

Advancing Regulatory Science through Integrative Engineering with COMSOL Multiphysics® Software Modeling

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Introduction: What is regulatory science? According to the US Food and Drug Administration (FDA), it is the science of developing tools, standards, and approaches to assess the safety, effectiveness, quality, toxicity, public health impact, and/or performance of FDA-regulated products. What it does not say is on what bases such science will be developed: based on the existing knowledge, and/or conventional investigative methods? Today, pretty much all investigative approaches are reductive and compartmentalized, thus they are insufficient for dealing with the complex biomedical problems¹. Yet, regulatory science has often been equated to developing standards. If so, will a standard developed based on incomplete scientific premises, though it may help assure consistency, help improve the regulatory pathways?² To truly make a dent, we need a breakaway from conventions through promoting a new way of scientific exploration through seeking convergence upon integration of knowledge, understanding, ways of exploration, etc. from transdisciplinary fields including the life sciences, physical sciences, engineering, social and behavioral sciences, etc. to address complex problems.

Computational Methods: On the physical science and engineering front, the problems need to be examined with a holistic consideration of all relevant governing principles. With COMSOL® software we can solve, non-reductively and non-destructively, complex problems that are not only of mechanical, but also of electrical, thermal, chemical, and biological in nature, which behave according to the governing laws of thermodynamics, chemistry, physics and biology.

A Case Study: A standard that invites uncertainty. A small punch-out test (ASTM F2977-13), designed to provide a simpler way to assess material failure, is found to possess a very complicated stress condition as shown in Fig.1, causing unnecessary ambiguity in failure analysis.

