W E L C O M E

www.ozeninc.com

OZEN ENGINEERING®

WHAT DO WE DO? WE SOLVE PROBLEMS

- Ozen Engineering, Inc. helps solving challenging and **multidisciplinary engineering problems** with industry leading computational simulation technologies

- We provide advanced **multi-physics FEA, Computational Fluid Dynamics analysis**

- We specialize in **Mechanical Structures**, **Design Optimization**, **Failure Analysis**, **Testing** and **R&D**

We are passionate about developing accurate simulation and realistic modeling as core competencies within client companies and helping them realize unparalleled results from their FEA and CFD investments.

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AN EXAMPLE OF MULTI-DISCIPLINARY APPROACH

Meshing

Technical Depth

Tet/Prism
Hex/Hex Core

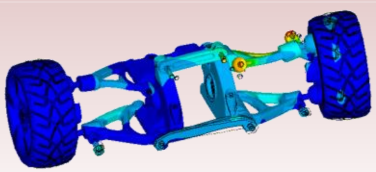
Structured
Unstructured

Multi-zone
Body-fitted Cartesian

Patch Independent
More…

Structural

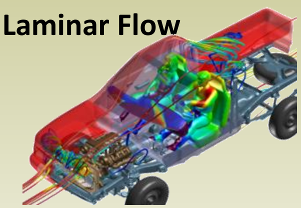
Large Displacements
Finite Strain
Contact
Multibody Dynamics
Random Vibration
Implicit & Explicit



More…

Fluids

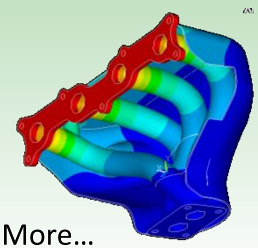
Compressible
Incompressible
Laminar Flow



Turbulence
Multiphase Flow
Non-Newtonian Fluids
More…

Thermal

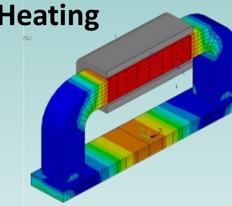
Conduction
Convection
Radiation
Phase Change
Mass Transport

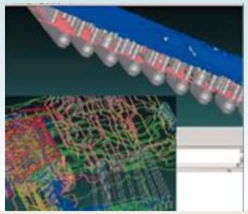


More…

Electromagnetics

Quasi static (Low Freq)
Full Wave
Joule Heating





Eddy currents
Current flow
Circuit Coupling
More…

Steady-State, Transient, Harmonic & Modal

Linear & Nonlinear

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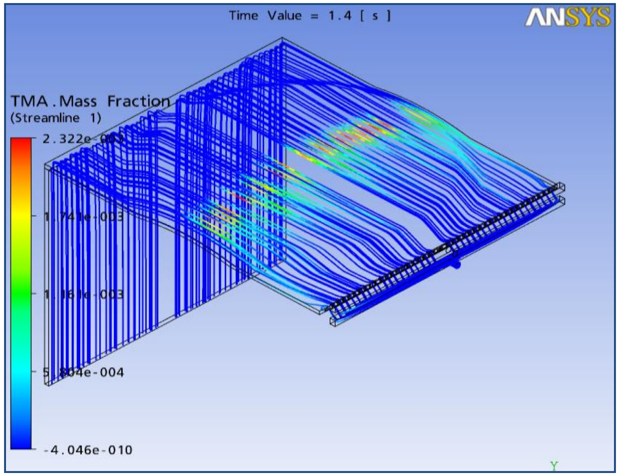
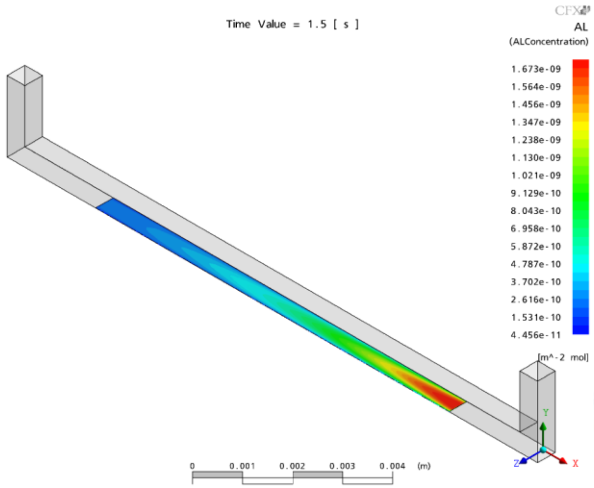
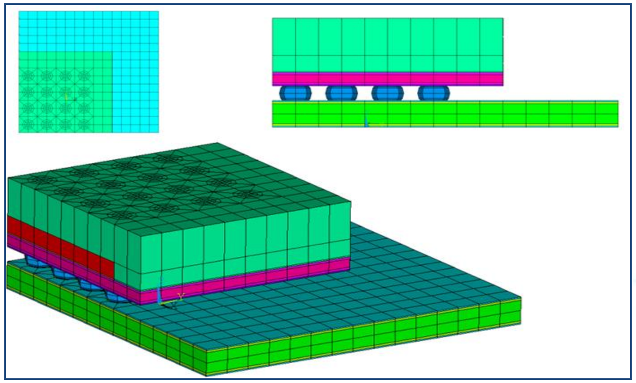
INDUSTRY SPECIFIC EXPERTISE - SEMICONDUCTOR

Example of analysis we can perform:

- Multi-physics simulations of Semiconductor chambers
- BGA Solder Joint Reliability Optimization
- Thermal-Stress
- Seismic vibration of chamber design
- MEMS
- High and Low Frequency Electromagnetics







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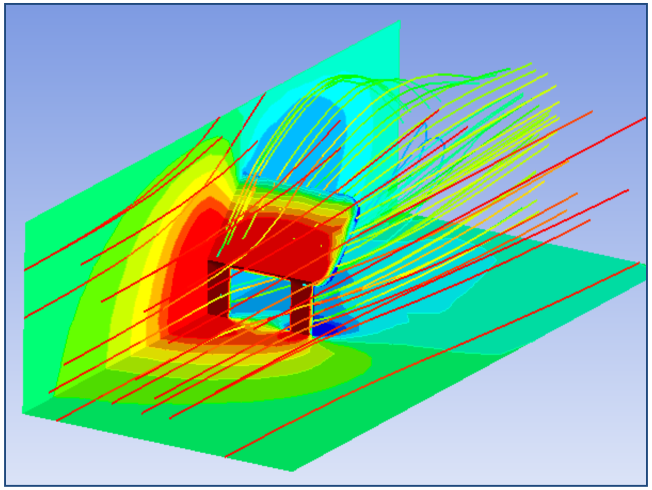
INDUSTRY SPECIFIC EXPERTISE – SOLAR INDUSTRY

Example of analysis we can perform:

- Multi-physics simulations of solar panel and support
- Electrical, thermal, mechanical and structural analysis
- Solar panel design optimization
- Modal analysis
- Virtual Prototyping

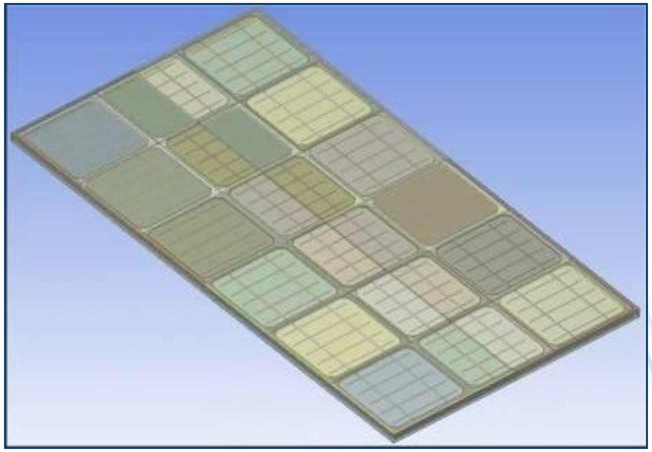


Example of case studies:

- Maximize the solar flux through a surface

- Structural optimization of the pole mount supports of a solar panel in a wind load case study

- Hail Impact on a solar panel



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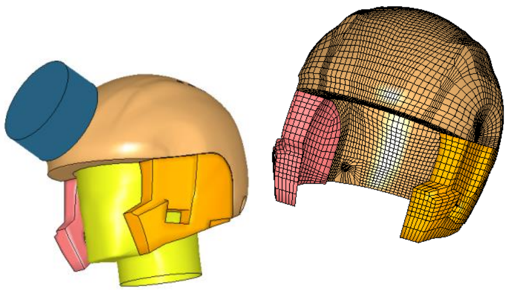
INDUSTRY SPECIFIC EXPERTISE – DOE AND DESIGN OF EXPERIMENT

Capabilities:

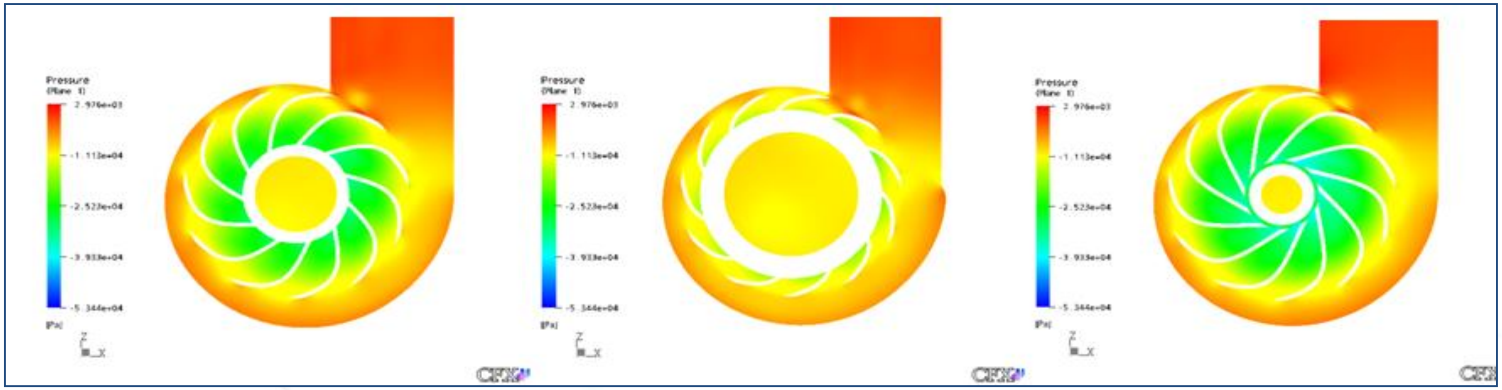
- Designs Exploration
- Mono and Multi-Objective Design Optimization (MDO)
- Process Integration
- Sensitivity Analysis
- Robust Design
- Decision Making Criteria and Tools



Impact simulation for a helmet
Matching Simulation Results with Lab Tests Data

Efficiency maximization of an hydraulic pump

Pressure plots



Initial Design | Intermediate Design | Optimal Design

Efficiency Improvement of 43% from the Initial design

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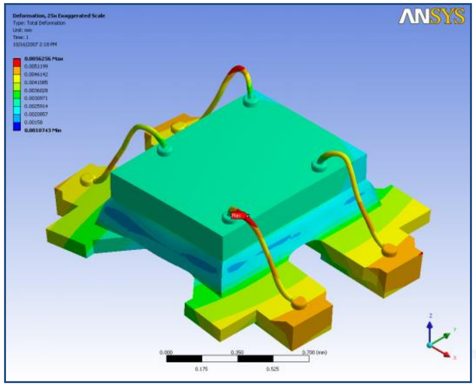
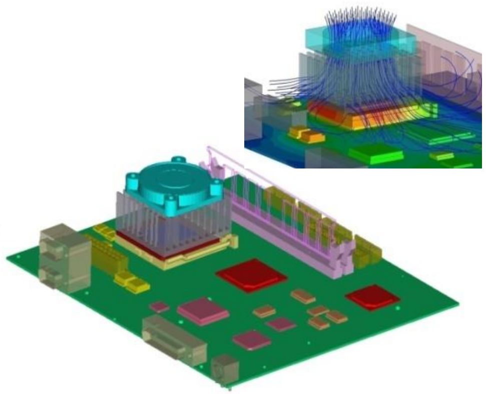
INDUSTRY SPECIFIC EXPERTISE – ELECTRONICS

Example of analysis we can perform:

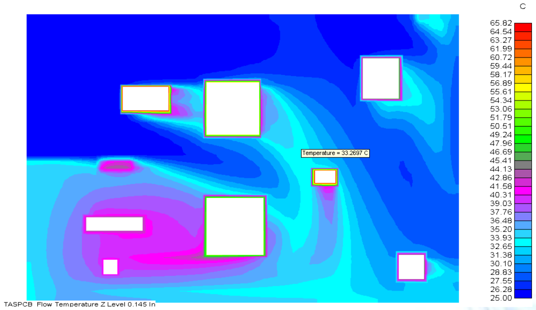
- BGA Solder Joint Reliability
- Theta Jc Thermal Characterization
- Thermal-Stress
- Fracture Mechanics & Fatigue
- Board & System Level CHT



Convection analysis



Cooling at System Level



Cooling at Board Level

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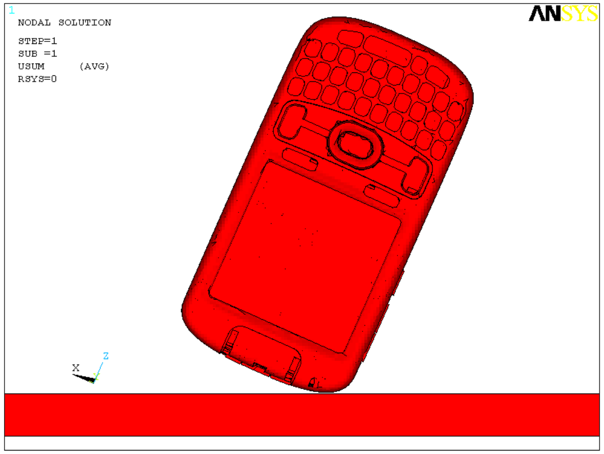
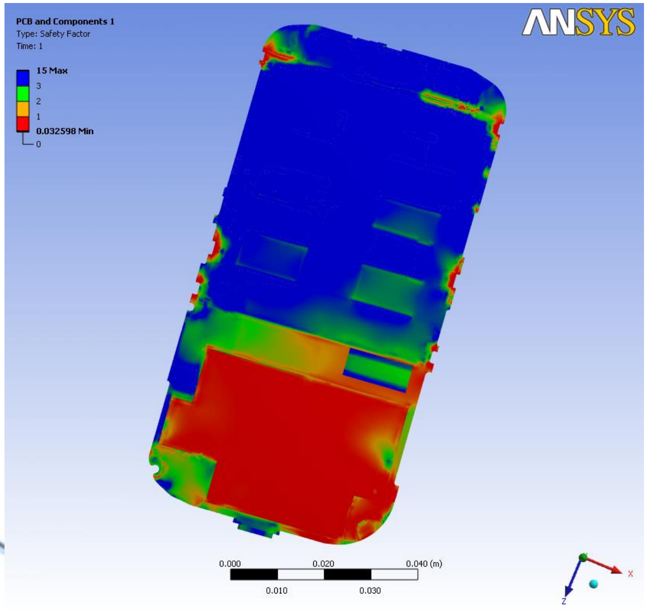
INDUSTRY SPECIFIC EXPERTISE – CONSUMER PRODUCTS



Example of analysis we can perform:

- Drop test
- Impact analysis
- Failure testing
- Reliability Simulation



Example of case studies:

- Drop test for cell phone
- …

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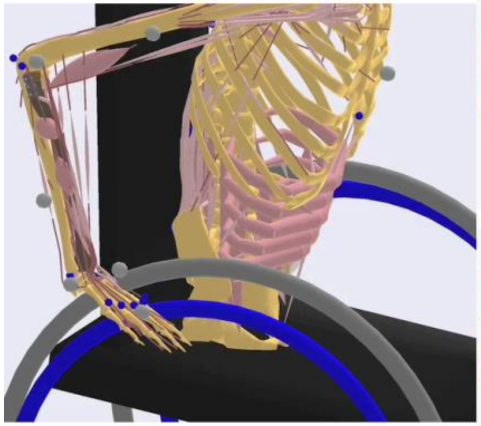
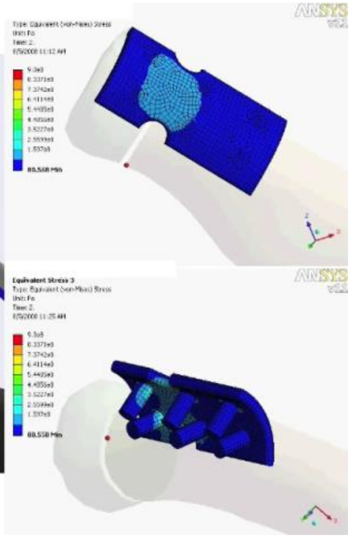
INDUSTRY SPECIFIC EXPERTISE – BIOMEDICAL INDUSTRY





Capabilities:

•Simulating how the human body performs when interacting with the environment

•Model the body, but also the objects it interfaces with

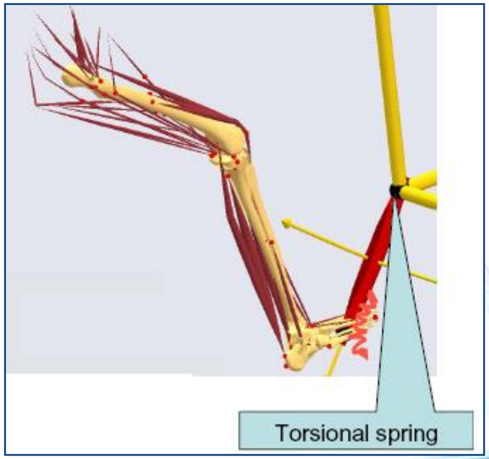
•Optimization of movement patterns

•Analysis of working movements and postures, scale results to population or subject anthropometric data

•Virtually assessing the exertion requirements of a new product or process

•Implant virtual prototyping

•Perform computational assessments and quantitatively investigate ergonomic consequences related to changes in design parameters.



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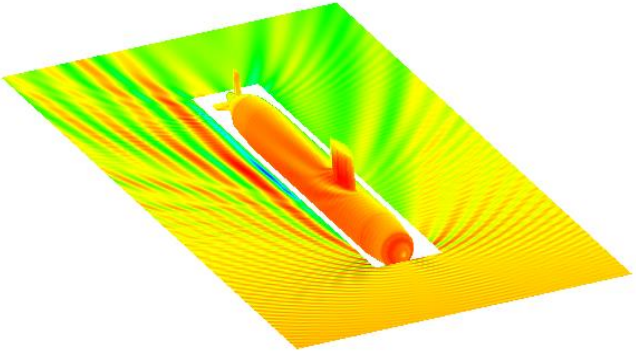
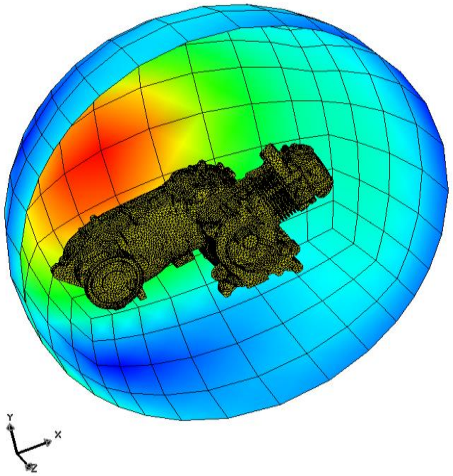
INDUSTRY SPECIFIC EXPERTISE – ACOUSTICS

Capabilities:

- Acoustics simulation for development of robust product
- Optimization of acoustic pressure distribution for maximizing product performance
- High frequency analysis of large scale acoustic models (400,000 + DOFs)
- Coupled structural-acoustic modeling for flexible resonant structures
- Prediction of acoustic pressure fields from machinery to musical instruments





