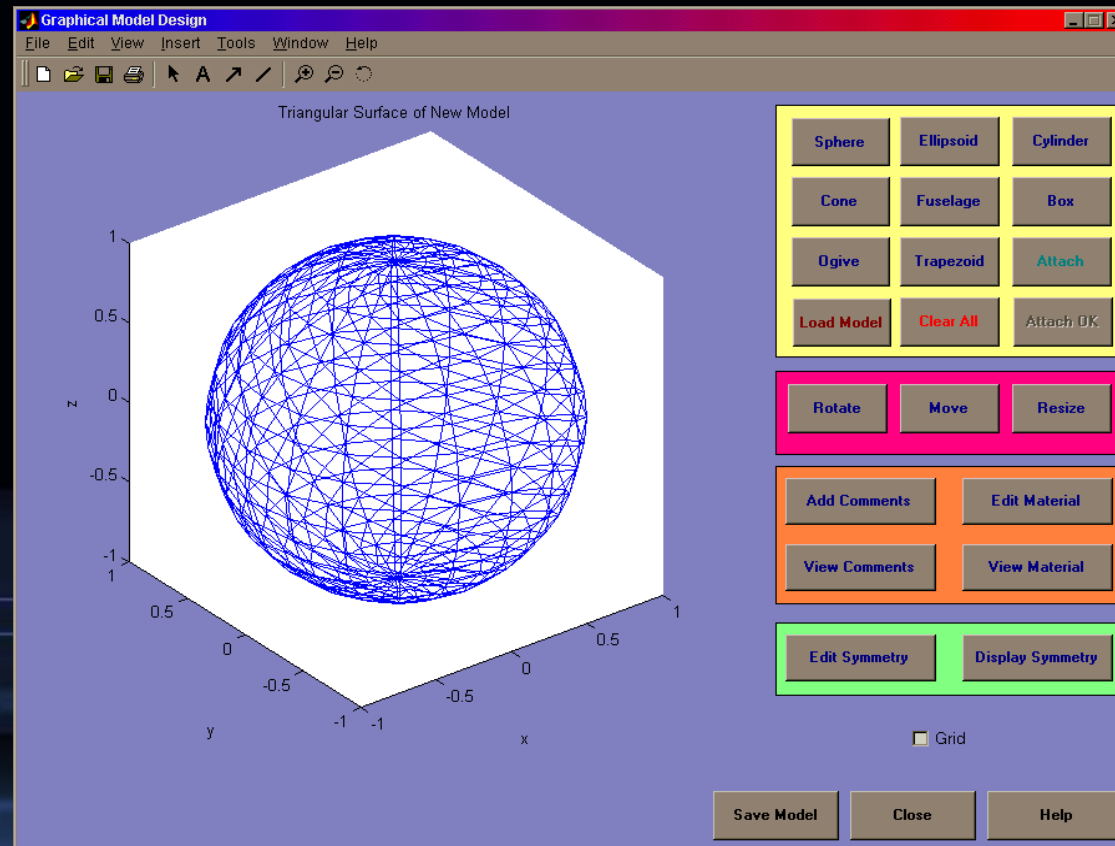
Numeric format: shortG Size: 2 by 5

	1	2	3	4	5
1	1	2	3	1	0
2	3	4	1	1	0



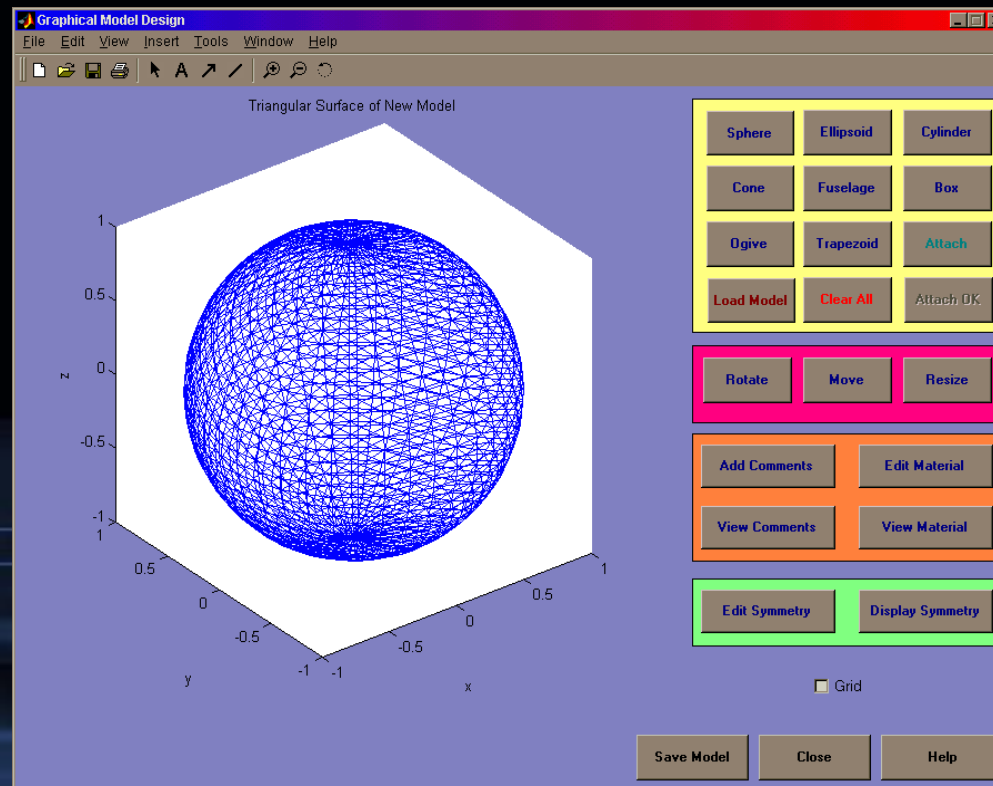
POFACETS 3.0

- NEW FUNCTIONALITIES
 - Graphical Model Design
 - Standard geometrical shapes implemented



