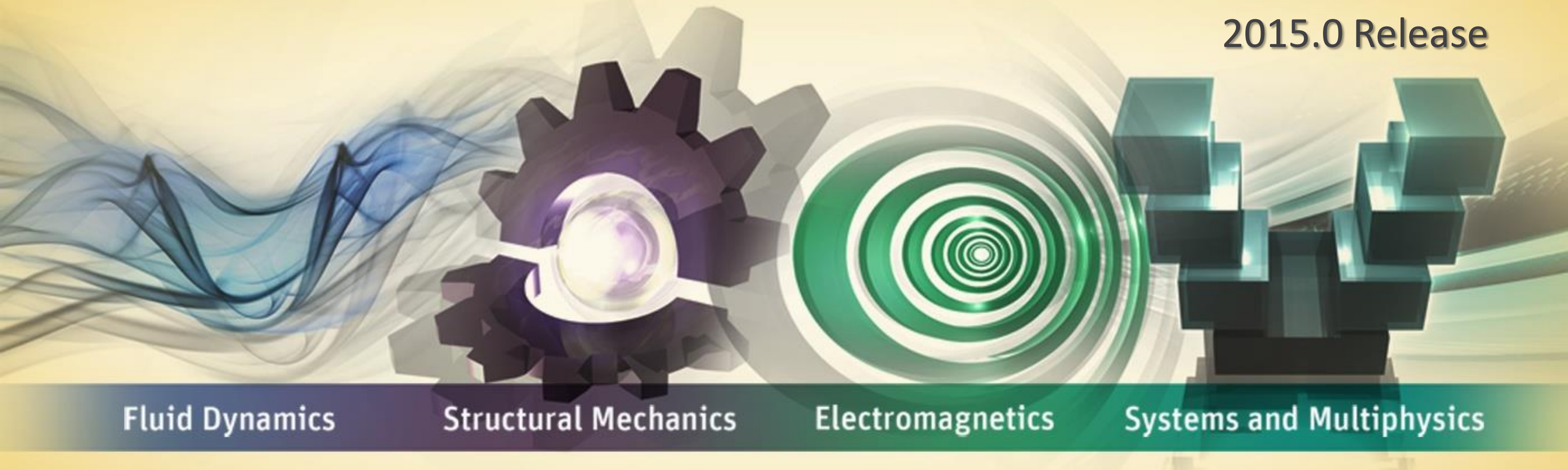
Realize Your Product Promise®

Lecture 7: Introduction to HFSS-IE

2015.0 Release



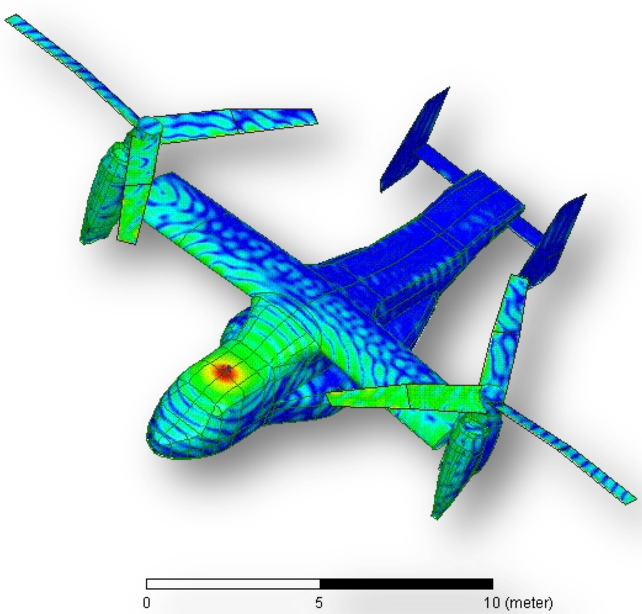
ANSYS HFSS for Antenna Design

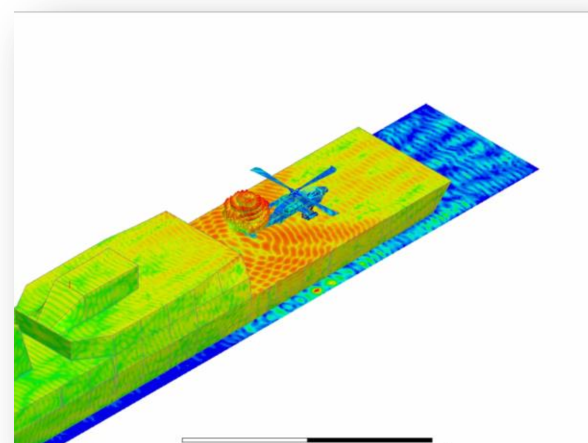
HFSS-IE: Integral Equation Solver Introduction

- **HFSS-IE: Technology**
  - An Integral Equation solver technology in the HFSS desktop
    - A 3D Method of Moments (MoM) Integral Equation technique
  - Efficient Solution Technique for Open Radiation and Scattering Analysis
    - Only surfaces are meshed and solved
  - Hybrid IE and FEM solution can be used to leverage most efficient techniques from either method simultaneously
  - Physical optics, high frequency solver also included within HFSS-IE design type

$$E(r) = j\frac{\eta}{k_0}\left(\nabla\nabla\bullet + k_0^2\right)\iint_S J(r')\,G(r-r')\,dS'$$