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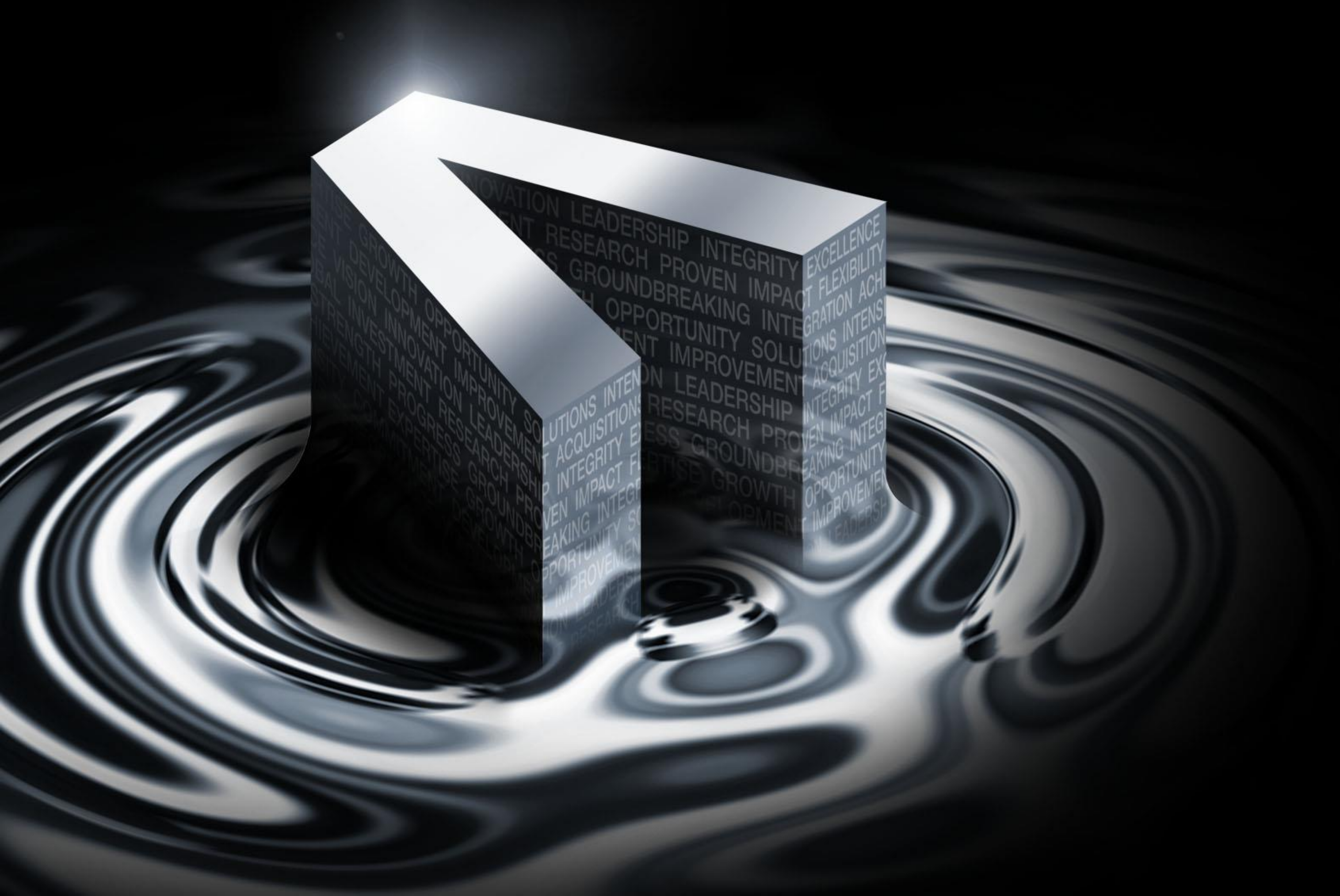
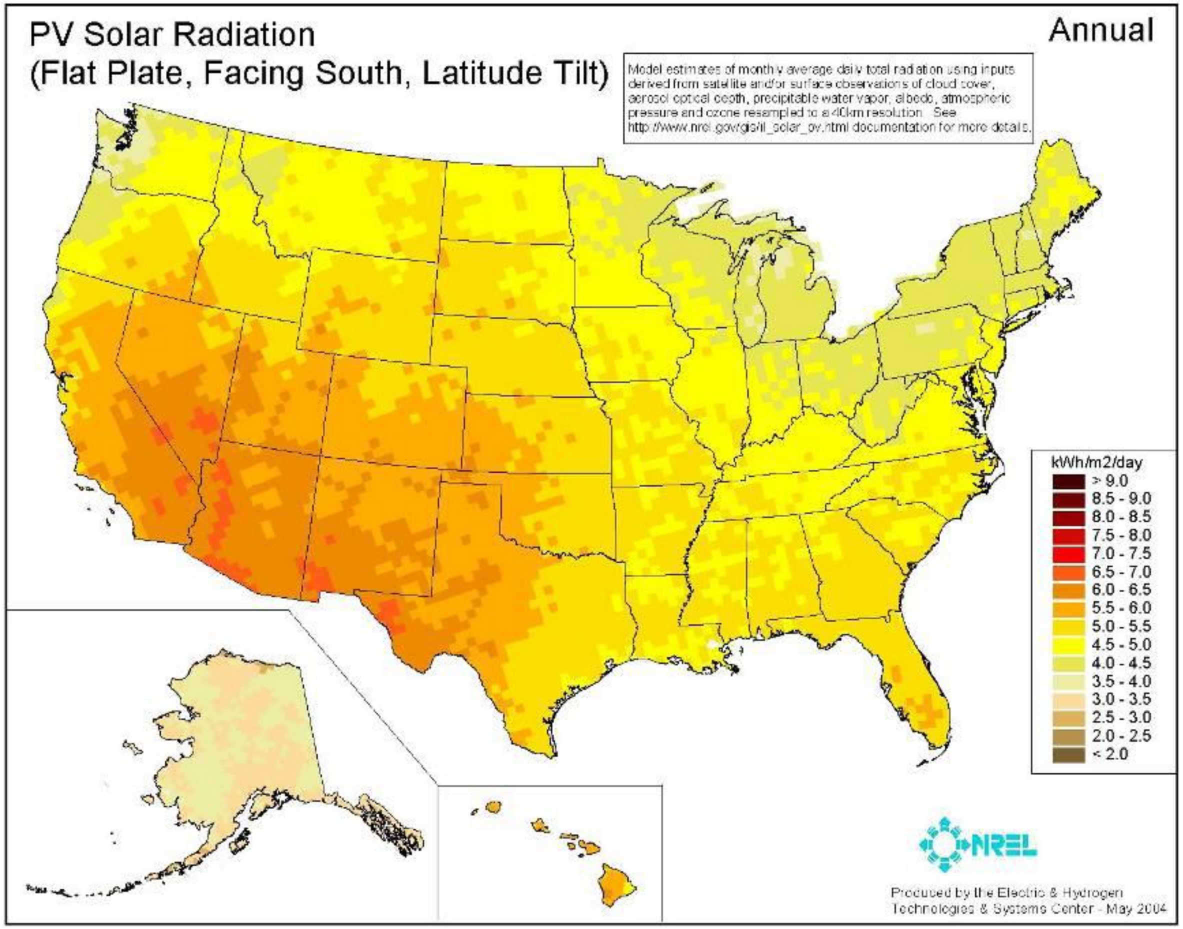
ANSYS®



LEADERSHIP INTEGRITY EXCELLENCE
RESEARCH PROVEN IMPACT FLEXIBILITY
GROUNDBREAKING
OPPORTUNITY SOLUTIONS
IMPROVEMENT
LEADERSHIP
RESEARCH

SIMULATIONS FOR SOLAR POWER TECHNOLOGIES



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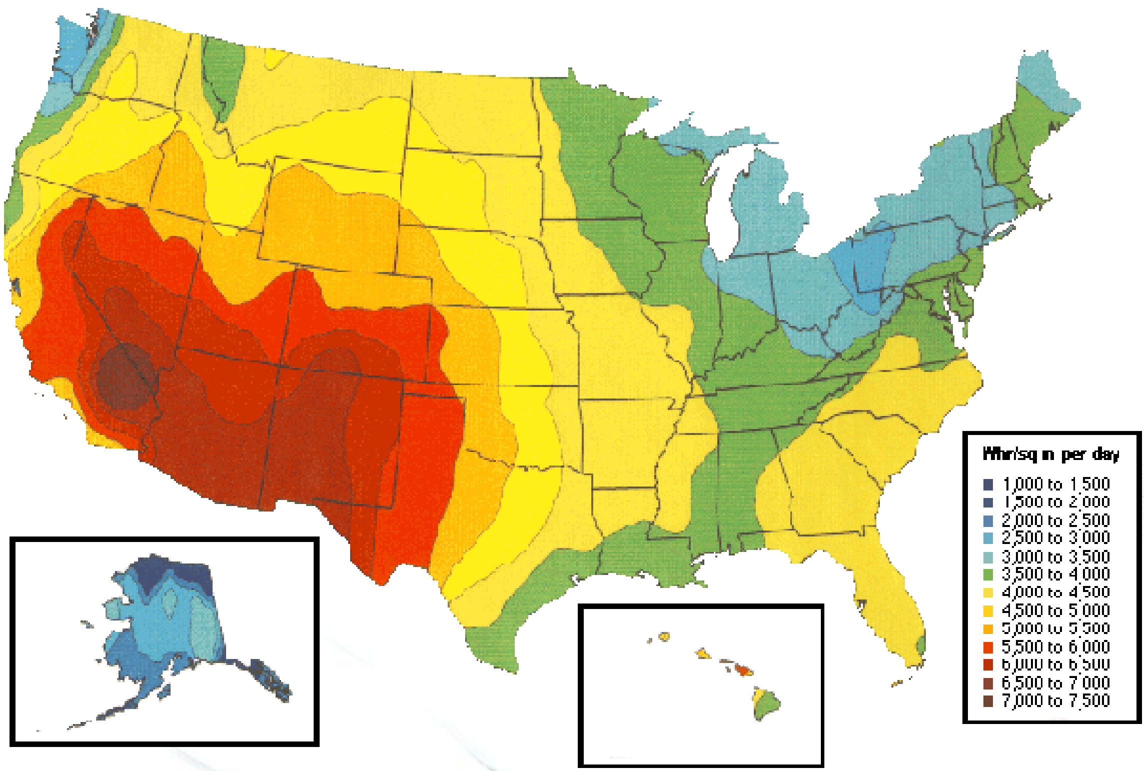
SOLAR



Source: EIA Annual Energy Outlook 2009 Reference Case Presentation – Dec 17, 2008

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ROLE OF SIMULATION IN SOLAR TECHNOLOGIES

Solar Materials

- Metallurgical grade to solar grade silicon purification is mainly achieved through gas phase precipitation processes
  - Fluidized Bed Reactors (FBR), Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD)
  - complex, nonlinear physics and chemistry
    - Multiple reaction pathways
    - Consistency, uniformity, scalability for CVD and allied processes
- Productization
  - Structural performance, formability, shaping
  - Specular performance, interface details for efficiency issues

Solar System Design

- Manufacturing costs
  - Traditional silicon
  - Thin film
  - Nanostructures
- Safety assurance
  - Seismic safety
  - Reliability in high wind conditions
- Performance

System Support Structures

- Basic integrity of structural supports for large solar panels
  - Seismic stability
  - Wind loadin
  - Fatigue

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SOLAR PV SIMULATIONS

- **Wafer/film level**
  - Manufacturing processes, breakthrough improvements in cell technologies
    - Si-based: CVD innovations, SG-Si-production, grain-structure control,
    - CIGs, Cd-Te and A-Si based: cell design, thin film technologies
- **Cell level**
  - Electrical designs
    - Circuit optimization, efficiency improvements
  - Optical designs
    - Coating, texture, reflection and refraction management
  - Thermal designs
    - Enclosure, connector and support organization, support insulations
  - Structural designs
    - Thermal stress, fatigue, cracks
- **Panel level**
  - Construction, installation, life and maintenance
  - Simulation is matured and similarities with other metal fabrication

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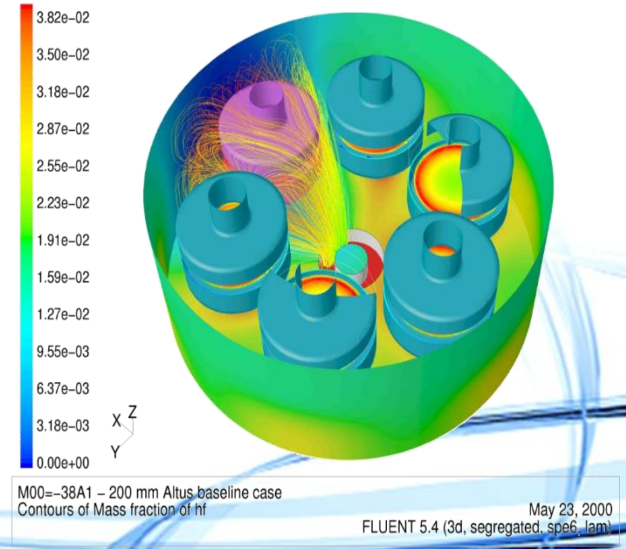
SOLAR SILICON MANUFACTURING EQUIPMENT & PROCESS MODELING

- **Multi-disciplinary effort**
- **Gas/mixture flow**
- **Conjugate heat transfer and radiation**
- **Complex chemistry**
  - Stiff gas phase and surface reactions
- **Electrostatics and electromagnetics**
- **Fluid-structure interactions**
- **Free surface and multi-phase flows**
- **Engineering equipment design**

Need to simulate interactions between various physico-chemical processes

Metal CVD (Concept Two ALTUS)
Courtesy: Novellus Systems



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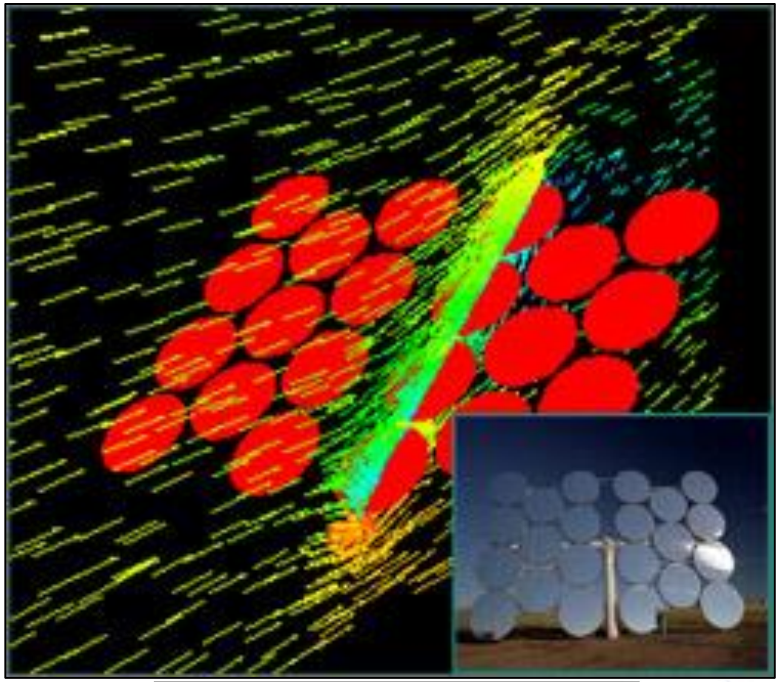
SIMULATION OF CONCENTRATED SOLAR POWER SYSTEMS

- Cooling for concentrating photovoltaic modules
- Heat transfer in novel heat exchangers and hybrid heat pipe designs
- Temperature profiles in thermal energy storage tanks – thermal stratification essential
- Wind loads on concentrator structures



Computed airflow over a multi-faceted heliostat structure
Source: NREL

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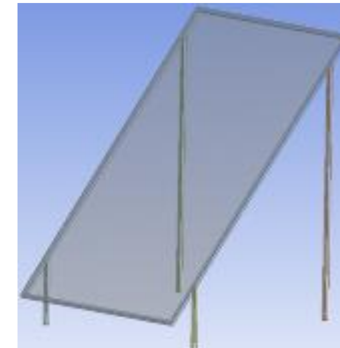
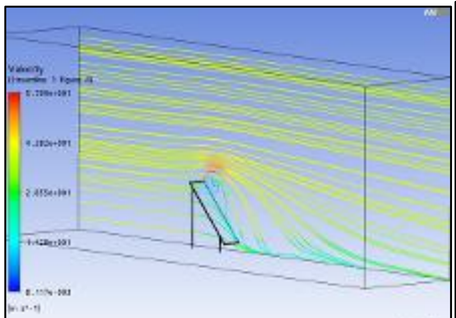
MULTIPHYSICS SIMULATION

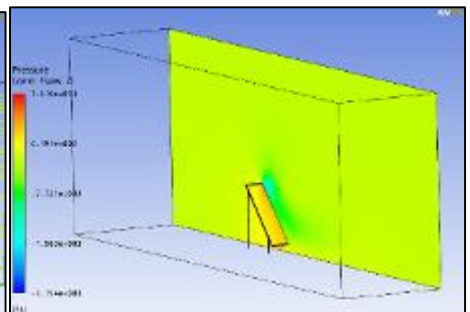
SOLAR PANEL & SUPPORT

- The wind loading on the solar panel can cause significant stress on the structure
- Thermal cycling also would lead to material fatigue

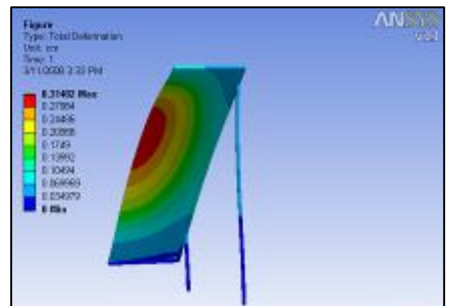




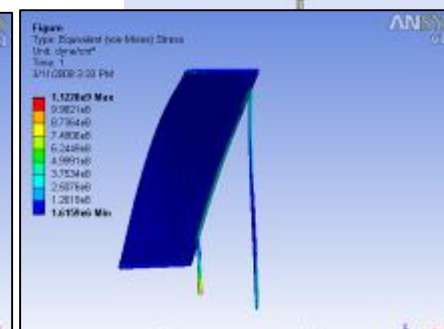
90 MPH stream



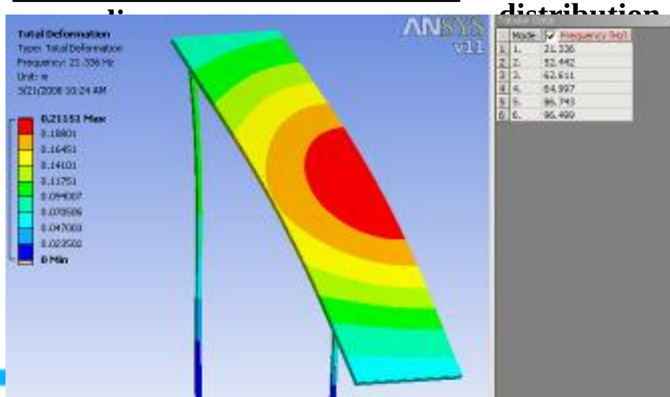
90 MPH pressure distribution



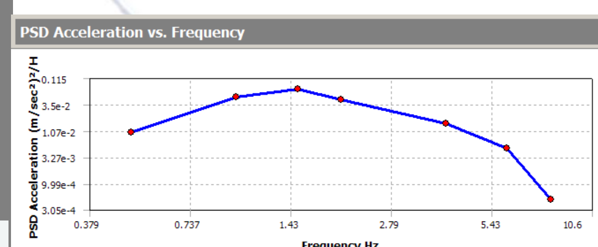
Structural Deformation Due to wind loading

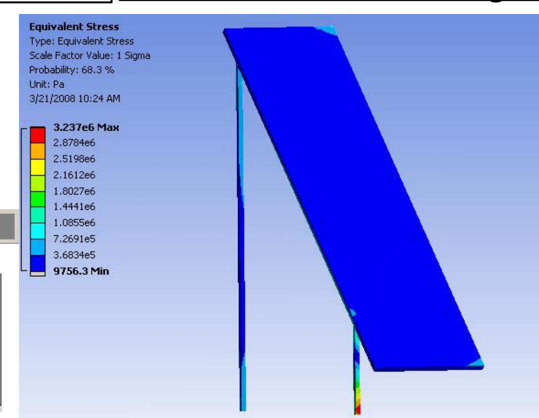


Stress due to wind loading



Pre-stressed Natural frequencies and mode shapes



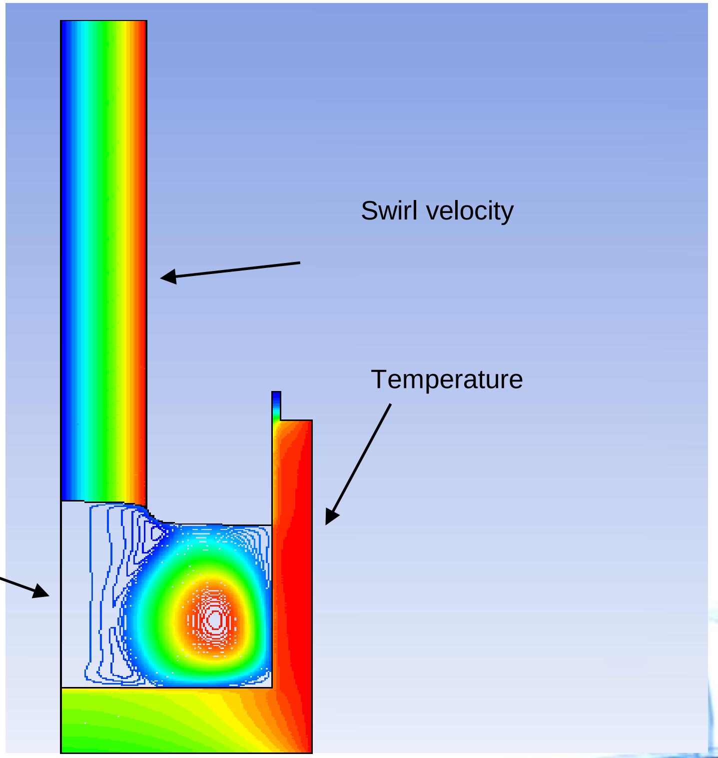


Random Vibrations Analysis

SOLAR SIMULATIONS

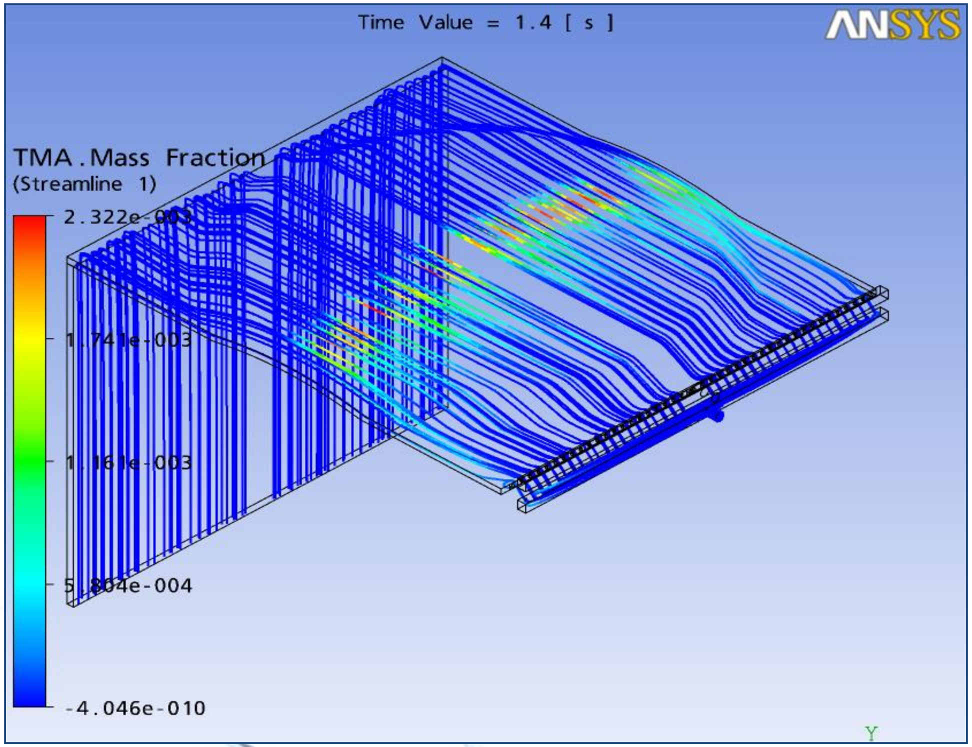
- For cases where silicon is involved, crystal growth simulations can be performed to analyze different techniques used.

