



A Computational Strategy for Corrosion Mitigation and Prevention

*Julio Mendez, Siva Palani,
Vinod Upadhyay, Alan Rose,
and Keith Legg.*



Context



Testing (too long)

- Actual fielding – qualitatively, takes years, no control, little measurement/sensors
- Beach front– months, different month to month

Quicker Options (not realistic)

Accelerated aging: *Cyclic and Constant*



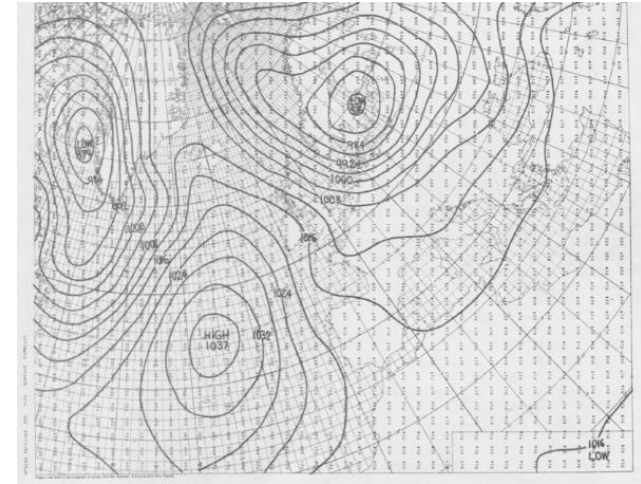
- Salt Fog Test ASTM B117
- ASTM G85, A2, A3, A5: Standard Practice for Modified Salt Spray (Fog) Testing
- ASTM D1735: Standard Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus
- GM9540/GMW 17872: Accelerated Corrosion Test
- SAE J2334: Laboratory cyclic Corrosion Test