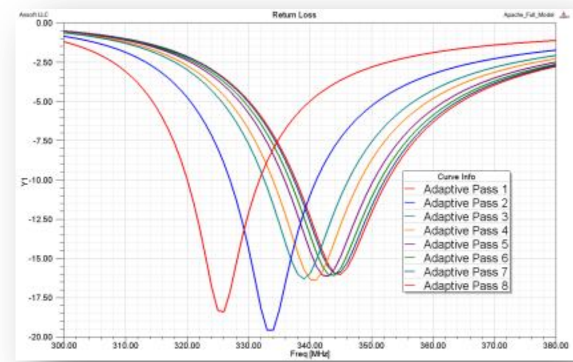
- **HFSS-IE: Applications**
  - Antenna design, antenna placement, Radar Cross Section, S-parameter extraction, EMI/EMC Analysis, Efficient analysis of electrically large structures



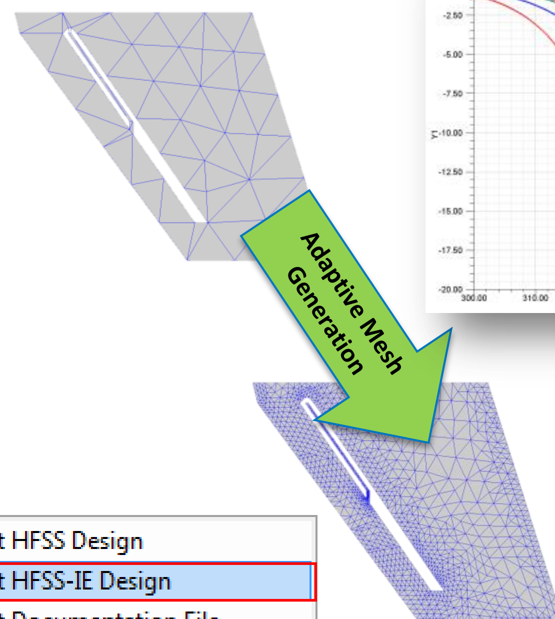


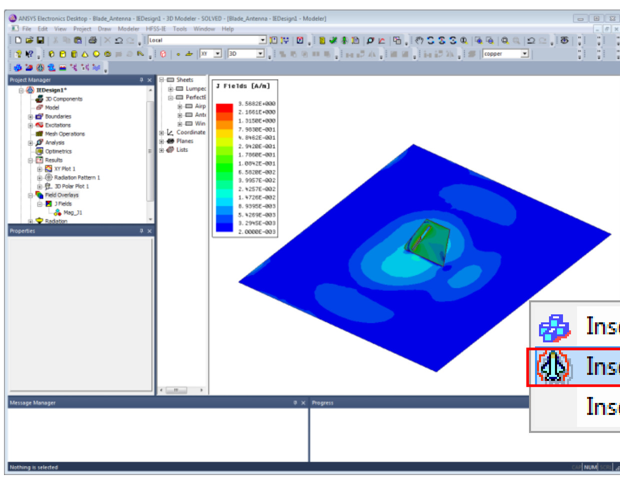
Adaptive mesh

- **HFSS-IE: Advantage**
  - Automated results with accuracy
    - Effective utilization of automated adaptive meshing technique from HFSS to ensure accuracy
    - Employs Adaptive Cross Approximation (ACA) technique
      - – Compression is independent of mesh creation leads to efficient results with minimal user interaction. Robust and invariant to problem description.
    - Employs Multilevel Fast Multipole Method (MLFMM)
      - – Decomposes geometry into boxes and then solves the fields based on a physics decomposition. Efficient for models with low complexity and geometric dynamic range.
  - Utilization of results from HFSS or HFSS-IE as a linked source excitation



- **HFSS-IE: User Interface**
  - Implemented as a design type in the HFSS desktop
    - – Shares same modeler interface and similar analysis setup
    - – Minimal user training required for existing users of HFSS

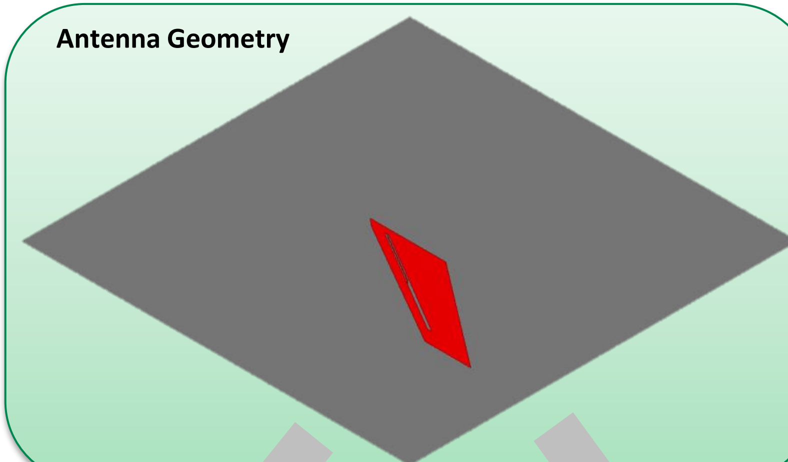




Choice of Solution Methods

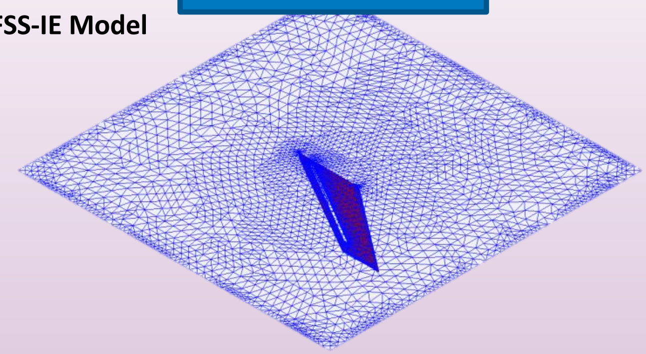
- **Solution to geometry using either FEM or IE**
- **Both solution yield the same results**
  - FEM solution requires an air volume surrounding antenna, IE solution does not
  - Integral equation solution would be most efficient when geometry is primarily metal

