



# Virtual Prototyping of Semiconductor Processing Equipment

Peter J. Woytowitz, Ph.D.

Manager, Mechanical Modeling Group

Novellus Systems, Inc.

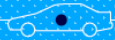


# VP of Semiconductor Processing Equipment



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- Introduction
- Semiconductor Equipment Technology
- Modeling and VP of Semiconductor Equipment
- Future of VP in Semiconductor Equipment
- Conclusions



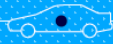
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## Introduction

- SC processing equipment is a design microcosm
- Key design considerations for SC processing equipment
  - Safety
  - Accuracy
  - Reliability
  - Cost Effectiveness



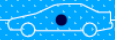
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## Introduction

- Expectations for Virtual Prototyping
  - Improve product quality (safety, accuracy, reliability)
  - Reduce material costs (cost effectiveness)
  - Reduce development cycle time (first to market)
  - Reduce required engineering resources



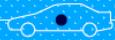
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## Introduction

- Economics of SC processing equipment
  - One 300mm wafer may hold  $\approx 300$  computer processor chips
  - At a retail value of \$800/chip, one wafer is worth \$240,000.
  - Typical FOUP (front opening unified pod) holds 25 wafers
  - Typical fab may produce 1000 finished wafers per day
  - Cost of building a 300mm fab ranges from \$2B - \$4B
- Desired reliability for individual system components result in probability of failures often less than  $P_f = 1 \times 10^{-5}$



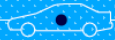
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## SC Equipment Technology

- Vacuum, chemical processing, plasma physics
- Fluid flow, thermal
- Materials, structures
- Robotics, software & controls



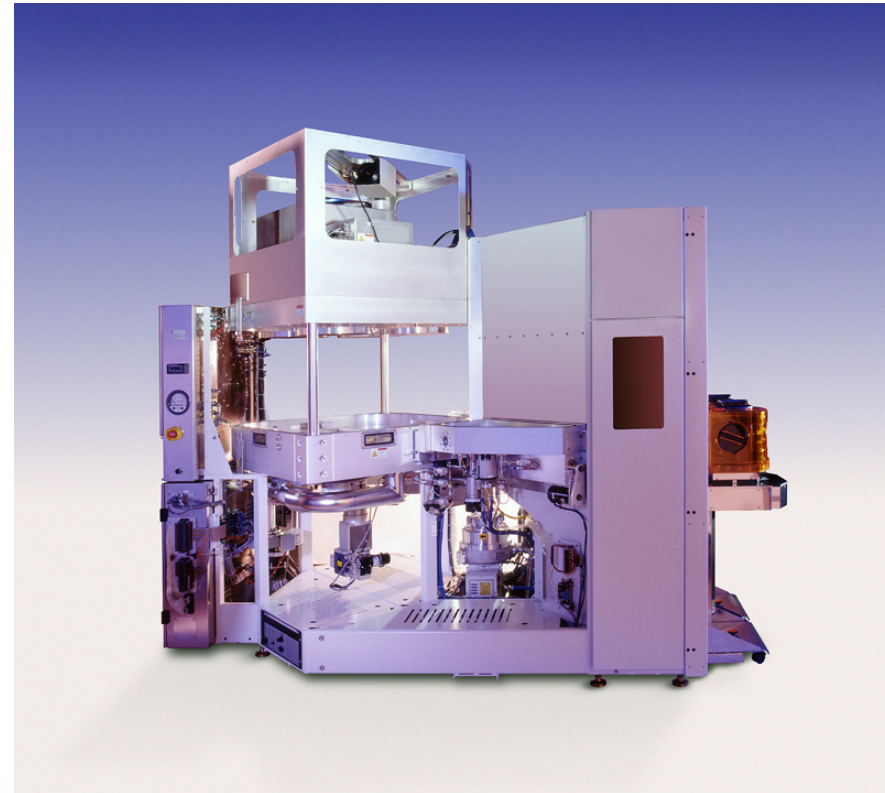
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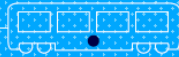
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Gamma 2130 : Strip/Clean