- ISO 9227: Corrosion Tests in artificial atmospheres-Salt Spray Tests
- NACE SP108: Corrosion Control of Offshore Structures by Protective Coatings



Context



COMET Computer - 1965



Surface Pressure



Aurora Supercomputer -2023



High AoA configuration (CFD)

Solution

We need computers and computational models !

- We have access to computational frameworks, i.e: CFD
- We have numerical models (electrodynamics potential models).
- Commercial software have gone through intense V&V.
- The challenge for CFD modeling is the **boundary conditions = DATA !**

In other words, (mathematically speaking)

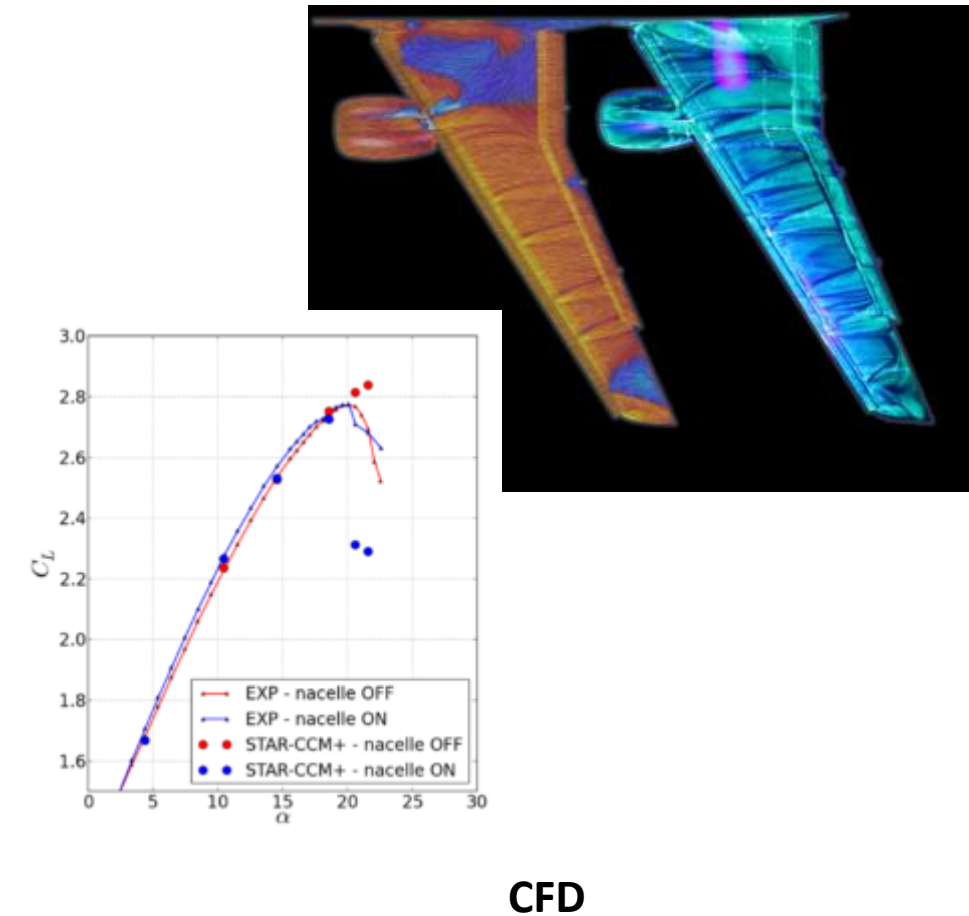
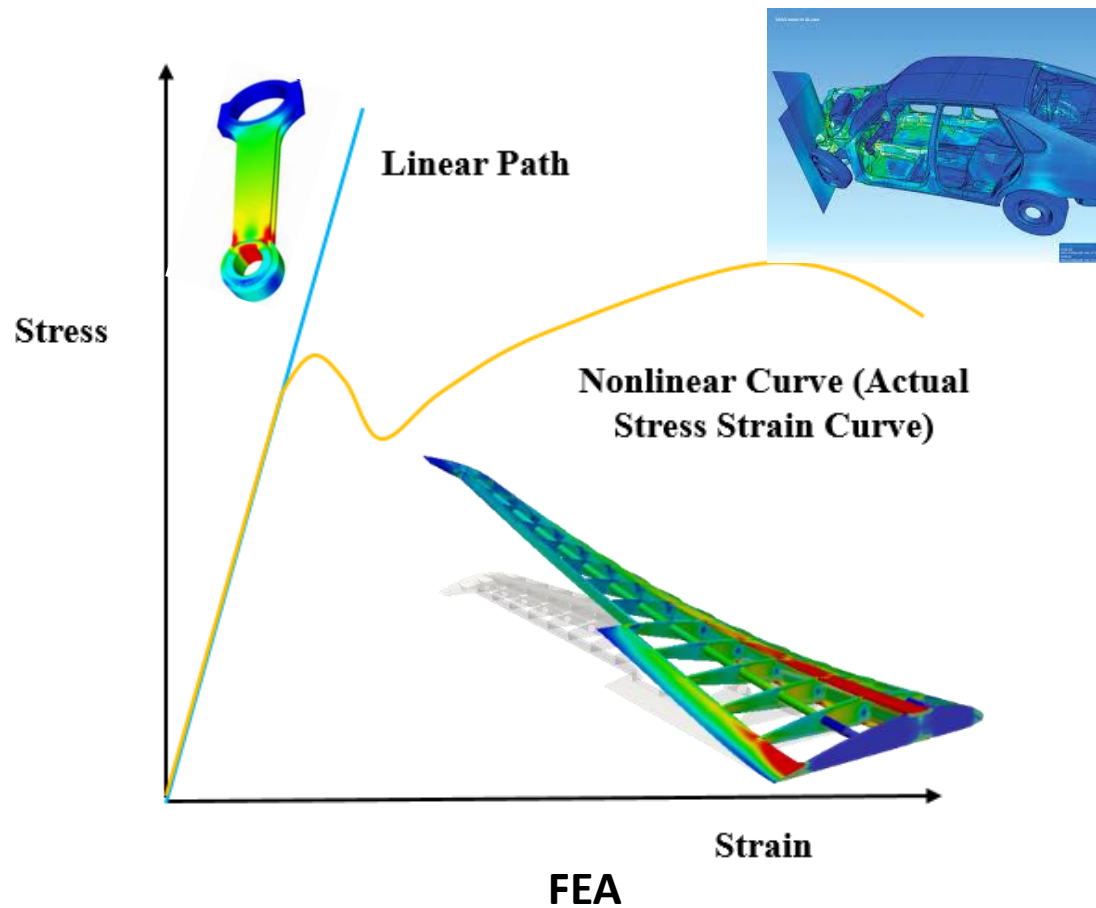
$$2 + 2 + 2 + 2 = 6$$