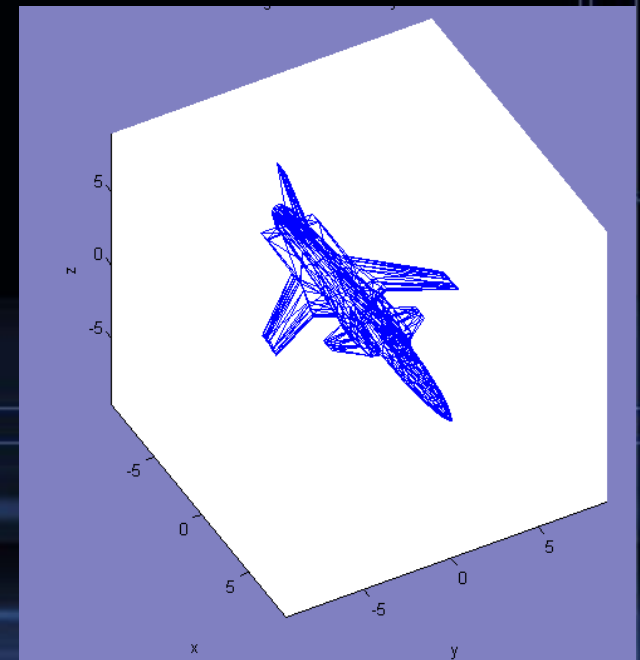
POFACETS 3.0

- NEW FUNCTIONALITIES
 - Graphical Model Design
 - Models can be resized, moved or rotated
 - User selectable number of facets for curved surfaces



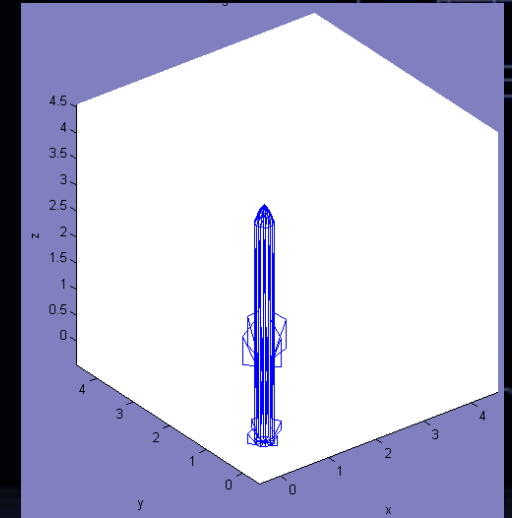
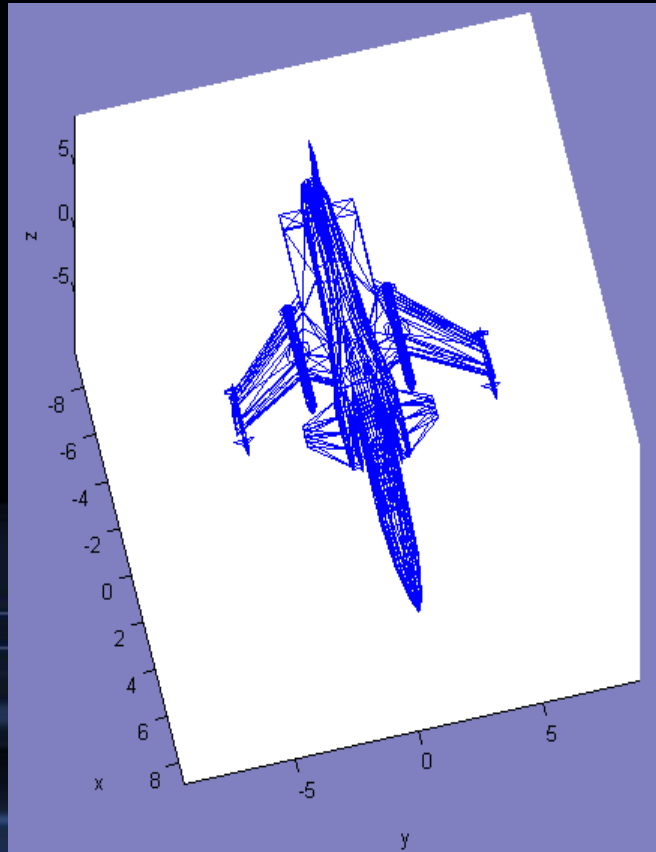
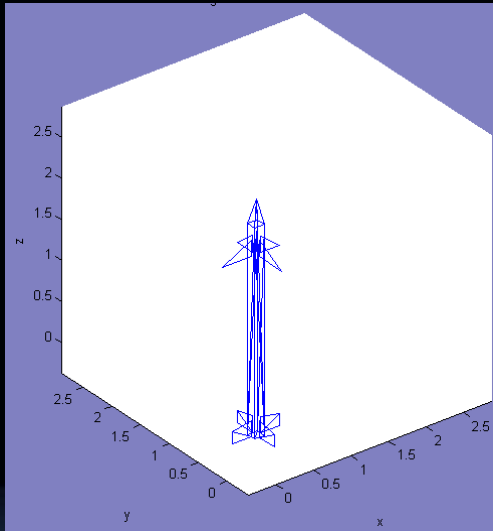
POFACETS 3.0

