ON

DrugDelivery

188

JULY 7TH 2026

INDUSTRIALISING DRUG DELIVERY

DCA

Helping our clients achieve success through great product design

PiccoJect Autoinjector

www.dca-design.com

LYOPHILIZATION VIALS

Proven to Significantly Reduce Lyophilization Fogging

Visit our website

70% reduction in overall fogging events

Validated under demanding freeze-drying conditions and test solutions

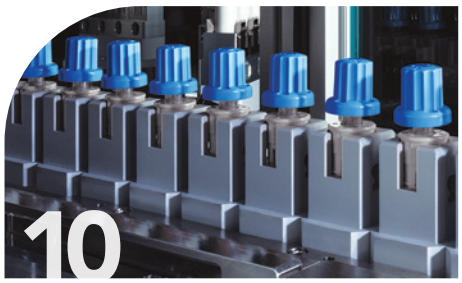
Latest 2025 tests conducted by external lyophilization experts confirm results

NIPRO
Live Longer. Live Better.

NIPRO Pharmapackaging International Headquarters
European Headquarters, Blokhuisstraat 42, 2800 Mechelen, Belgium
pharmapackaging@nipro-group.com | www.nipro-group.com

NIPRO Corporation
www.nipro.co.jp

Contents



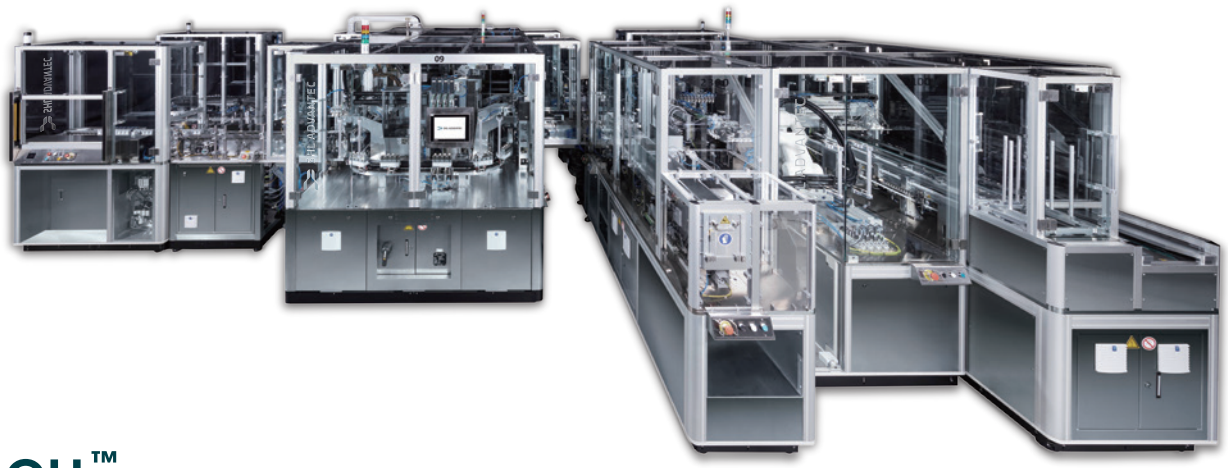
INDUSTRIALISING DRUG DELIVERY

ONdrugDelivery Issue N° 188, July 7th, 2026

This edition is one in the ONdrugDelivery series of publications. Each issue focuses on a specific topic within the field of drug delivery, and is supported by industry leaders in that field.

SHL ADVANTEC

Future-proof your final assembly



AOU™

The **AOU** is a market-proven assembly machine platform **engineered for scalability.**

With **upgradable feeding stations** and **versatile project compatibility**, it can seamlessly adapt to your **evolving production needs.**

shl-advantec.com
Innovate. Mold. Automate.

Your project.
Your configuration.

Autoinjectors | Pen injectors | Syringes | Cartridges | Tubs and/or trays

Industrialisation in a Changing World:

Considerations for Manufacturing Drug Delivery Devices

When discussing pharmaceuticals, it is easy to focus in on the drug, its delivery device and its relation to the patient in isolation, especially when considering key topics such as human factors, self-administration and adherence. However, these only come into play if the drug can be manufactured and shipped successfully – behind every drug delivered is a major industrial process and its attendant supply chain. In this issue of ONdrugDelivery, we zoom out to the industrial scale, considering critical aspects of drug development around manufacturability, supply chain security and scale-up best practices.

Opening the issue, our Outstanding Sponsors, **SHL Medical** and its specialist equipment subgroup, **SHL Advantec**, discuss how to overcome the challenges inherent in manufacturing a dual-chamber autoinjector with extremely tight tolerances at scale through integrated pharma, medtech and equipment engineering teams (Page 10). Following that, **Covestro** presents a technology showcase on the use of digital twins for enhancing autoinjector development, including how they can contribute to improved reliability, cost efficiency and time-to-market (Page 16).