- Simulation of Czochralski crystal growth
  - Computational fluid dynamics enables a detailed view of the process and the impact of varying input parameters



SOLAR SIMULATIONS

- For thin film depositions, CFD coupled with chemistry can be used to analyze and optimize the chamber designs as well as deposition.



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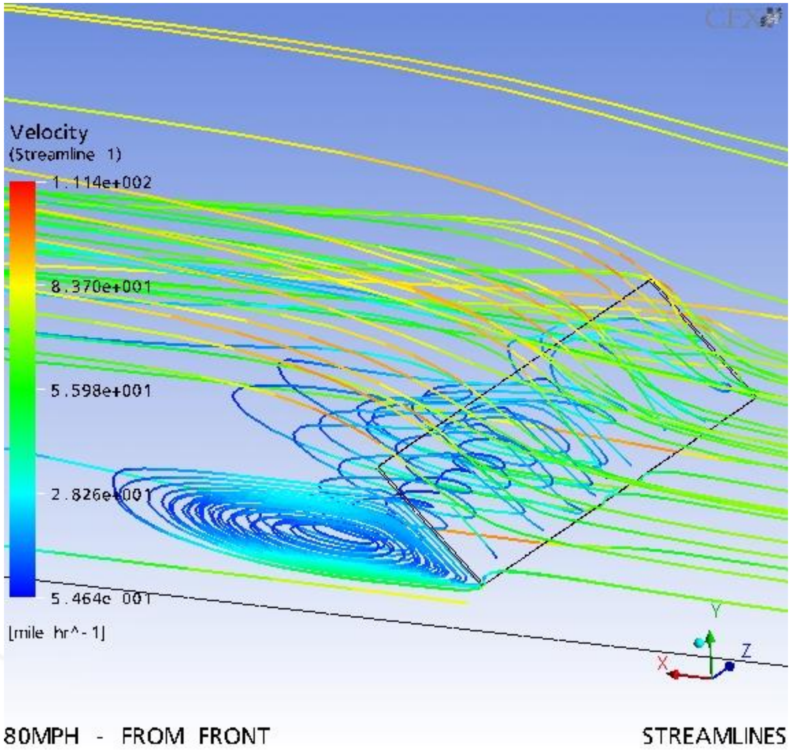
SOLAR SIMULATIONS

- For solar panel farms where they may be subjected to high winds, coupled Fluid-Structure Interaction (FSI) simulations are required to design the support structure for these large panels.



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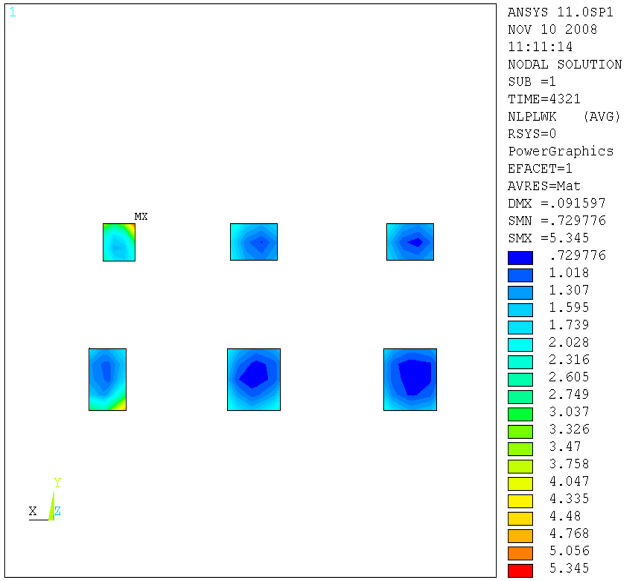
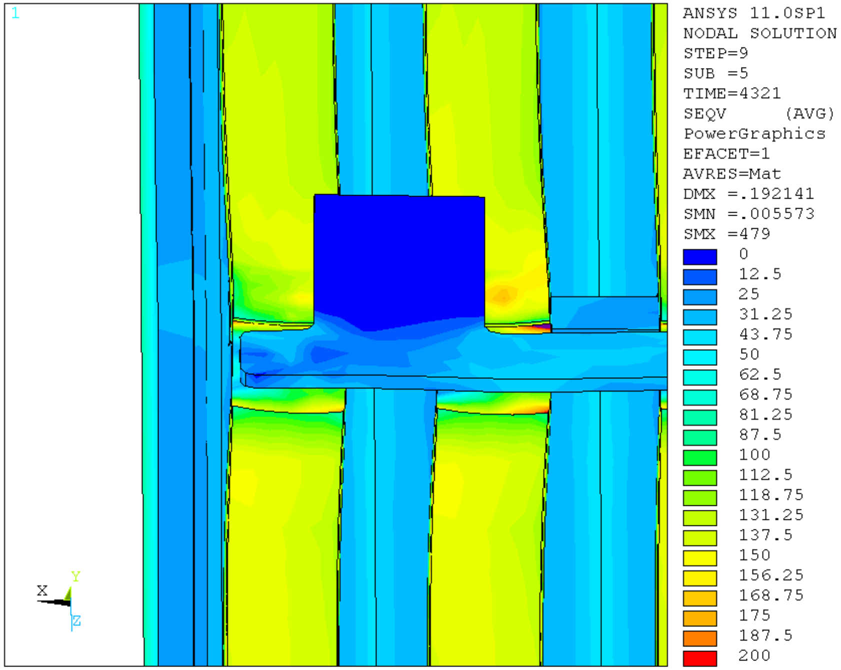
SOLAR SIMULATIONS

- The PV panels have copper wires that connect to each other by solder joints. As the panels expand and contract, the solder joint reliability becomes an issue. Simulations are required to characterize and identify the causes of failure, predict different solder joint material performance, and optimize (maximize) the fatigue lives of these solder joints.



SOLAR SIMULATIONS

- The solar cell consists of many different layers as well as different materials. When these materials expand and contract due to heating during the day and cooling during the night, the difference in coefficient of thermal expansion create high stresses at the interfaces where these different materials meet. Minimization of the stresses require temperature cycling simulations to understand the failure modes and then to correct for the failure by making design changes (optimizing) the way these components interact with each other.



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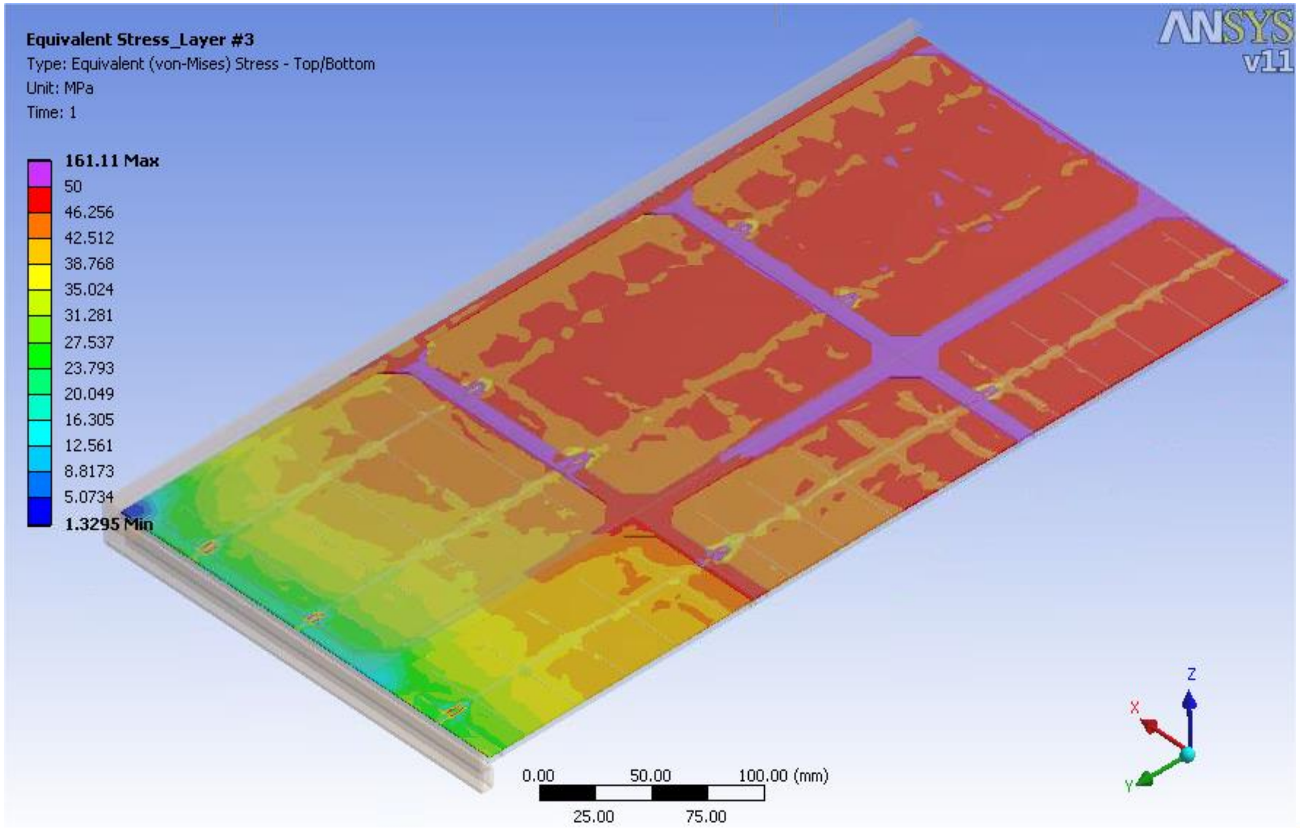
SOLAR SIMULATIONS

- Joule heating due to the generated electric current can also be simulated in these solar cells. This type of simulation can be performed in conjunction with the thermal cycling simulations to determine the thermal loads.



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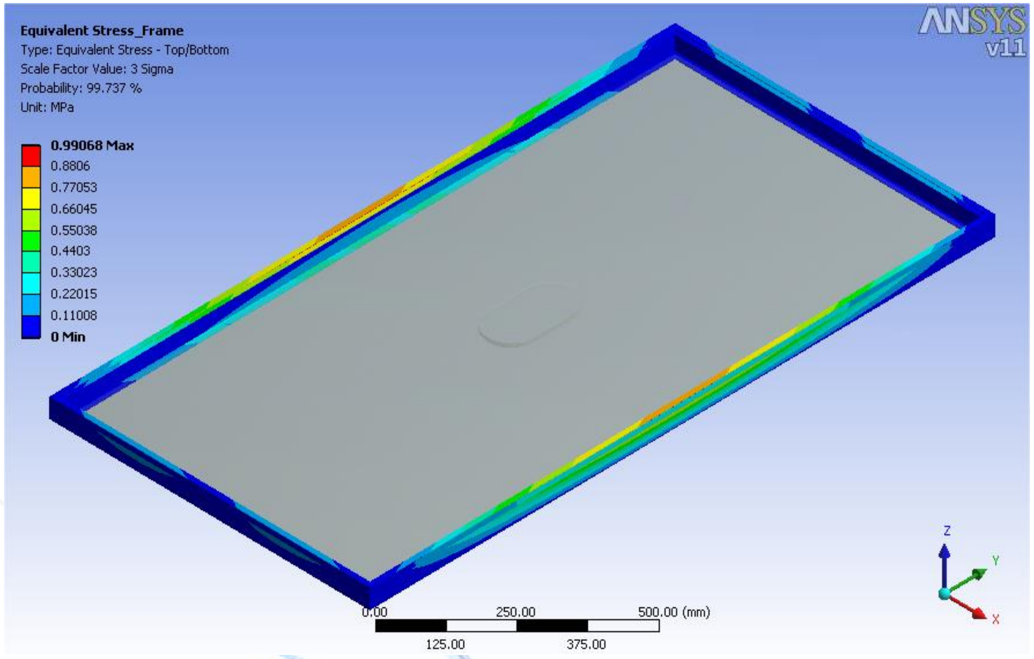
SOLAR SIMULATIONS

Hail impact simulations can be performed to determine if the panels will fracture. These types of simulations are classified under “explicit” simulations since the dynamic loads take place under extremely short transient time.

In addition, a random vibration load simulation can be performed for these solar panel assemblies to predict the stresses created during the transportation of these panels.



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SOLAR SIMULATIONS

All the simulations that are discussed above can be performed to address the following business issues:

- Decrease time to market
- Accelerate testing and certification
- Optimize performance (electrical, heat, reliability, etc.)
- Increase reliability and quality
- Decrease prototyping as well as manufacturing costs
- Manage financial risk

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SOLAR SIMULATIONS

Simulations today can be performed to address the business issues as well as the technical (engineering) issues such as:

- Production and manufacturability of solar panels
- System design issues
- Design of system support structures
- Solar cell electrical designs for circuit optimization
- Solar cell thermal designs
- Solar cell structural designs for thermal stress, fatigue/reliability, cracks
- Solar panel system design for construction, transportation, installation, fatigue life, and maintenance.

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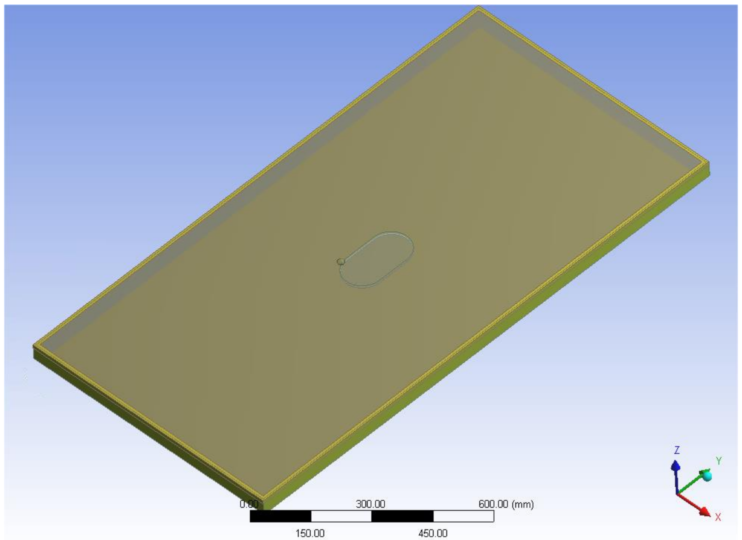
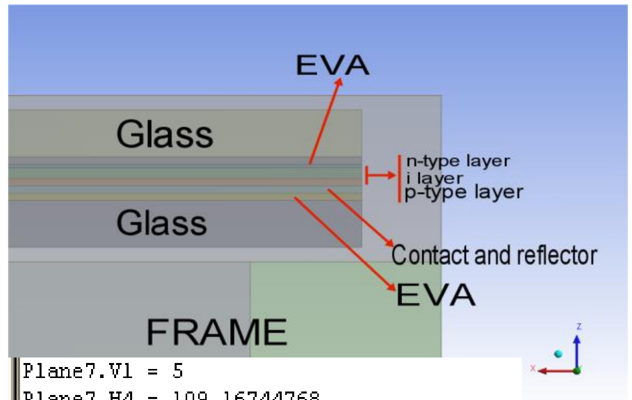
DEMO CASE #1

- In order to simulate the robustness and the thermal behaviour of a solar panel a parametric model has been generated.



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Plane7.V1 = 5
Plane7.H4 = 109.16744768
Plane7.V5 = 143.99442707
Extrude9.FD1 = 9,4
Plane8.FD1 = -3.2
Plane8_TCO.FD1 = -0.5
Plane8_Ptype.FD1 = -0.25
Plane8_Isilicon.FD1 = -0,75
Plane8_Nsilicon.FD1 = -0.5
Plane8_Contact_reflector.FD1 = -0.5
Plane8_PVB.FD1 = -0,5
Plane14.FD1 = 2.00000000
Plane15.FD2 = 375.00000000
Plane15.FD1 = 700.00000000
Plane15.FD3 = 55.00000000
```

Parameter Manager

```
XYPlane.V3 = 1559
XYPlane.H4 = 798
Extrude1.FD1 = 46
XYPlane.H5 = 28
XYPlane.H6 = 64.02283112
XYPlane.V7 = 76.87133354
XYPlane.V8 = 49.85688918

Plane5.FD1 = 0.00000000
Plane5.V1 = 1580.41924643
Plane5.H2 = 827.62077437
Plane6.FD1 = 0.00000000
Plane6.H1 = 12
Plane6.V2 = 12
Plane6.V6 = 1000
Plane6.H7 = 249.14539816
Extrude6.FD1 = 100.00000000
Extrude7.FD1 = 46.00000000
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ZXPlane.V2 = 43.32302923
ZXPlane.R3 = 9.12030422
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XYPlane.V10 = 19.23219879
Plane7.FD1 = -1.00000000
Plane7.H3 = 5
```

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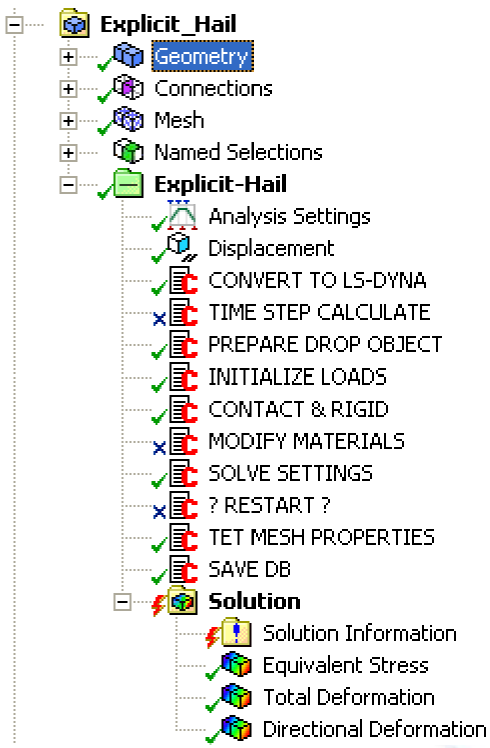
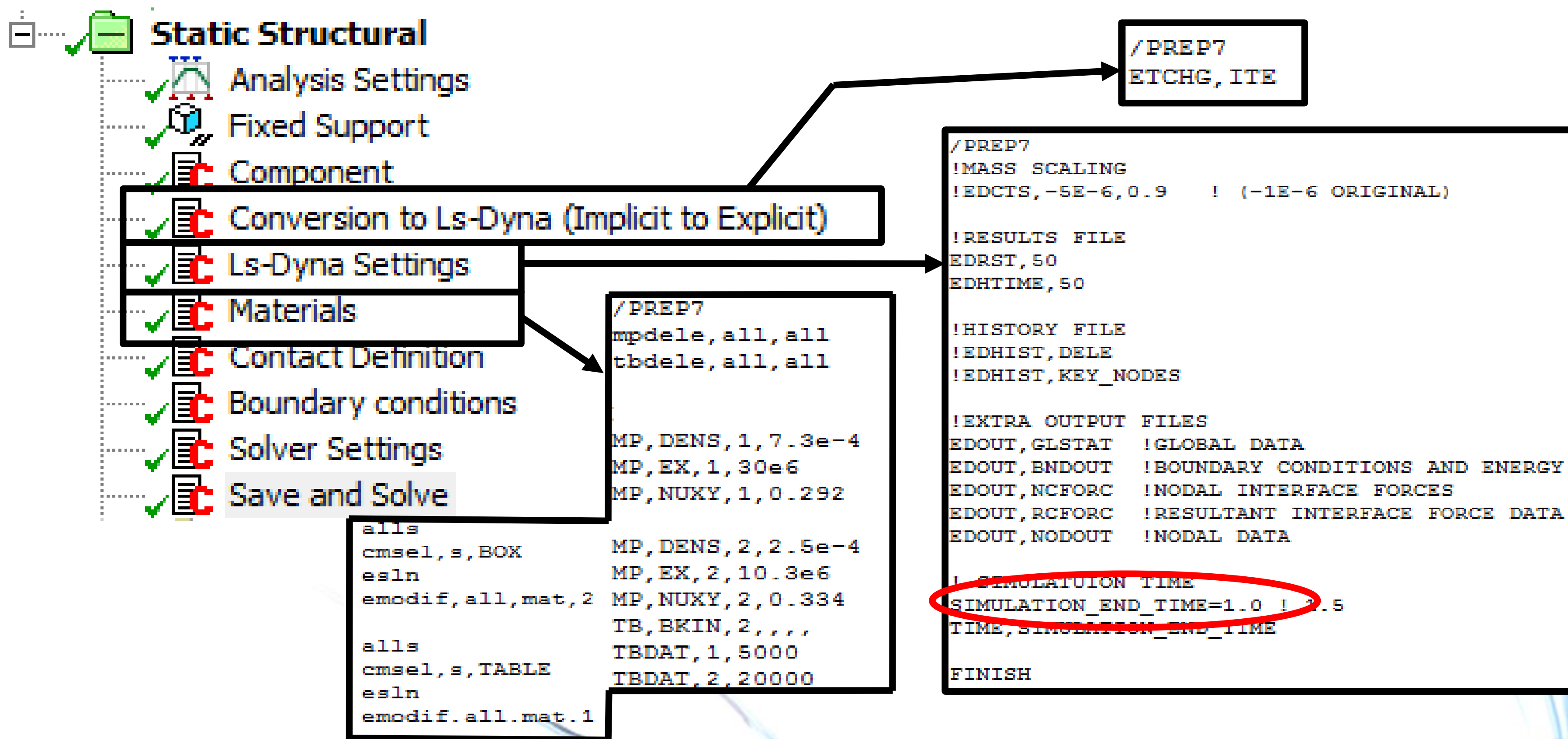
DEMO CASE #1

- **UL/IEC test requirements : Steel ball impact (51 inch, 1.18lb)**



DEMO CASE #1

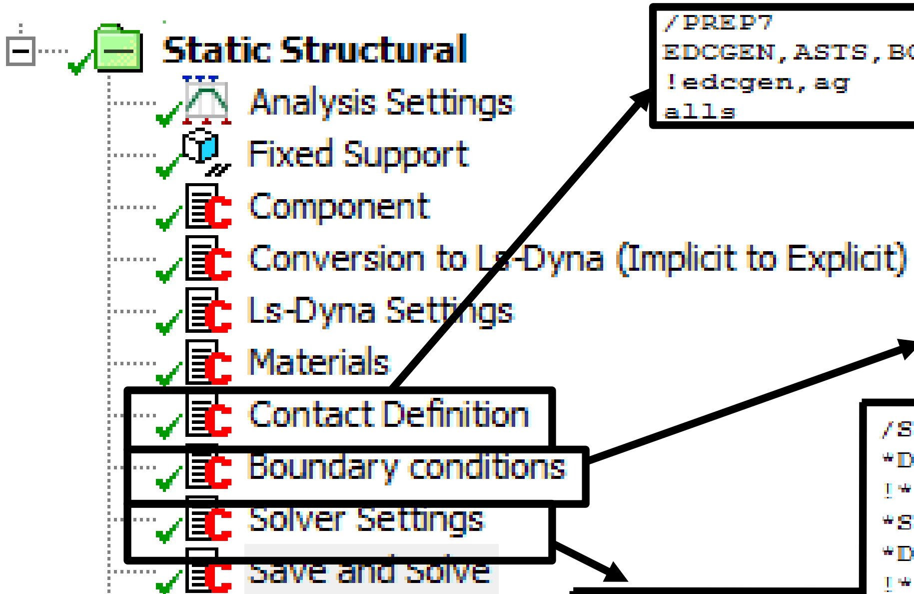
- **UL/IEC test requirements : Steel ball impact (51 inch, 1.18lb)**



OZEN ENGINEERING

DEMO CASE #1

- **UL/IEC test requirements : Steel ball impact (51 inch, 1.18lb)**