- **NEW FUNCTIONALITIES**
 - Import/Export of models from/to other CAD & RCS software
 - Import from CIFER, ACADS, AUTOCAD (stereolithographic format only), MATLAB's PDETOOL
 - Export to CIFER and ACADS



POFACETS 3.0

- **NEW FUNCTIONALITIES**
 - Combination of existing models
 - Allows the design of very complex models



POFACETS 3.0

- **NEW FUNCTIONALITIES**
 - RCS computations vs Angle or vs Frequency
 - Monostatic and Bistatic cases implemented

CALCULATE MONOSTATIC RCS

Calculation of Monostatic RCS for the plate model

Load File

☐ Ground Plane XY?

☒ PEC

Rel. Permittivity: 4

	Theta	Phi
Starting Angle	0 deg	0 deg
Ending Angle	360 deg	0 deg
Increment Angle	1 deg	1 deg

Computational Parameters

Taylor Series

Length of Region: 0.05

Number of Terms: 5

Incident Polarization: Theta (TM-z)

Frequency: 1 GHz

☐ Show 3D Display ☐ Show Polar Graph

Calculate RCS Print Close Help

CALCULATE BISTATIC RCS

Calculation of Bistatic RCS for the plate model

Load File

☐ Ground Plane XY?

☒ PEC

Rel. Permittivity: 4

Incidence Angle		Observation Angle	
Theta:	30 deg	Theta Start:	0 deg
Phi:	0 deg	Theta Stop:	360 deg
		Increment:	1 deg
		Phi Start:	0 deg
		Phi Stop:	0 deg
		Increment:	1 deg

Computational Parameters

Taylor Series

Length of: 0.05

Number of: 5

Incident Polarization: Theta (TM-z)

Frequency: 3 GHz

☐ Show 3D Display ☐ Show Polar Graph

Calculate RCS Print Close Help

POFACETS 3.0

- **NEW FUNCTIONALITIES**
 - RCS computations vs Angle or vs Frequency
 - All user input is checked for errors

The screenshot shows the 'CALCULATE RCS vs FREQUENCY' dialog box. It has a title bar with a red gradient and standard window controls. The main area is light gray. At the top, it says 'Press the Load File button to select a model'. Below this is a 'Load File' button. To the right are two angle selection controls: 'Select Theta Angle' with a value of 0 and 'Select Phi Angle' with a value of 0, each with a slider. On the left, there's a 'Frequency' section with 'Start' (0.3 GHz), 'End' (10 GHz), and 'Step' (0.1 GHz) fields. Below that is a 'Ground Plane XY?' section with a checked 'PEC' checkbox and a 'Rel. Permittivity' field set to 4. Further down is a 'Surface Roughness' section with 'Correlation Dist.(m):' and 'Standard Dev. (m):' fields, both set to 0. On the right, there's a 'Computational Parameters' section with a 'Taylor Series' subsection containing 'Length of Region:' (0.05) and 'Number of Terms:' (5). To the right of this is an 'Incident Polarization' dropdown menu set to 'Theta (TM-z)'. At the bottom are four buttons: 'Calculate RCS', 'Print', 'Close', and 'Help'.

CALCULATE RCS vs FREQUENCY

Press the Load File button to select a model

Load File

Select Theta Angle: 0

Select Phi Angle: 0

Frequency

Start: 0.3 GHz

End: 10 GHz

Step: 0.1 GHz

Ground Plane XY?