Next up, we feature a trio of articles that consider how well-considered prototyping and pilot production can lead to significant savings further down the line. **IGS GeboJagema** and **FRP** focus on injection moulding, detailing how the use of small-batch moulds for prototyping can both be more cost-effective and offer smooth scale-up in the long run (Page 18), with **H&T Presspart** considering the potential of 3D-printed moulds for rapid iteration (Page 68). **Cambridge Design Partnership** then puts forward the case for using pilot production to de-risk changes made to products already on the market, explaining how doing so can help avert major issues that could put commercial supply at risk (Page 24).

Turning our attention to global supply, **Ypsomed** explains how it has achieved success within the Chinese market, highlighting how its strategy has led to successful integration into the local market and has established bonds of trust and partnerships with local pharmaceutical companies (Page 30). Looking at today's tumultuous geopolitical landscape, **Quvara** then discusses how supply chain considerations are shifting away from previously established assumptions and just-in-time models, as well as how its UK-based production hub fits into the new global paradigm (Page 36).

Next, as it celebrates its 40-year anniversary, **Team Consulting** shares key insights on best practices for manufacturing organisations built up over its decades of experience (Page 42). Focusing in on pen injectors, **Phillips Medisize** discusses the key aspects and considerations of scaling development programmes up from clinical to commercial production (Page 48).

Rounding out the issue, we take a look at a trio of enabling technologies. First, **Nanexa** discusses how its PharmaShell technology holds the potential to reduce the required frequency for GLP-1 injections – a critical factor considering the significant portion of global manufacturing capacity currently dominated by these therapies (Page 52). Second, **NIPRO** introduces its VIALEX™ thermal treatment for combatting vial fogging during the lyophilisation process – a phenomenon that leads to unnecessary rejects during camera-based visual inspection (Page 58). Third, concluding the issue, **Kistler Group** considers the value offered by advanced monitoring technologies and enhanced data integrity to insulin pen production lines (Page 64).

James Arnold
Production Editor

EDITORIAL:
James Arnold, Production Editor
james.arnold@ondrugdelivery.com
Subeditors:
Sarah Tomblin, Zoe Billyard

CREATIVE DESIGN:
Simon Smith, Head of Creative
simon.smith@ondrugdelivery.com

SUBSCRIPTIONS:
Print + Digital subscription:
£99/year + postage.
Digital Only subscription: free.
subscriptions@ondrugdelivery.com

ADVERTISING & SPONSORSHIP:
Guy Furness, Founder and Publisher
+44 1273 47 28 28
guy.furness@ondrugdelivery.com

ONdrugDelivery is published by
FURNESS PUBLISHING
The Candlemakers, West Street, Lewes,
East Sussex, BN7 2NZ, United Kingdom
Board Directors: **Guy Furness**, **Audrey Furness**
Registered in England: Company No 8348388
ISSN 2049-145X print / ISSN 2049-1468 pdf

The ONdrugDelivery logo is a registered trademark of Furness Publishing Ltd.

www.ondrugdelivery.com

RECYCLED
Paper made from recycled material
FSC® C022819
www.fsc.org

WORLD LAND TRUST™
www.carbonbalancedpaper.com

GOGREEN PLUS

ONdrugDelivery Magazine is printed sustainably by Newman Thomson Ltd, West Sussex, UK, using Forest Stewardship Council® certified recycled paper, vegetable-based inks, biodegradable laminates and carbon balanced materials offset via the World Land Trust™ following ISO14001 processes. ONdrugDelivery in print is sustainably shipped to events by DHL using GoGreen Plus whereby carbon insetting of at least 30% is achieved through the use of Sustainable Aviation Fuel (SAF), a biofuel substitute for traditional jet fuel, produced from renewable sources such as vegetable oils, animal fats, waste products, and agricultural crops. The magazine is mailed to individual readers outside the UK by DHL using GoGreen, which offsets 100% of CO_2 emissions.

team

Forty years of medical innovation

Designed Built Delivered

Bringing 40 years of drug delivery device innovation to rapidly transform your concept into robust, scalable solutions ready for high-volume production.

Want to learn more about our expertise?

Visit our website at **team-consulting.com**

BESPAK

YOUR COMPLETE PARTNER

Deliver your inhaled or nasal innovation with the trusted technology leader.

FUTURE FACING, ESTABLISHED EXPERTS

As the specialist inhalation Contract Development and Manufacturing Organisation (CDMO) we focus solely on inhaled and nasal drug delivery. We're an agile company built on decades of specialist experience, investing for the future of the industry and the planet. From development to regulatory approval to commercial delivery, we're a partner for every small step in the process, and every giant leap in the industry.

Discover our world-class capabilities.

