

Robustness Evaluation of Mobile Phone Drop Test Simulation

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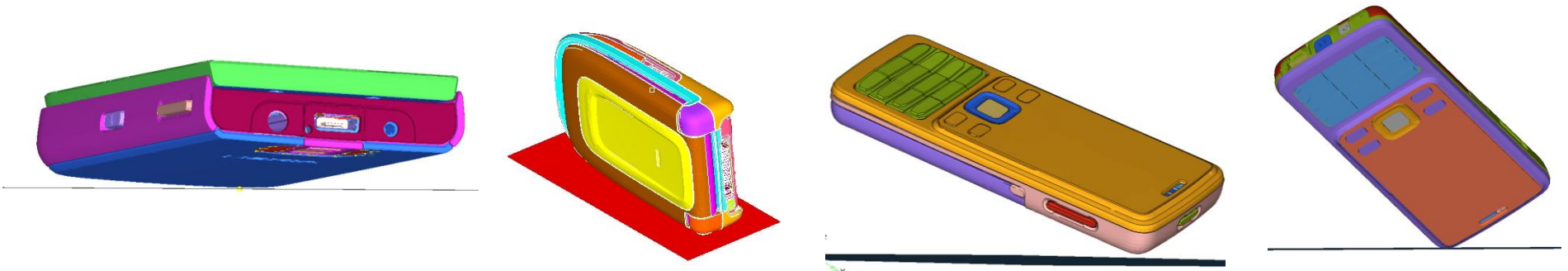
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Mechanical Requirements for Mobile Phones

- Nokia's technical specification requires **very high mechanical reliability**
- Mechanical loads comprise **drop, bend, twist, impact of hard objects** and others
- One of the hardest requirements: No failure in **repeated, randomly oriented drops on a hard floor.**

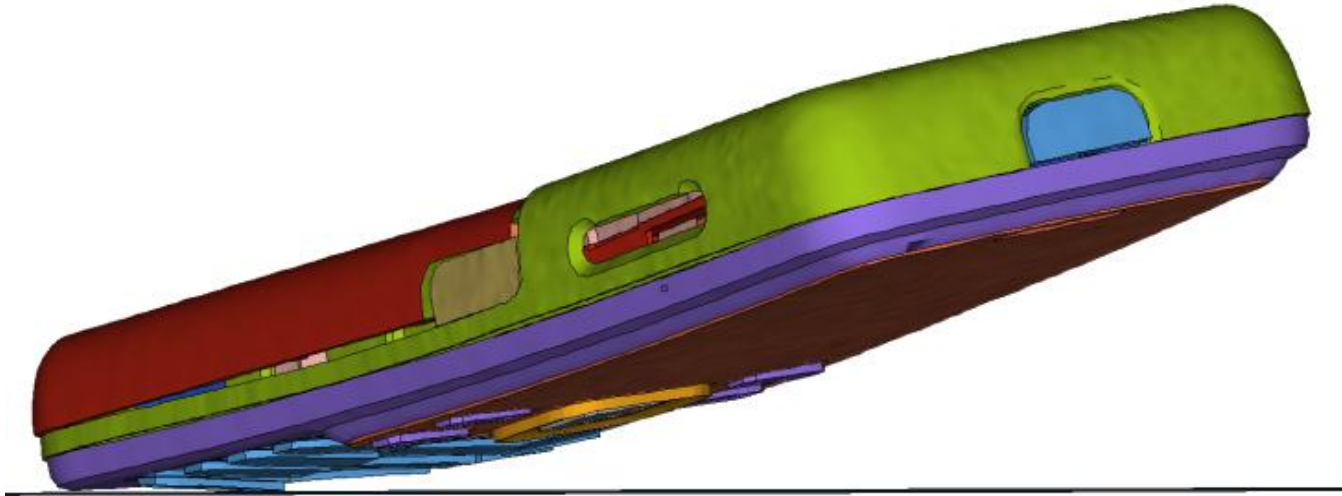
Most sensitive components: display and printed wiring board (PWB)+soldered parts

- **Impact orientation is randomly distributed**
→ *difference to car crash simulation*, where impact direction is defined by legal regulations.
- At Nokia, mechanical simulation is applied widely to support early design process



Challenges in Drop Test Simulation

- **Stress results** in components are **very sensitive to the drop orientation**
- Generally the **drop on a corner** with 2 or more subsequential impacts ("clattering") leads to **maximum stresses**
- For different drop orientations **strongly non-linear variation of results** due to different contact histories which are sensitive to small angle changes
- **Geometric and material non-linearities** to be considered additionally



Robustness Evaluation for Varying Drop Orientation

Two important questions to answer:

How to find the design-relevant drop orientation (worst case) ?