```
/PREP7
EDCGEN,ASTS,BOX,TABLE,0,0,0,0,0, , , , ,0,10000000
!edcgen,ag
alls
```

```
/SOL
alls
cmsel,s,box
esln
velocity=200
EDVE,VELO,BOX,0,-200,0,0,0,0,
alls
```

```
/SOL
*DIM,TIME,ARRAY,2,1,1, , ,
!*
*SET,TIME(2,1,1),1
*DIM,ACCG,ARRAY,2,1,1, , ,
!*
*SET,ACCG(1,1,1),386.4
*SET,ACCG(2,1,1),386.4
EDLOAD,ADD,ACLY,0,BOX,TIME,ACCG,0, , , , ,
! /REPLOT,RESIZE
```

```
EDRST,50,
EDHTIME,50,
EDDUMP,1,
!*
EDENERGY,1,1,1,1
```

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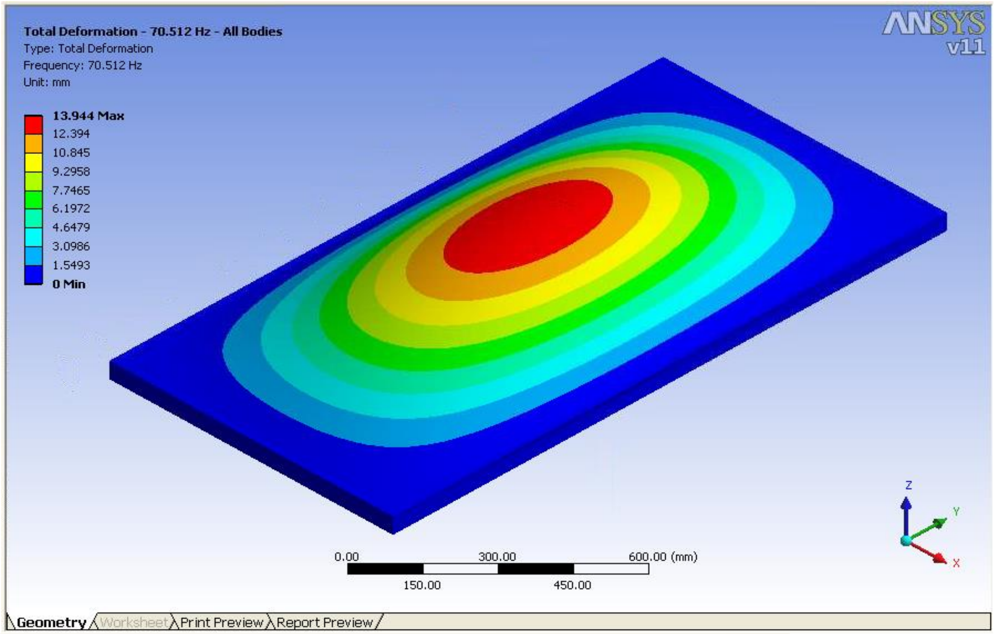
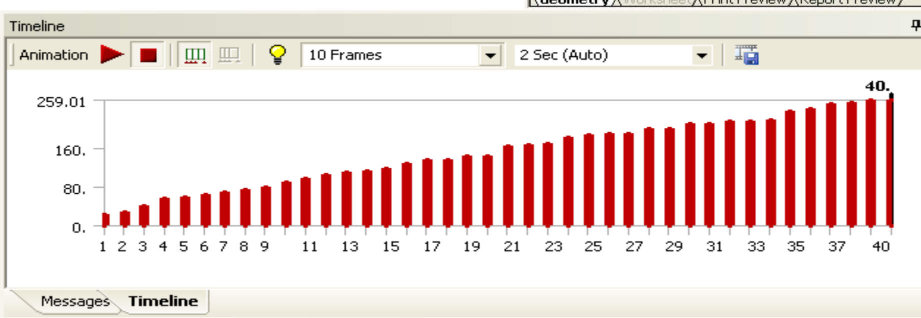
DEMO CASE #1

- **UL/IEC test requirements : 400 pound weight loading (*Static and Transient Dynamic*)**
- **Modal analysis is request to better investigate the dynamic behaviour**

- **Modal_Wind**
  - Initial Condition
  - Analysis Settings
  - Fixed Support
  - **Solution**
    - Solution Information
    - Total Deformation - 97.749 Hz - All Bodies
    - Total Deformation - 22.299 Hz - All Bodies
    - Total Deformation - 28.762 Hz - All Bodies
    - Total Deformation - 40.32 Hz - All Bodies
    - Total Deformation - 56.902 Hz - All Bodies
    - Total Deformation - 57.956 Hz - All Bodies
    - Total Deformation - 64.308 Hz - All Bodies
    - Total Deformation - 70.512 Hz - All Bodies
    - Total Deformation - 75.209 Hz - All Bodies
    - Total Deformation - 78.285 Hz - All Bodies
    - Total Deformation - 90.857 Hz - All Bodies





Tabular Data

	Mode	Frequency [Hz]
1	1.	22.299
2	2.	28.762
3	3.	40.32
4	4.	56.902
5	5.	57.956
6	[illegible]	[illegible]
7	7.	70.512
8	[illegible]	[illegible]
9	9.	78.285
10	10.	90.857
11	11.	97.749
12	12.	104.29
13	13.	111.3
14	14.	111.58

$T=1/f$

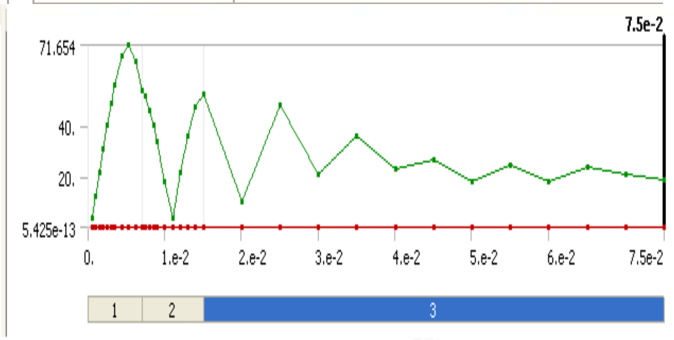
0.015 = 1/70

DEMO CASE #1

- **UL/IEC test requirements : 400 pound weight loading (Transient Dynamic)**

Details of "Force"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
ID	2395
Define By	Components
Type	Force
X Component	0. N (step applied)
Y Component	0. N (step applied)
Z Component	= -1820*sin((360/0.015)*time)
Function Unit System	Metric (mm, kg, N, °C, s, mV, mA) Degrees
Suppressed	No

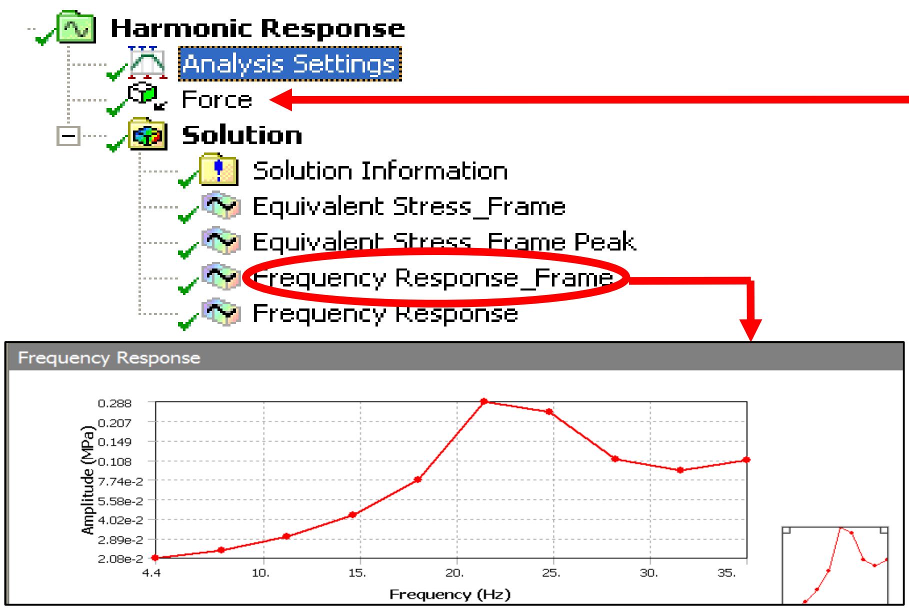


INPUT

OUTPUT

DEMO CASE #1

• **A complete characterisation of dynamic behaviour is also possible by means of an harmonic response analysis...**



Details of "Analysis Settings"

Options	
Range Minimum	1. Hz
Range Maximum	35. Hz
Solution Intervals	10
Solution Method	Mode Superposition
Cluster Results	No
Modal Frequency Range	Program Controlled
Store Results At All Frequencies	Yes
Output Controls	
Calculate Stress	Yes
Calculate Strain	Yes
Damping Controls	
Constant Damping Ratio	0.
Beta Damping Define By	Direct Input
Beta Damping Value	0.
Analysis Data Management	
Solver Files Directory	C:\Documents and Settings\All Users\D...
Future Analysis	None
Save ANSYS db	No
Delete Unneeded Files	Yes

An harmonic response analysis is very easily setting in WorkBench and give an essential deep understanding of the dynamic behaviour of the structures undergoing a periodic load. <u>The designer can probe the stress and strain levels on each specific part of the solar panel</u>.

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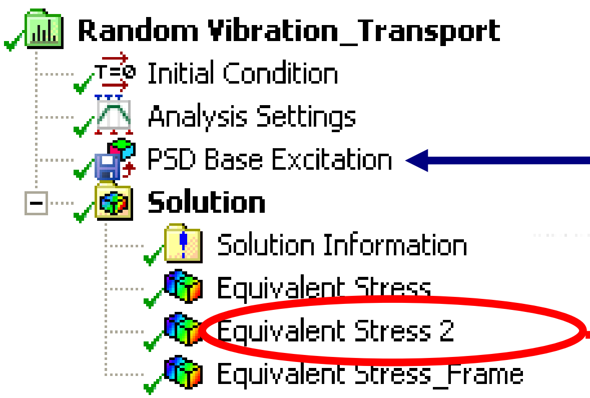
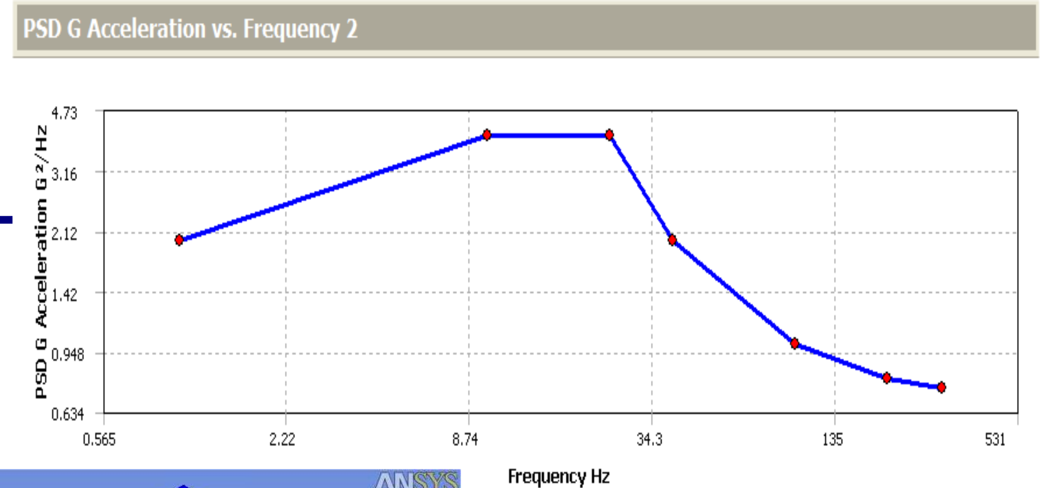
DEMO CASE #1

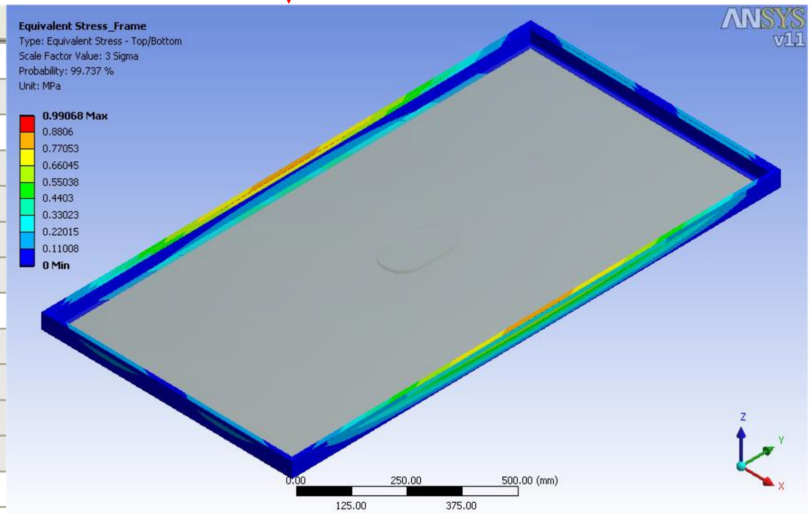
...and a Random Vibration Analysis.





Details of "Equivalent Stress_Frame"

Scope	
Geometry	7 Bodies
Definition	
Type	Equivalent Stress
Scale Factor	3 Sigma
Probability	99.737 %
Type	Equivalent Stress
Results	
Minimum	0. MPa
Maximum	0.99068 MPa
Minimum Occurs On	Surface Body
Maximum Occurs On	Surface Body
Information	



An Random Vibration analysis is very easily setting in WorkBench and is the best way to test any kind of structure undergoing a random load like for instance vibrations induced during the transport.

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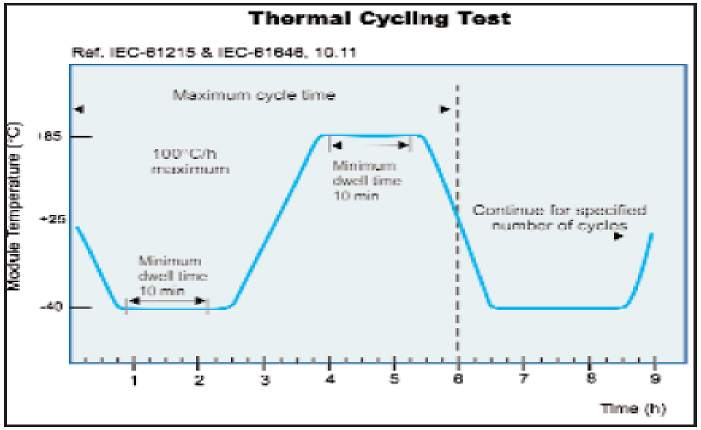
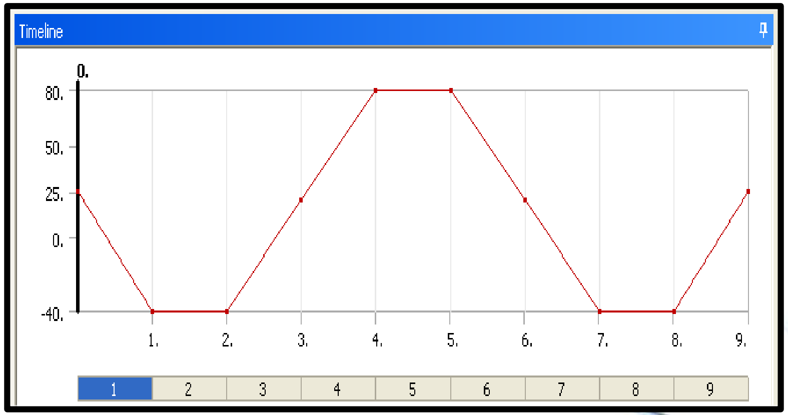
DEMO CASE #1

- EC 61646 test requirements : Thermal Cycling





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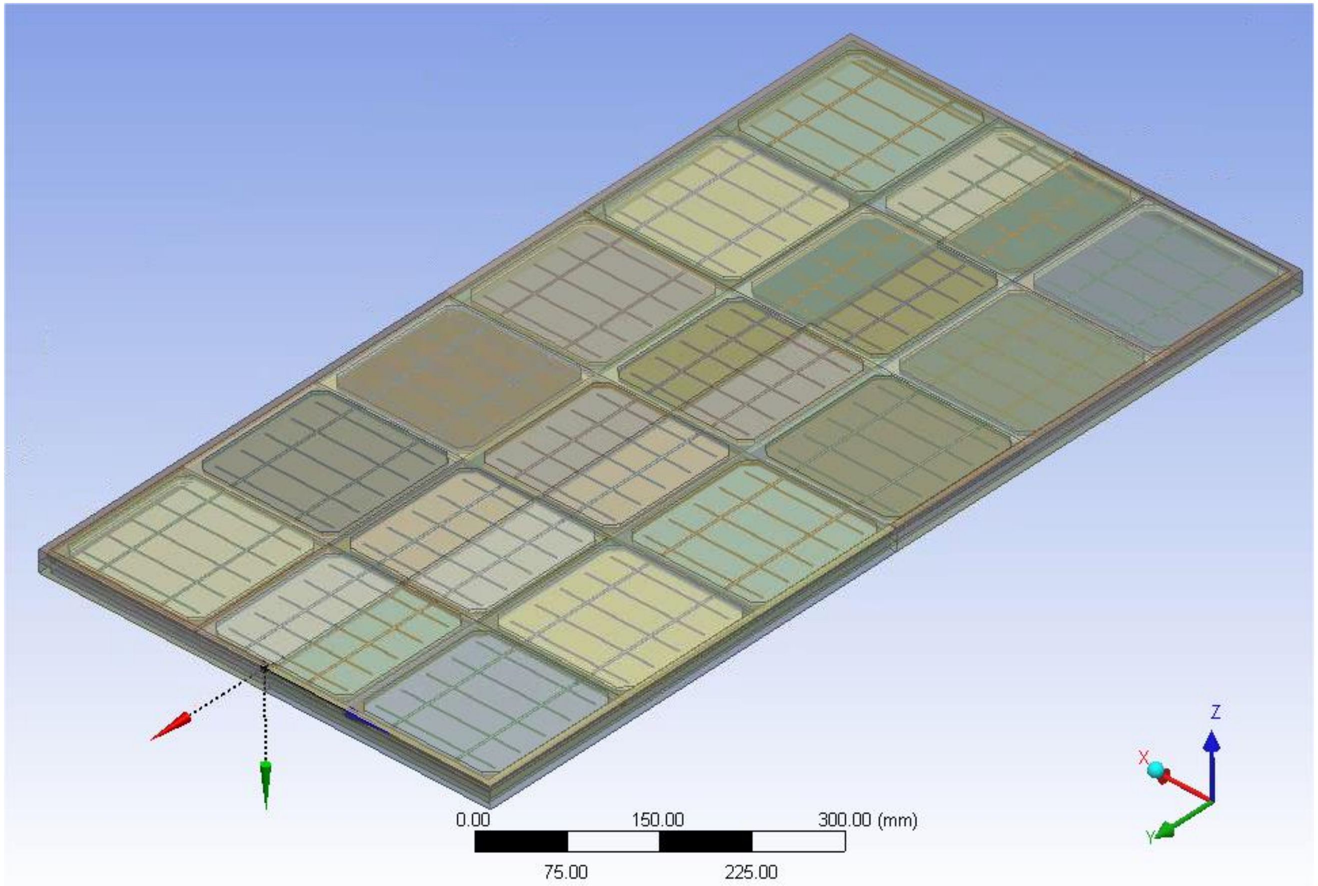
DEMO CASE #2

- As more deeply we need to investigate the behaviour of our solar panel as more accurate have to be the model we generate...