BESPAK.COM

Analytical and formulation

Drug product development

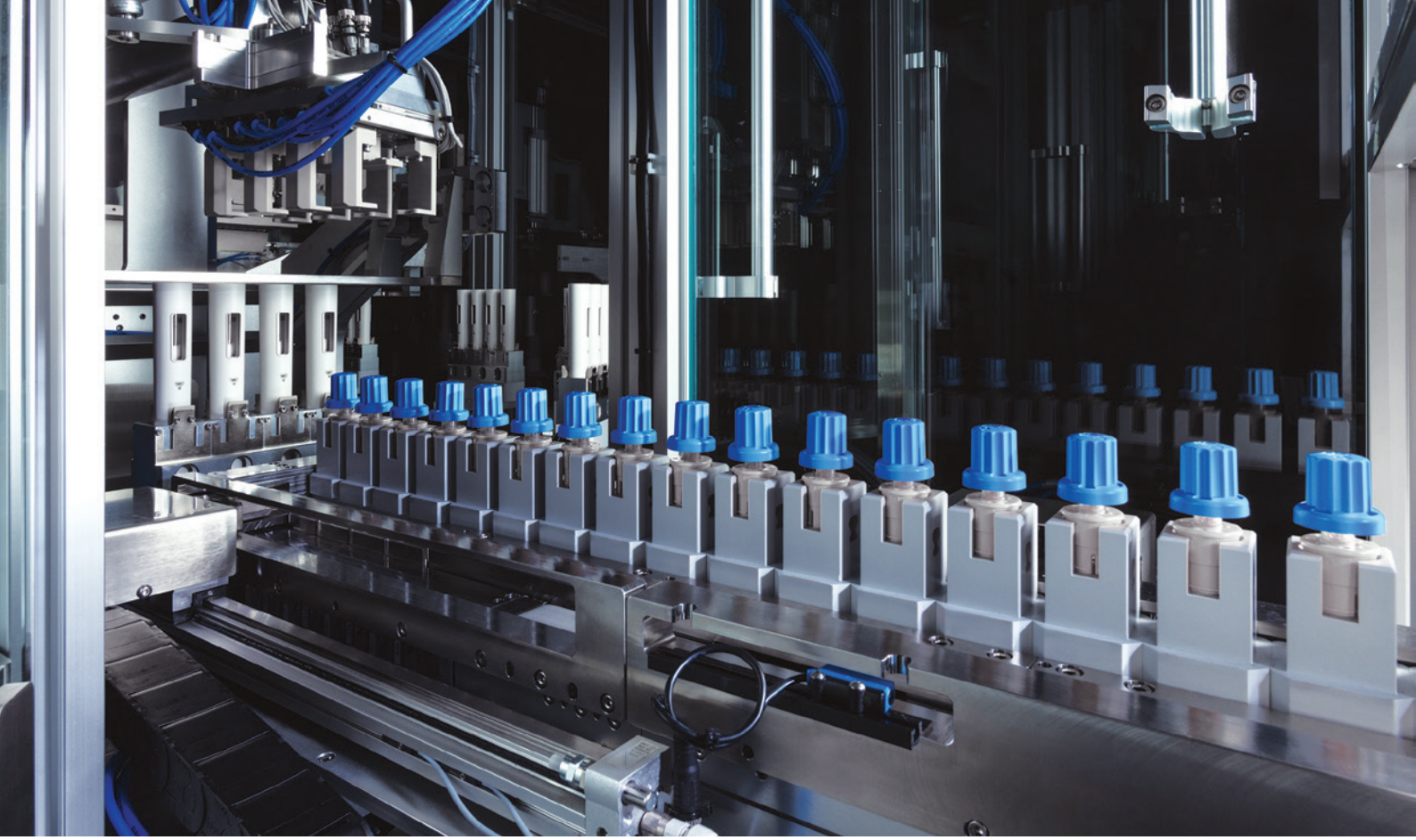
Device design and development

Regulatory support

Clinical supply

Scale up and tech transfer

Commercial supply



INNOVATION AND AUTOMATION REUNITED – ENABLING SCALABLE FINAL ASSEMBLY FOR CARTRIDGE-BASED AUTOINJECTORS

SHL ADVANTEC SHL MEDICAL

Christy Chen at **SHL Advantec**, the specialised equipment subgroup of **SHL Medical**, and **Alberto Flores** at **SHL Medical** explore the critical synergy between flexible automation architecture and expert final assembly services. Using the Reunite™ dual-chamber autoinjector and the AOU™ assembly machine platform as a case study, the authors discuss how integrating agile automation technologies with robust final assembly operations can help to build highly resilient supply chain strategies that enable seamless scalability from clinical validation through to commercial launch and post-market scale-up.

The first wave of commercialised complex biologics changed self-injection devices in ways the industry did not anticipate. Treatments once limited to complex, manual handling processes were introduced into easy-to-use autoinjectors, establishing them as the industry benchmark for the self-injection experience.

Almost two decades after the launch of those first modern autoinjectors, complex biologics are introducing another layer of difficulty. Roughly a third of US FDA-approved parenteral medications entering the market are lyophilised products,[1] and the entire injection device ecosystem is feeling the pressure. Device developers need to develop patient-centric devices that afford patients the level of convenience and safety that they expect; manufacturers and CMOs must accelerate speed-to-market to help their pharmaceutical customers capitalise on stringent launch windows; and equipment suppliers need to respond with agile manufacturing infrastructure capable of absorbing unpredictable surges in commercial demand.

From a device perspective, the industry is addressing the user experience gap through a range of innovative dual-

chamber technologies, as highlighted in ONdrugDelivery's first dual-chamber delivery systems issue, published in 2025.[2] Prominent among these solutions is SHL Medical's Reunite™ autoinjector – a three-step, dual-chamber device that automates reconstitution and injection while incorporating SHL Medical's market-proven Needle Isolation Technology (NIT®), an integrated, pre-attached needle system that allows cartridges to function as ready-to-use autoinjectors (Figure 1).