Antenna Geometry



Integral Equation

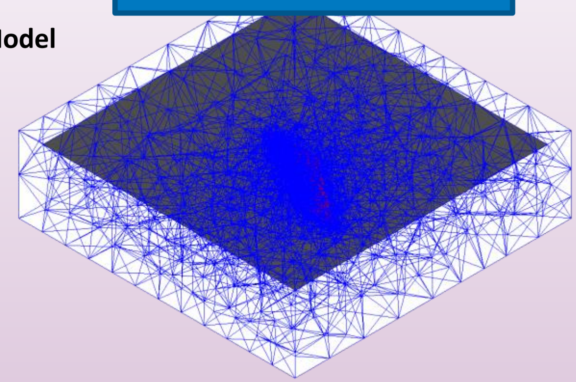
HFSS-IE Model



- Efficient solution technique for open radiation and scattering
- Currents solved only on <u>surface mesh</u>
- Efficiency is achieved when structure is primarily metal

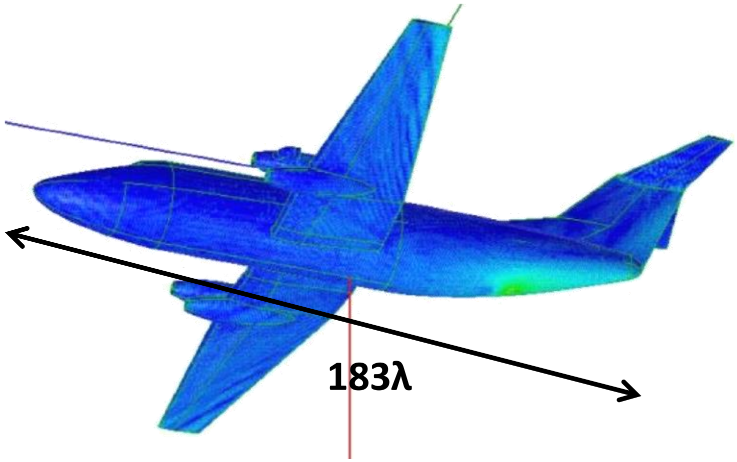
Finite Element Method

HFSS Model



- Efficiently handles complex material and geometries
- <u>Volume based mesh</u> and field solutions
- Fields are explicitly solved throughout entire volume