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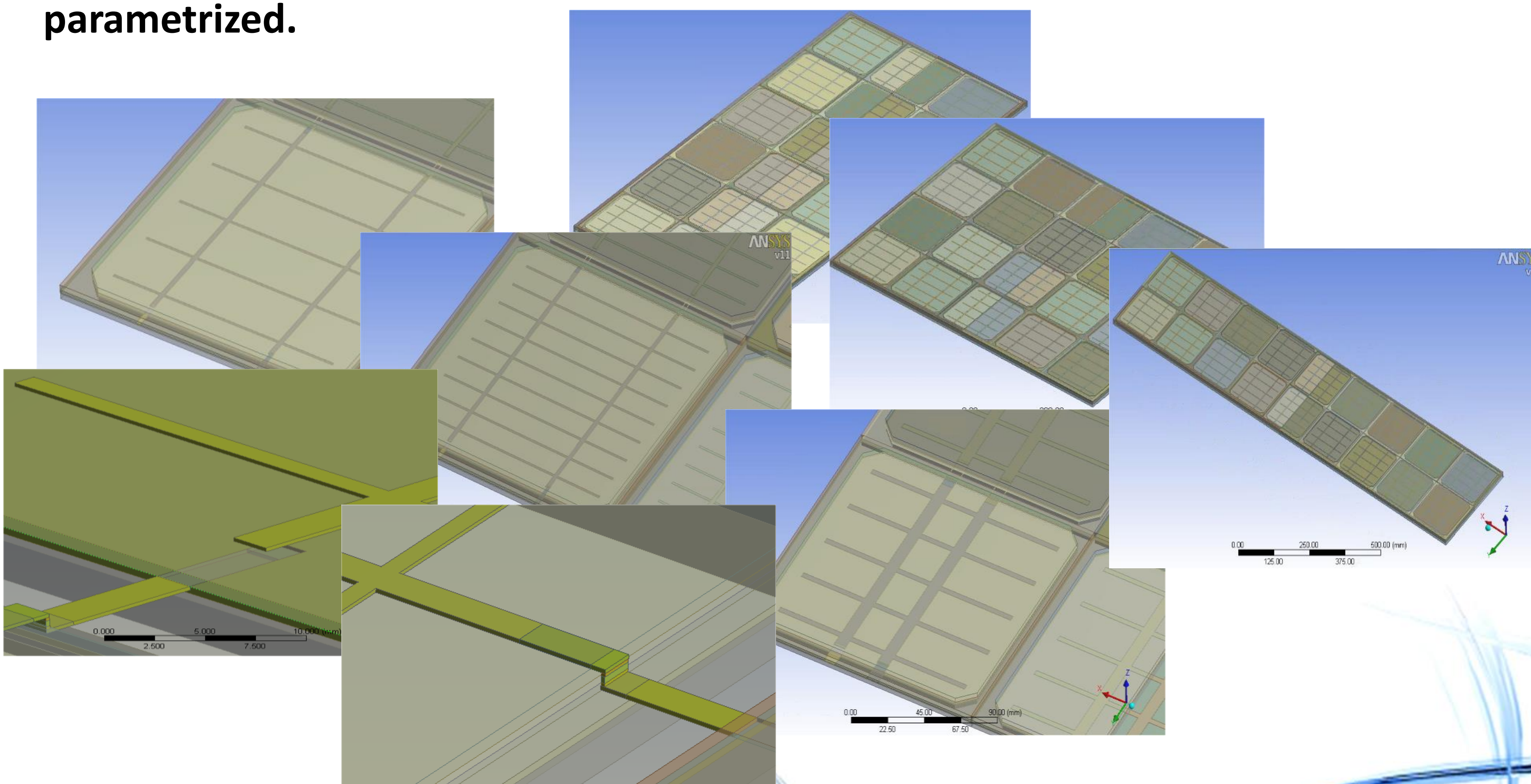
DEMO CASE #2

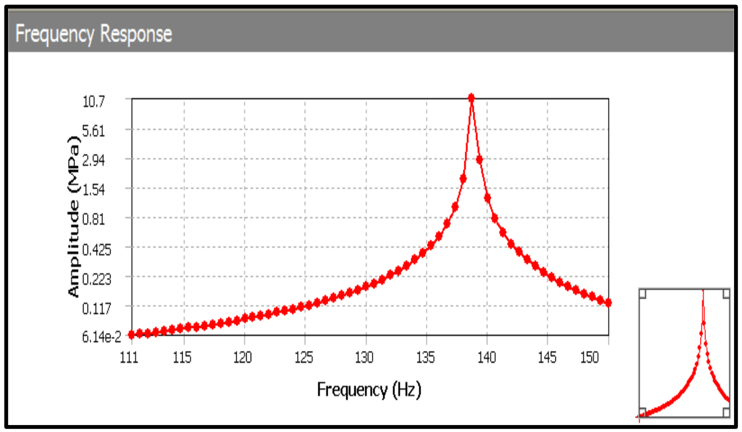
- **Each specific detail insert on a real solar panel can be taken into account and parametrized.**

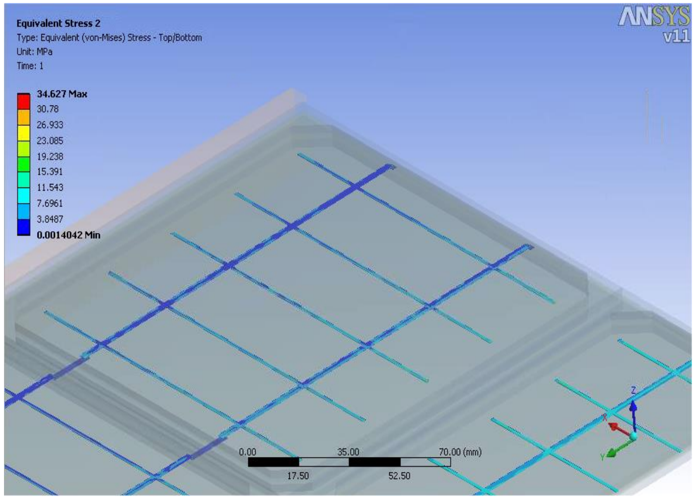


DEMO CASE #2

- **The tests required by Standard UL/IEC have also been simulated on this model**

(since the increased number of elements the analysis are computationally more expensive, but perfectly manageable by a normal dual core workstation)

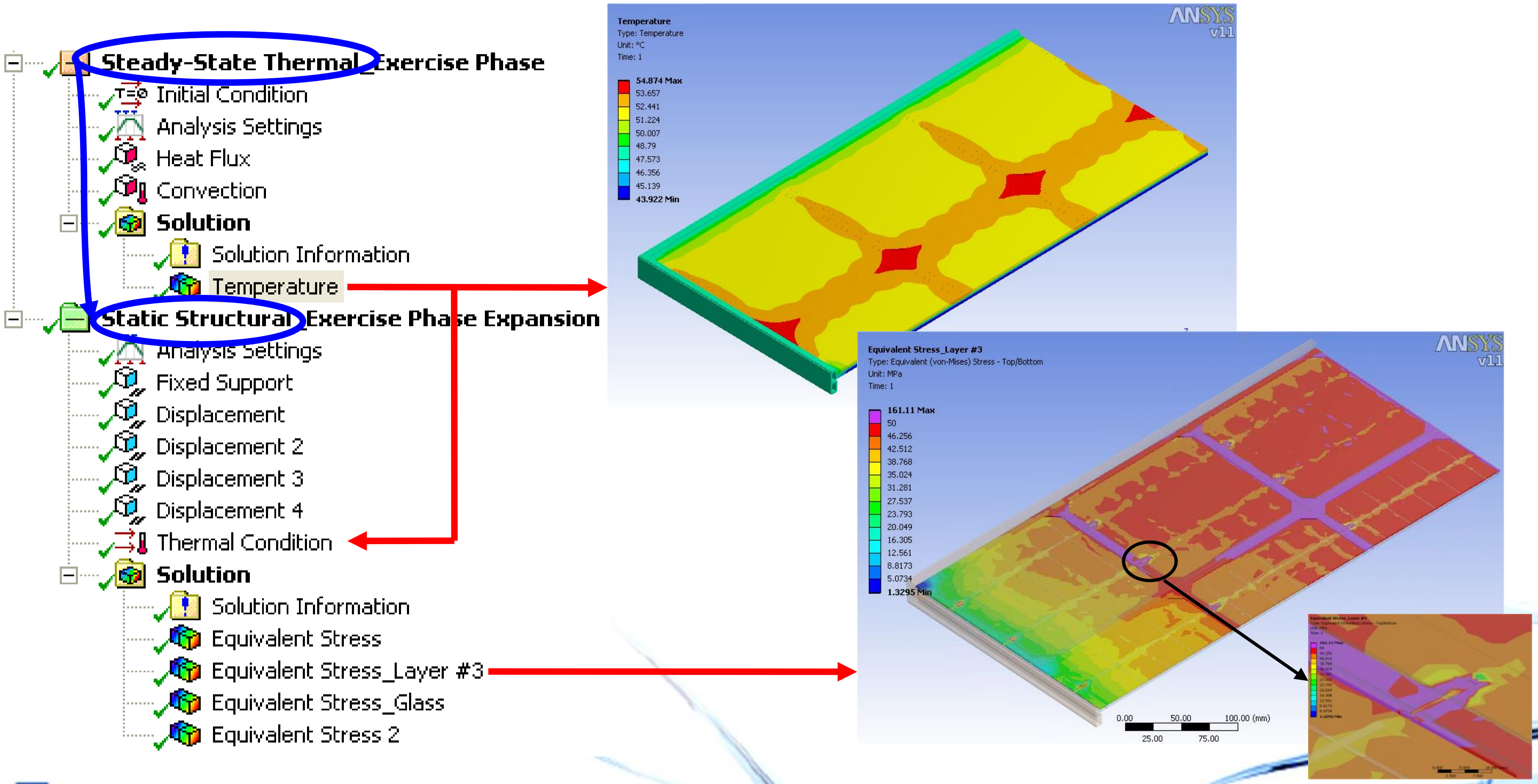




OZEN ENGINEERING

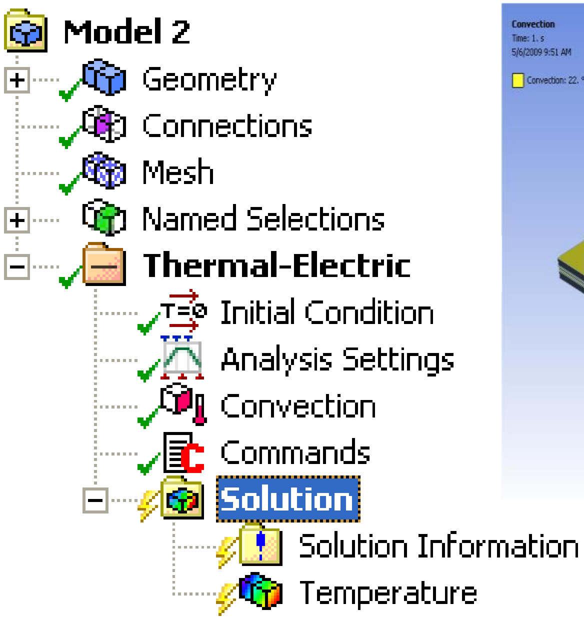
DEMO CASE #2

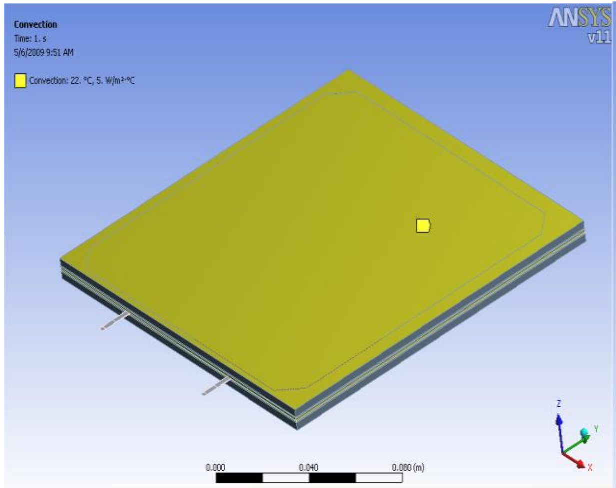
- A simulation coupling thermal-mechanical field has also been performed in order to determine the stress on the layers close to the conductors

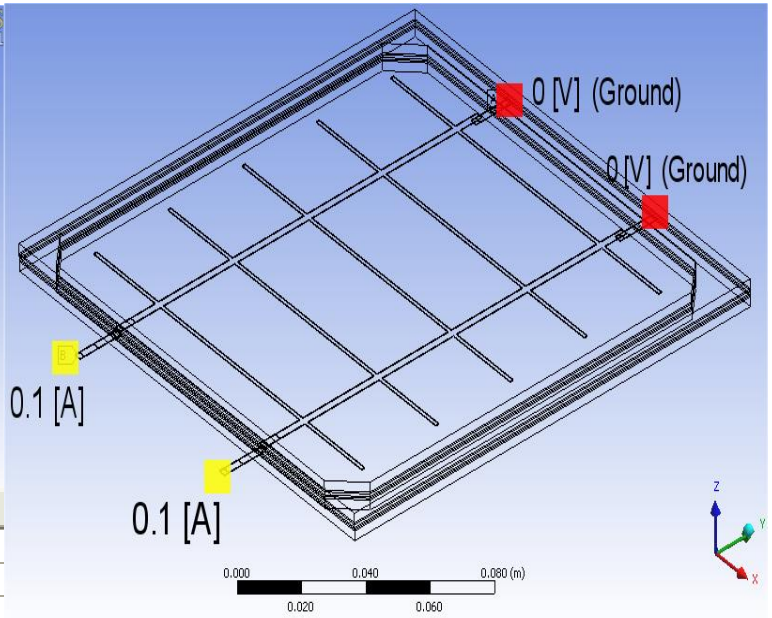


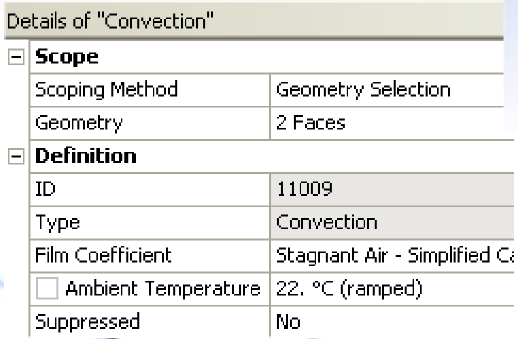
DEMO CASE #2

- A simulation coupling thermal-electric field has also been performed in order to determine the joule heating







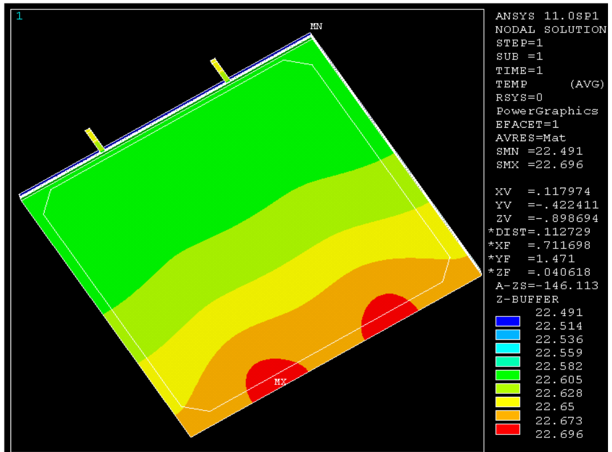


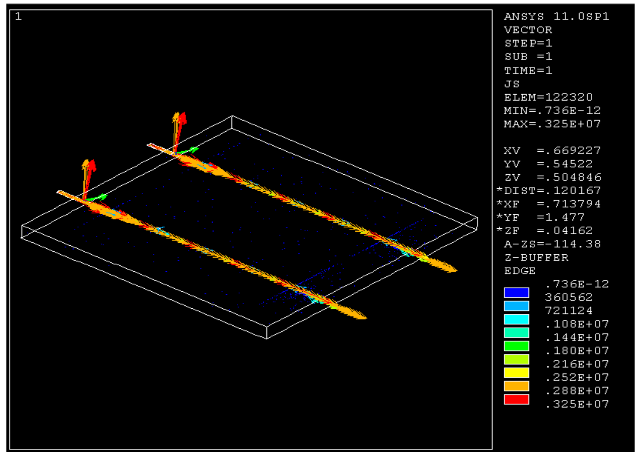
Details of "Convection"

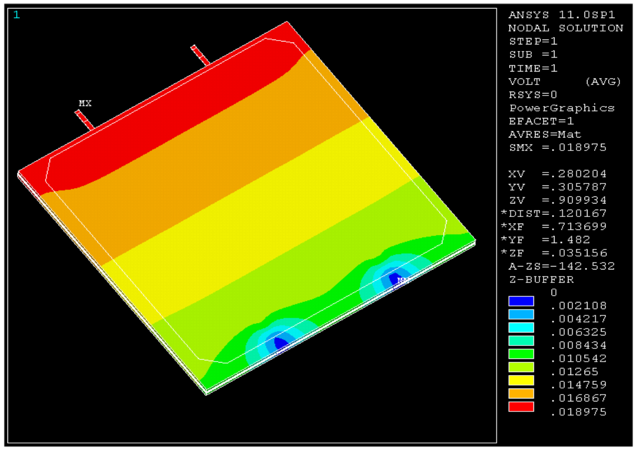
Scope	
Scoping Method	Geometry Selection
Geometry	2 Faces
Definition	
ID	11009
Type	Convection
Film Coefficient	Stagnant Air - Simplified Ca
Ambient Temperature	22. °C (ramped)
Suppressed	No

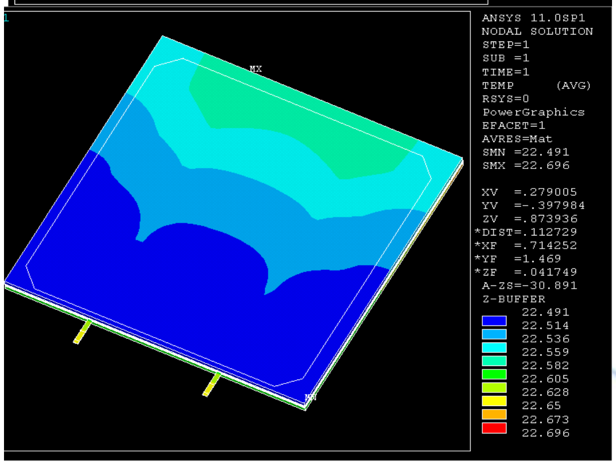
DEMO CASE #2

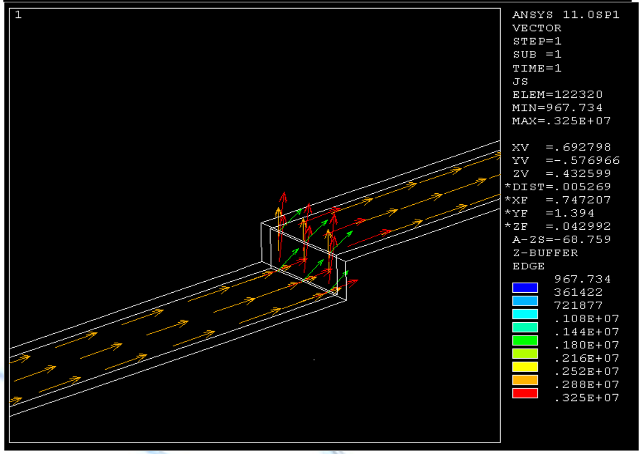
- A simulation coupling thermal-electric field has also been performed in order to determine the joule heating

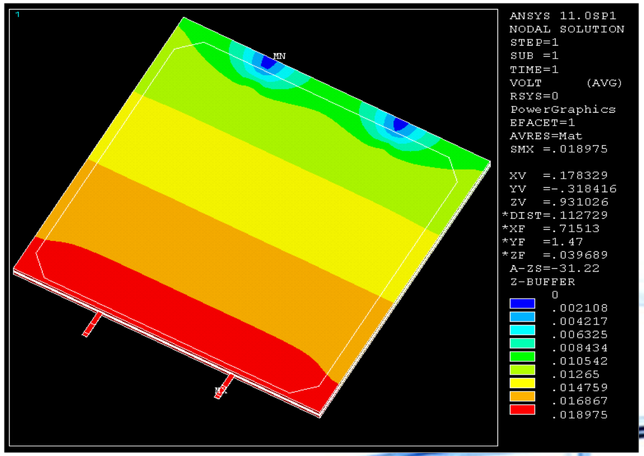












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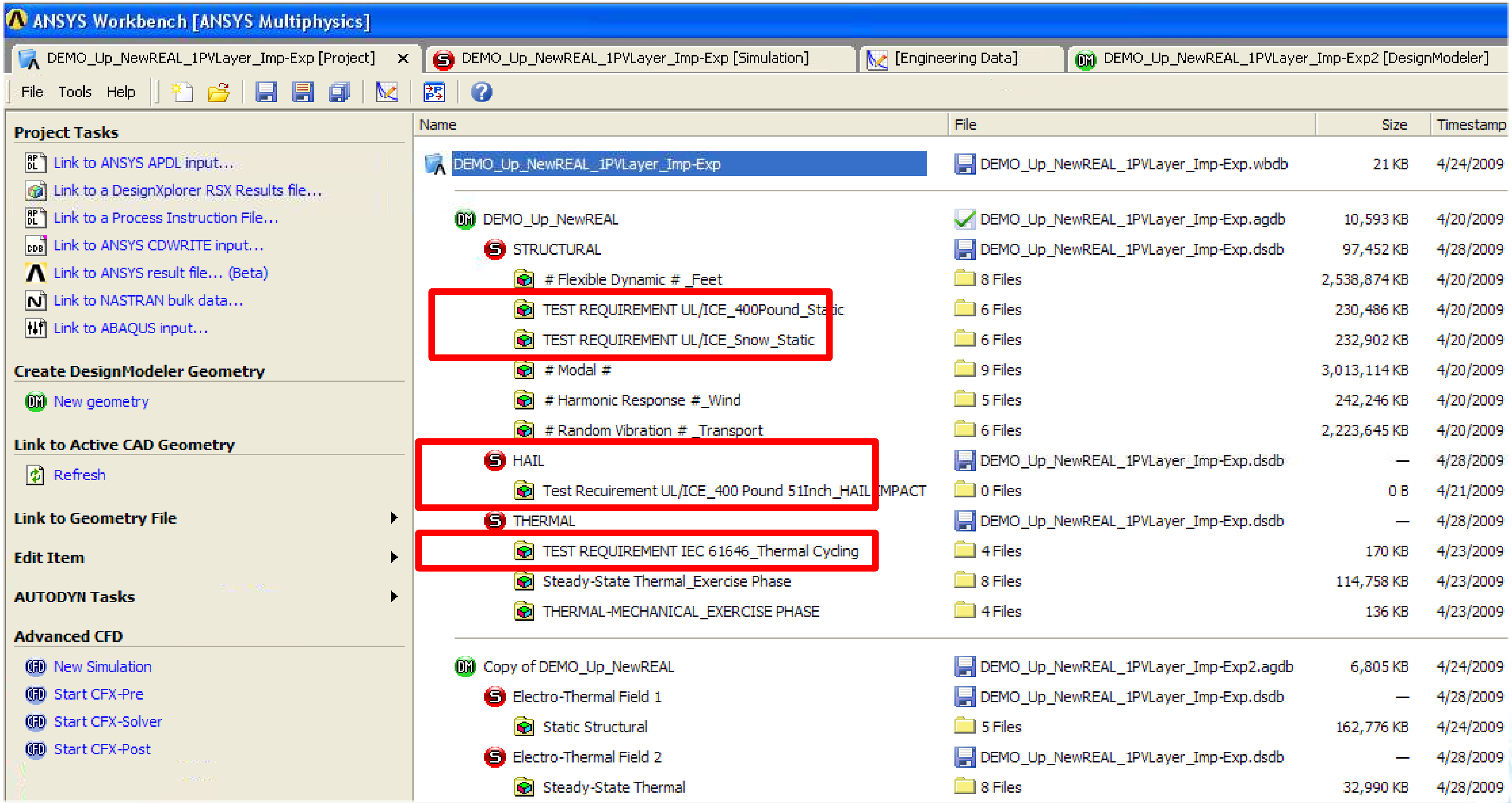
POWERFUL SOFTWARE TOOLS



- **All the simulations performed can be handle in one main page**

ENGINEERING

In order to use the cells in practical applications, they must be:

- Connected electrically to one another and to the rest of the system
- Protected from mechanical damage during manufacture, transport and installation and use (in particular against hail impact, wind and snow loads). This is especially important for wafer-based silicon cells which are brittle.
- Electrically insulated including under rainy conditions
- Mountable on a substructure or building integrated.

Source :Wikipedia (Photovoltaic module)

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ENGINEERING

...and also...

• Diodes are included to avoid overheating of cells in case of partial shading. Since cell heating reduces the operating efficiency it is desirable to minimize the heating. Very few modules incorporate any design features to decrease temperature, however installers try to provide good ventilation behind the module.

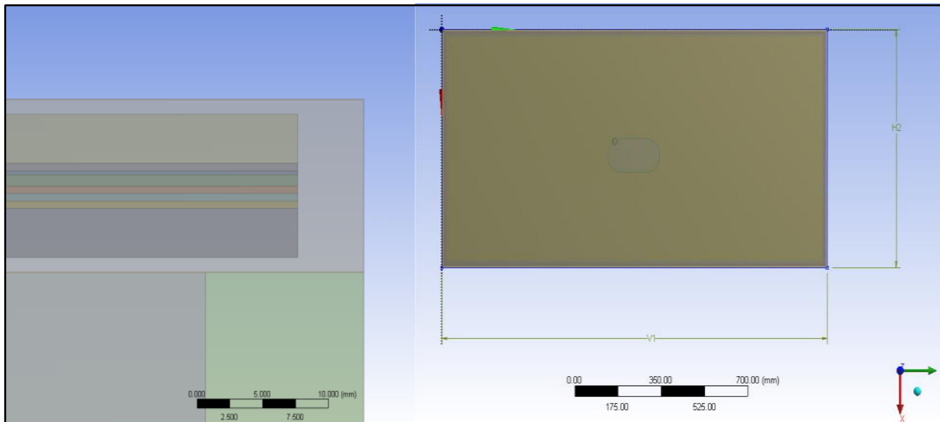
Source :Wikipedia (Photovoltaic module)

"The battle is going to be won on the manufacturing floor."
David Pearce, CEO of CIGS manufacturer Miasolé

OZEN ENGINEERING

OPTIMIZATION

- **Why to optimize a design?**



Parameter1 → th1
Parameter2 → w1
Parameter3 → l1
Parameter4 → E1

th1 w2 l1 E2

th2 w1 l1 E1

th1 w2 l2 E2

th1 w1 l2 E2

th2 w2 l2 E2

th1 w1 l2 E2

th1 w3 l2 E2

th1 w1 l3 E2

th1 w2 l3 E2

th1 w1 l3 E2

th1 w2 l2 E2

th1 w1 l2 E2

th1 w1

OPTIMIZATION

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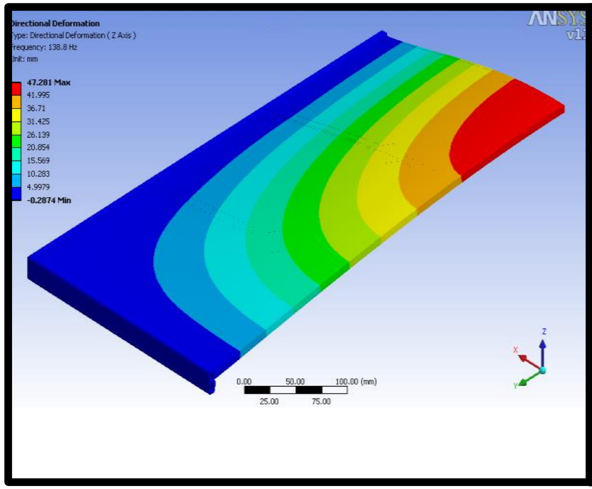
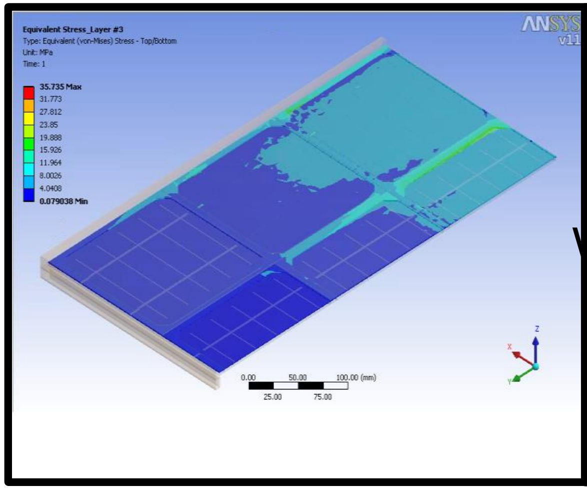
OPTIMIZATION

- **What we want to optimize**



Modal Analysis

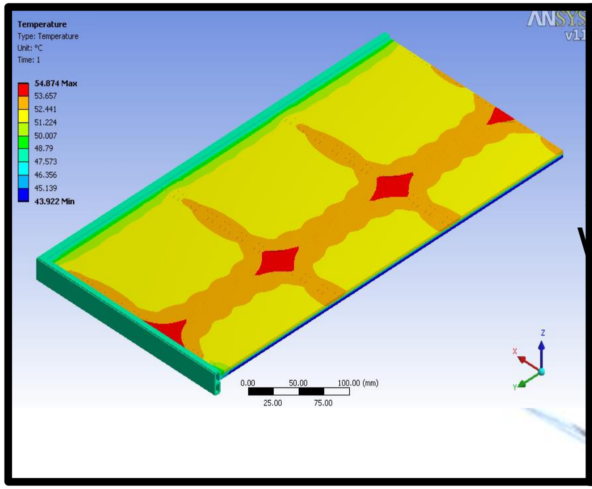
WE WANT TO **Increase frequency**



TEST REQUIREMENT

UL/ICE 400 Lb

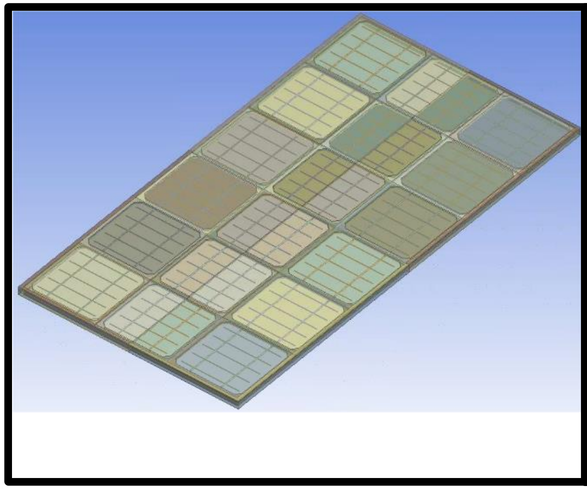
WE WANT TO **Reduce Max Displacement**



TEST REQUIREMENT

Thermal Cycling

WE WANT TO **Reduce Max Displacement**



Geometry

WE WANT TO **Increase Area**

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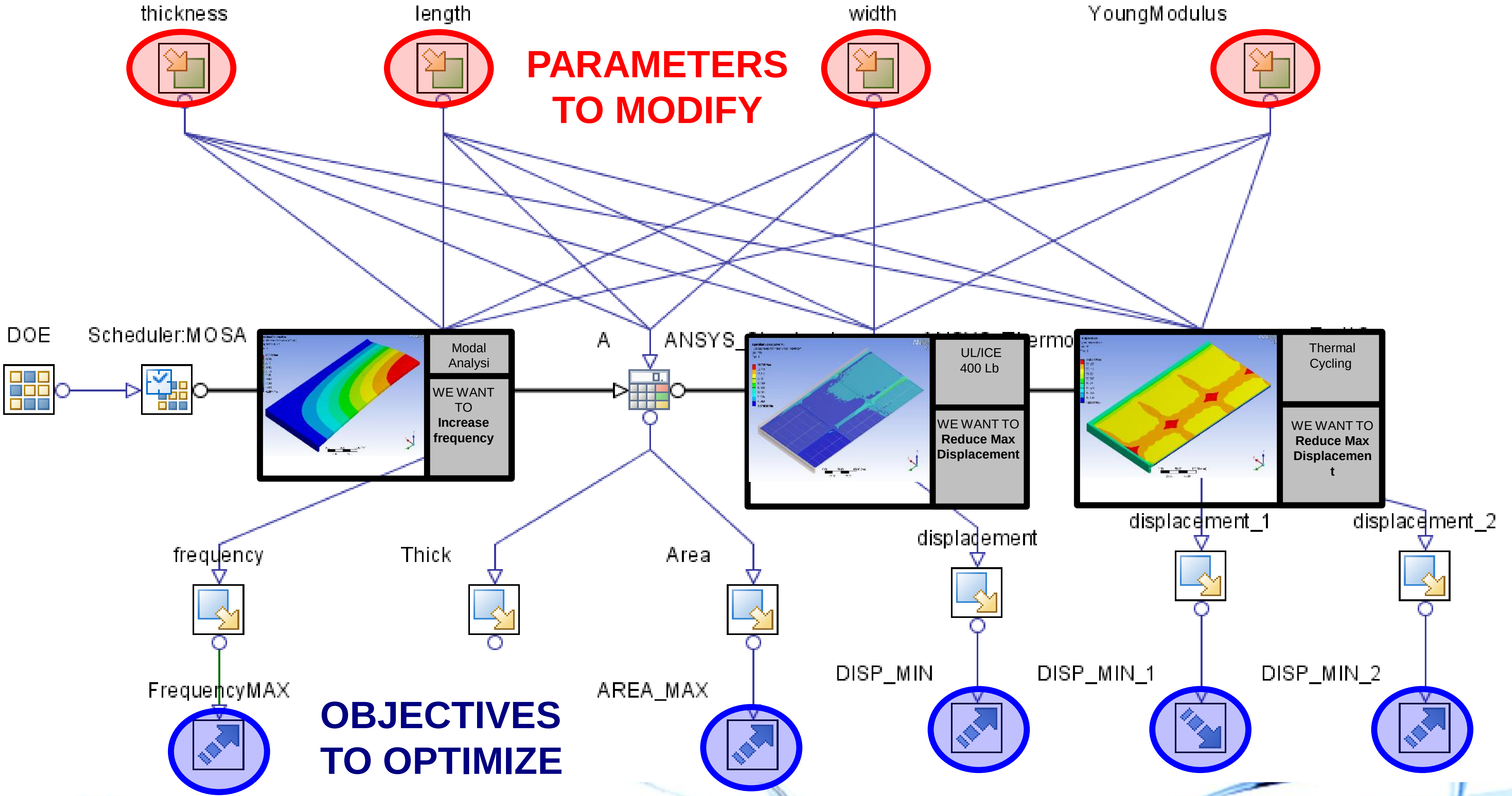
OPTIMIZATION

- **How to optimize a design?...**



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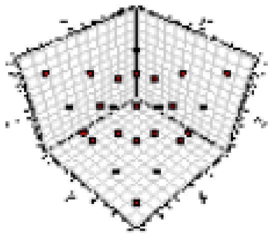
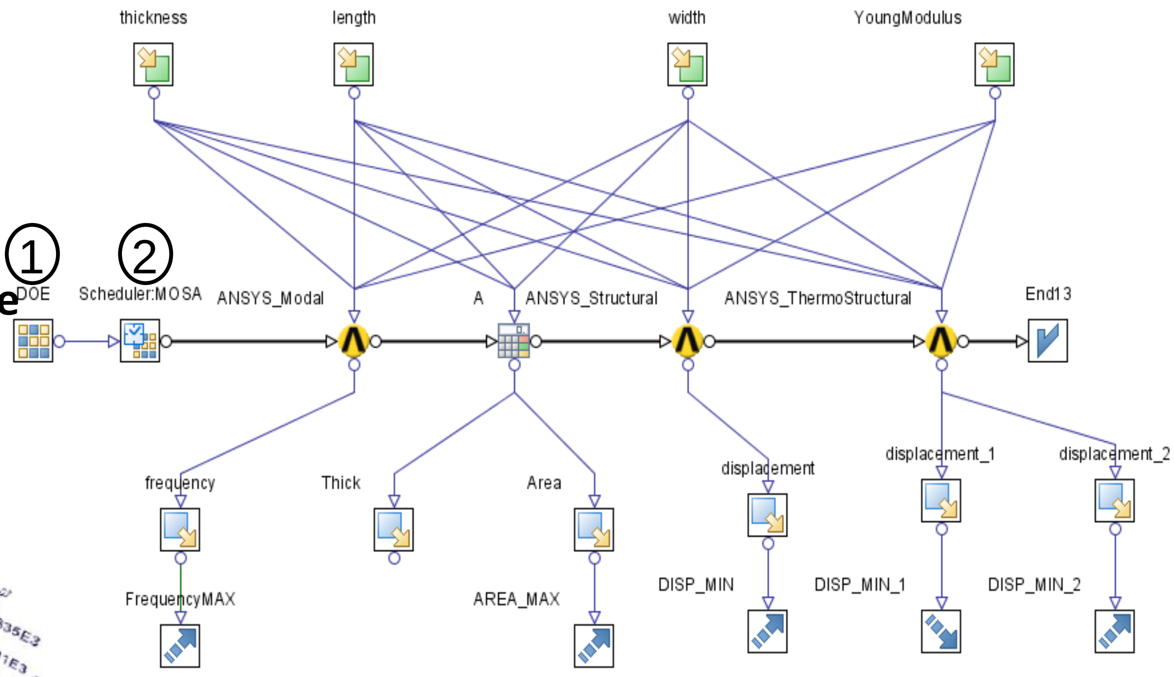
OPTIMIZATION

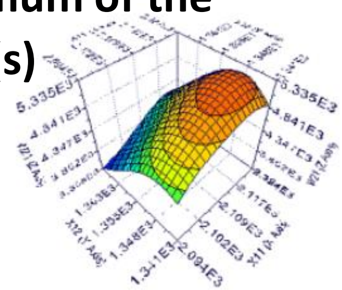
- **What does optimization do?**

1) Optimization performs a Design of Experiments (DOE)