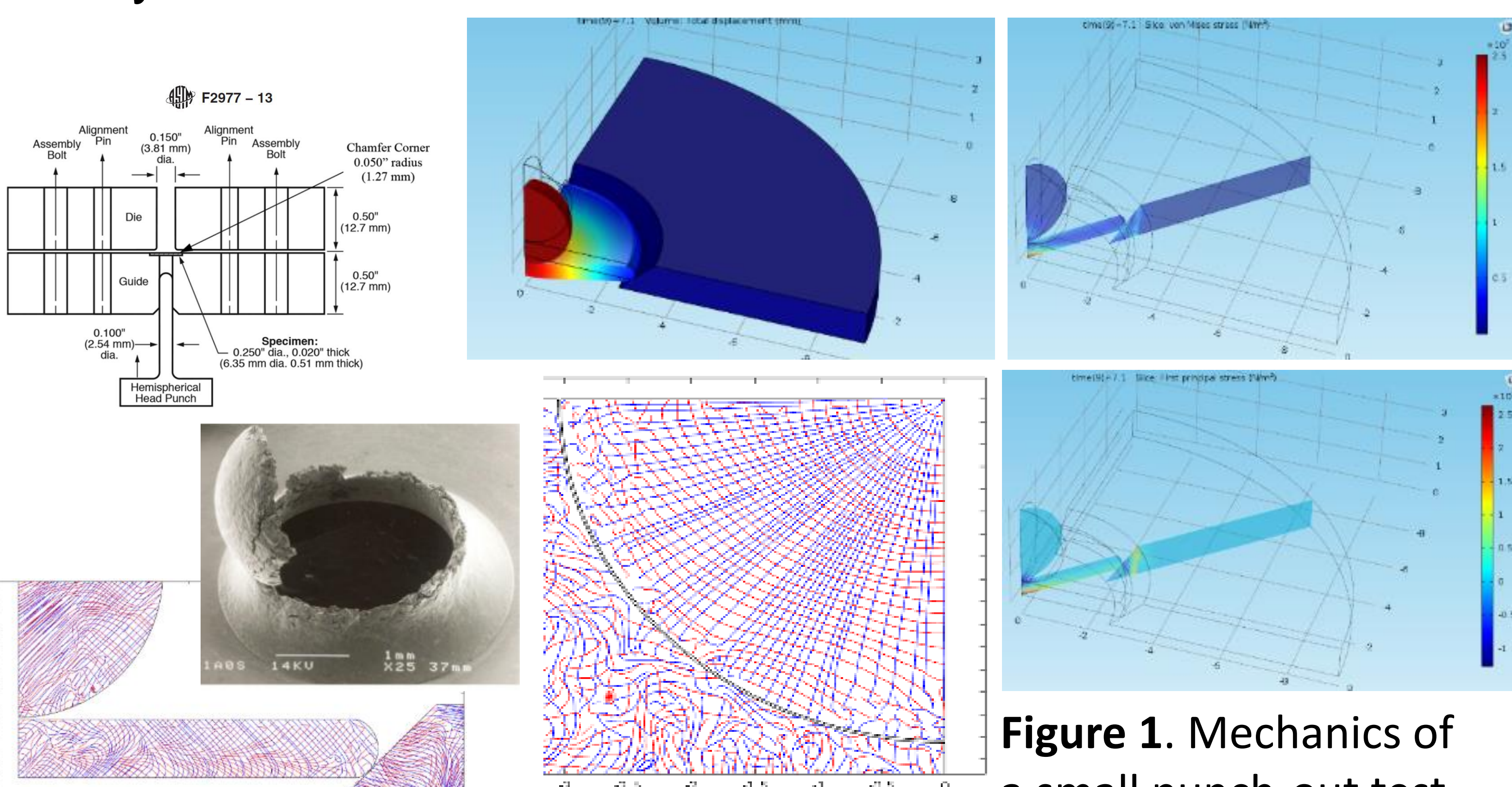


Figure 1. Mechanics of a small punch-out test.

What Differences Can Integrative Engineering Make? An *Integrative Engineering* approach will enable us to break the trap of “blind men touching an elephant” limitation in our scientific exploration. A computational modeling approach facilitated by COMSOL® Multiphysics can provide a holistic investigative means to develop better and relevant standards, which could predict clinical failures (Fig.2), deal with combination effects (Fig.3) and help interpret spectroscopic outcomes (Fig.4), etc.