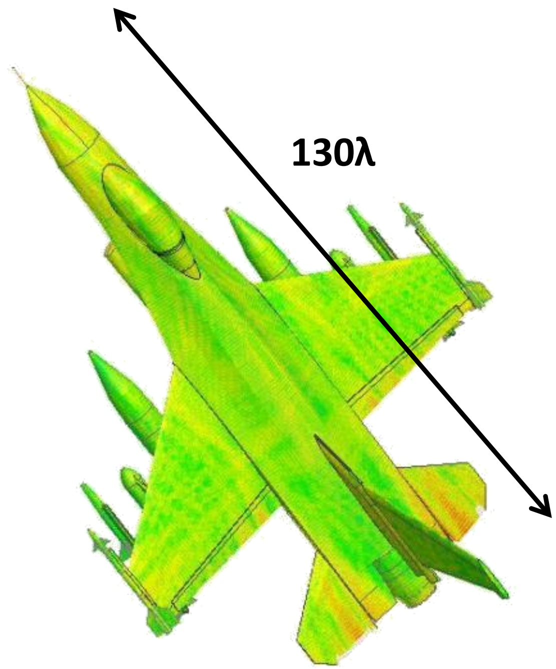
HFSS-IE Solver Examples



Solver	Memory (GB)	CPU
HFSS-IE	84.4	0.5 hours

Antenna Placement on Commercial Aircraft @ 2.45GHz

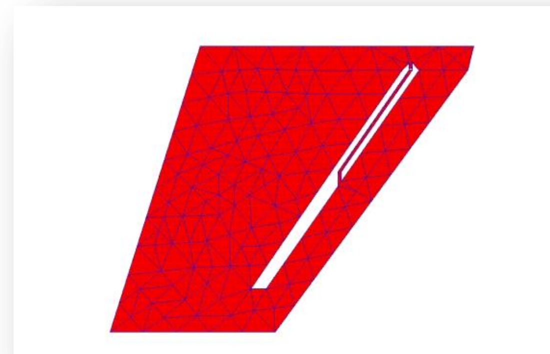
RCS of Fighter Aircraft @ 2GHz



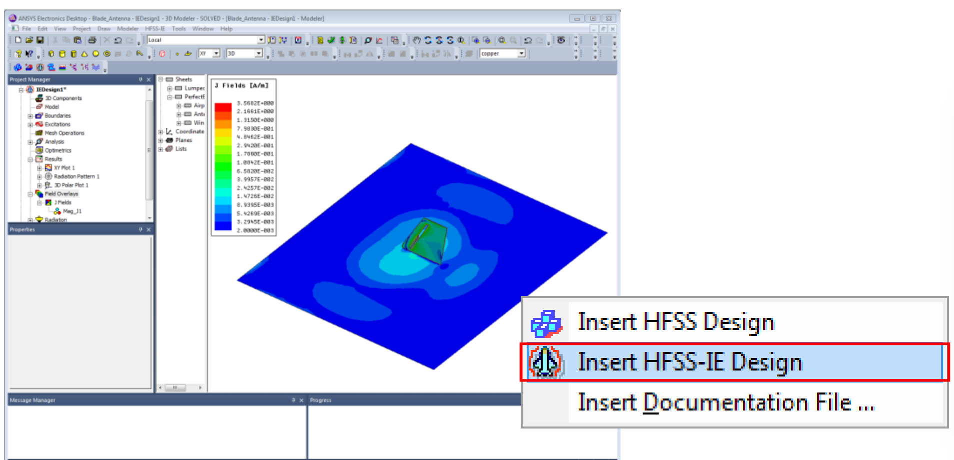
Solver	Memory (GB)	CPU
HFSS-IE	94.3	2 hours

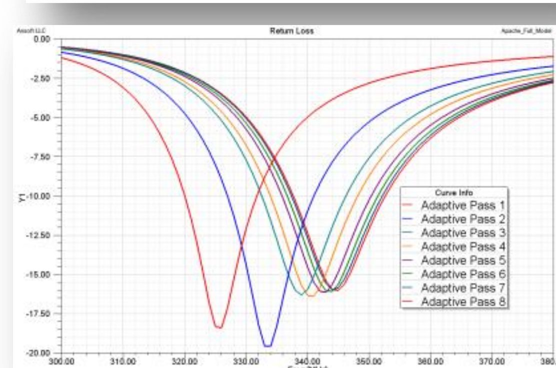
Adaptive mesh

- **HFSS-IE: Advantage**
  - Automated results with accuracy
    - Effective utilization of automated adaptive meshing technique from HFSS to ensure accuracy
    - Employs Adaptive Cross Approximation (ACA) technique
      - Compression is independent of mesh creation leads to efficient results with minimal user interaction
    - Employs Multilevel Fast Multipole Method (MLFMM)
      - Decomposes geometry into boxes and then solves the fields based on a physics decomposition
  - Utilization of results from HFSS or HFSS-IE as a linked source excitation



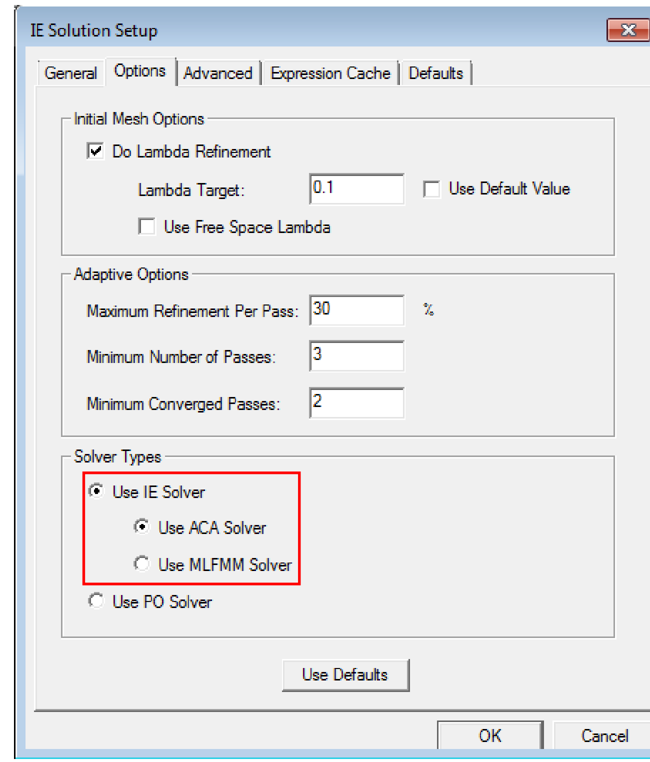
- **HFSS-IE: User Interface**
  - Implemented as a design type in the HFSS desktop
    - Shares same modeler interface and similar analysis setup
    - Minimal user training required for existing users of HFSS



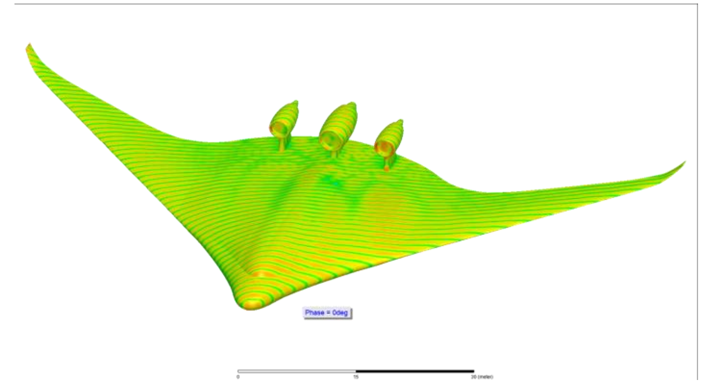


HFSS-IE Solvers

- **HFSS IE Solver:**
  - ➢ **ACA Solver:**
    - Is an algebraic method without physics consideration
  - ➢ **MLFMM Solver:**
    - MLFMM solver decomposes geometry into boxes
    - Fields in these boxes are solved based on a physics decomposition
- **Factors that influence efficiency of MLFMM relative to ACA:**
  - Feature size variation
    - High complexity and geometric dynamic range cause longer simulation
  - Aspect ratio of bounding box of model
    - High aspect ratio results in longer simulation
- **In general ACA is more robust and invariant to problem description**
  - When in doubt use ACA