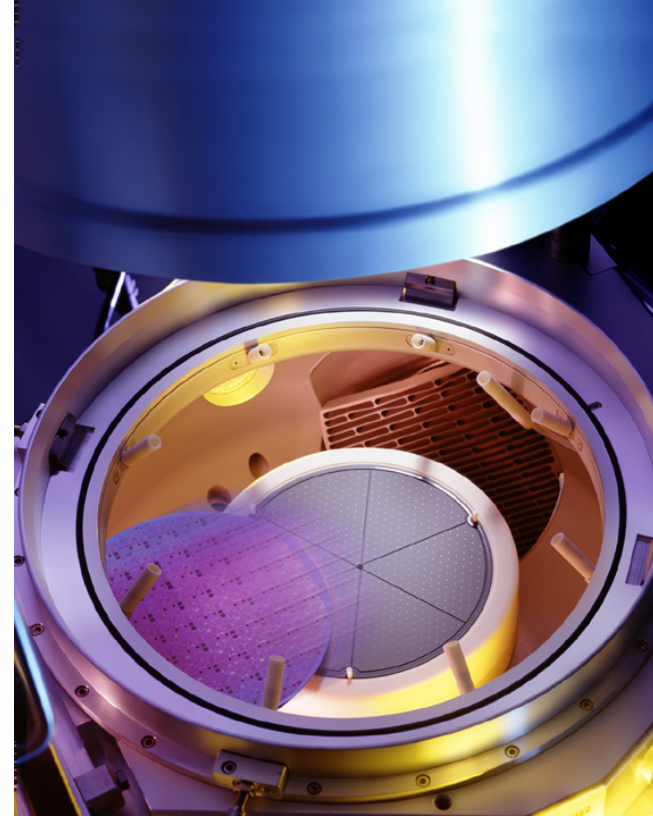
Vector : PECVD



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Speed Module : HDP



Speed Process Chamber

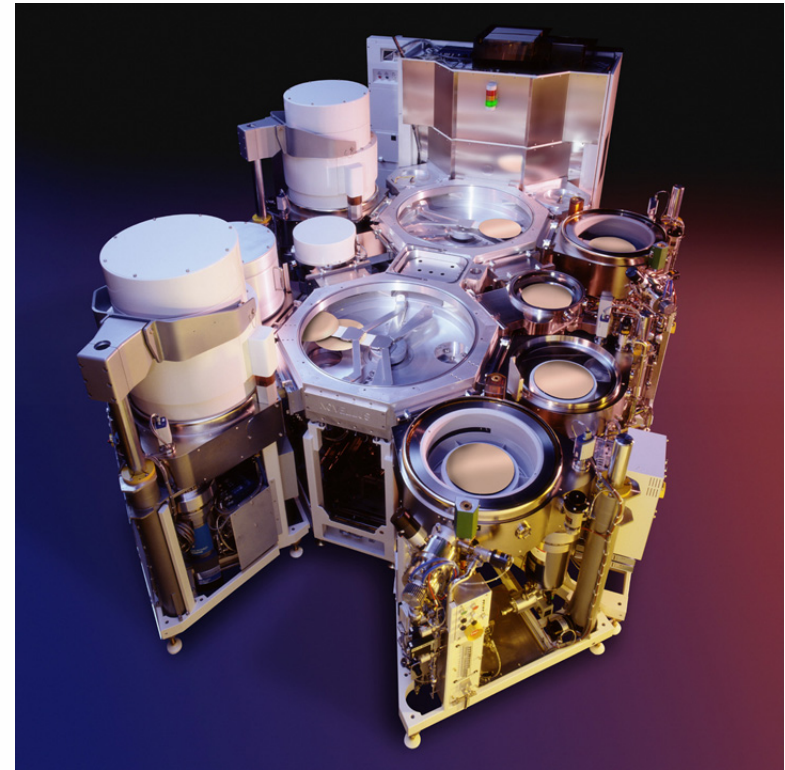
PRODUCT DEVELOPMENT CONFERENCE



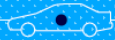
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Inova : PVD