2) Optimization starting from the data acquired from the DOE explore all the domain of the parameters searching the maximum or minimum of the objective function(s)





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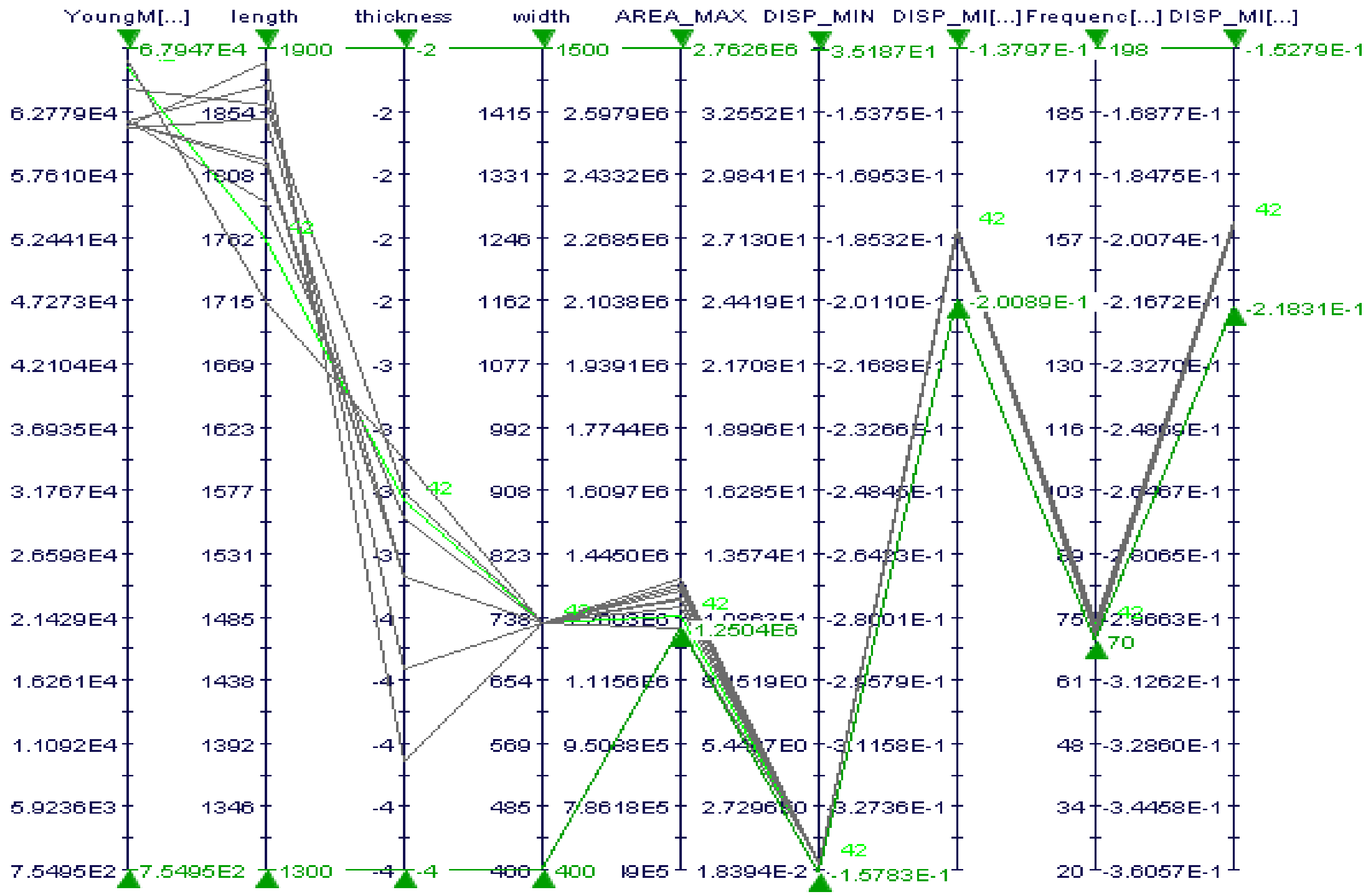
OPTIMIZATION

- **What does optimization give?**

Basically optimization gives several different combinations of the parameters we chose to optimise...

...among them there is/are the best one(s)!



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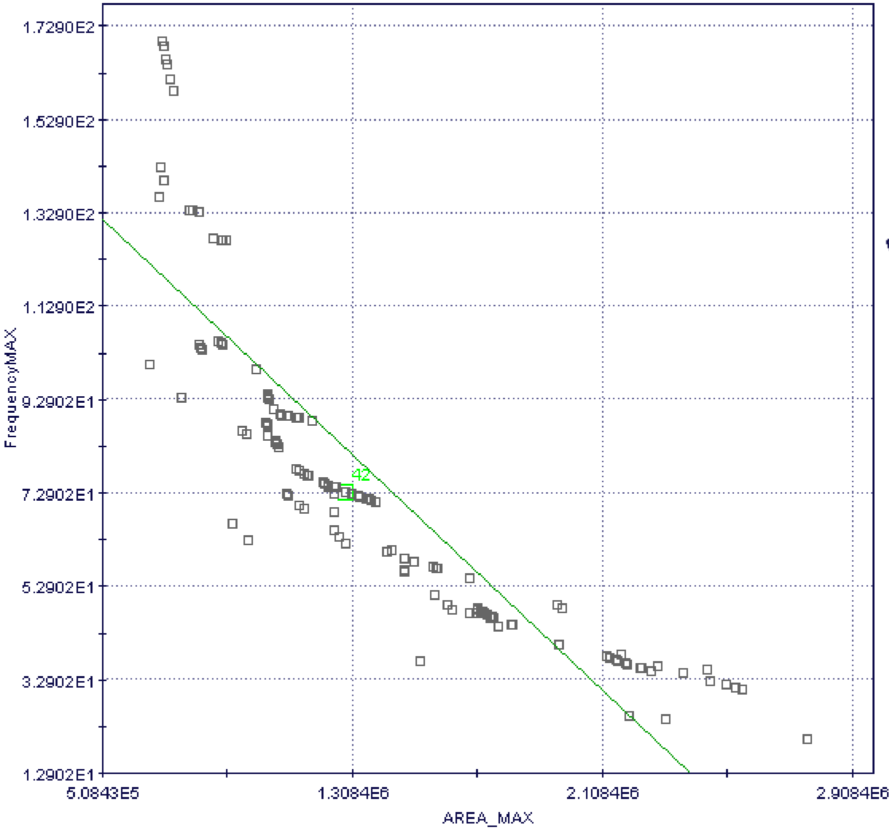
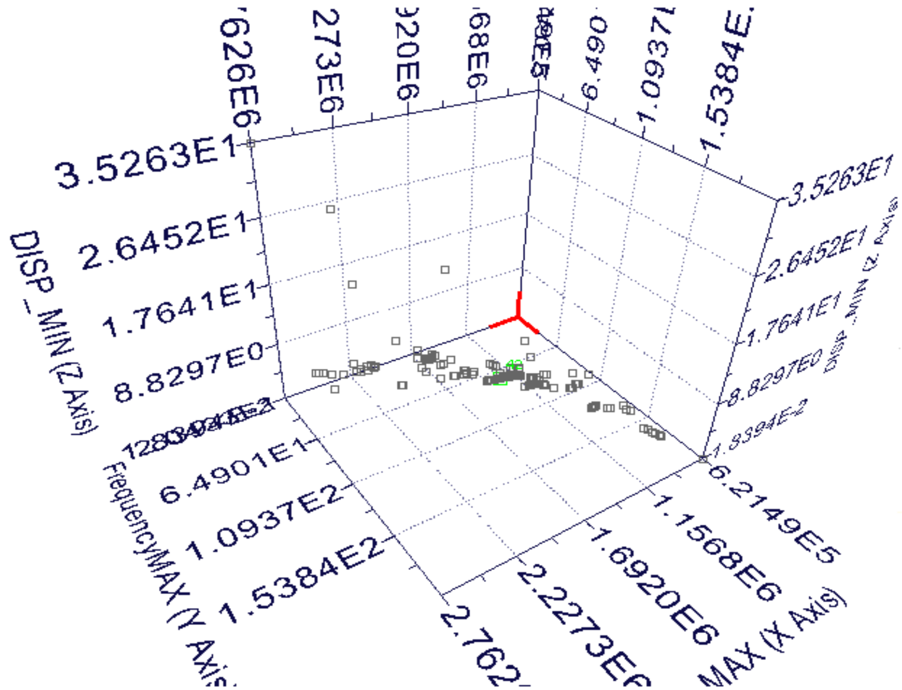
OPTIMIZATION

- **How can we choose the best solution(s)?**





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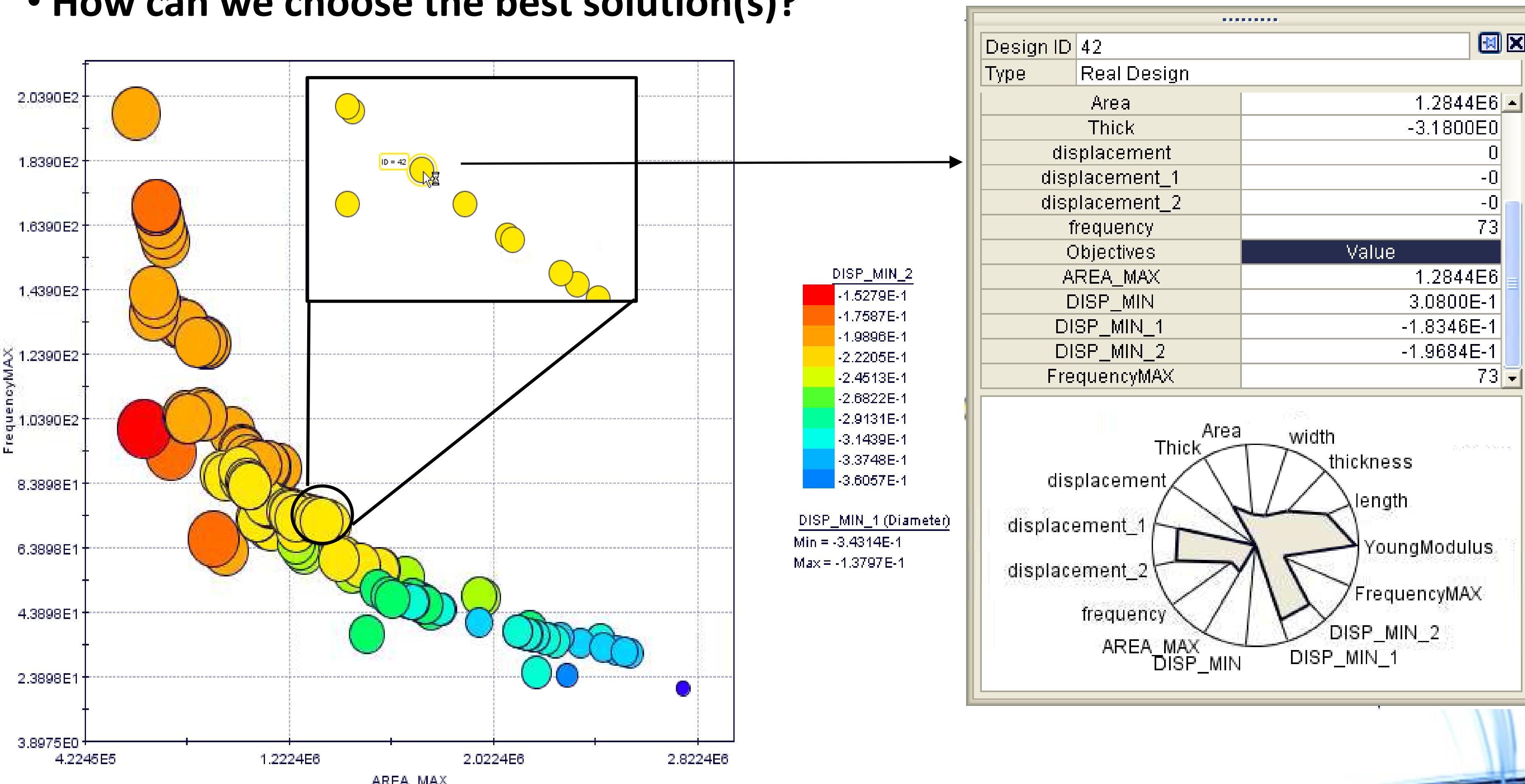
OPTIMIZATION

- **How can we choose the best solution(s)?**



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OPTIMIZATION

- **Improvement after optimisation**

Original Parameter Value	Optimised Parameter Value	%
(Area) 1,244 m^2	(Area) 1,284 m^2	3.2
(Frequency) 70 Hz	(Frequency) 73 Hz	4.3
(Displacement_1) 0,42 mm	(Displacement_1) 0,31 mm	35.5
(Displacement_2) -0,19 mm	(Displacement_2) -0,18 mm	5.5
(Displacement_3) -0,20 mm	(Displacement_3) -0,19 mm	5.0

WARNING

This test case optimisation has taken into account only 4 geometric parameters to improve the mechanical robustness of solar panel BUT several different parameters can also be optimise simultaneously to improve, for instance, the thermal efficiency and/or the electric performance and everything else the designers need to improve.

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MAGAZINE ARTICLES

ENERGY

HOT STUFF

NEM reduces cost and improves efficiency for concentrated solar power generation.

By Ingmar van Dijk, Solar Team, NEM Energy b.v., Leiden, The Netherlands

Power tower research facility in Spain where NEM tests its heliostats PHOTO CREDIT: © PLATAFORMA SOLAR DE ALMERIA / CIEMAT.

Advanced technology is playing an important role as the world looks for efficient and cost-effective sources of energy. Solar energy generation is growing, especially in sunny areas such as Africa, the Middle East, the Mediterranean and the southwestern United States. Photovoltaic (PV) energy has been a long-time leader in this field, but concentrated solar power (CSP) systems (which use mirrors or lenses to concentrate a large area of sunlight onto a small area to drive a heat engine connected to an electrical power generator) have been around for a long time and have now started to pick up steam. The U.S. Department of Energy (DOE) has offered roughly $5.89 billion in loans to four CSP projects, an amount greater than what it has offered to developers of photovoltaic projects[1].

CSP is experiencing rapid growth, with about 740 MW of global generating capacity added between 2007 and the end of 2010, bringing the total installed capability to 1,095 MW. NEM Energy b.v. is developing a power tower system type of CSP that uses a field of sun-tracking mirrors called heliostats to concentrate light onto a receiver on top of a tower. The difference between CSP and the more widely known photovoltaic form of solar power is that PV converts sunlight directly to electricity using the photovoltaic effect, while in CSP, concentrated sunlight is converted to heat. The heat can be used to directly produce steam, or a heat-transfer fluid can be used to store some of the heat to provide a buffer so that steam can be produced after the sun goes down. The steam, in turn, is used in a conventional turbine generator to produce electricity.

A key design challenge for NEM is increasing the stiffness of the mirrors to put as much reflected light as possible onto the target, called a receiver, without paying a cost premium. The company uses ANSYS Mechanical software within the ANSYS Workbench environment to evaluate the stiffness of large numbers of heliostat design alternatives. The results are fed into a ray tracing program that determines the energy generated by the design. This makes it possible to determine the performance-to-cost ratio of each design alternative without having to build physical prototypes. NEM is one of the top five producers of steam-generating equipment in