☒ PEC

Rel. Permittivity: 4

Surface Roughness

Correlation Dist.(m): 0

Standard Dev. (m): 0

Computational Parameters

Taylor Series

Length of Region: 0.05

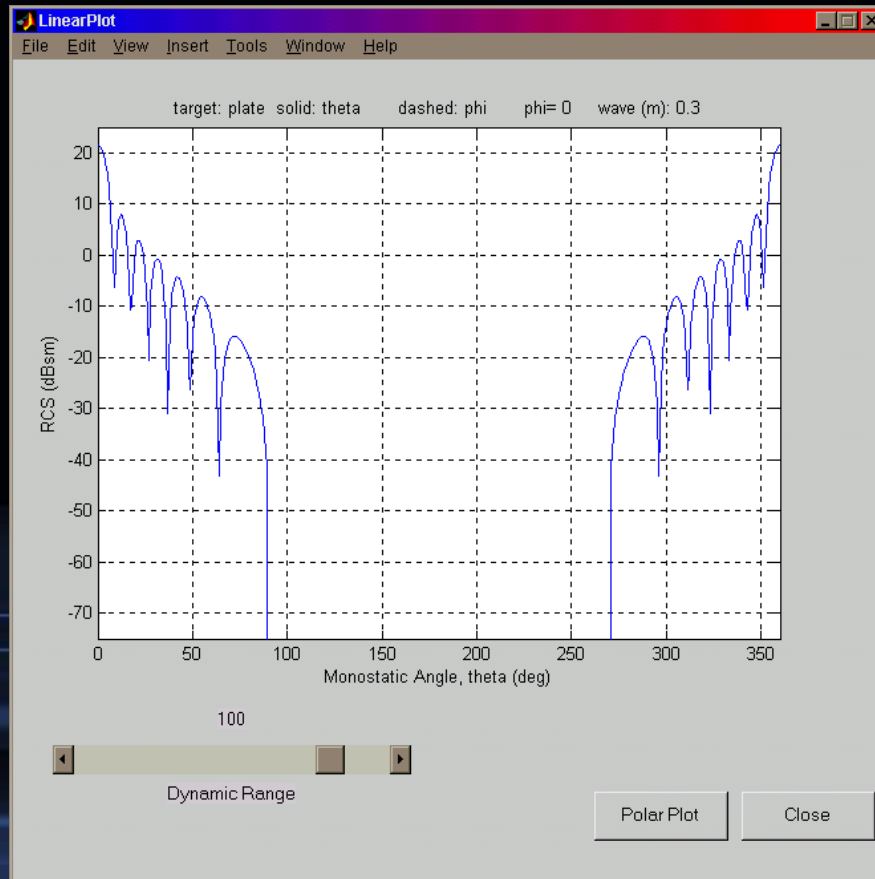
Number of Terms: 5

Incident Polarization: Theta (TM-z)

Calculate RCS Print Close Help

POFACETS 3.0

- NEW FUNCTIONALITIES
 - RCS results display options
 - Standard RCS plot versus angle (1 m by 1 m sphere at 1 GHz)



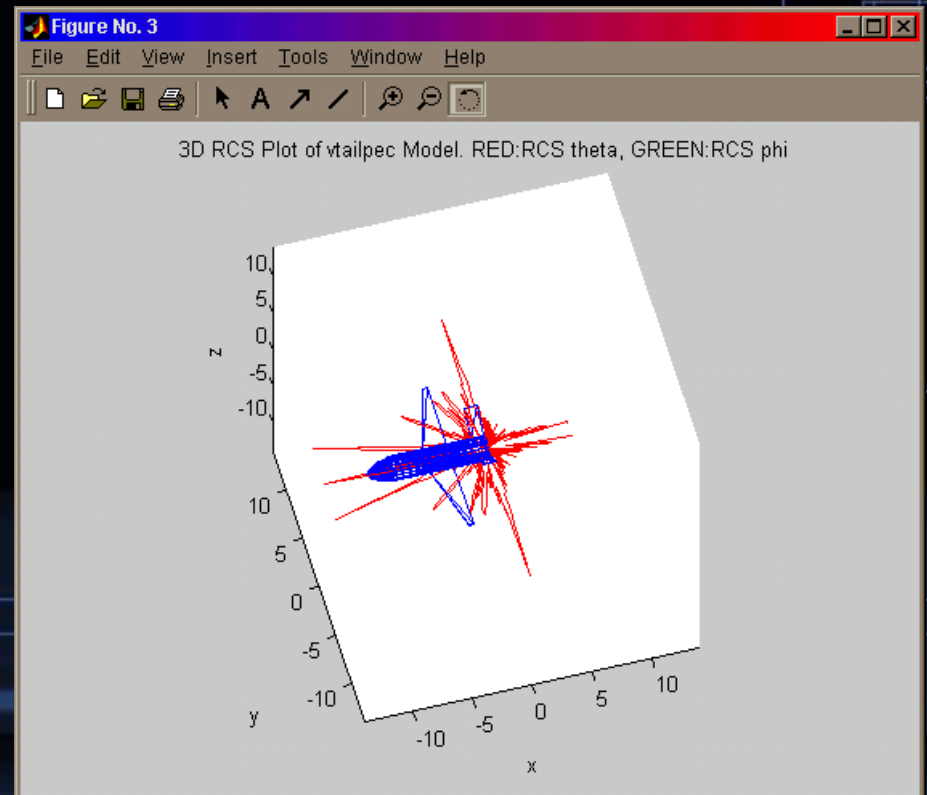
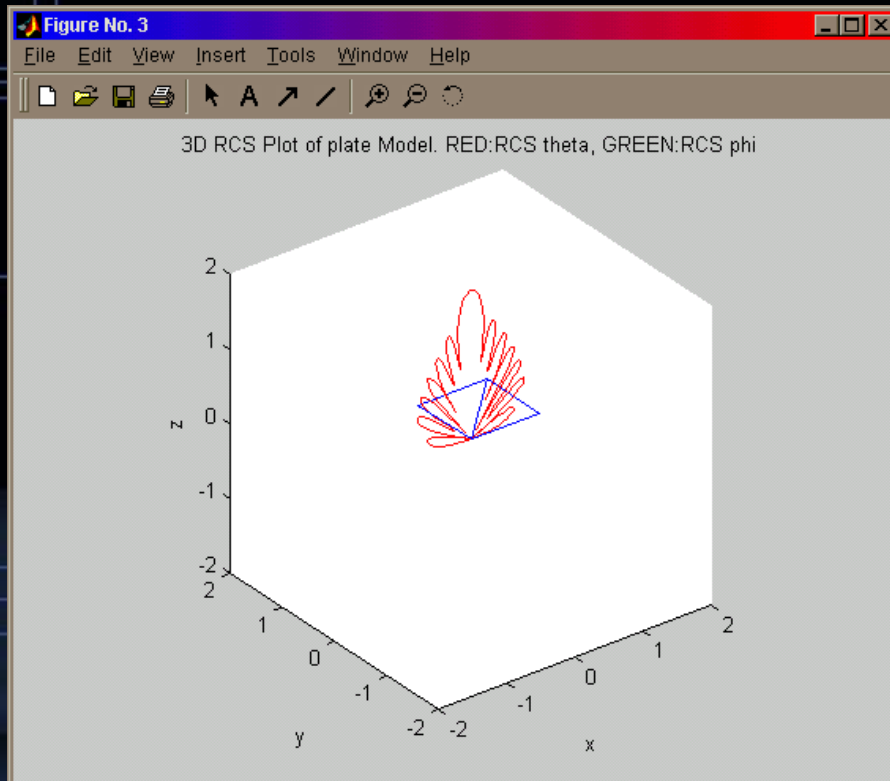
POFACETS 3.0