Inova : PVD



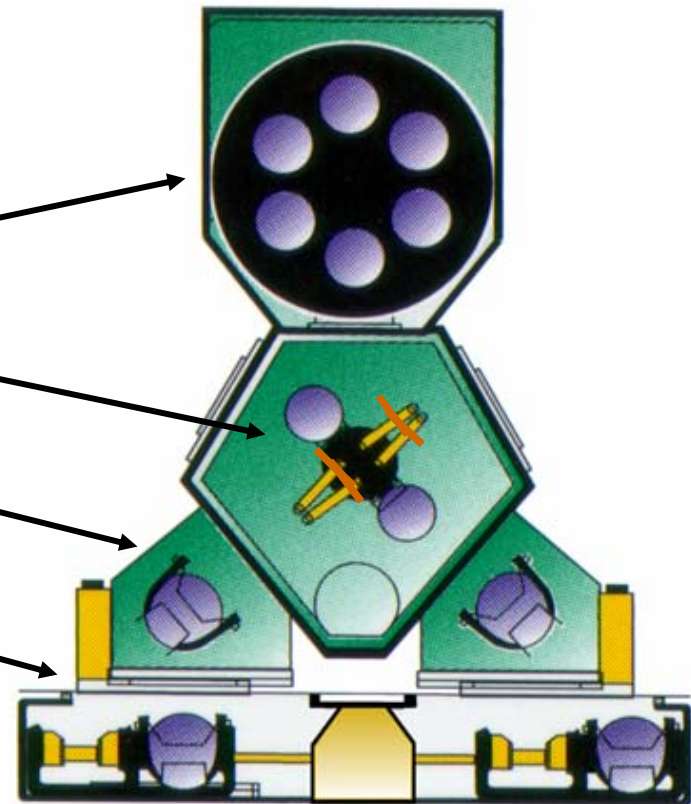
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## SC Equipment Technology

- Typical Sub-System Breakdown
  - Processing chamber (chemistry, plasma, fluids, controls)
  - Wafer handling subsystem (structures, robotics, controls)
  - Preheat, cooling & load-lock chambers (vacuum, thermal, structures)
  - Frame & operator interface (structures, software & controls)





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## Modeling and VP of SC Processing Equipment

- Examples
  - Kinematics of atmospheric robot
  - Wafer & end-effector structural displacements
  - Wafer & end-effector thermo-structural
  - Chamber vacuum loading
  - Vibration analysis of Novellus Xceda CMP system



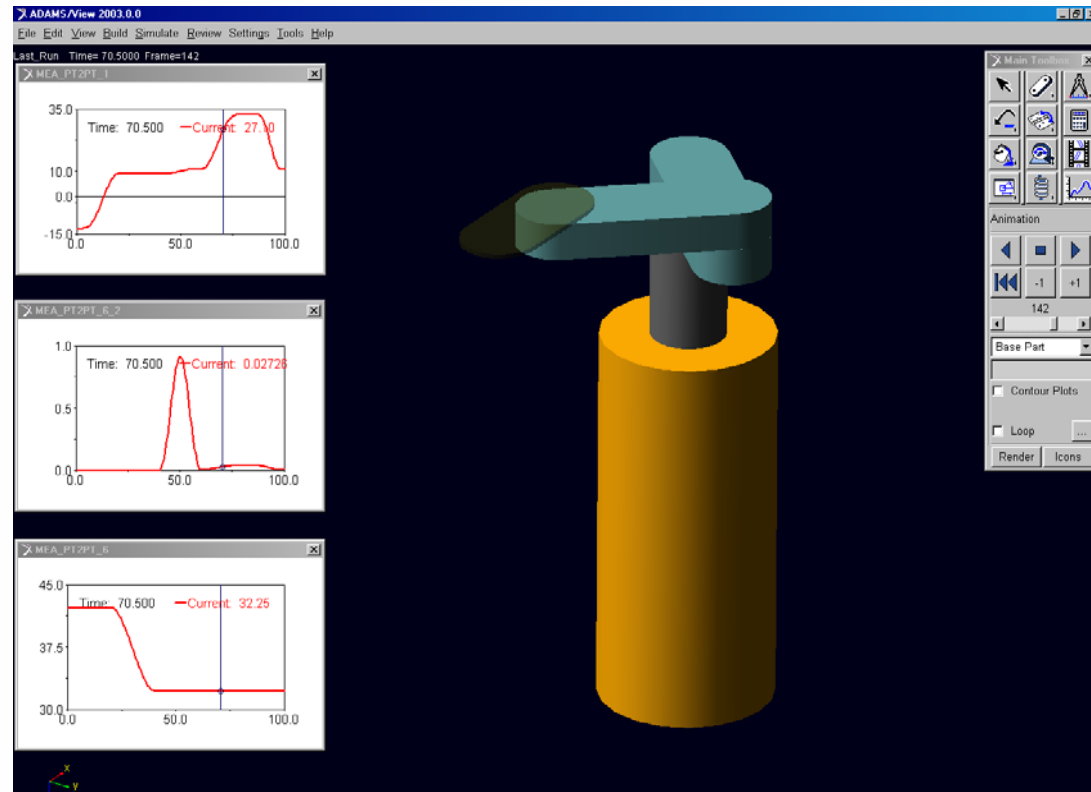
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## Modeling and VP of SC Processing Equipment