How to verify that proposed design improvements for one impact direction lead to allowed loadings for arbitrary impact orientations as well?

Step 1: Numerical **sensitivity analysis** with OptiSlang:

- Determine "worst case" drop test orientation for each output variable.
- Evaluate most efficient optimisation variables and optimisation potential

Step 2:

- Find design modifications to comply with failure criteria
- Verify robustness of these modifications against deviations of the drop orientation by simulation-based optimisation

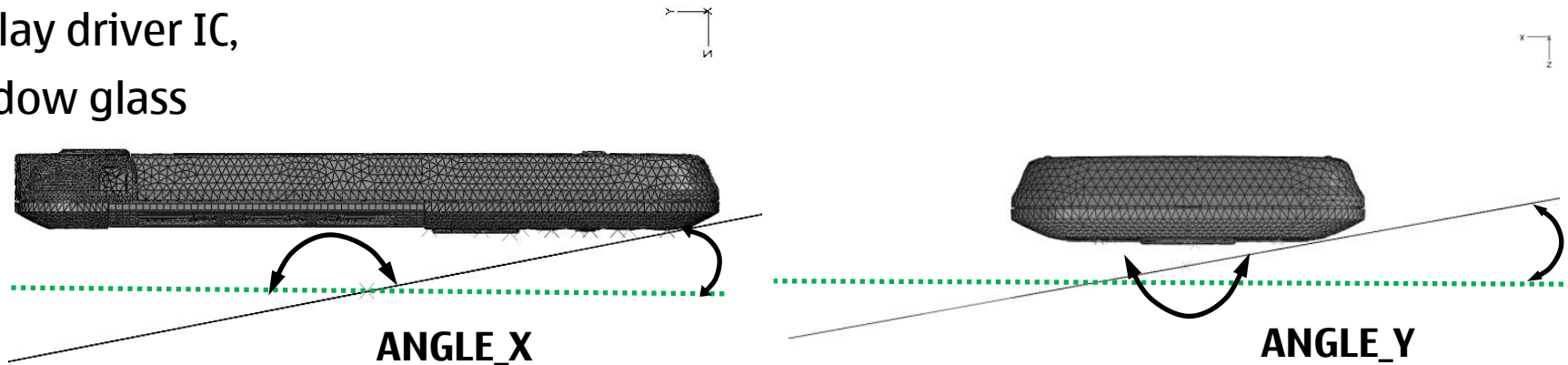
Step3:

- Evaluate robustness of the solution against material scatter and production tolerances
With the estimation of scatter, safety margins can be extracted and implemented in the deterministic design process to ensure robust structures.

Step 1:

Sensitivity Analysis for the Drop Orientation

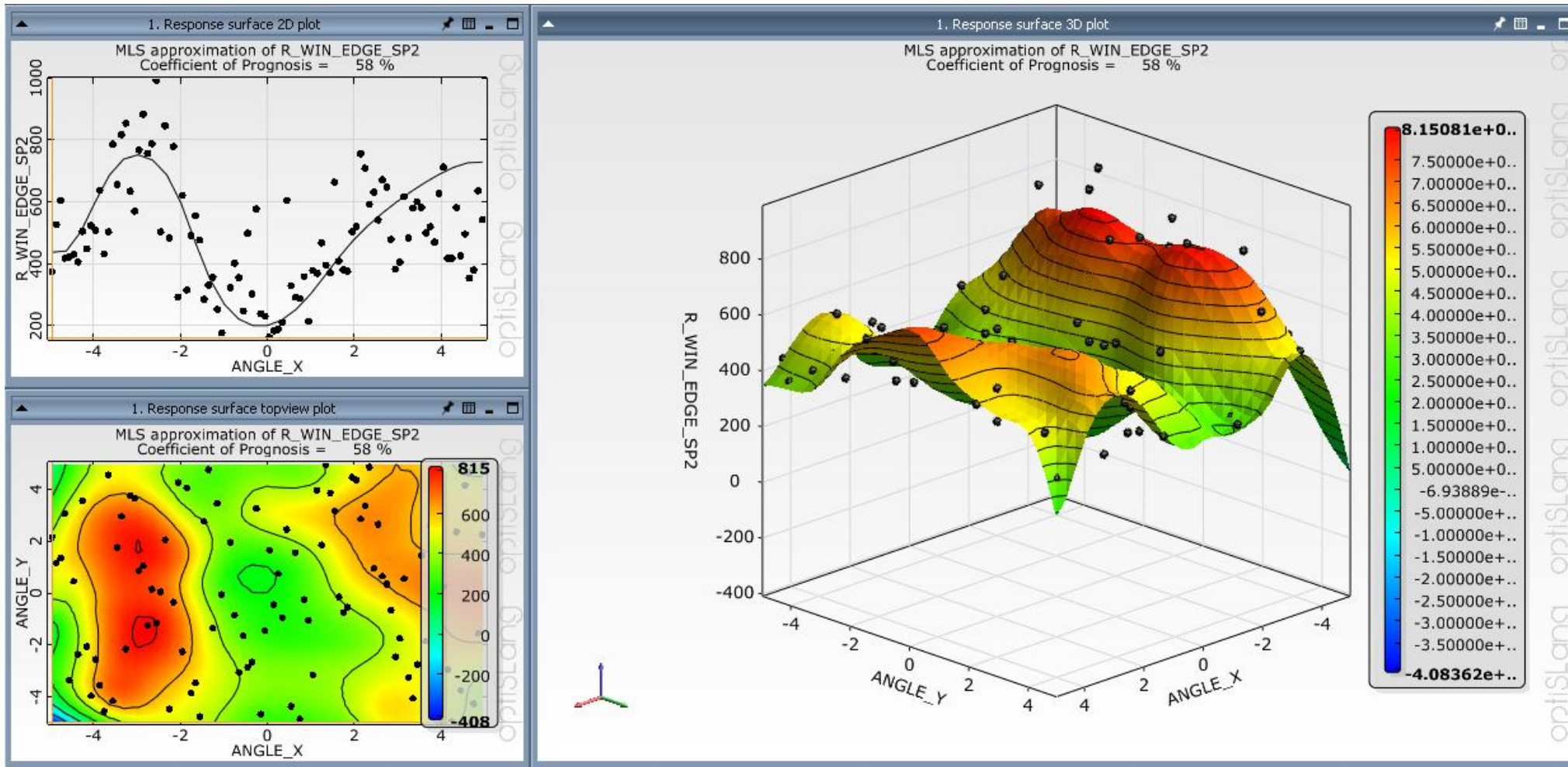
- Interesting for sensitivity and robustness study: **influence of drop orientation** to the mechanical loads on phone components
- Investigated load case: **horizontal position with small inclination**
- **The sensitivity to geometric and material parameters is lower than that to drop orientation angles**
- **Input parameters** for this work: **2 angles** which define the drop orientation
- **Output parameters: Stress results** in
 - display glass,
 - display driver IC,
 - window glass