Not quite right, but almost there !

Solution

Why is it not 8 ?

1. Numerical models are useful but not perfect



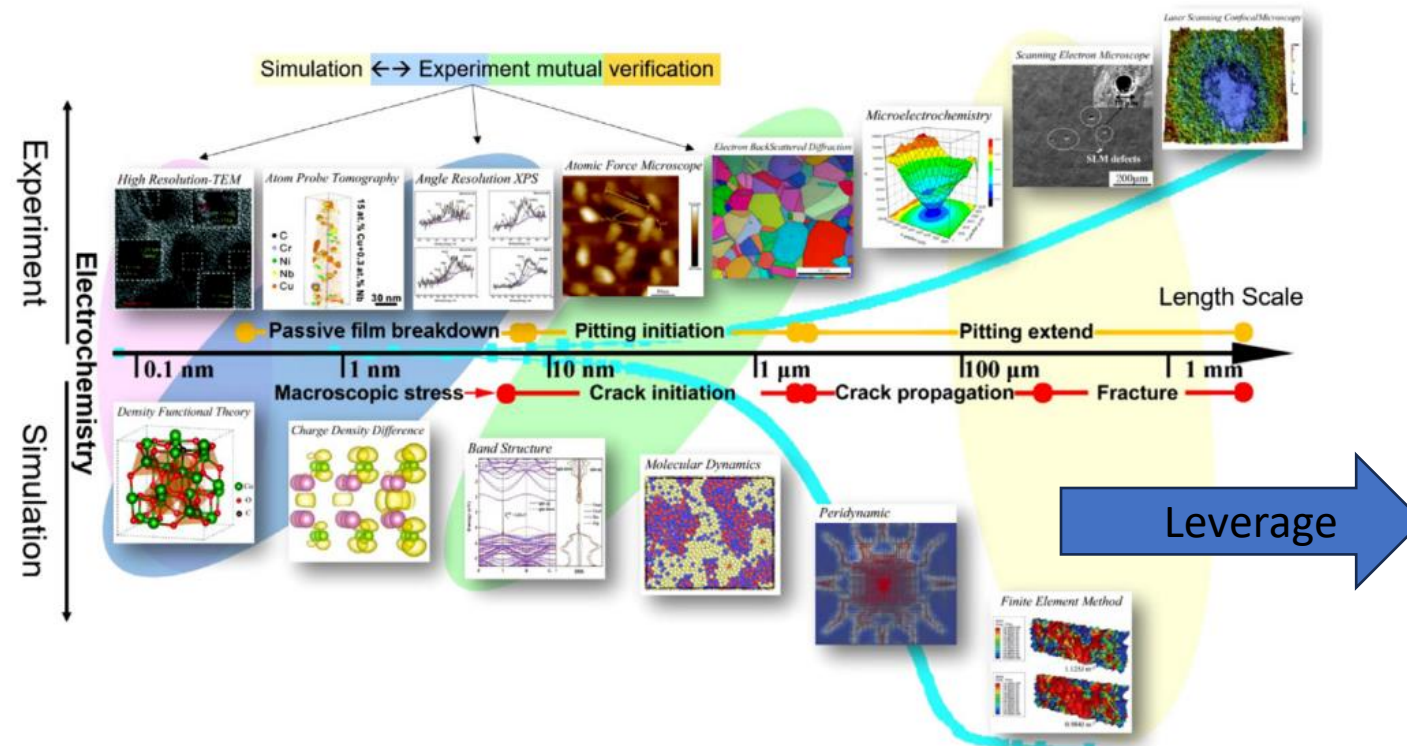
Solution

Why is it not 8 ?

1. Numerical models are useful but not perfect

Modeling complexity increases due to multiple corrosion mechanisms:

1. Galvanic Corrosion
2. Pitting Corrosion
3. Crevice Corrosion
4.



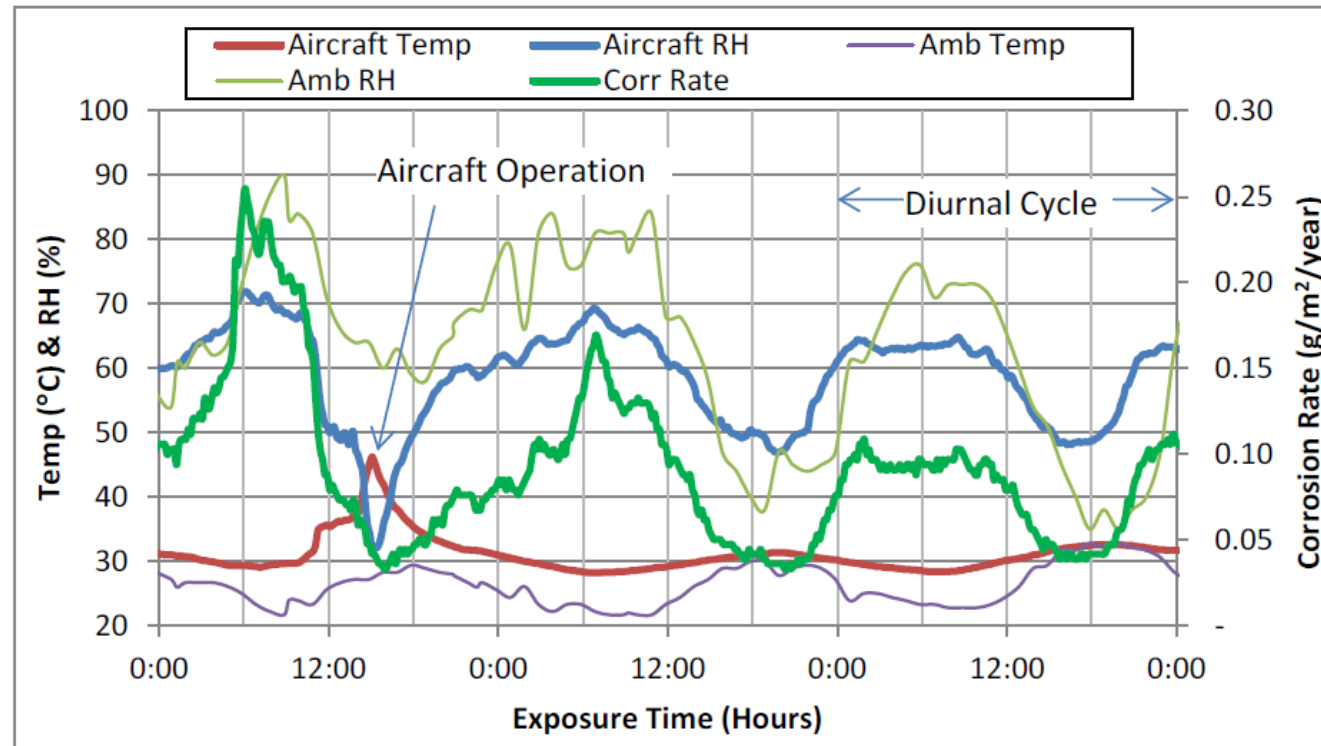
Integrated computation of corrosion, a construct used to illustrate the multiscale modelling and experimental verification¹

1.- Dong, Chaofang, et al. "Integrated computation of corrosion: Modelling, simulation and applications." *Corrosion Communications* 2 (2021): 8-23.

Solution

Why is it not 8 ?

1. Uncertainty in data and conditions



Environment – Diurnal weather effects²

Solution

How do we make it close to 8 ?

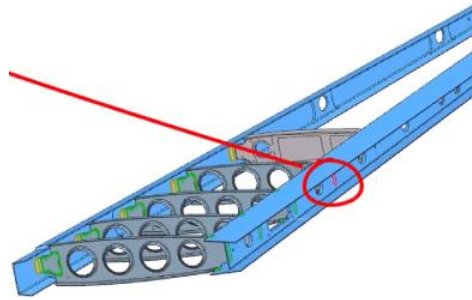
1. We accept that models are not perfect but they are useful.