- Kinematics of atmospheric robot
  - Predict trajectory
  - Controls/dynamics simulation
  - Structure/controls interaction





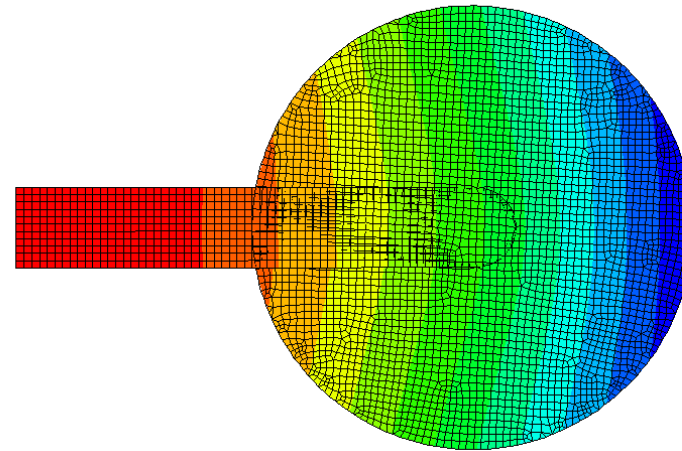
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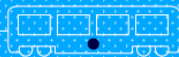
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## Modeling and VP of SC Processing Equipment

- End-effector & wafer distortion
  - Effects of gravity
  - Thermal effects
  - Loading from vacuum chuck



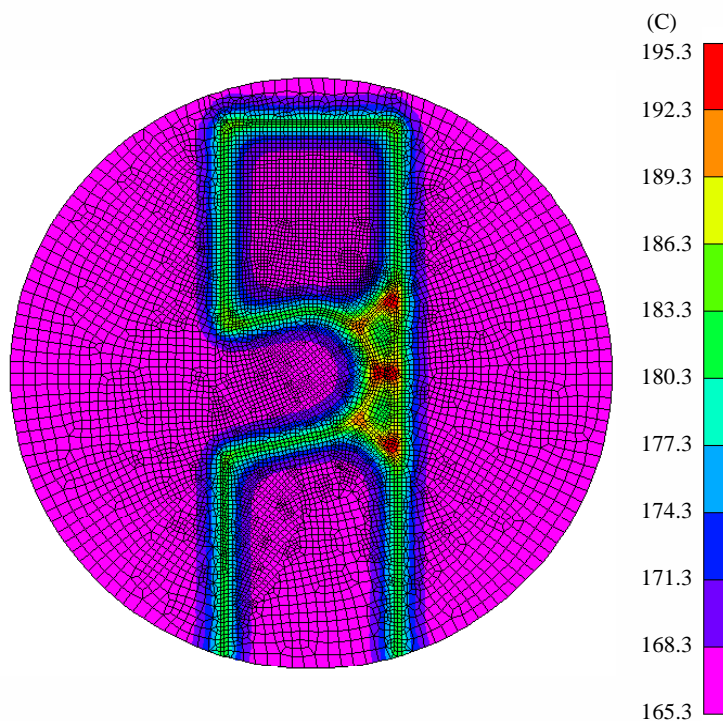
Displacements Vary from 0. (red) to – 1.43 mm (dark blue), Outline of Wafer Chuck Can be Seen in Wafer Center