Examples for Results

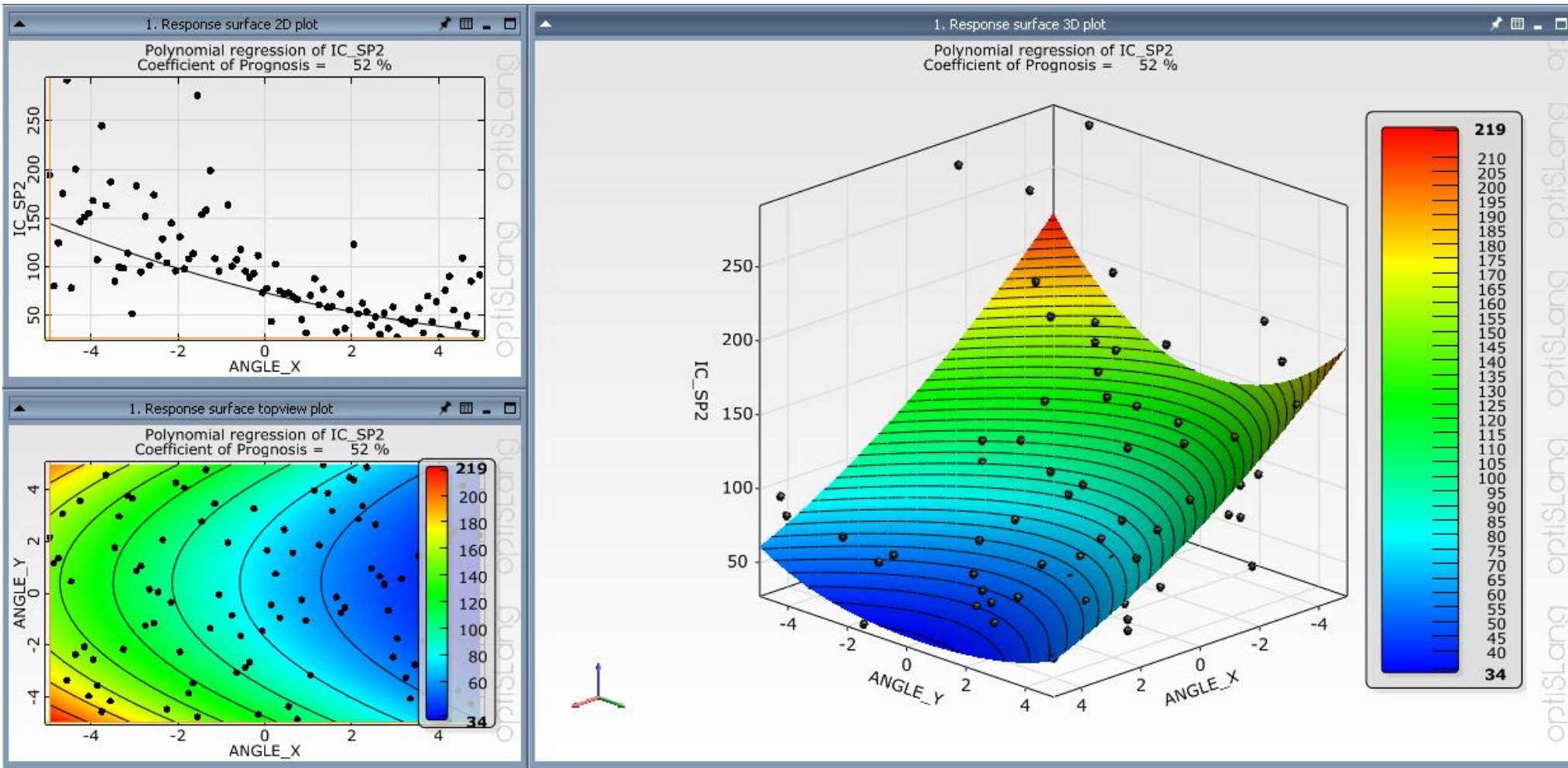
- Pictures in previous pages were examples for existing products.
- The following results are from a new product which was not yet published – no design pictures can be shown here.
- The results represent a very early development stage where many modifications are ongoing.

