Digital Offsetting the Physical: Increase the Speed of Development and Regulatory Evidence Generation for Medical Devices

Computational modeling and simulation (CM&S) is generally used in the medical device industry to inform early development. These models answer questions regarding stress, flow rates, electromagnetic interference, etc.. Once these values are determined, most manufacturers move on to build and test physical prototypes — rarely touching simulations again.

Leaving these simulations to electronic recycle bins is a missed opportunity. Models can produce numerous benefits if they are used throughout product development, design, verification, lifecycle management and even regulatory evidence gathering. For instance, models can supply answers to frequent customer complaints, assess and optimize product performance in the field, and — perhaps most importantly — reduce the amount of physical testing needed to gain regulatory compliance and get to market.

Medical Design & OUTSOURCING

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Engineering services can help integrate simulations into product lifecycle workflows. And being able to utilize prototyping, manufacturing and material testing to support computational modeling and simulation makes providers such as PSN Labs uniquely qualified.

Computational Modeling and Simulation is a well understood tool for product development. What isn't well known is its advantages in compliance and beyond.

> "Really what we're trying to do is increase the visibility of using computational modeling and simulation for speeding up the build, test, fail cycles and making sure that you learn as much as you can [with] limited [physical] prototypes, Some of the ways that it can be used include [during] virtual design cycles [to inform] the next prototype build. Also, we can assess risks that are very difficult to assess with physical testing. Either they're statistically the outliers, or there are conditions in the body or with a patient that are very difficult to replicate."

— Mark Burchnall, Engineering Director PSN Labs

CM&S involves the use of physics-based tools and first principles to model and simulate a device in a given environment. In advanced examples, tools like FEA, CFD, electromagnetic simulations and more can be linked into a multiphysics model that acts as a virtual representation of a medical device — sometimes referred to as a digital twin. These models are verified and validated based on the data gathered via physical prototypes, trials, devices in the field, manufacturing and more.

This last example demonstrates the power of CM&S for regulatory processes. Human trials can prove products work with the average patient in a typical scenario. But what about the outliers? Simulations can test the product's performance during conditions that could naturally occur in real-life but would be dangerous to persons or products in a lab. Though human trials are unlikely to go away, simulations can reduce the amount they are needed and fill in the gaps between the average situations, the statistically unlikely (but nonetheless eventual) situations and everything in between.

Industry and regulatory compliance guidance and standards have been provided to help manufacturers with the verification and validation (V&V) of computational models and simulations. For instance:

- **ASME V&V 40** provides a risk-based framework to complete the V&V of CM&S for medical devices. This risk-based framework should be aligned with other quality objectives and risk approaches within a company.
- **FDA-2021-D-0980** provides similar frameworks to ASME V&V 40. However, some differences include the recommendation to pre-submit computational models to allow for validation against other items besides benchtop tests.

Either way, these guidelines outline how data from real-world tests must be used to verify and validate simulations and models. In other words, prototypes, manufacturing and materials testing must support computational modeling and simulation so that all stakeholders are confident in their output. These outlines are designed to ensure confidence with even the most risk-averse and skeptical stakeholders while also maintaining patient safety.

> "What you can see here is that regulatory is currently ... encouraging the use of CM&S for evidence generation in recent years," said Burchnall. "It really provided the guidance on how to assess the credibility of computational modeling and simulation through verification, validation [and] application to medical devices.
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> If there's benchtop testing that will be used in combination with the model and simulation, that'll drive down your risk level. If your model stands alone as the only evidence generated, that'll increase your risk level. It's key to use risk-based thinking, just like we do in all medical device development and design."
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> **— Mark Burchnall, Engineering Director, PSN Labs**

A risk-based approach is outlined in the regulatory compliance as a tool to uncover the potential hazards of a model or simulation. One way to approach this is through decision consequence which assess the potential outcomes that could arise if a model was incorrect or influenced an incorrect decision. This risk assessment then informs how much physical testing (benchtop testing, human testing and animal testing) is needed to verify and validate a model.

Callout: Benefits of CM&S

- **Lower the burden of regulatory evidence generation** — after V&V proves accuracy, simulations can supplement the evidence needed to comply with regulations.
- **Decrease development time** — gain a greater understanding of the task at hand, enable informed decisions, assess extreme cases and discover environmental impacts faster than with physical prototypes.
- **Lower development cost** — rapidly evaluate design concepts and reduce the manufacturing and budgets of physical prototypes.
- **Reduced device risk** — identify 'critical to quality' parameters or explore high risk events that would be difficult, or dangerous, to recreate.
- **Find errors early in development** — identify mistakes early in development so they can be solved before products are manufactured or in the field.
- **Understand how assets work in the real world** — use data from customer feedback, warranty claims and assets in the field to understand and optimize product behavior in the real-world.