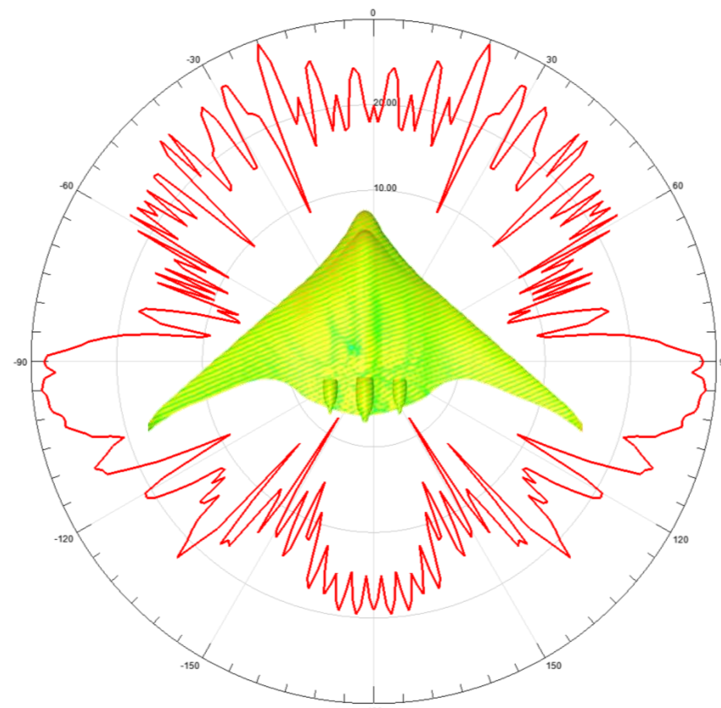
HFSS-IE Solvers



Boeing X-48 Blended Wing Body (BWB)