A key design challenge for NEM is increasing the stiffness of the mirrors to put as much reflected light as possible onto the target without paying a cost premium.

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MAGAZINE ARTICLES

ENERGY: SOLAR

Blending Solar Panels with Roof Profiles

Simulation guides the design of innovative solar panel frames, reducing molding time, material and cost.

By Matthew Stein, President, Stein Design, California, U.S.A.

Open Energy SolarSave® panels are designed to integrate and interweave with standard roofing tiles so as to blend in with the roof profile and color.

One of the most efficient sources of renewable energy is rooftop photovoltaic (PV) solar cells, which convert sunlight into electricity for homes and business. Use is hampered, however, by high upfront costs as well as aesthetics, with most solar panels mounted on unattractive brackets that do not blend well with house and building designs.

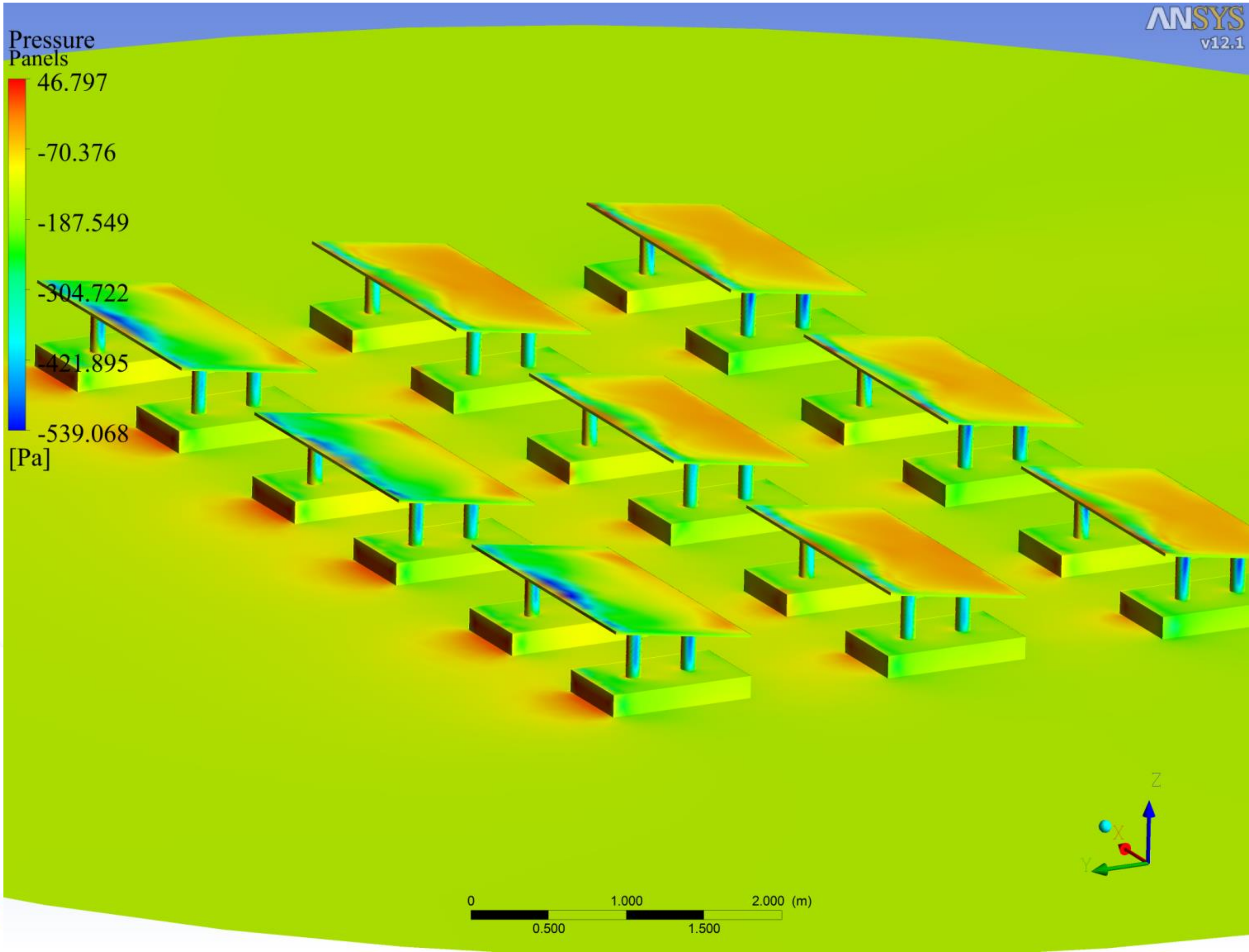
Open Energy Corp. of Solona Beach, California, has overcome these drawbacks with SolarSave® panels — a solar roof solution unlike anything previously available in the industry. Panels are designed to integrate and interweave with standard roofing tiles so as to blend in with the roof, an important consideration in subdivisions with strict homeowner bylaws pertaining to roof profiles and solar panel installations. These integrated panels are also cost-effective, as they are installed as tiling over part of the roof rather than as an add-on above traditional coverings. The lightweight panels are warranted for 25 years, are easily handled, and can be walked on, simplifying installation for roofing contractors and solar integrators.

Open Energy solar panels being installed

In their continuing efforts to improve the cost-effectiveness and performance of these solar panels, Open Energy commissioned Stein Design to complete a redesign of the panel with the goal of reducing unit cost while improving strength and reliability. The new design was to be a four-foot-long PV panel to replace existing three-foot models, cutting square-foot costs by reducing the number of electrical connections, related junction boxes and other hardware. Analysis work was done exclusively using ANSYS DesignSpace software.

Stein Design started the redesign by first evaluating the existing three-foot panel product. Three-dimensional solid CAD model assemblies were generated in SolidWorks® and then imported into the ANSYS DesignSpace tool to perform the stress analysis. Two load cases were considered: (1) a 300-pound per-square-foot pressure, satisfying at least 99 percent of structural building code requirements across the United States and Canada for snow loads; and (2) a 400-pound load concentrated in a three-inch-diameter area, representing a concentrated heel-load of an installer on the

DEMO CASE #3



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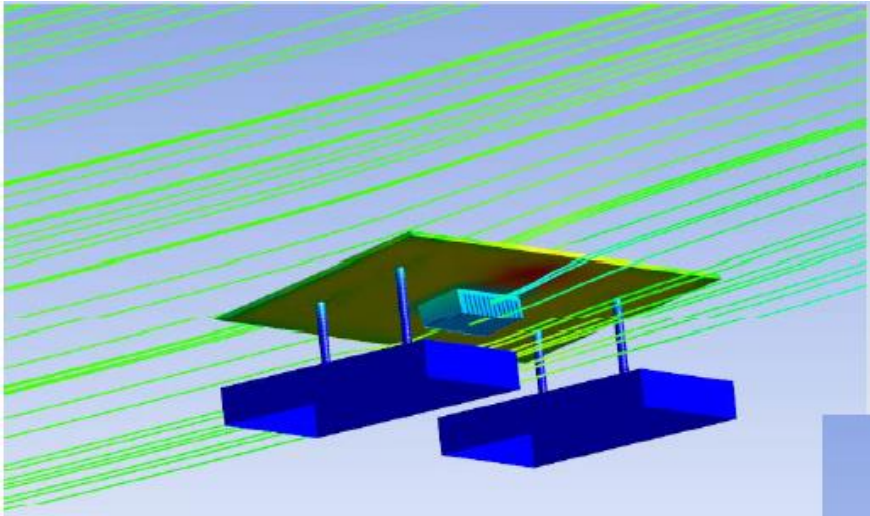
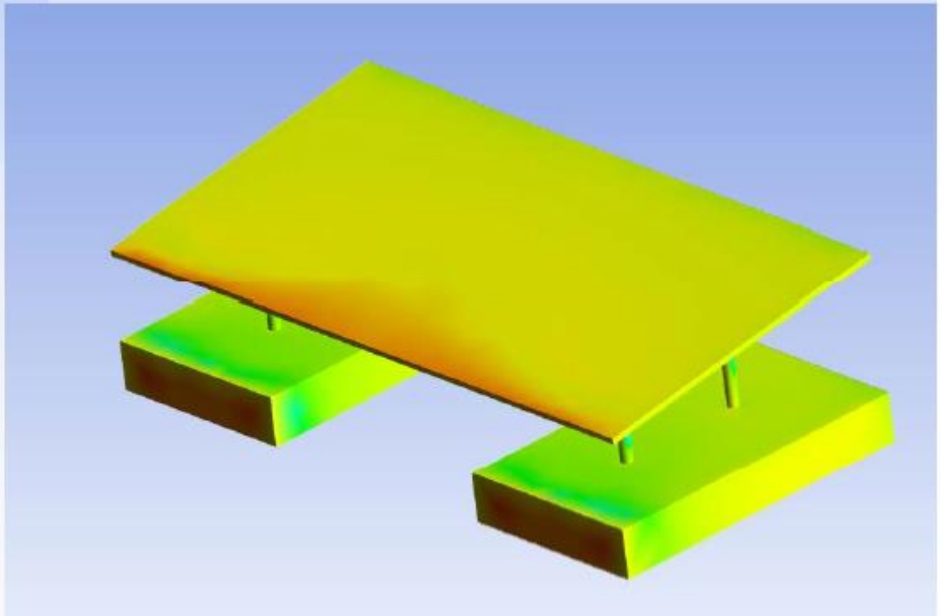
DEMO CASE #3

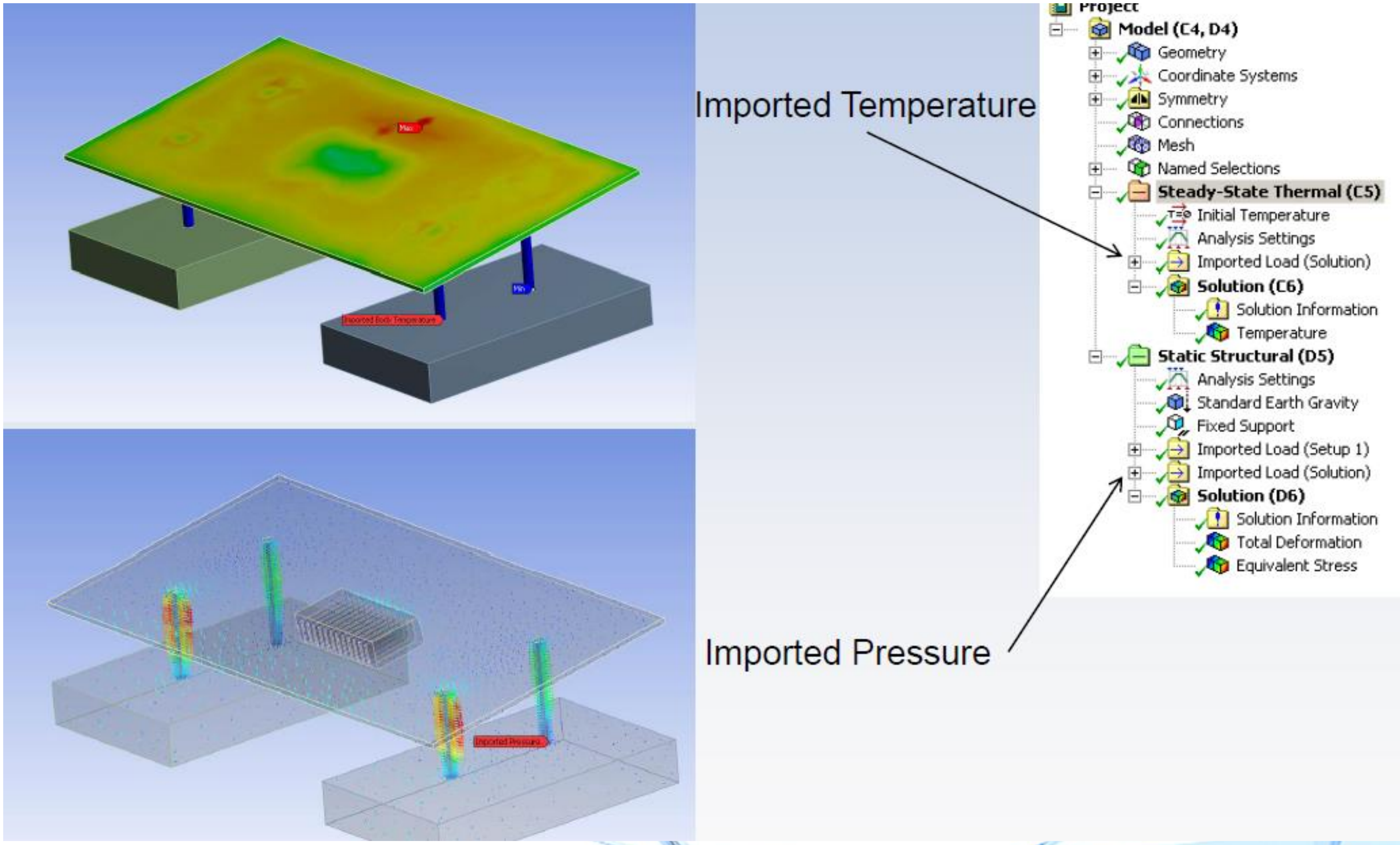


CHT temperature and streamlines

Pressure profile

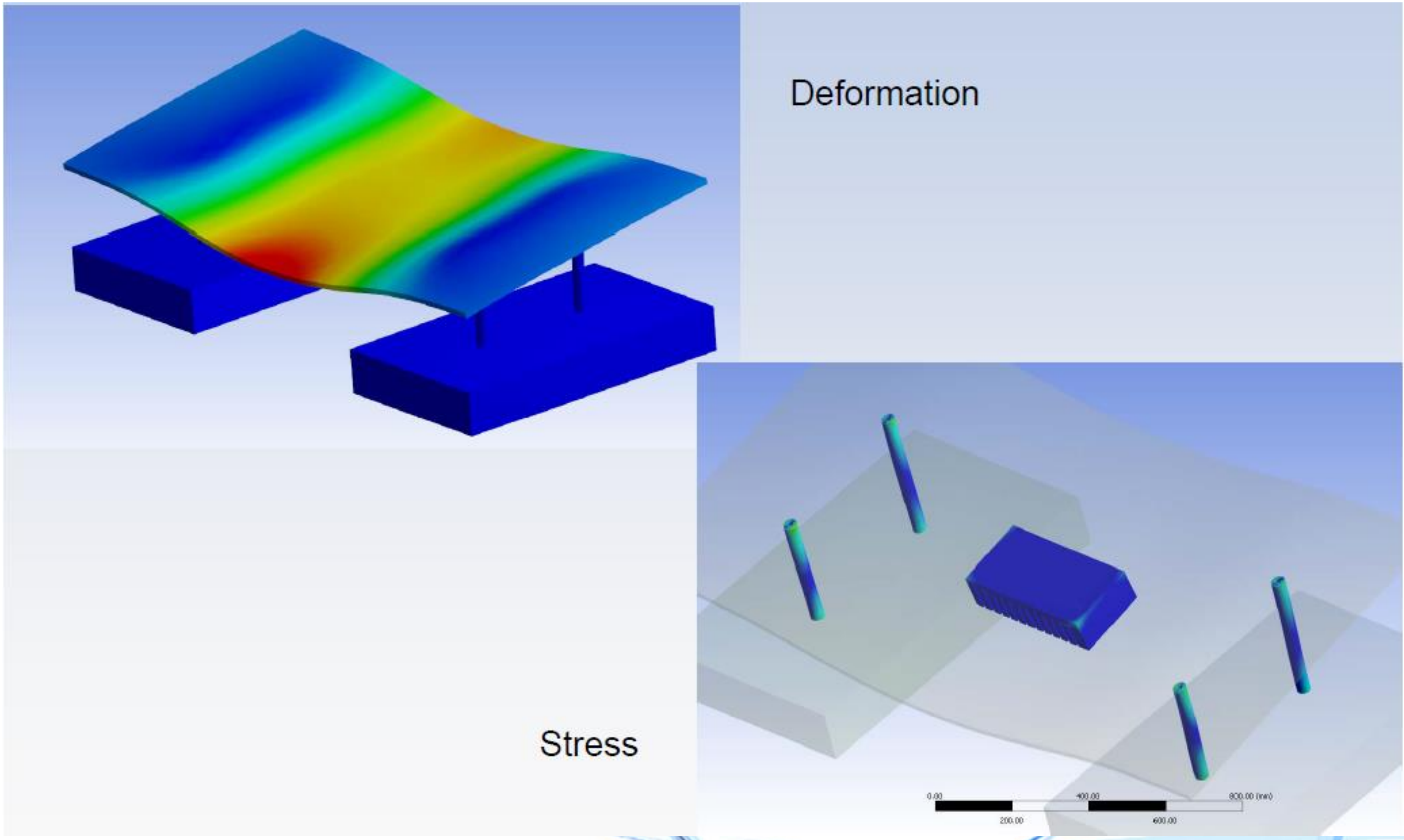


DEMO CASE #3



Imported Temperature
Imported Pressure
Project
Model (C4, D4)
Geometry
Coordinate Systems
Symmetry
Connections
Mesh
Named Selections
Steady-State Thermal (C5)
Initial Temperature
Analysis Settings
Imported Load (Solution)
Solution (C6)
Solution Information
Temperature
Static Structural (D5)
Analysis Settings
Standard Earth Gravity
Fixed Support
Imported Load (Setup 1)
Imported Load (Solution)
Solution (D6)
Solution Information
Total Deformation
Equivalent Stress

DEMO CASE #3



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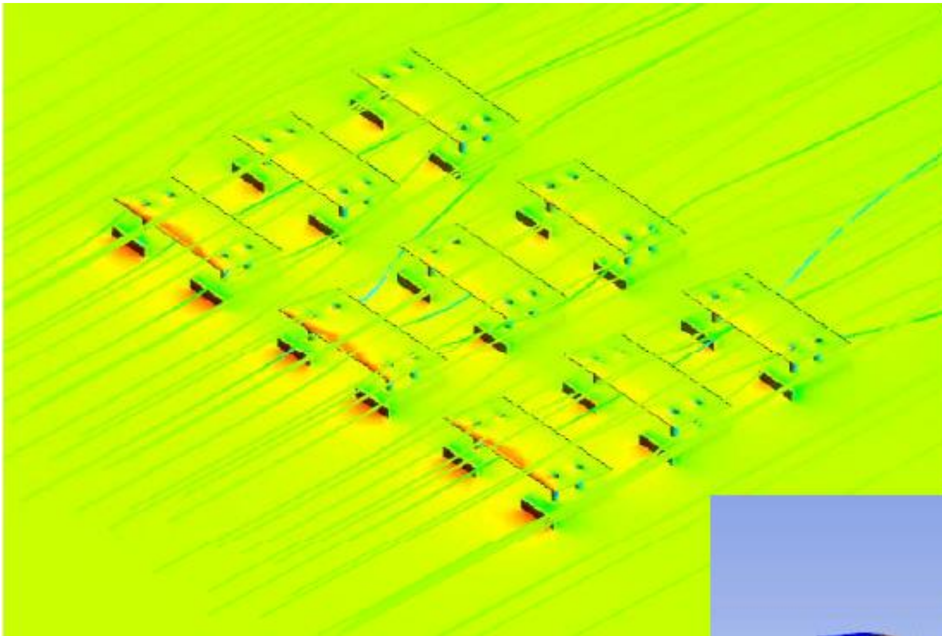
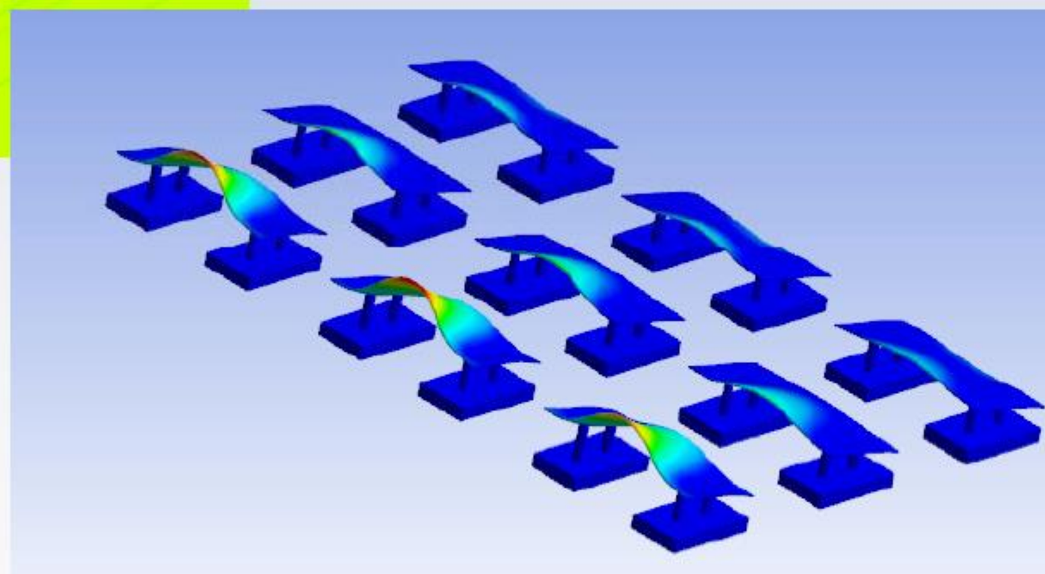
DEMO CASE #3



Pressure and streamline



Wind induced deformation

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DEMO CASE #3

Outline of Schematic H2: Design of Experiments

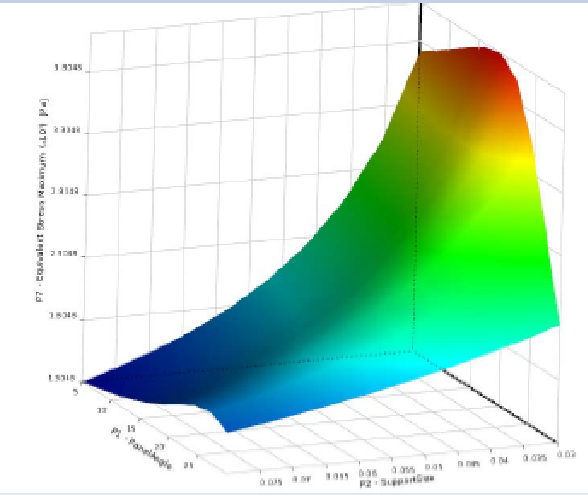
	A	B
1		Enabled
2	⊟ Design of Experiments	
3	⊟ Input Parameters	
4	P1 - PanelAngle	☑
5	P2 - SupportSize	☑
6	P3 - AirSpeed	☑
7	P4 - HeatLoad	☑
8	⊟ Output Parameters	
9	P5 - Temperature Maximum	
10	P6 - Total Deformation Maximum	
11	P7 - Equivalent Stress Maximum	
12	⊟ Charts	
13	Parameters Parallel	