In other words, (mathematically speaking)

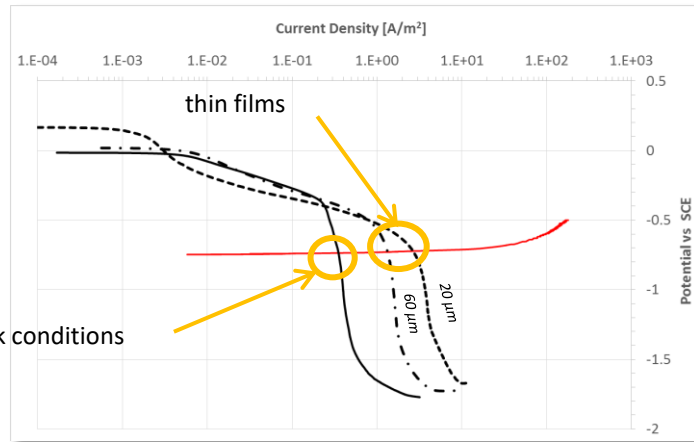
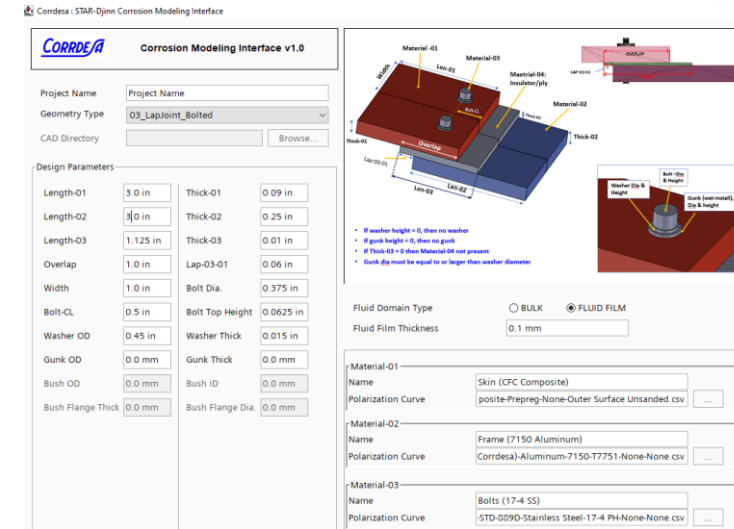
$$2 + 2(?) + 2 + 2 = 6$$

2. We make it close to 8 by leveraging **ACCURATE DATA**

Solution



Curve Crossing (1D)
3D CAD (Siemens NX)

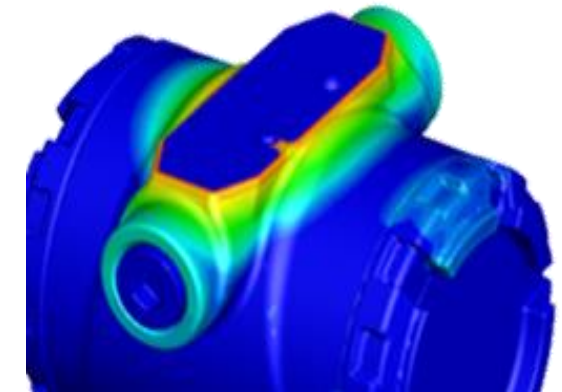


Curve Crossing (1D)