The first lyophilised therapy using the Reunite autoinjector technology received marketing authorisation for prurigo nodularis and atopic dermatitis in the US in 2024, followed by the EU, UK and Switzerland in 2025. This milestone makes it the first lyophilised monoclonal antibody to be commercialised in a dual-chamber autoinjector with automated reconstitution and injection.

Figure 1: The Reunite autoinjector displayed in its three states of use (from bottom to top): locked, unused device with lyophilised drug visible; unlocked device following automated reconstitution; final post-injection state with extended needle shield.

"THE ENGINEERING ELEGANCE THAT MAKES REUNITE SIMPLE FOR PATIENTS INTRODUCES UNIQUE REQUIREMENTS ON THE MANUFACTURING FLOOR – PARTICULARLY AT FINAL ASSEMBLY, THE LAST CRITICAL STOP BEFORE MARKET LAUNCH."

The engineering elegance that makes Reunite simple for patients introduces unique requirements on the manufacturing floor – particularly at final assembly, the last critical stop before market launch. For pharmaceutical companies backing therapies with uncertain demand trajectories, the challenge is not just getting the device right; it is deploying an assembly infrastructure agile enough to support a quick initial launch that is also capable of scaling with the drug demand. By proactively synchronising the technical transfer of sub-assemblies with final assembly, CMOs can reduce the risk of capacity constraints at this critical stage and secure a smooth trajectory to commercialisation.

A HISTORY OF PIONEERING INNOVATION

SHL's ability to scale complex technologies is rooted in over two decades of first-to-market innovations, including the launch of the syringe-based DAI® and Molly® autoinjectors in 2006 and 2015, respectively, and the first NIT-based cartridge autoinjector in 2017.

While these devices set the baseline for standard self-injections, SHL's experience with lyophilised delivery represents yet another highly specialised lineage. SHL has previously successfully developed three separate devices for lyophilised therapies (Figure 2), making the fourth, Reunite, the culmination of 25 years of engineering

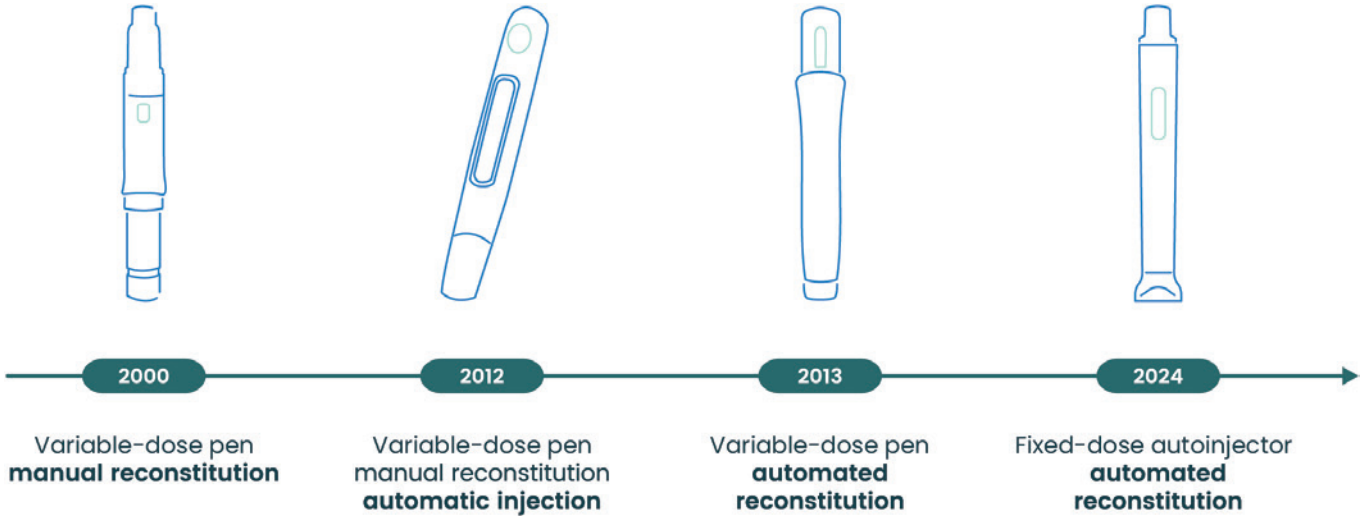


Figure 2: SHL Medical's extensive history delivering dual-chamber device solutions for lyophilised therapies.

excellence. While earlier iterations inherently required more user steps, SHL Medical's underlying purpose remained uncompromisingly patient-centric, hiding the needle and automating critical user steps to reduce the burden and risk of manual preparation.

For all these projects, SHL's automation engineers and final assembly experts played crucial roles in delivering the manufacturing infrastructure required for project success. This fully aligned approach to device design and production ensures that complex handling requirements are engineered into assembly and final assembly from day one, establishing the foundation for the manufacturing agility and scalability often required for innovative therapies.