14	Design Points vs Parameter	

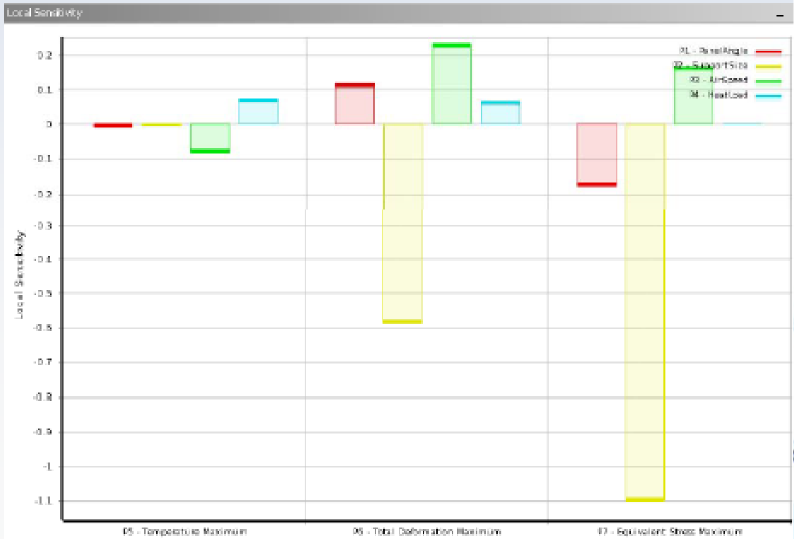
Properties of Schematic H2: Design of Experiments

	A	B
1	Property	Value
2	⊟ Design Points	
3	Preserve Design Points After DX Run	☐
4	⊟ Design of Experiments	
5	Design of Experiments Type	Central Com...
6	Design Type	Auto Defined

Table of Schematic H2: Design of Experiments

	A	B	C
1	Name	P1 - PanelAngle	P2 - SupportSize
2	1	17.5	0.055
3	2	5	0.055
4	3	30	0.055
5	4	17.5	0.03
6	5	17.5	0.08
7	6	17.5	0.055
8	7	17.5	0.055
9	8	17.5	0.055
10	9	17.5	0.055
11	10	8.6974	0.037395
12	11	26.303	0.037395
13	12	8.6974	0.072605
14	13	26.303	0.072605
15	14	8.6974	0.037395
16	15	26.303	0.037395
17	16	8.6974	0.072605
18	17	26.303	0.072605
19	18	8.6974	0.037395
20	19	26.303	0.037395
21	20	8.6974	0.072605
22	21	26.303	0.072605
23	22	8.6974	0.037395
24	23	26.303	0.037395
25	24	8.6974	0.072605
26	25	26.303	0.072605





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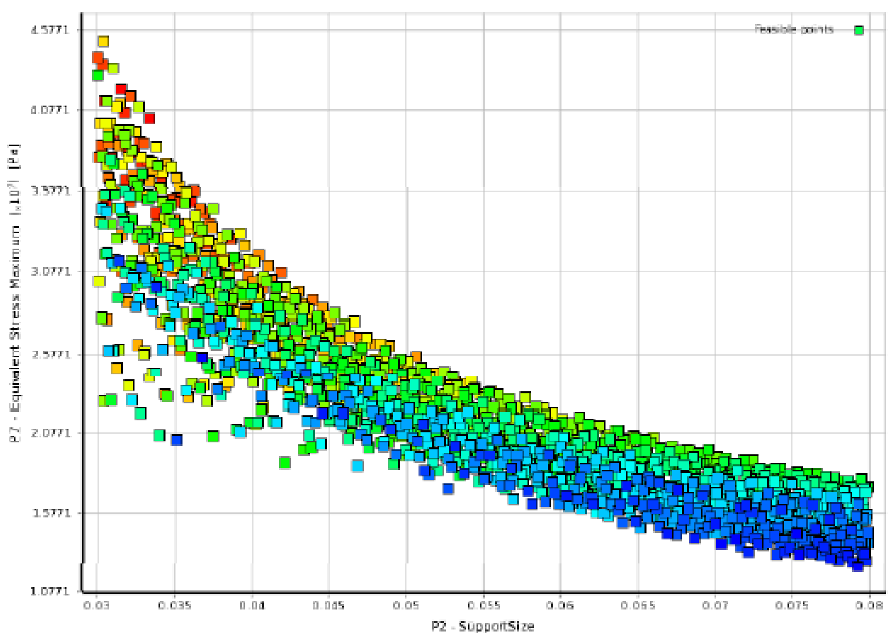
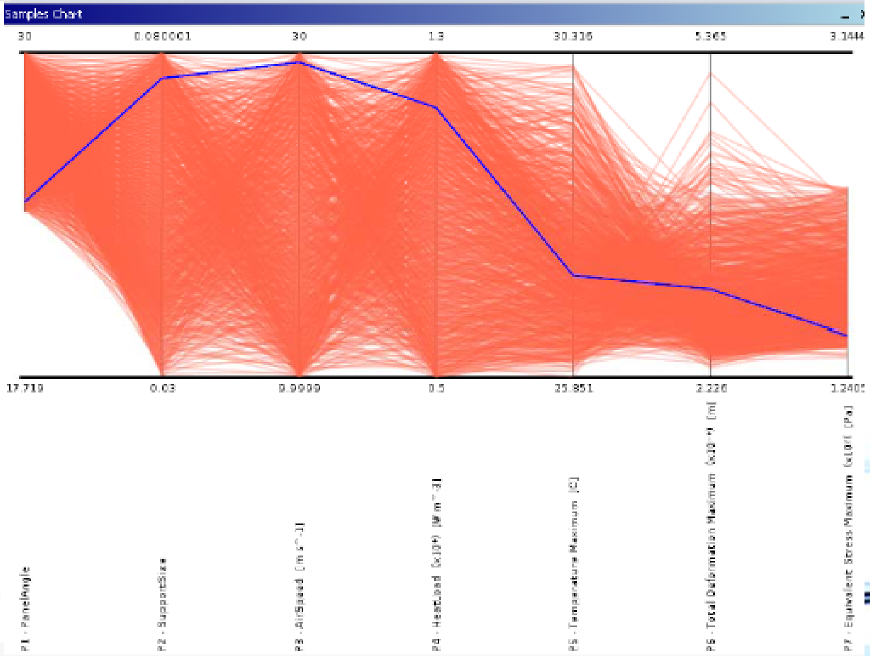
DEMO CASE #3

	P1 - PanelAngle	P2 - SupportSize	P3 - AirSpeed (m s^-1)	P4 - HeatLoad (W m^-3)	P5 - Temperature Maximum (C)	P6 - Total Deformation Maximum (m)	P7 - Equivalent Stress Maximum (Pa)
Optimization Study							
Objective	No Objective	No Objective	Maximize	No Objective	Maximize	No Objective	Minimize
Target Value							
Importance	Default	Default	Default	Default	Default	Default	Default
Candidate Points							
Candidate A	13.994	0.077522	29.237	12557	27.336	0.00029771	1.5193E+07
Candidate B	15.794	0.078987	29.603	10713	27.025	0.00030232	1.5294E+07
Candidate C	18.494	0.076131	29.383	11635	27.234	0.0003072	1.655E+07





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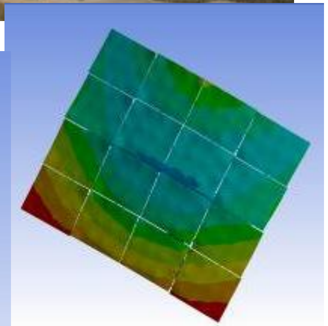
ANSYS IN ENERGY

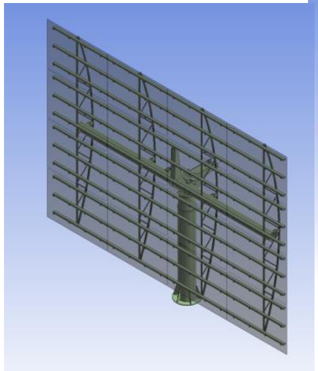
Problem

Increase the stiffness of the mirrors for a concentrated solar power system so that as much reflected light as possible is directed onto the target.

Solution

- Use ANSYS Workbench to automatically add more than 1,000 contacts using a 5 mm tolerance value.
- Employ ANSYS Mechanical plastic deformation calculations on small sections of the model to account for permanent deformations of the structure.
- Use ANSYS Parametric Design Language (APDL) command snippets to evaluate the model at different angles and wind speeds as part of a batch process.





Result

Simulation helps NEM to quickly improve performance and reduce the cost of heliostat designs.

"With simulation we can improve performance and reduce cost of our heliostat designs at a much faster pace than could be accomplished solely by building and testing prototypes."

Solar Team
NEM Energy b.v.

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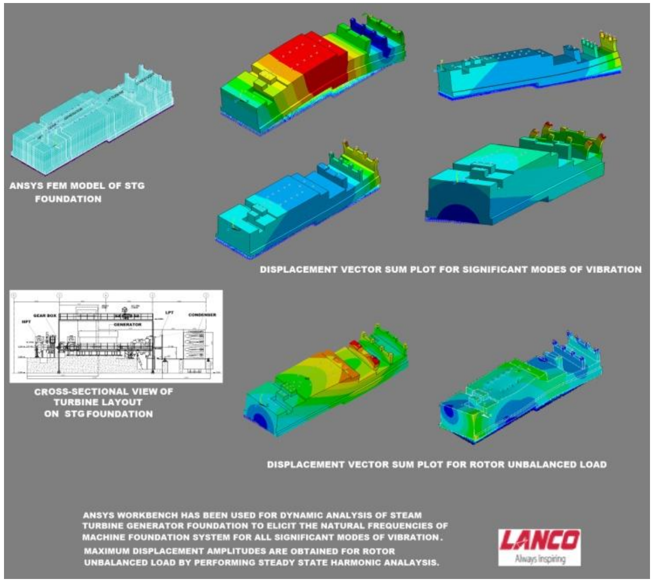
ANSYS IN ENERGY

Problem

Design the foundation for a concentrated solar thermal project with thermal storage facilities. The foundation must satisfy all the stringent design criteria stipulated by the equipment manufacturer on a tight project schedule and budget.



Solution

Use ANSYS Structural software to design a complex 3-D model of the foundation and perform dynamic analysis. The complete dynamic behaviour of the foundation was obtained using ANSYS software.

Using ANSYS, the design cycle time was reduced, resulting in higher efficiency and better manpower utilization.

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CONCLUSIONS

- Finite element analysis program can simulate almost all the physical phenomenon experienced during the solar panels operational life

- Numerical simulation focussed on process manufacturing can also be performed

- DesignXplorer can optimize all kind of parameter defining the solar panel or solar cell project, respecting all the constrains imposed by the designers

↓

Significant improvement of the efficiency and reliability of solar panels can be achieved by coupling <u>numerical simulations</u> and <u>optimization</u> techniques.

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THANK YOU FOR YOUR ATTENTION!

FOR FURTHER INFORMATION, PLEASE CONTACT:

OZEN ENGINEERING, INC.

1210 E. ARQUES AVE. SUITE: 207

SUNNYVALE, CA 94085

(408) 732-4665

info@ozeninc.com

www.ozeninc.com

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