Example for Result: Stress at Glass Window Edge



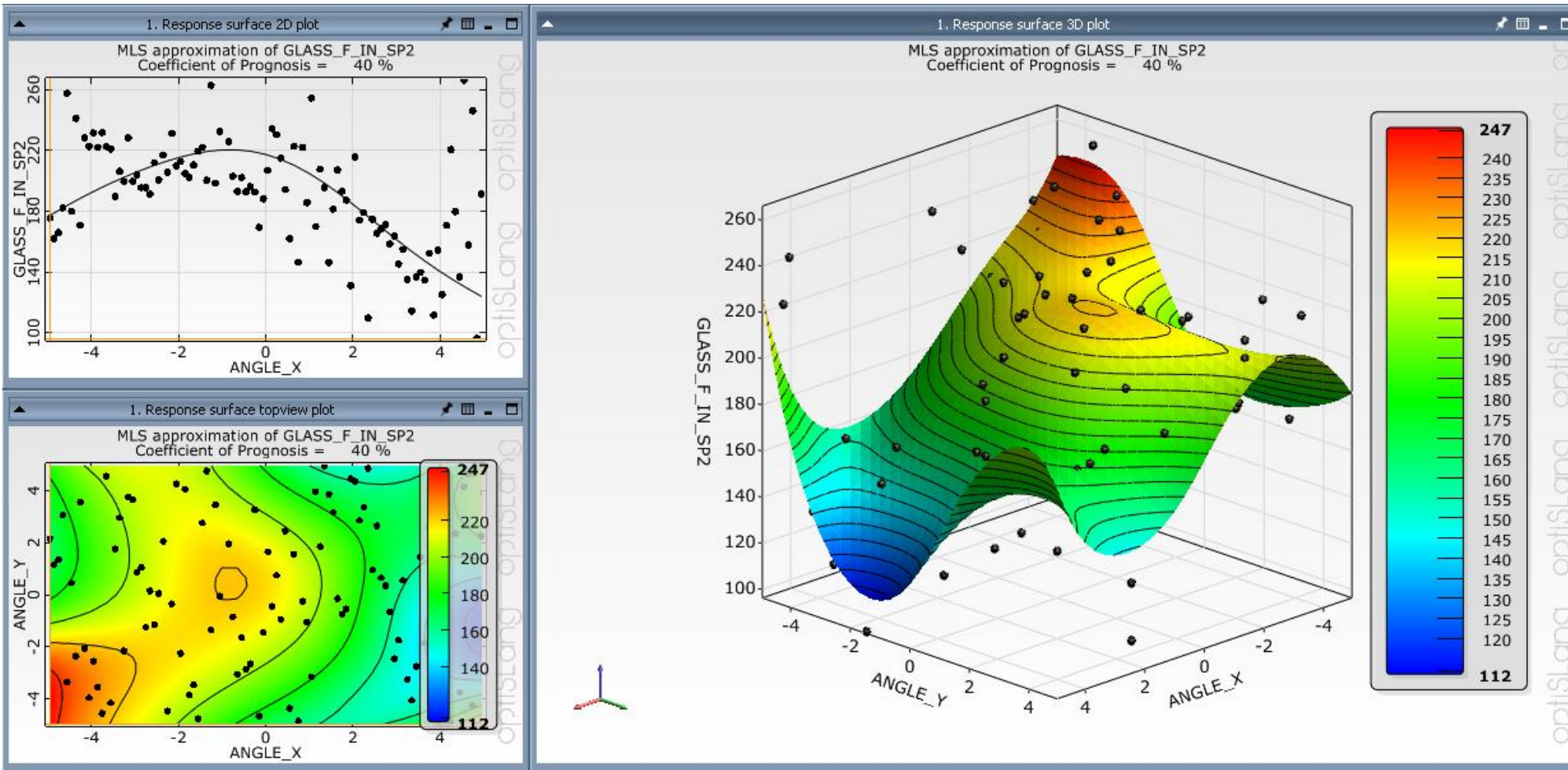
Conclusion: Horizontal position ($0^\circ, 0^\circ$) is less critical than impact on corners.
Investigate possible modifications to decrease stress peaks for $\text{ANGLE_X} = -3^\circ$.

Example for Result: Stress in Display Driver IC



Conclusion: Extension of angle range is required to identify worst case orientation.

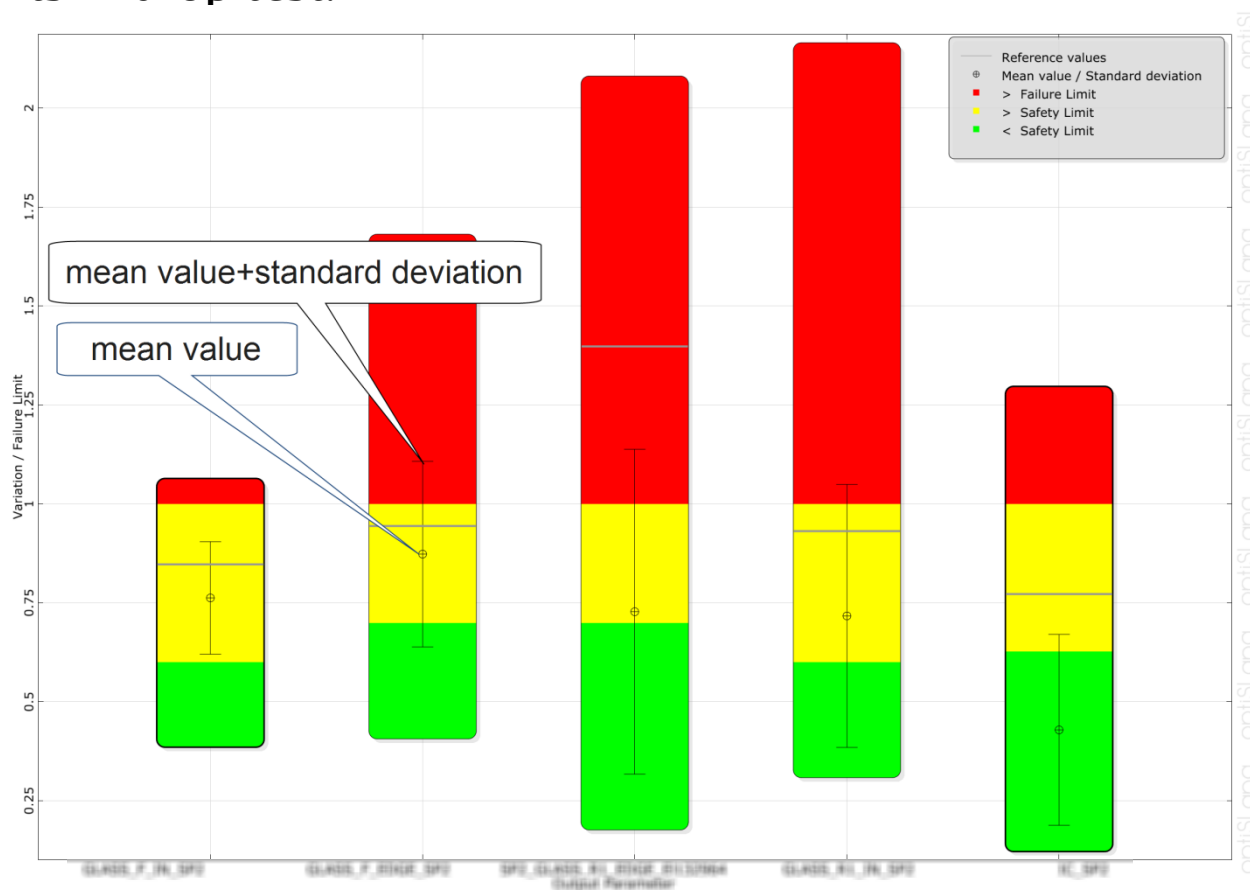
Example for Result: Stress in Display Glass