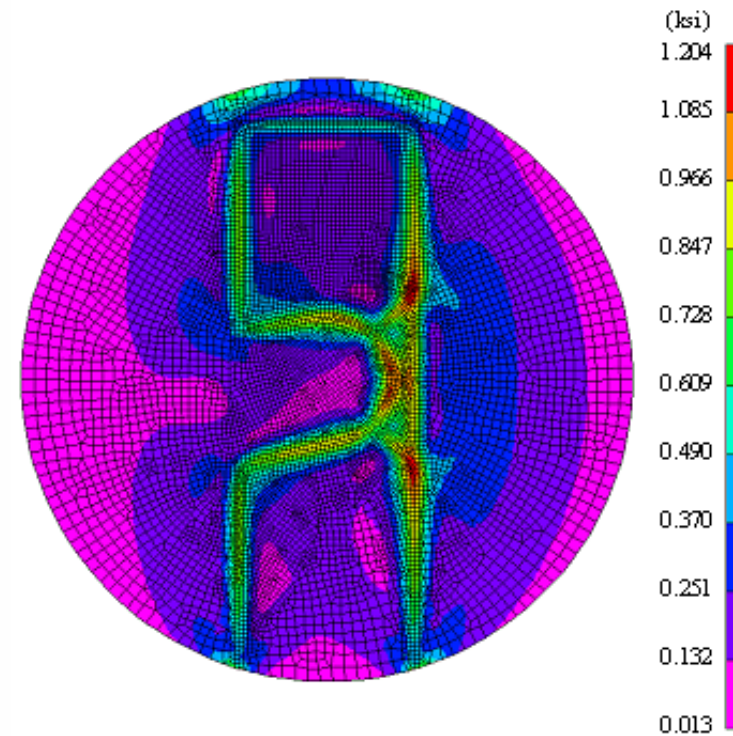
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Wafer temperatures due to end-effector influence on cool pedestal



Wafer stresses predicted due to end-effector influence on cool pedestal



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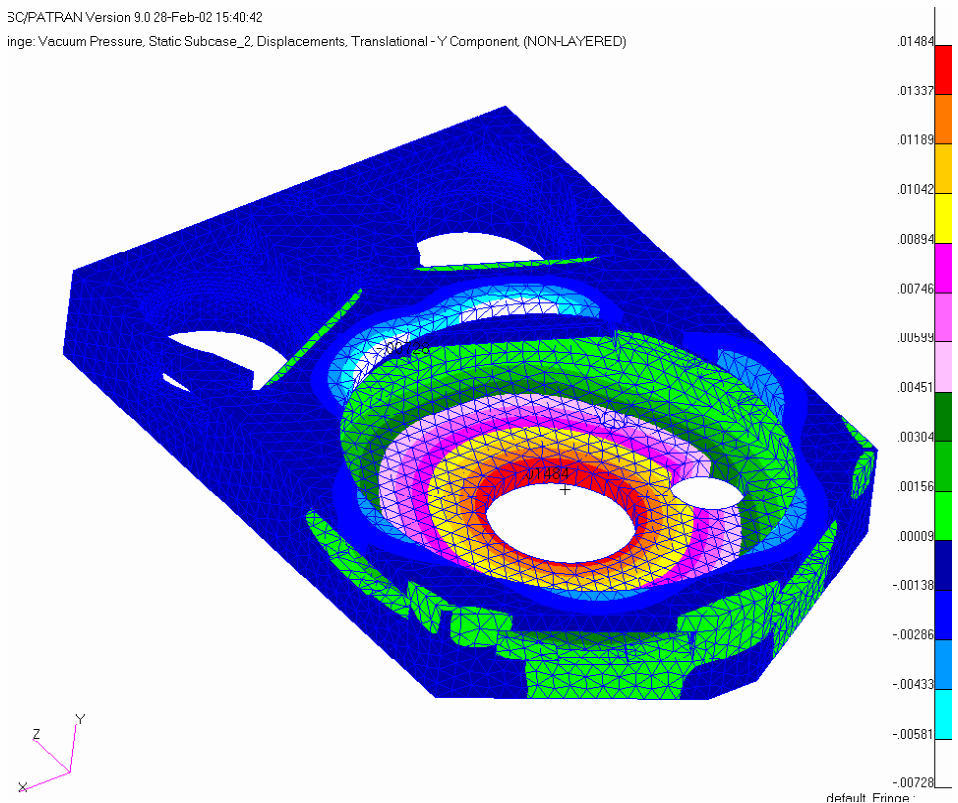
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inge: Vacuum Pressure, Static Subcase\_2, Displacements, Translational -Y Component, (NON-LAYERED)