DESIGNING RECONSTITUTION FOR SCALE

As SHL Medical's flagship dual-chamber autoinjector platform, Reunite was designed to solve a multifaceted manufacturing challenge: supporting a combination drug product's clinical validation – proving that a new formulation and an equally novel device mechanism functioned as intended in the clinical phase – while ensuring that the device could be assembled efficiently at commercial scale.

From a final assembly perspective, translating this validated clinical performance to commercial production presented unique mechanical considerations. Requiring just three steps – unlock, uncap and inject – to operate,[3] Reunite's dual-chamber cartridge relies on highly precise internal bypass mechanics and strict spatial tolerances to execute automated reconstitution. The final assembly process needs to safeguard these features while the manufacturing equipment ensures that separate components – the NIT front sub-assembly (FSA), dual-chamber cartridge and rear sub-assembly (RSA) – are treated as a single, interconnected system whose ultimate clinical integrity depends on final assembly tolerances (Figure 3).

> "REQUIRING JUST THREE STEPS – UNLOCK, UNCAP AND INJECT – TO OPERATE, REUNITE'S DUAL-CHAMBER CARTRIDGE RELIES ON HIGHLY PRECISE INTERNAL BYPASS MECHANICS AND STRICT SPATIAL TOLERANCES TO EXECUTE AUTOMATED RECONSTITUTION."

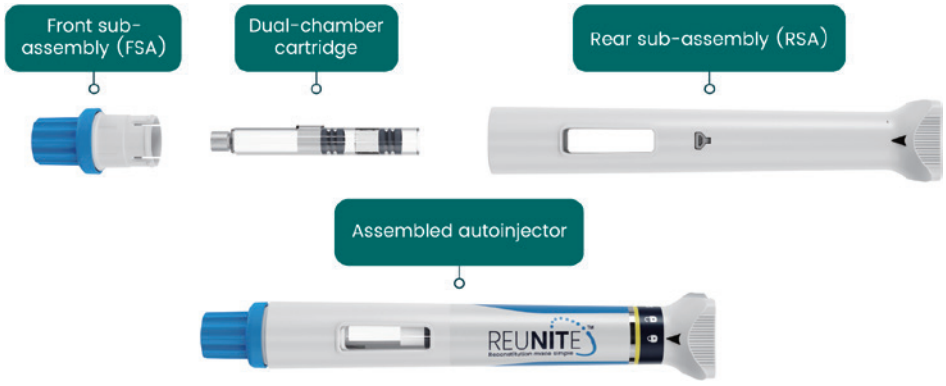


Figure 3: Reunite autoinjector parts for final assembly. Unlocking the RSA enables automated reconstitution. The FSA houses the sterile NIT system, which connects the needle to the cartridge septum upon cap twisting.

To bridge this gap between clinical validation and commercial reality, the device design and final assembly teams at SHL Medical, along with the automation engineers at SHL Advantec, adopted a concurrent design for manufacturing and assembly (DfMA) strategy during the early phases of development. Rather than adapting the final assembly process after device design was completed, the teams co-developed Reunite and the final assembly equipment's architecture specifically to optimise automated handling.

This early alignment dictated stringent assembly requirements. The final assembly process was thoughtfully engineered to control orientation, verify alignment and monitor component insertion forces. High-resolution checks confirm part presence and orientation before any critical operation, while insertion forces are governed by exact control ranges. Coupled with final height verification and the automated segregation of nonconforming units, this integrated approach ensures that every autoinjector meets precise dimensional standards before progressing downstream.

By embedding these DfMA principles into the platform from the beginning, the micro-stresses and alignment errors that commonly plague complex multicomponent devices were prevented and breakthrough mechanics validated in the clinical phase were preserved at commercial scale.

ENSURING AGILITY AND QUALITY AT LAUNCH

Bringing cutting-edge therapies to market in novel drug delivery devices such as Reunite is a complex balancing act between quality, speed and navigating market uncertainty. This pressure is felt particularly by final assembly CMOs who bear the brunt of capital equipment investments. While lower initial launch volumes naturally call for entry-level, lower-throughput machines, the underlying market future extends beyond the volume forecast of a single commercialised product – it also encompasses the broader pipeline of subsequent drug-device projects on their way to help millions of patients manage their treatments.

To give the launch of the first Reunite project immediate agility and long-term scalability, SHL Advantec deployed the Advantec Oval Unlimited (AOU™) platform – a market-proven, oval track technology designed for highly flexible manufacturing strategies at SHL Medical's final assembly site in Deerfield Beach (FL, US). The machine is currently configured for semi-automatic operations with manual loading and unloading stations, serving as an agile, cost-effective entry point for the drug's initial commercialisation volumes.

"SHL'S COMMITMENT TO THE SUCCESS OF THE PROJECT IS UNDERPINNED BY A CULTURE OF UNCOMPROMISING QUALITY AND REGULATORY READINESS DEMONSTRATED AT ITS DEERFIELD BEACH SITE. FOLLOWING A RECENT FDA SURVEILLANCE INSPECTION, THE SITE SUCCESSFULLY CONCLUDED THE AUDIT WITH ZERO OBSERVATIONS."