Electrochemical
Database based on
MIL-STD-889D
Corrosion Djinn

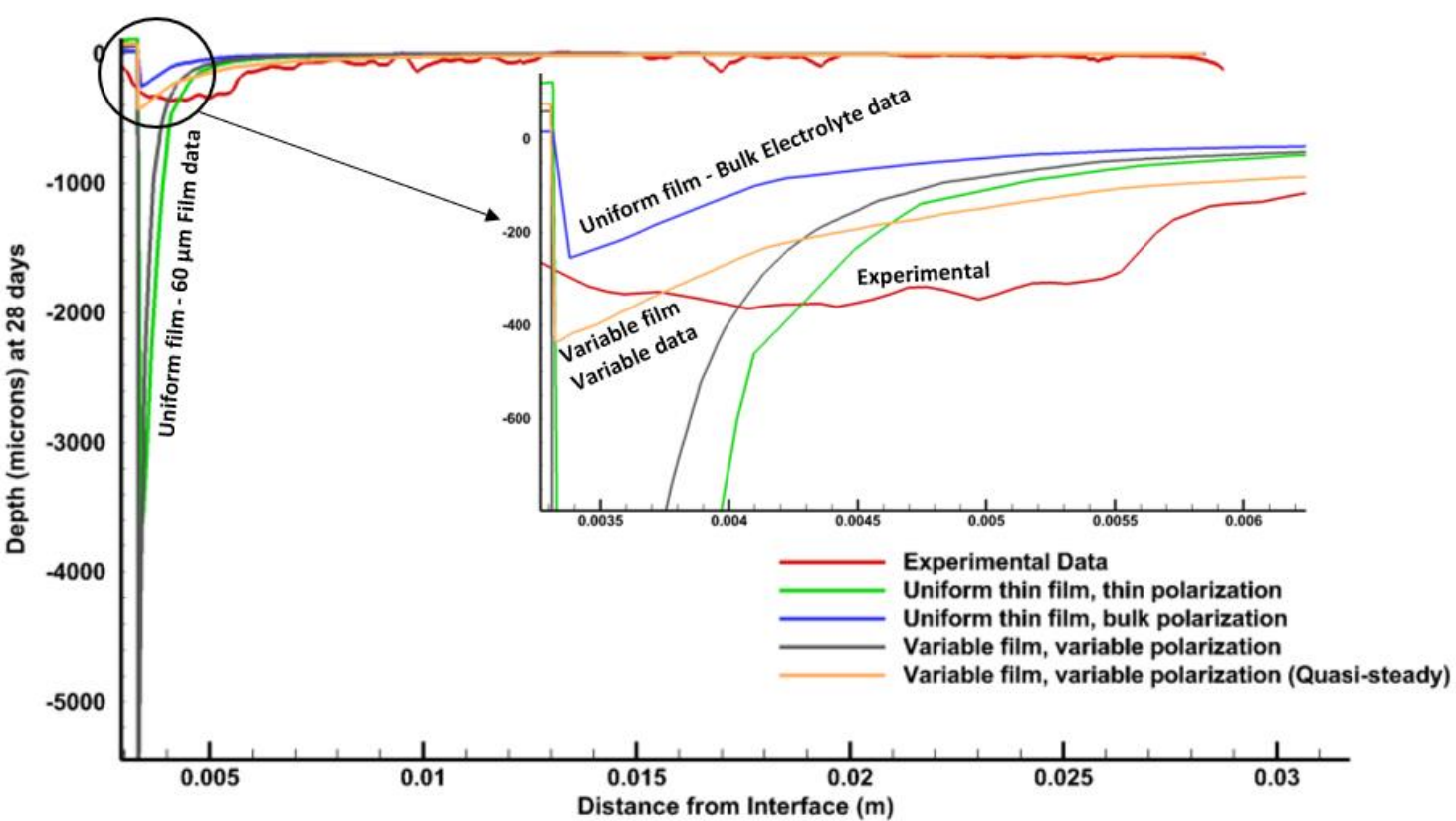
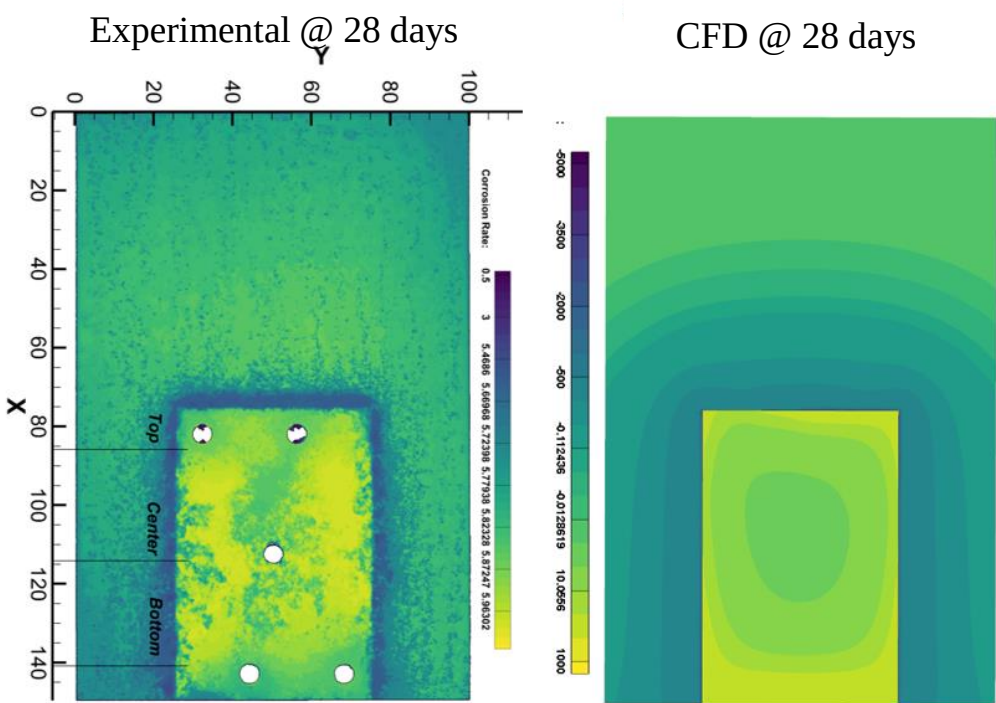
Templates
3D CFD



Full 3D CFD

Solution

How close are we from 8 ?