## Modeling and VP of SC Processing Equipment

- Transfer chamber stress & distortion analysis
  - Driven by vacuum loads
  - Center robot mount critical with regards to rotational distortion



Displacements vary from 15.4 mils (red) to -7.3 mils (white)



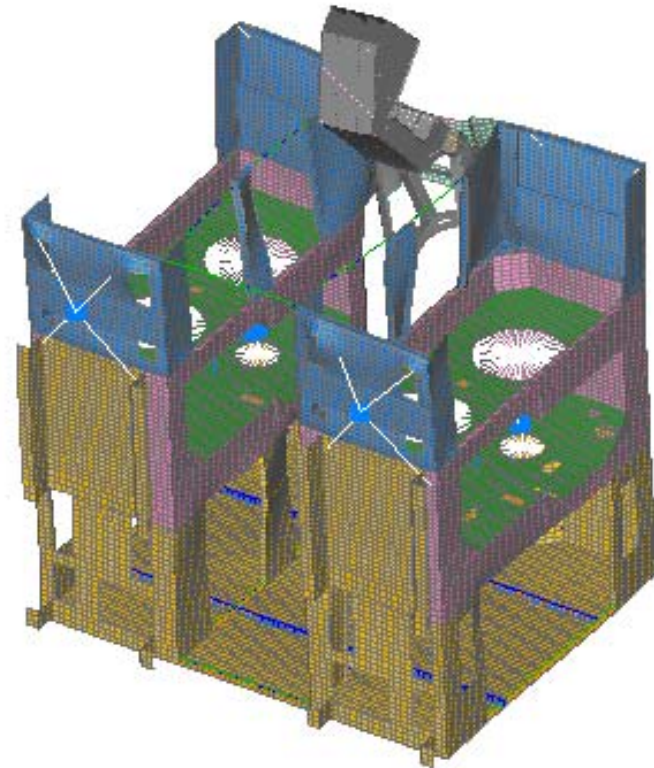
# VP of Semiconductor Processing Equipment



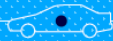
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## Vibration modeling of Xceda CMP tool

- Four micro-polishing heads driven in range of 0 to 800 RPM
- Analysis used to predict natural frequency, critical stiffnesses & resulting dynamic motion
- Verification of seismic loading capability



Predicted  $f_1=21.3$  Hz, measured  $f_1=19.2$  Hz



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## Future of Virtual Prototyping for SC Equipment

- Requirements
  - Improve product quality (safety, accuracy, reliability)
  - Reduce material, manufacture & engineering costs (cost effective design)
  - Reduce development cycle time (first to market advantage)
- Needs
  - Improve coupling between different physical phenomenon
    - Thermal/structural, CMP fluid/structural
  - Convenient user routines & better physics (radiation modeling)
  - Convenient & complete multi-disciplinary optimization capability
  - Improved modeling (meshing, expert knowledge system)