Figure 4: Interchangeable, project-specific puck carriers, fixtures and grippers on the transportation and assembly modules enable multidevice compatibility.

SHL's commitment to the success of the project is underpinned by a culture of uncompromising quality and regulatory readiness demonstrated at its Deerfield Beach site. Following a recent FDA surveillance inspection, the site successfully concluded the audit with zero observations. This achievement highlights the critical synergy between advanced equipment architecture and expert final assembly services, proving that aligned manufacturing operations can deliver both speed and compliance.

INSIDE AOU: MODULARITY, PRECISION AND SCALABILITY

A deeply integrated modular platform, SHL Advantec's AOU supports various manufacturing configurations in terms of device compatibility, container variation and production volume. This flexibility is enabled by decoupling the core machine base from project-specific modules and component feeding systems. Specifically, this strategic architecture delivers several distinct technical advantages:

- **Multiproject Compatibility**: AOU uses interchangeable grippers and fixtures equipped with a patent-pending Quick Project Change interface (Figure 4). Paired with a modular control system and an easy-to-operate human machine interface, AOU's architecture enables efficient project changeover, supporting the rapid and flexible onboarding of a new device variant onto the same equipment.

- **Primary Container Versatility**: AOU features a fully automatic loader that can be built with in-feeding modules for tubs and/or Rondo trays. Capable of handling both syringes and cartridges – including dual-chamber systems – on the same equipment, the machine can be configured for a wider range of device types. This project-to-project adaptability significantly reduces capital expenses by eliminating the need to build dedicated, siloed lines.

- **In-Line Quality Controls**: AOU uses a suite of integrated technologies – including vision systems, force-monitoring load cells and laser sensors – to verify the integrity of the primary container, assembly processes and the final, assembled device. This rigid, data-driven approach to quality ensures that every device leaving the manufacturing floor meets critical quality attributes and performs exactly to its validated clinical specifications.

- **Integrated Labelling Capabilities**: AOU offers the flexibility to incorporate labelling modules from leading industry suppliers into the final assembly line. Thus, device assembly, labelling and packaging can be consolidated into a single manufacturing line, ensuring strict serialisation and traceability while significantly reducing overall equipment footprint.

- **Seamless Automation Upgrades**: AOU incorporates manual sub-assembly loading and assembled device unloading modules that can be efficiently replaced with fully automated handling systems as commercial demand grows. By removing the need for a complete machine overhaul, this modular approach allows throughput to scale with minimal downtime and significantly compressed revalidation cycles.

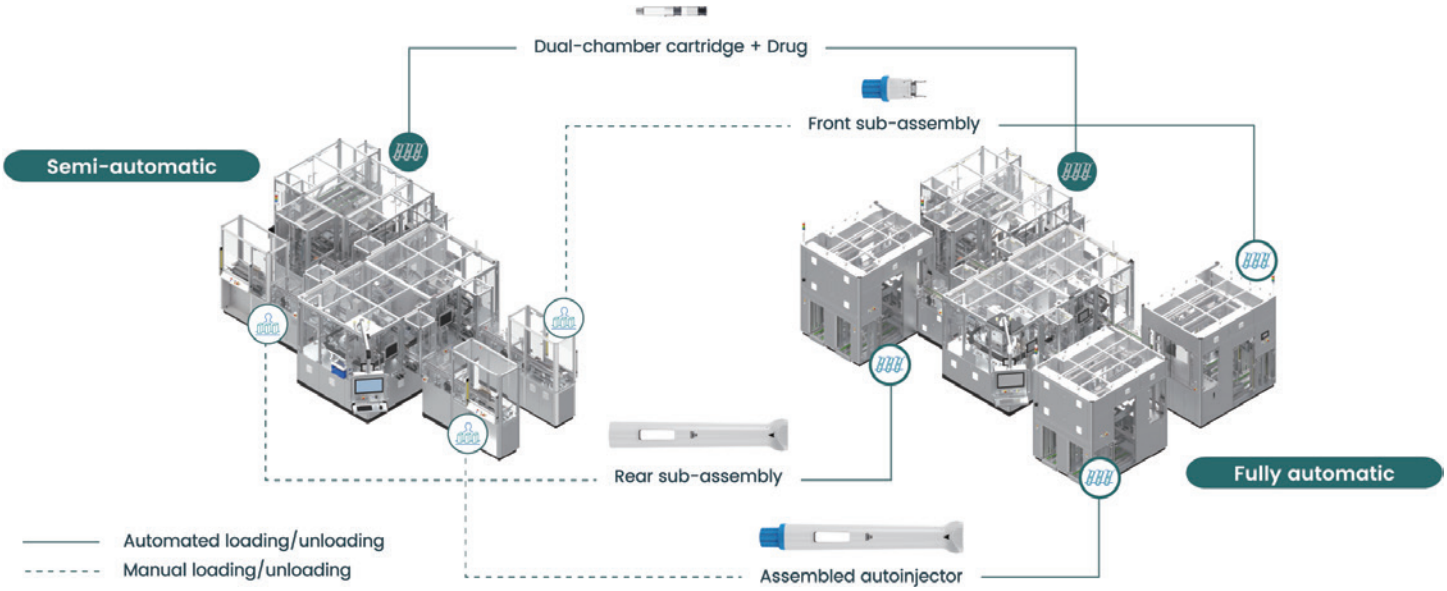


Figure 5: The final assembly AOU automation upgrade pathway with the Reunite autoinjector as an example. The semi-automatic configuration (left) is upgraded to a fully automated line (right) by replacing the manual handling stations with automated modules. The primary container loader remains unchanged.