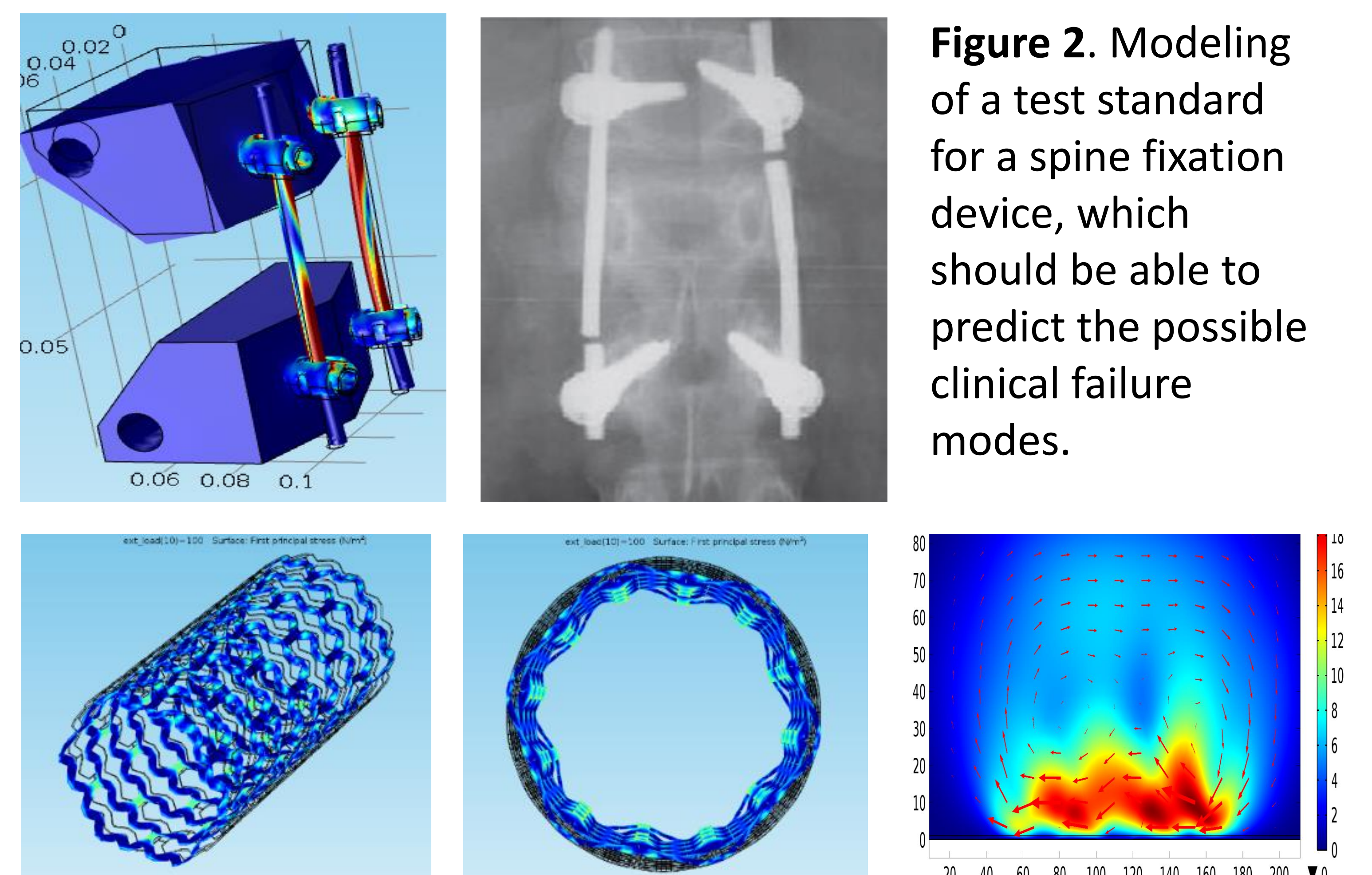


Figure 2. Modeling of a test standard for a spine fixation device, which should be able to predict the possible clinical failure modes.

Figure 3. Modeling of the mechanics in a stent coupled with fluidic and reactive responses due to eluted drugs inside the lumen.

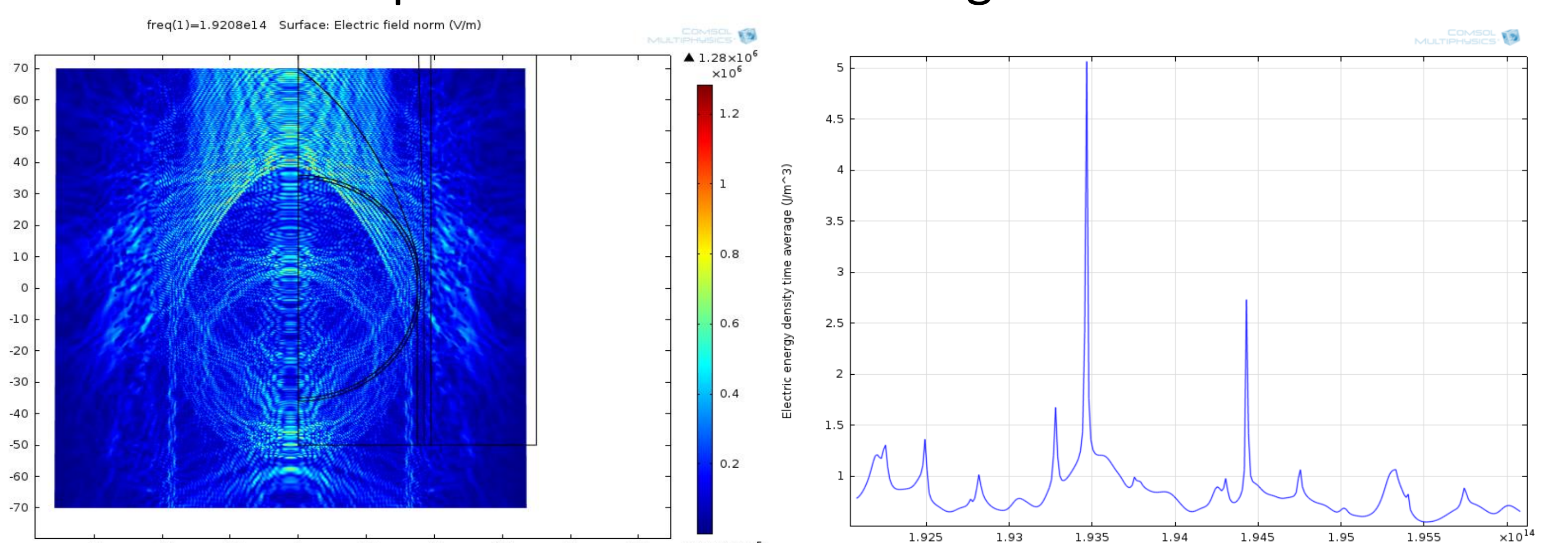


Figure 4. Modeling of spectroscopy performance by considering the effect of physical, chemical and molecular couplings.

Conclusions: In addition to developing relevant tools, standards, and approaches, regulatory science should be regarded as the **ultimate science of the highest level** calling for seeking convergence based on information gained from life and clinical sciences, physical sciences, computer science, engineering, social and behavioral sciences, etc. Thus to advance regulatory science, it is necessary to change the ways we do science.

References:

1. “Introduction to Integrative Engineering – A Computational Approach to Biomedical Problems.” Guigen Zhang, CRC Taylor & Francis Group, 2017.
2. “The Cure in the Code – How 20th Century Law is Undermining 21st Century Medicine.” Peter Huber, Basic Books, 2013.

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