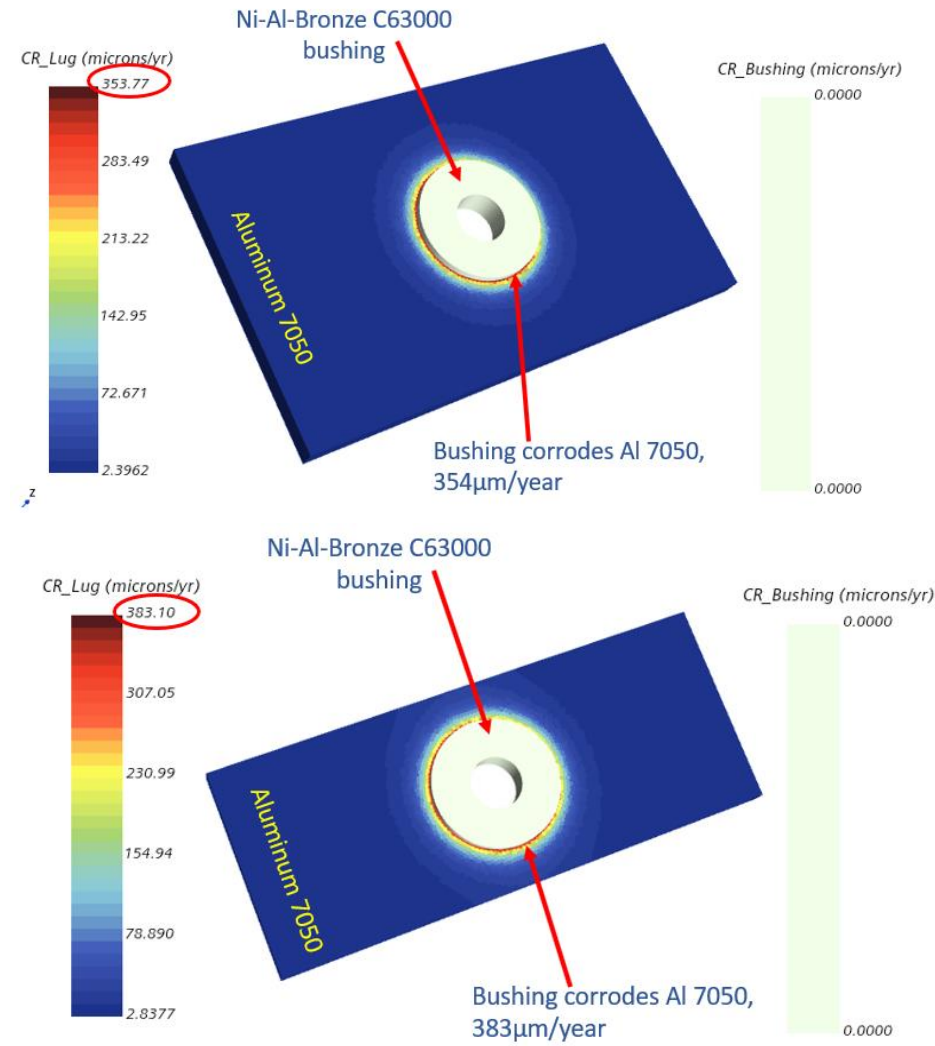
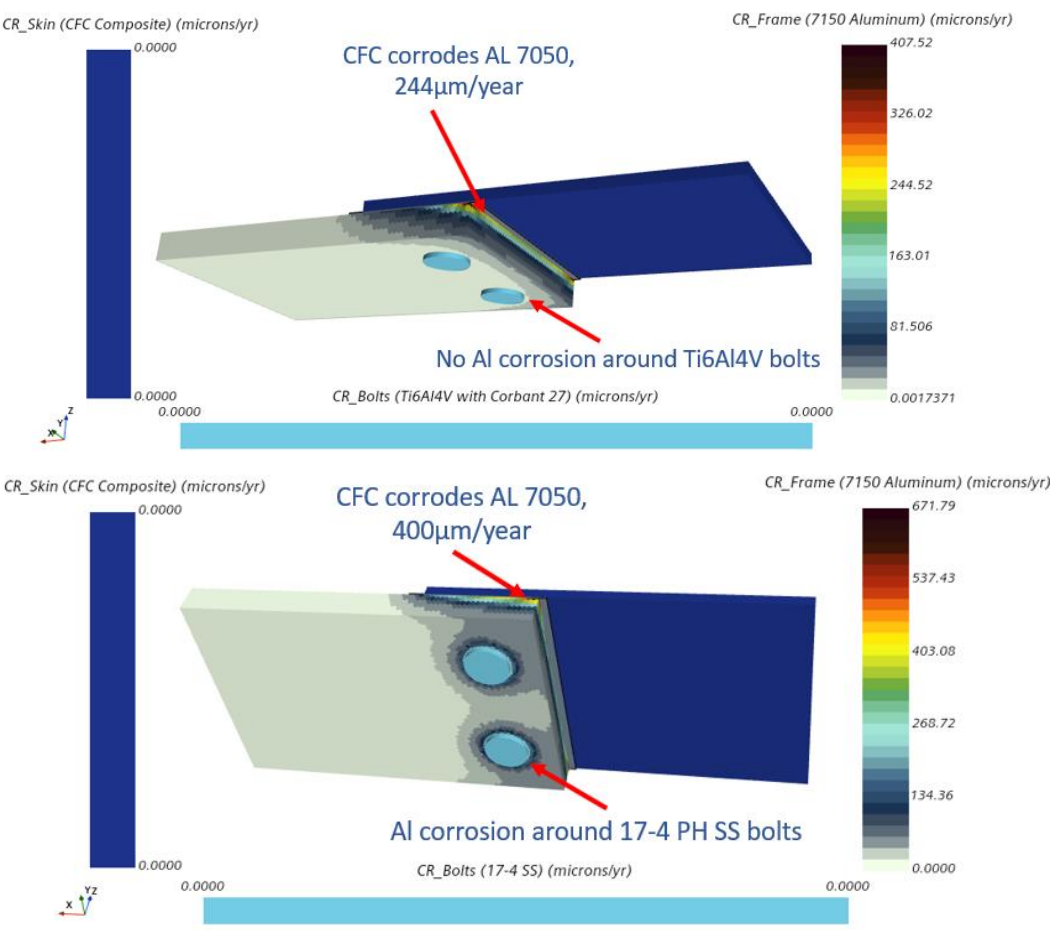