By isolating customisable modules from core assembly operations, final assembly sites can dynamically adapt to shifting pipeline demands, continuously deriving value from the original equipment infrastructure (Figure 5).

Christy Chen

Christy Chen is Manager of Application Engineering at SHL Advantec, an SHL Medical subgroup specialising in high-precision moulds and advanced automation systems for medical device manufacturing. Ms Chen is a seasoned automation product and application engineering professional with over 20 years of experience in the medtech, electronics and manufacturing industries. Since joining SHL in 2012, she has also held pivotal roles in project management and technical services, aligning cutting-edge technical solutions with customer needs. Ms Chen holds a BS in mechanical engineering and earned an MSc in Sustainable Engineering Technology from the University of Southampton (UK).

E: christy.chen@shl-advantec.com

SHL Advantec

Gubelstrasse 22, 6300 Zug, Switzerland

www.shl-advantec.com

CONCLUSION

The real-world impact of this modular assembly machine strategy is already unfolding at SHL Medical's final assembly operations in Deerfield Beach. The first combination product built on the Reunite technology has generated a strong market response since launch, and preparations to upgrade the current semi-automatic line to a fully automated, high-speed commercial configuration are already underway. Furthermore, capitalising on the AOU's inherent multiproject versatility, SHL's engineering teams are actively collaborating to integrate two additional cartridge-based NIT autoinjectors – Maggie 3.0 and Maggie 5.0 – onto the same equipment, expanding the site's output without requiring new machine installations.

Ultimately, the successful commercialisation of new therapies requires more than just cutting-edge drug delivery devices – it demands a manufacturing

foundation capable of absorbing market uncertainty without compromising speed or quality. By adopting a highly robust platform-based equipment architecture, final assembly services can protect their investments while securing both launch agility and long-term scalability. When pharma, medtech and equipment engineers share a singular vision for patient care, the traditional barriers to scaling complex combination products dissolve. This shared commitment reflects the power of being aligned and united, working together to ensure that complex, innovative science safely reaches the patients who need it.

Alberto Flores

Alberto Flores is Senior Manager of Manufacturing Sciences at SHL Medical Assembly and Services, leading combination product programmes from design transfer and process validation to commercial launch. Mr Flores has over 20 years' experience in pharmaceutical and medical device manufacturing, and is committed to advancing drug delivery through operational excellence, team development and a strong focus on patient outcomes. Since joining SHL Medical, Mr Flores has led cross-functional teams to commercialise six autoinjector products, including a life-saving emergency-use device. Mr Flores holds a Master's degree in Engineering Management and a BS in Mechanical Engineering and is a Lean Six Sigma Green Belt.

E: alberto.flores@shl-medical.com

SHL Medical

588 Jim Moran Boulevard, Deerfield Beach, FL 33442, United States

www.shl-medical.com

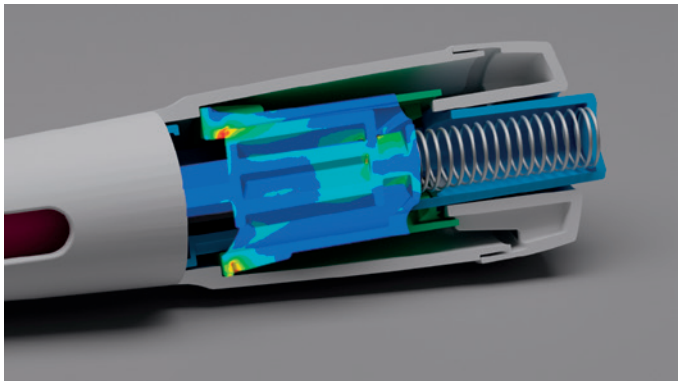
REFERENCES

1. *Kumar S et al, "Application of lyophilization in pharmaceutical injectable formulations: An industry and regulatory perspective". J Drug Deliv Sci Technol, 2024, Vol 100, art 106089.*
2. *Fetz N, "Advancing Lyophilised Drug Delivery with Reunite™: Reconstitution Made Simple". ONdrugDelivery, Issue 177 (Sep/Oct 2025), pp 26–31.*
3. *"Reunite™". Product web page, SHL Medical, accessed Jun 2026.*

Technology Showcase

DIGITAL TWIN TECHNOLOGY FOR AUTOINJECTORS

Digital twins – physics-based virtual models of materials, components and processes – enable engineers to simulate the full lifecycle of a part or device. From optimising mechanical and impact performance to simulating manufacturing by injection moulding, digital twins minimise or eliminate the need for physical prototyping, improving reliability, accelerating time-to-market and, ultimately, reducing costs.