361 incident angle in Phi

@ 150 MHz, 0.9M matrix unknowns



- **ACA Performance**

  Time: 2:28:15

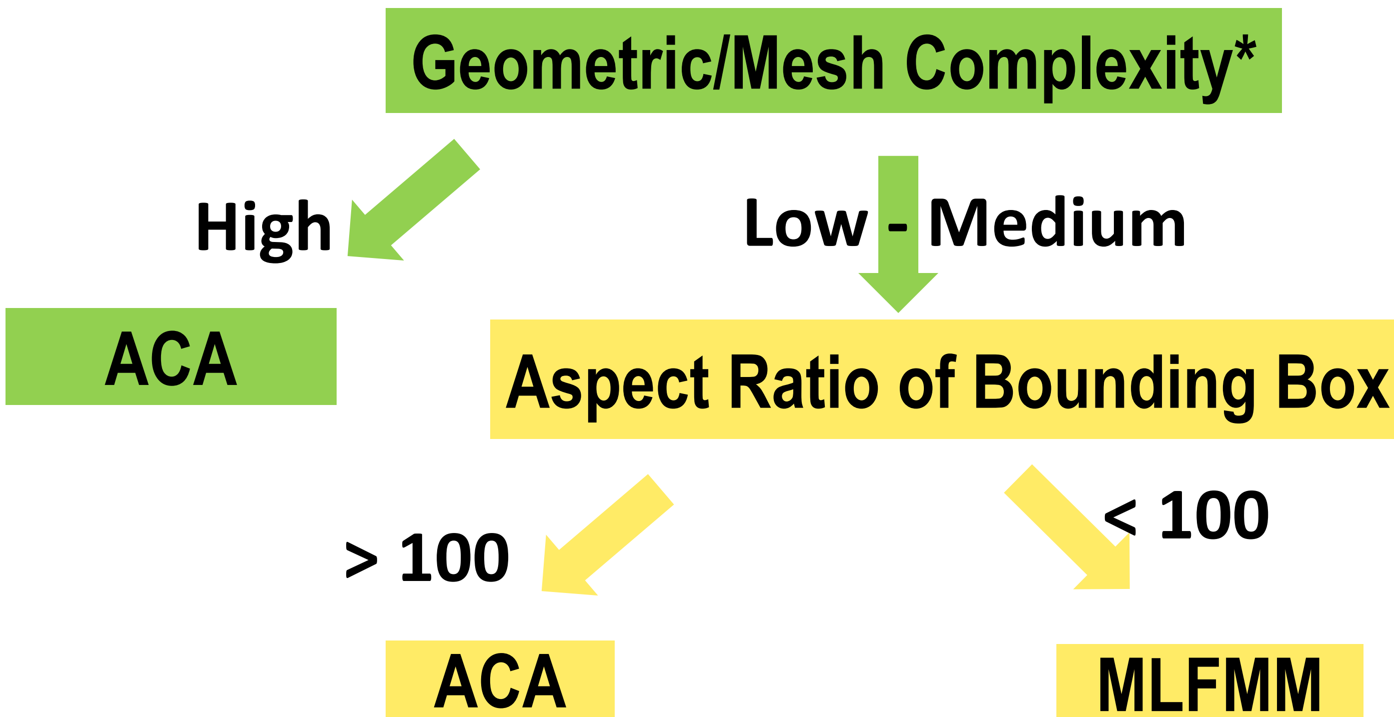
  Memory: 97.3 GB

- **MLFMM Performance**

  Time: 1:20:39

  Memory: 51.7 GB

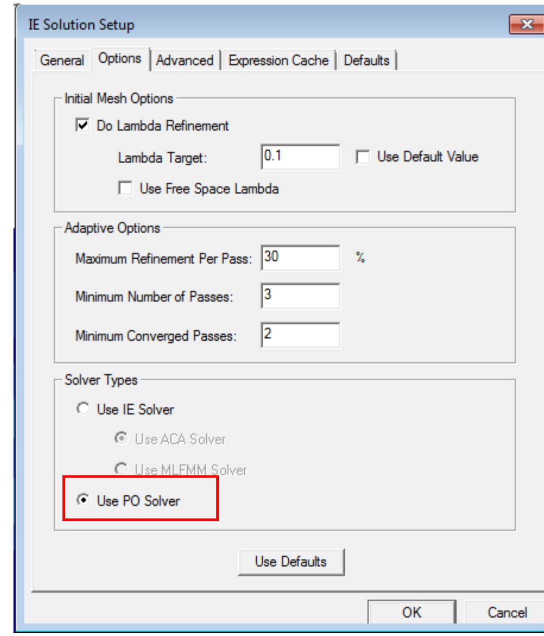
Guidelines for Choosing IE Solver

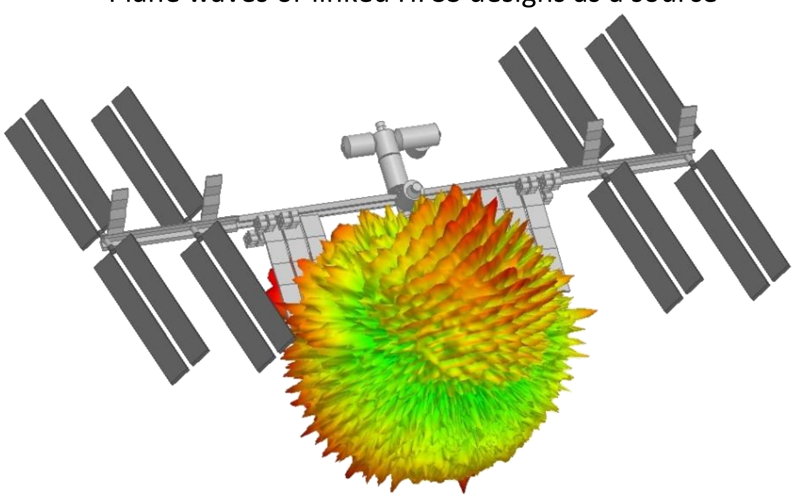


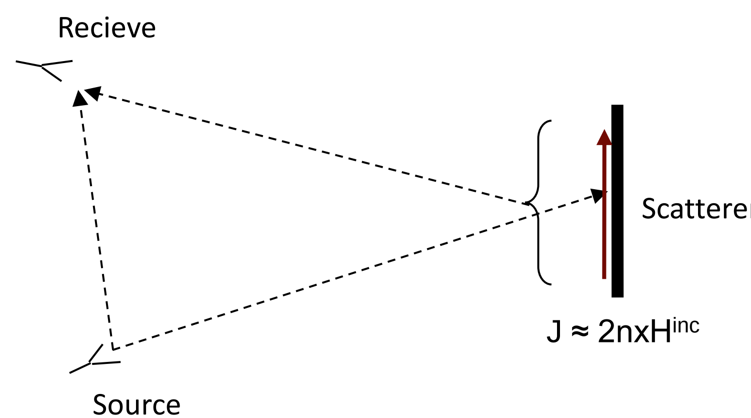
*** Automatic adaptive meshing for accuracy can result in large elements variation. An example could be a small antenna on an aircraft**

HFSS-IE, Physical Optics Solver Introduction

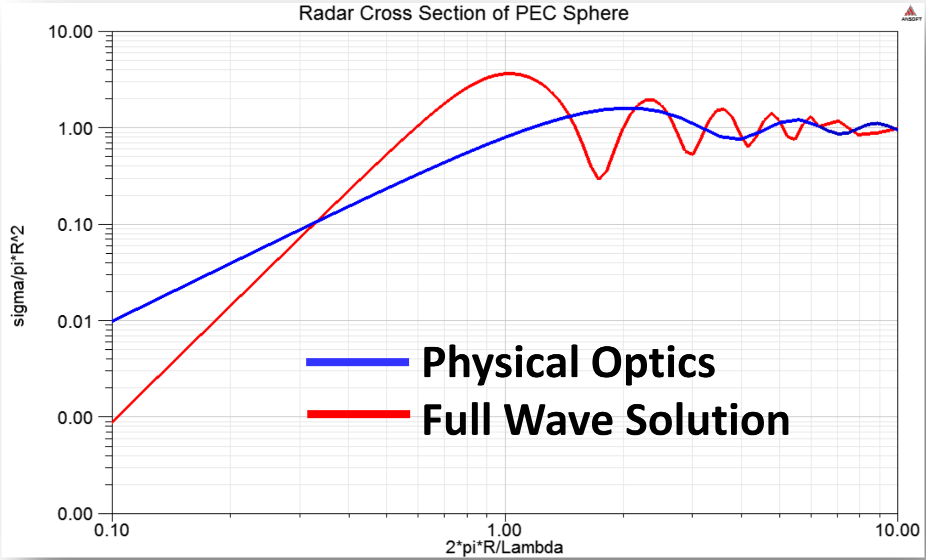
- **Asymptotic solver for extremely large problems**
  - Included in HFSS-IE
  - Solves electrically huge problems
  - Currents are approximated in illuminated regions
    - Set to zero in shadow regions
  - No ray tracing or multiple "bounces"
- **Target applications:**
  - Large reflector antennas and antenna placement
  - RCS of large objects such as satellites
- **Option in solution setup for HFSS-IE.**
- **Sourced by incident wave excitations**
  - Plane waves or linked HFSS designs as a source