Total Volume loss (experiment) = 239 mm³

Total Volume loss (model) = 261 mm³

Solution

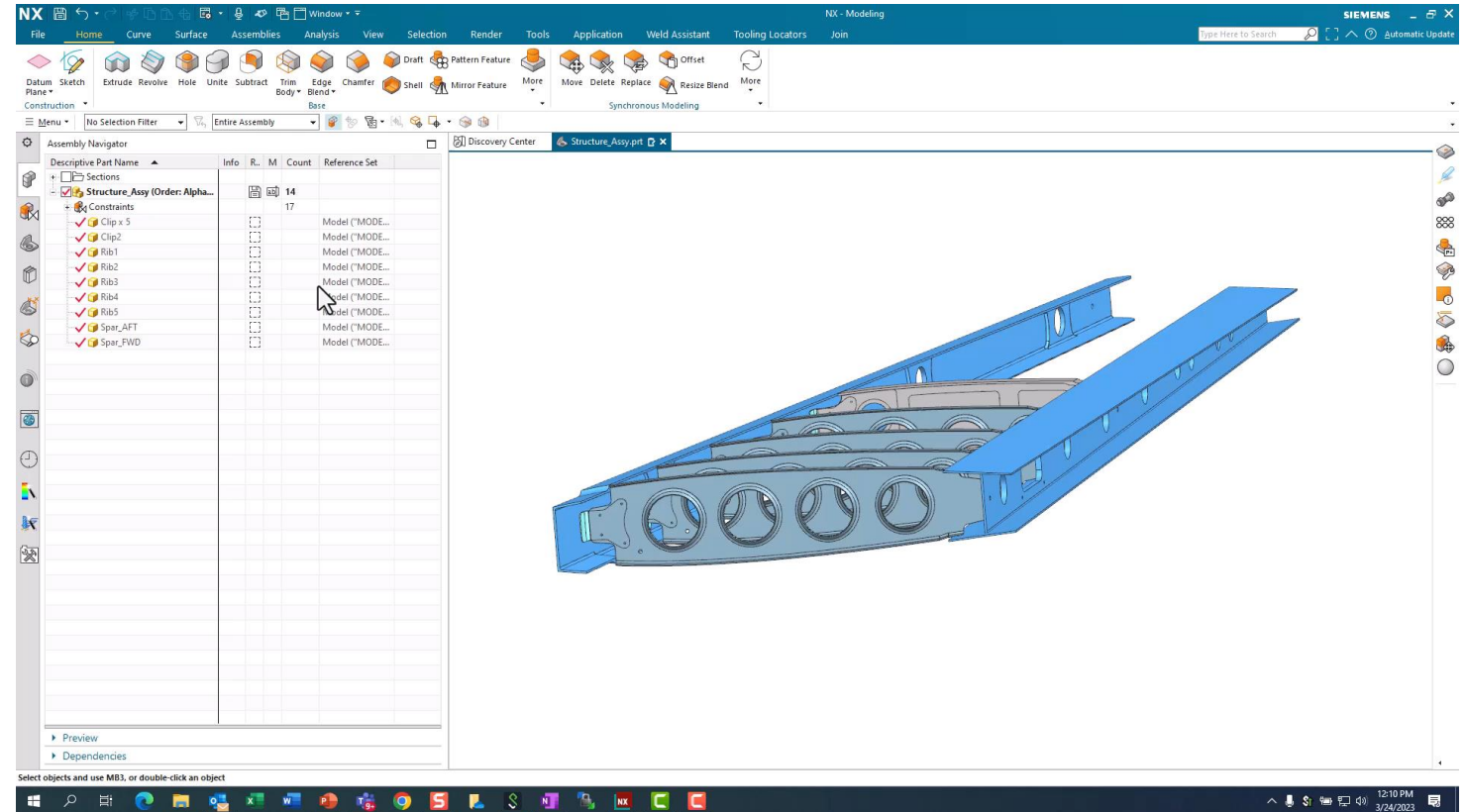
$2 + 2 + 2 + 2 = 7.28 \text{ ?}$



Solution

$$2 + 2 + 2 + 2 = 7.28 ?$$

We don't know, but we are close enough to make decisions that will save billions of dollars in the early design stage!