Opportunities in evidence generation

Functional prototyping is the concept that ideation fuels design. It uses tools and simplified geometry to iterate a design until it works. The goal is to identify performance windows that ultimately allow for scaling to whatever your production needs might be. Problems can then be discovered and solved early in development when it is easy and economical to fix. As a result, manufacturers avoid costly recalls and manufacturing delays.

Simulation can be used between prototypes to help inform future iterations. The idea is to reduce the number of physical prototypes needed to get to a functional product. The data collected from the physical prototypes can then be used to verify and validate models, so they are accurate digital representations (aka digital twins) of real assets.

> “As with all things, when we’re talking about simulation, garbage-in equals garbage-out, That underscores … the need to do some of that developmental testing. Understand the stress levels. Instrument [your] materials [and your] prototypes with strain gauges [and] thermal couples. Figure out [all] those constraints so that then [you] can take it back and plug that … into [your] analysis and validate those models and make better-informed decisions.”

— Mike Alabran
President, PSN Labs

Benefits of Functional Prototyping:

- V&V simulations so they can be used throughout a product’s lifecycle.
- The best way to reduce risk during product development.
- Enable large production quantities.
- Benchmark multiple materials.
- Scale multi-cavity tools.
- Identify contribution of material, design and process to part variation.
- Allows for cliff studies.
- Considers all process variables.
- Avoid costly recalls and manufacturing delays.

Healthcare Trends That Rely on Simulation:

1. **Clinical use vs home healthcare –** simulations can be used to, for example, assess how to clean, disinfect and sterilize products in various environments, how the product will react and if it is still safe to use.
2. **Supply chain resiliency –** when material supplies run out, simulations can help ensure alternative materials will work and meet regulatory compliance.
3. **Connected care** - less invasive surgery demands smaller, more complex and stronger parts. Simulation can:
    a. Qualify sterilization processes.
    b. Improve reliability and patient value.
    c. Gather instrumentation and actionable data.
4. **Sustainability** – simulation can, for example, be used to assess how a product might be used within a circular economy.

> I think one of the important uses of functional prototyping and CM&S are that these are really our key tools in our toolbox to help us address these trends in a rapid fashion. We can address our clinical use in home health care where we're getting novel CD&S and novel use environments, and we can assess those using simulation and using functional prototypes in combination.
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> — Mark Burchnall,
> Engineering Director, PSN Labs

4 Ways to Take Prototyping and CM&S into Regulatory Certification:

1. **Know your devices' use environment** – use physical tests and simulations to determine if it is a consumable or durable device. Is it going to last 7 days, 14 days, two years, three years? What requirements must it meet? Where and how will it be used? What is the consequence of a failure (is it a nuisance or life-threatening)?
2. **Select the appropriate prototype and manufacturing process** – use testing, engineering experience and simulation to choose manufacturing processes that meet the demand and ensure product quality.
3. **Materials are unique and affected by various conditions** - consult with experts and simulations, not just the material supplier, to ensure you're using the right material for the right application.
4. **Understand the product's whole lifecycle** use testing and simulation to inform design, manufacturing, lifecycle decisions and generate regulatory evidence.

PSN Labs' willingness to put patients above budgets and timelines only further stresses the importance of computational modeling and simulation. They can improve product performance, speed up development and help gain evidence for regulatory compliance — all while improving patient safety.

> Here at PSN Labs, our number one goal in both testing and developing products is patient safety. We will sacrifice the budget and we will sacrifice the timeline to ensure at the end of the day, the patients that are going to use these devices are safe.
>
> — Mike Alabran
> President, PSN Labs

PSN Lab's prototype and manufacturing capabilities:

- Computational modeling and simulation.
- Short run prototypes for process development.
- Contract manufacturing.
- Injection molding.
- Extrusion/twin-screw extrusion.
- Compression molding.
- In-house tooling.
- On-site CM Assistance.
- ISO 13485:2016 Certified.
- 100+ years of combined experience in material processing.

PSN Labs is a Full-Service Engineering Partner that solves your toughest design, material and manufacturing challenges. To learn more, visit: https://www.psnlabs.com/.