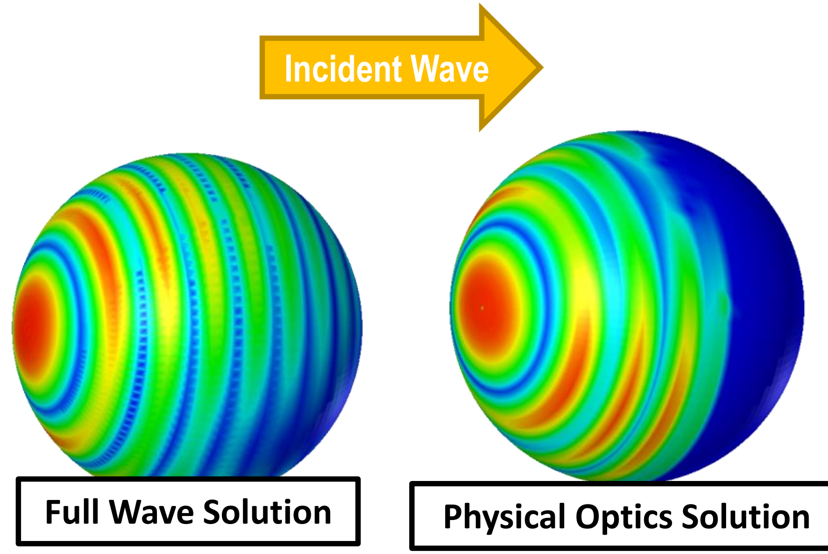






Physical Optics



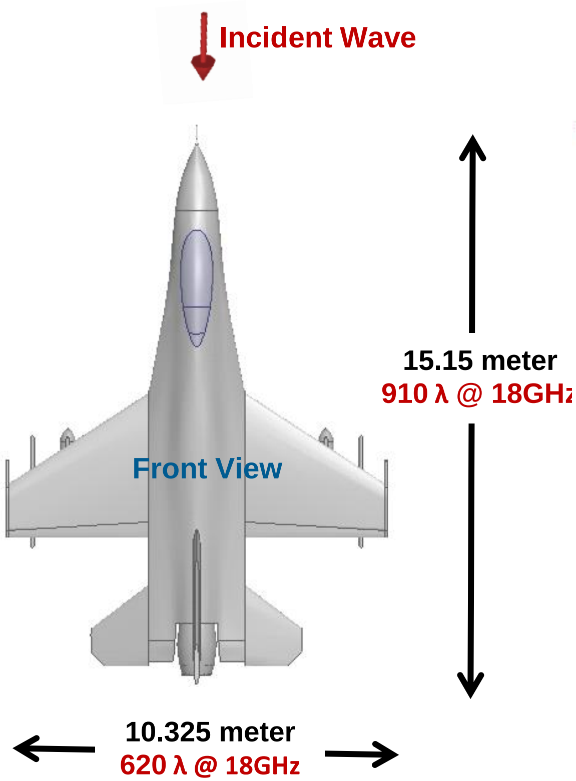


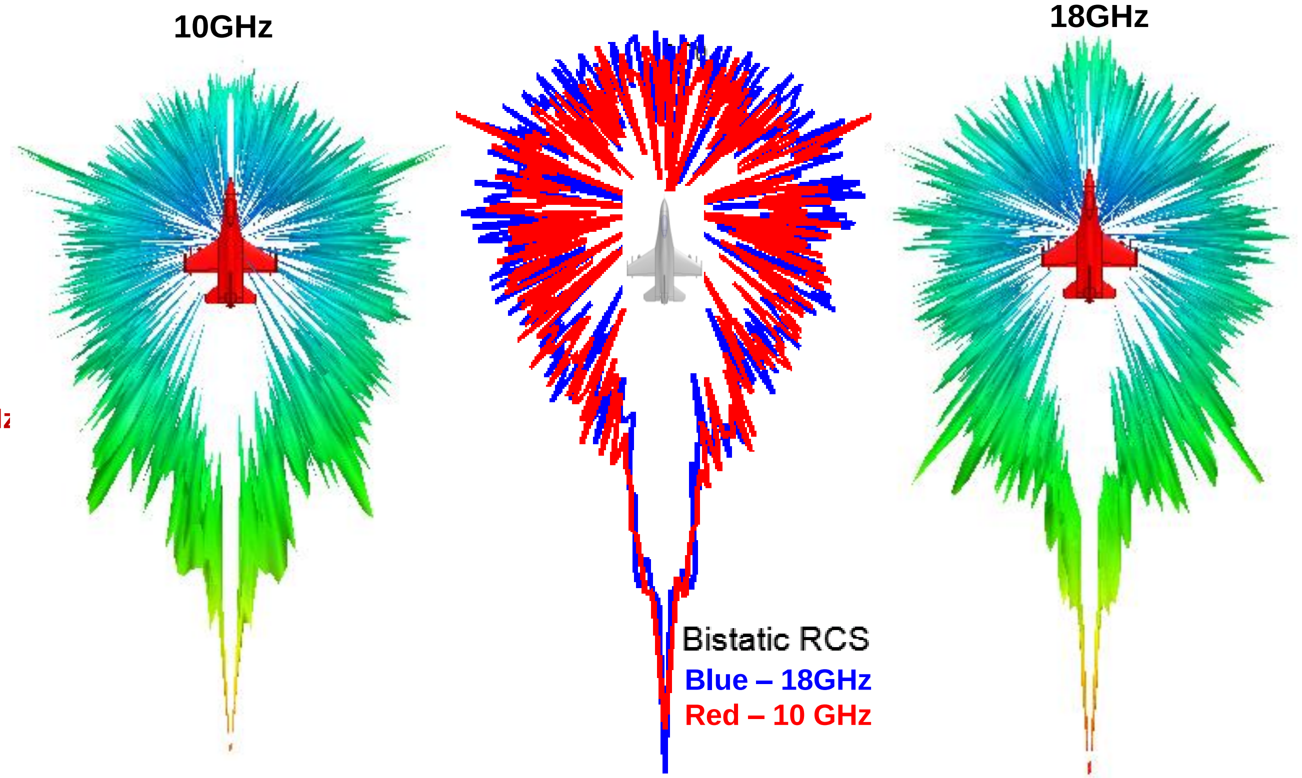
Solution @ High Freq.	Total RAM (GB)	Elapsed Time (sec)
Full Wave (HFSS-IE)	1.4	87
Physical Optics	0.1	14