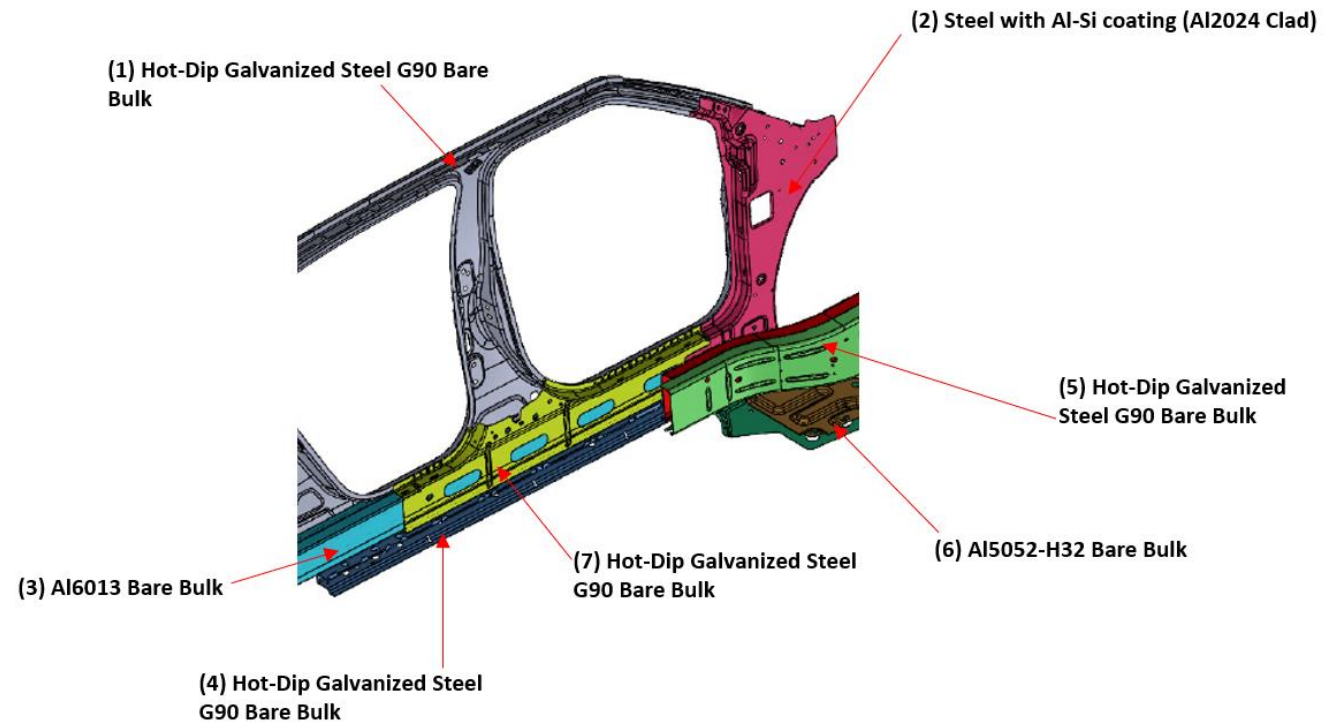
Solution

$$2 + 2 + 2 + 2 = 7.28 ?$$

Close enough to make informed decisions

Goal:

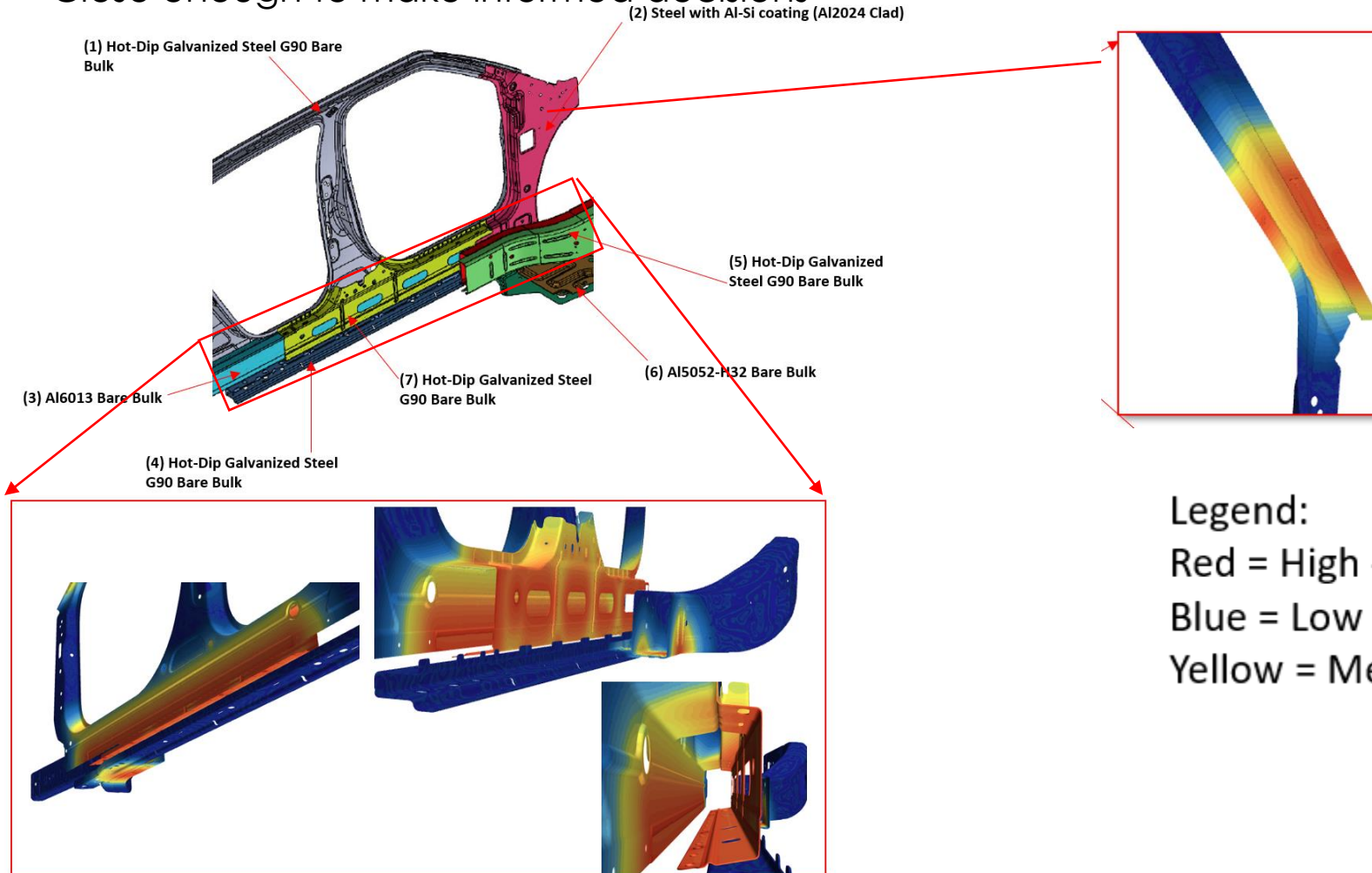
Determine the areas with higher corrosion rate



Solution

$$2 + 2 + 2 + 2 = 7.28 ?$$

Close enough to make informed decisions



Legend:

Red = High corrosion rate

Blue = Low corrosion rate

Yellow = Medium Corrosion rate

Conclusion

1. Numerical Models are not perfect, but they are good enough to make informed decisions.
2. Data is crucial since it is the boundary condition for your mathematical problem.
3. We developed different solutions for various specialties.
4. With current computational workflows, you can test multiple materials, coatings, paints, etc, in hours, not months or years.
5. This can be integrated into PLM solutions, connecting your solution to multidisciplinary teams in the early stages of engineering projects.