Conclusion: Extension of angle range is required to identify worst case orientation. Investigate possible modifications to decrease stress for orientations around $(-4^\circ, -4^\circ)$.

Traffic Light Plot (new in OptiSlang 3.2.0)

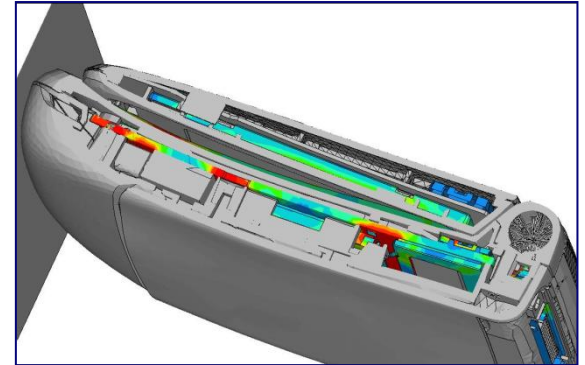
Compare selected output parameters to safety limits (yellow) and failure limits (red). Due to the random character of the drop orientation also the *range* [mean value + standard deviation] is a criterion to evaluate the risks to exceed failure limits in drop test.



Conclusions from step 1 (sensitivity analysis)

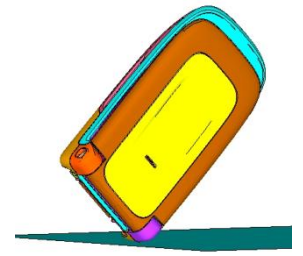
- **The angle range should be increased** to capture all critical drop orientations
- Some **"worst-case-orientations" were found**, these orientations for maximum stress results are hardly to predict on the basis of theory or engineering experience.
- **Strongly non-linear character of results**, Coefficients of Prognosis are relatively low due to steep result peaks which are randomly distributed. Result animations of the samples with the maximum stress deliver plausible pictures.

Next steps (Modification and Robustness Analysis)



- Implement structural modifications to decrease stress levels for worst-case orientations
- Evaluate robustness of the modifications by use of OptiSlang

Summary



- The design-relevant impact direction for drop simulation is unknown - sensitivity analysis is an appropriate and efficient tool to identify worst-case orientations.
- The stochastic approach for load case definition ensures to cover risks much better than deterministic investigation – by dense coverage of the space of possible impact orientations.
- Important precondition: availability of powerful simulation hardware for parallel solving of explicit FEM simulations
- Very robust simulation models are required to get valid results.
- Future work will focus to develop sensitivity and robustness analyses as a standard for each product: criteria for validity of results, number of required samples, FEM model robustness must be defined.