- NEW FUNCTIONALITIES
 - RCS results display options
 - Polar Plot



POFACETS 3.0

- NEW FUNCTIONALITIES
 - RCS results display options
 - Combination Plot



POFACETS 3.0

- **PRESENTATION OVERVIEW**
 - RADAR CROSS SECTION BASICS
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 - **NEW COMPUTATIONAL CAPABILITIES**
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POFACETS 3.0

- **NEW CAPABILITIES**

- Exploitation of symmetry planes

- Monostatic RCS is the same for symmetrical angles of incidence
 - Can be exploited to expedite RCS computation time
 - Up to three symmetry planes can be defined



Array Editor: symplanes

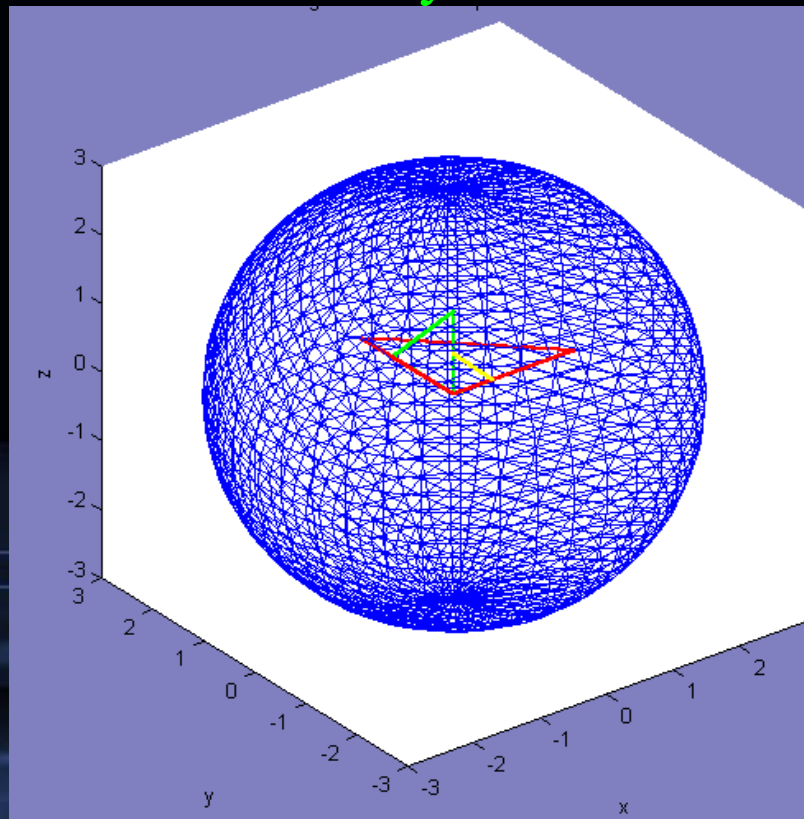
File Edit View Web Window Help

Numeric format: shortG Size: 9 by 3

	1	2	3
1	0	0	0
2	1	0	0
3	0	1	0
4	0	0	0
5	0	1	0
6	0	0	1
7	0	0	0
8	0	0	1
9	1	0	0

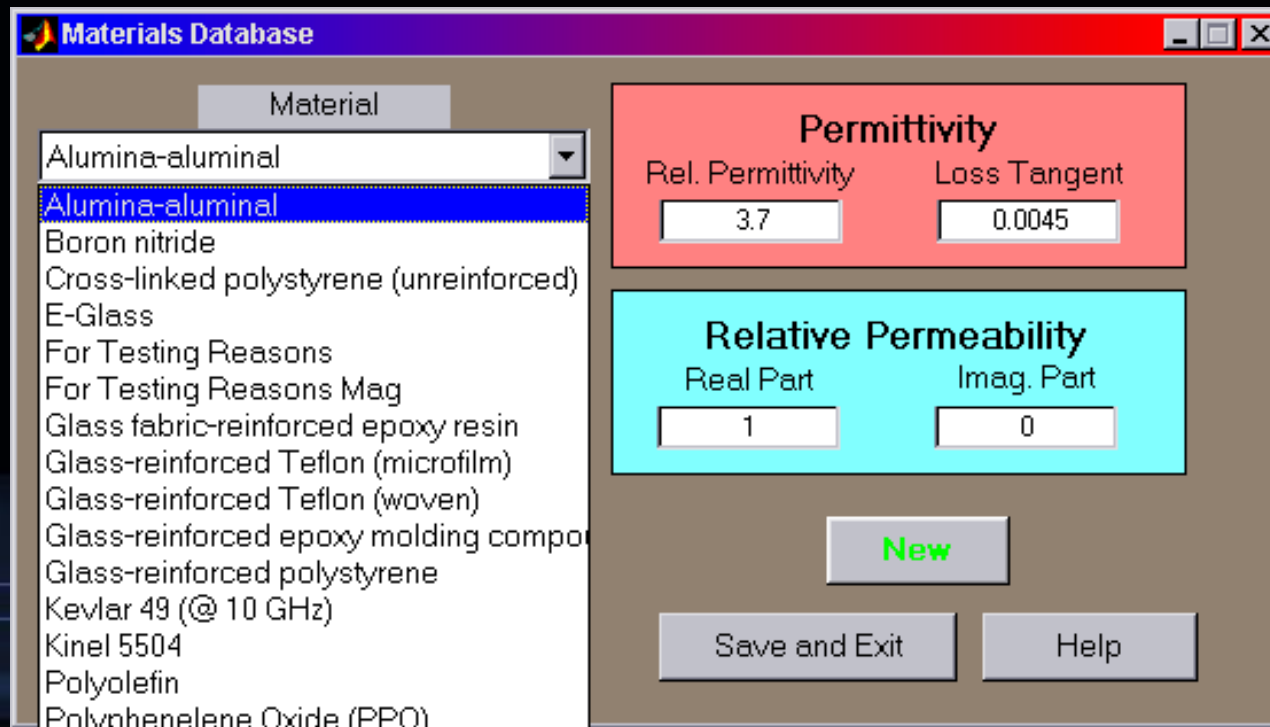
POFACETS 3.0

- **NEW CAPABILITIES**
 - Exploitation of symmetry planes
 - Program execution for the RCS calculation of this sphere was reduced by 73%



POFACETS 3.0

- **NEW CAPABILITIES**
 - Effects of Materials on RCS
 - A user-updateable database of materials was created



POFACETS 3.0

- **NEW CAPABILITIES**
 - Effects of Materials on RCS
 - Materials can be applied to each facet of a model in one or more layers