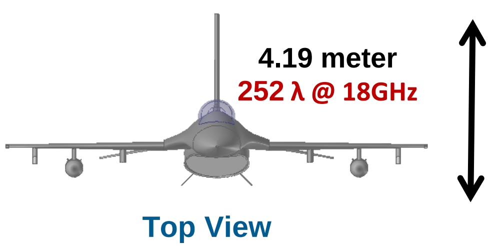
RCS of PEC Sphere

- Highlights capabilities and limitation of physical optics
- Creeping wave effects not accounted for by PO
- When electrical size of sphere becomes large, full wave solution converges with physical optics solution

Fighter Aircraft RCS using PO





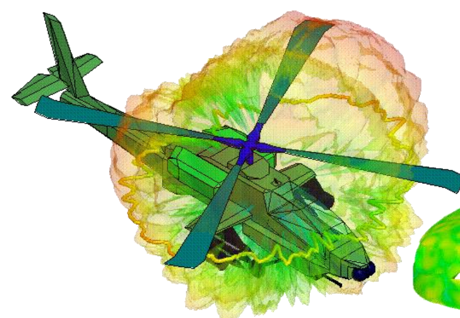


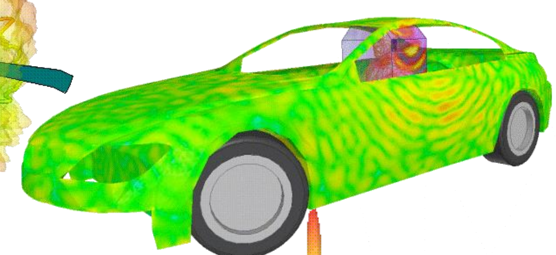
	Mesh #	RAM	Elapsed Time
10GHz	5.03 million	15.4 G	27.5 minutes
18GHz	**16.19 million**	50.6G	174.5 minutes

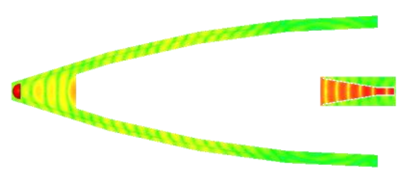
HFSS-IE: Offers Advanced Features for Antenna Design

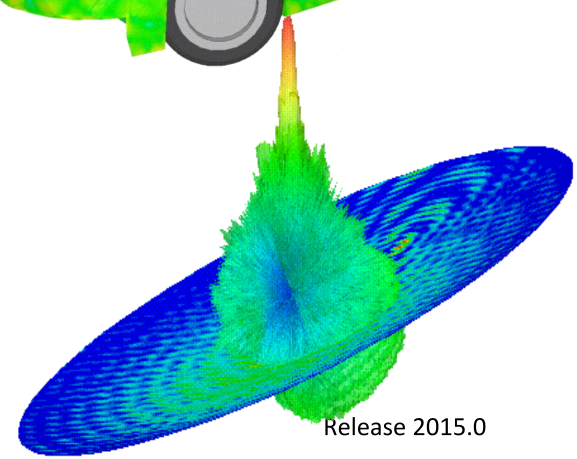
- **Advanced solver technology**
  - ACA Solver robust Method for Efficient Solution
  - MLFMM solver efficient for structures with low complexity New in R16
  - Hybrid FEM-IE solver takes advantage of strengths from both FEM and IE technologies
- **Advanced Functionally**
  - Layered Impedance Boundary Condition
  - Spatially Dependent Boundary Conditions New in HFSS 2014
  - Data-Link Source Excitations
    - HFSS to HFSS-IE
    - HFSS-IE to HFSS-IE New in HFSS 2014
  - High Loss Impedance Boundaries New in HFSS 2014
  - Anisotropic Impedance Boundary New in HFSS 2014
  - Curvilinear Mesh Elements New in HFSS 2014
- **High Performance Computing**
  - Scalable Multi-Threading
  - Distributed Parametric and Frequency Sweeps
  - Distributed meshing for hybrid solutions
  - Distributed memory solution for large scale simulations
    - Hybrid solution supports distributed FE-BI and IE-Regions New in HFSS 2014
    - Hierarchical distributed solutions New in HFSS 2014

- **Output quantities**
  - Network Parameters
  - Antenna trace characteristics (Beamwidth, SLLs)
  - Near fields and far fields
- **Design automation**
  - Parametric modeling
  - Parametric sweeps
  - Optimizations
  - Sensitivity and statistical analysis









This page intentionally left blank