Material List for Each Facet

File Edit View Insert Tools Window Help

1

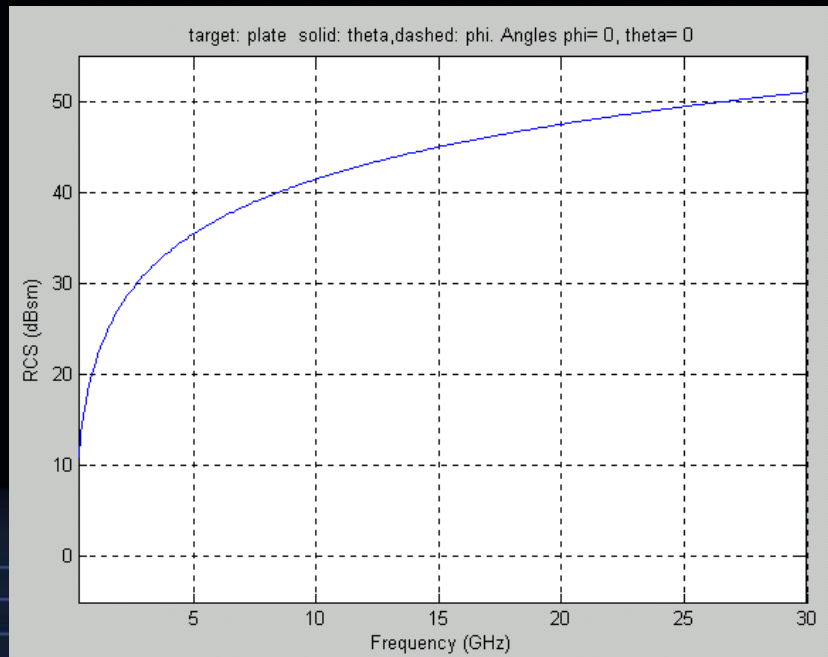
Select Facet Number

Material Type: Multiple Layers

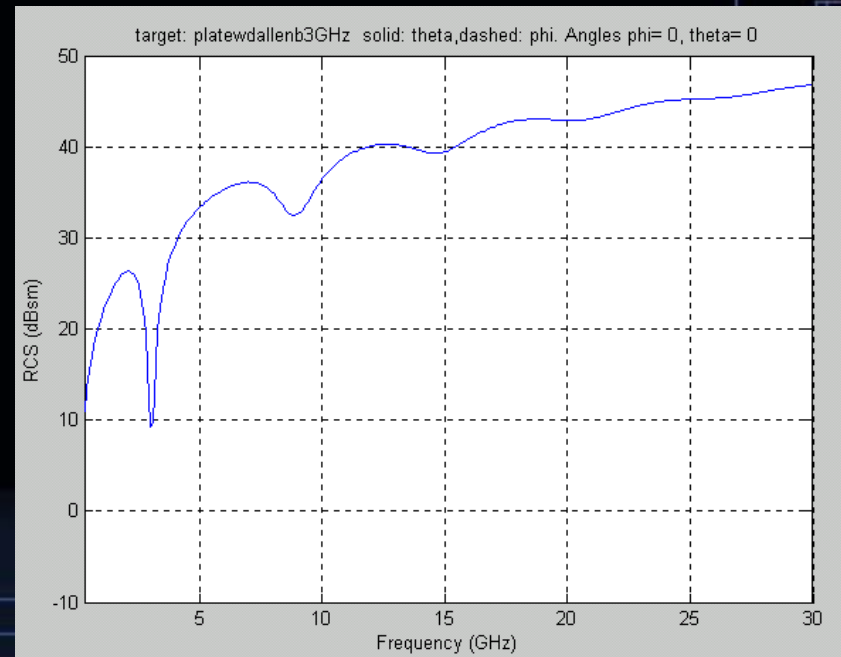
Layer	Rel Permit.	Loss Tangent	Real Part	Imag. Part	Thickness
1	2.5	0.00045	1	0	5
2	16	0.275	1	0	5
3					
4					
5					

POFACETS 3.0

- **NEW CAPABILITIES**
 - Effects of Materials on RCS
 - Example of a 1 m by 1 m plate (normal incidence)



Perfect Electric
Conductor (PEC)



6.25 mm Composite
Layer on PEC ($\epsilon_r=16$)

POFACETS 3.0

- **NEW CAPABILITIES**
 - Effects of Infinite Ground Plane
 - Ground effects must be considered for ground targets, naval targets and low-flying airborne targets
 - Option to include or exclude ground effects
 - Ground characteristics can be specified

CALCULATE MONOSTATIC RCS
Calculation of Monostatic RCS for the plate model

Load File

☐ Ground Plane XY?

☒ PEC

Rel. Permittivity: 4

☐ Use Symmetry?

Surface Roughness

Correlation Dist.(m): 0

Standard Dev. (m): 0

Theta

Starting Angle: 0 deg

Ending Angle: 360 deg

Increment Angle: 1 deg

Phi

Starting Angle: 0 deg

Ending Angle: 0 deg

Increment Angle: 1 deg

Computational Parameters

Taylor Series

Length of Region: 0.05

Number of Terms: 5

Incident Polarization

Theta (TM-z)

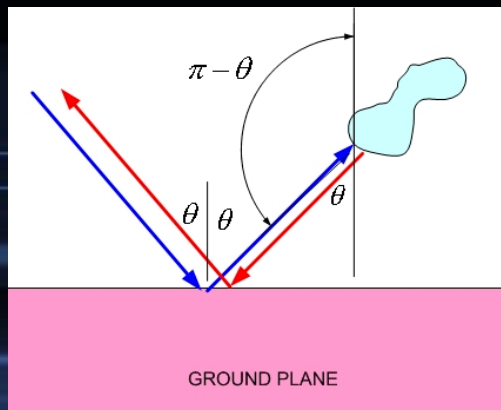
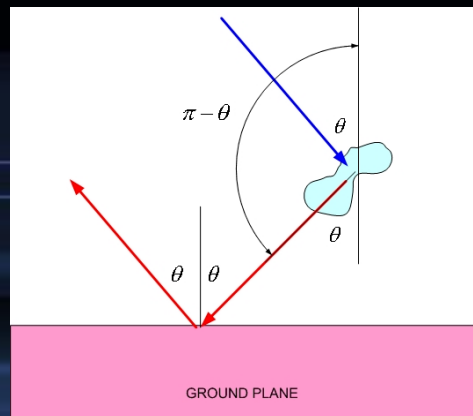
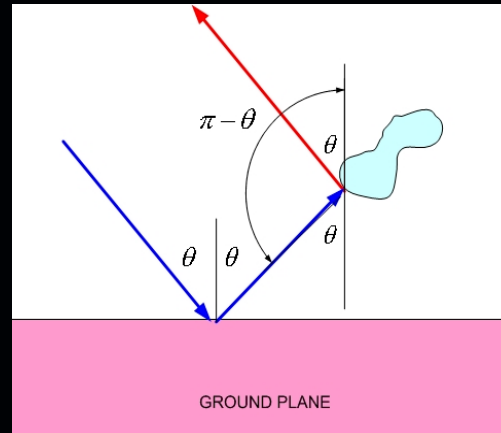
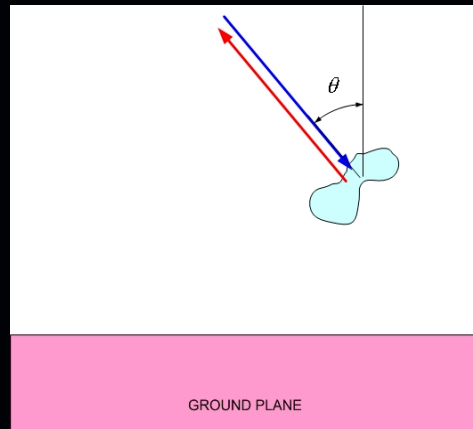
Frequency: 1 GHz

☐ Show 3D Display ☐ Show Polar Graph

Calculate RCS Print Close Help

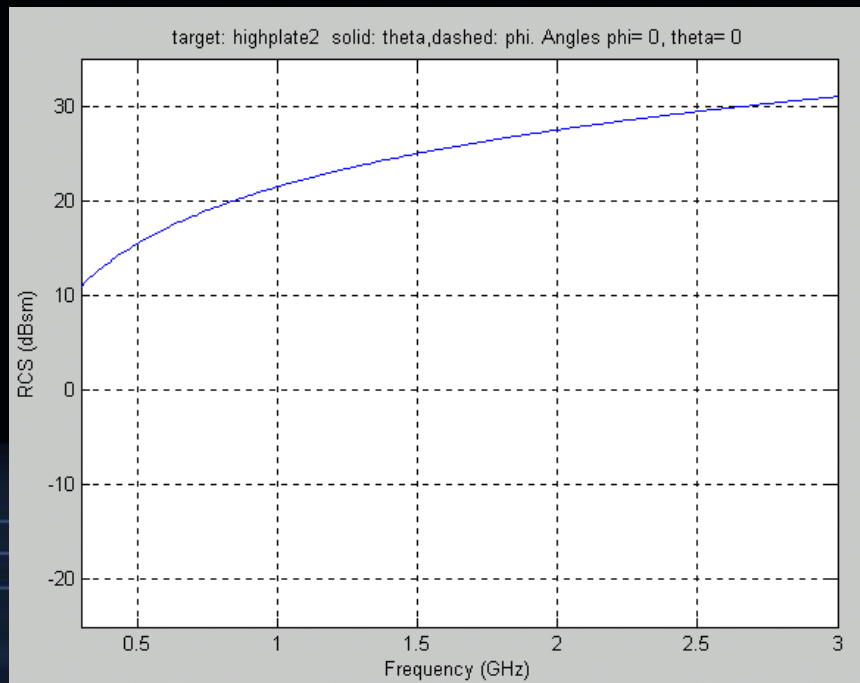
POFACETS 3.0

- **NEW CAPABILITIES**
 - Effects of Infinite Ground Plane
 - Four cases are taken into account

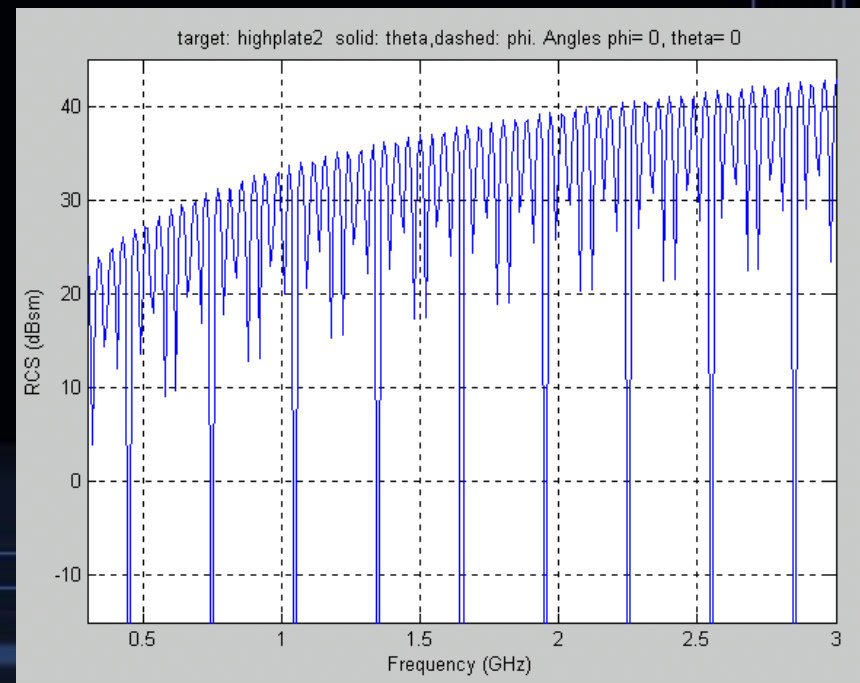


POFACETS 3.0

- **NEW CAPABILITIES**
 - Effects of Infinite Ground Plane
 - 1 m by 1 m plate 9.25 m above PEC ground, normal incidence



Ground Effects
Excluded



Ground Effect
Included

POFACETS 3.0

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 - FURTHER IMPROVEMENTS



POFACETS 3.0

- **CONCLUSIONS**

- User friendly program
 - Use of standard GUI components
 - Minimization of errors in user input
- Complex models can be handled
 - Combination of models
 - Model Import/Export from/to CAD software
- New computational capabilities had minimal effect on execution time. Exploitation of symmetry planes can drastically reduce run-time



POFACETS 3.0

- **CONCLUSIONS**
 - Added Versatility
 - RCS versus Angle and versus Frequency
 - Options for displaying RCS results
 - RCS prediction and RCS analysis can be performed
 - Closer to “real-world” RCS problems
 - Use of ground plane
 - Use of materials
 - POFACETS 3.0 can be used as an instructional tool and as a “first –cut” approach to RCS prediction and analysis

POFACETS 3.0

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POFACETS 3.0

- **FURTHER IMPROVEMENTS**
 - Capability to import models from:
 - Other RCS software
 - Other CAD software, especially AUTOCAD
 - Overcome Physical Optics limitations by including other scattering mechanisms:
 - Diffraction
 - Double Reflections
 - Surface Waves
 - Shadowing



POFACETS 3.0

Questions ?