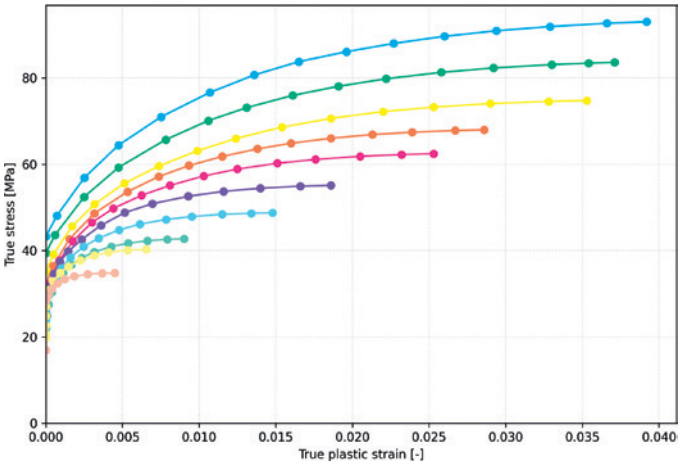


Figure 1: Evaluation of a static load case.

Autoinjectors rely on precision-engineered plastic components that must maintain mechanical performance and dimensional stability under everyday conditions. Medical-grade polycarbonate is widely used for these applications due to its combination of toughness, transparency and chemical resistance. It is used for housings, plungers and safety guards, among other components, due to the following characteristics:

- Consistent toughness and rigidity across a wide temperature range
- Dimensional stability, which is critical for precise actuation and component fit
- Compatibility with common chemicals and sterilisation methods
- Amenability to micro-moulding for mass production of miniature components.

Newer designs favour high mechanical loads with the thinnest possible components, which presents challenges to both design and manufacturing. Polycarbonate has a long history and has been well-characterised, enabling digital-twin-based simulations and optimisation prior to building tooling.

STAGE 1 – STRUCTURAL AND MECHANICAL TESTING

Designs often begin with the evaluation of the mechanical performance of a material as a component in a device, under realistic loads. Finite-element analysis (FEA) predicts stress, strain and deformation under actuation, assembly forces and environmental conditions. Therefore, comprehensive materials data are required, going far beyond typical technical data sheet data.

This step validates whether the design can withstand the required loads and identifies potential weak points. The parts are subjected to a static load from a preloaded spring in the ready-to-use state while maintaining mechanical integrity (Figure 1). By comparing virtual predictions with physical measurements, the digital twin can be calibrated for improved accuracy in subsequent iterations, reducing the need for repeated prototyping.

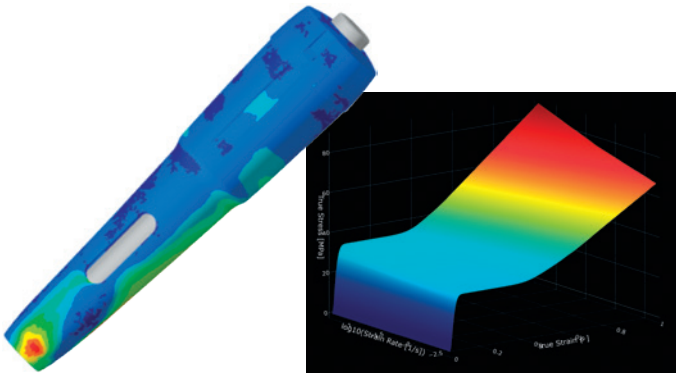


Figure 2: Drop test of an autoinjector.

To increase time efficiency further, basic mechanical components, such as snap hooks, can be virtually designed and optimised with calculation tools that use artificial intelligence (AI). Covestro's "**FEMSnap AI**" is an AI-powered tool that reliably predicts the snap-fit performance of designs with Covestro's material portfolio early in development, based on extensive FEA data under realistic loading scenarios, accelerating designs towards an optimised geometry. This can significantly reduce testing and design-verification efforts or the risk of snap-fit failures, increasing reliability.

STAGE 2 – DROP-TEST SIMULATION

The next step evaluates impact resistance, simulating accidental drops that a device might experience during handling. Explicit-dynamics FEA captures transient stress and deformation, identifying areas of potential fracture or mechanism failure. High-quality material cards of the selected materials are required to generate accurate and reliable results.

Digital twin simulations enable the systematic assessment of design variations such as wall thickness, fillet radius and material selection, as well as helping to ensure structural robustness and minimise material usage. Upon validation, dynamic analyses, such as drop-test simulations (Figure 2), can be employed to significantly reduce the extent of physical testing required.

STAGE 3 – FILLING SIMULATION

The final layer of the digital twin models is the injection-moulding process, predicting how the polycarbonate fills, cools and packs within the mould. Simulation tools such as Moldflow® or Moldex3D® allow engineers to assess:

- Flow-front progression and potential air traps
- Prediction of cavity pressure during the process
- Approximation of the location of weld lines (Figure 3)
- Cooling profiles and residual stresses
- Crucial information for the selection of injection-moulding machinery.

Filling simulations enable the optimisation of gate placement, moulding parameters and cooling channel locations to help maximise dimensional accuracy, reduce scrap rates and support thinner-walled or more complex designs without physical trial and error.

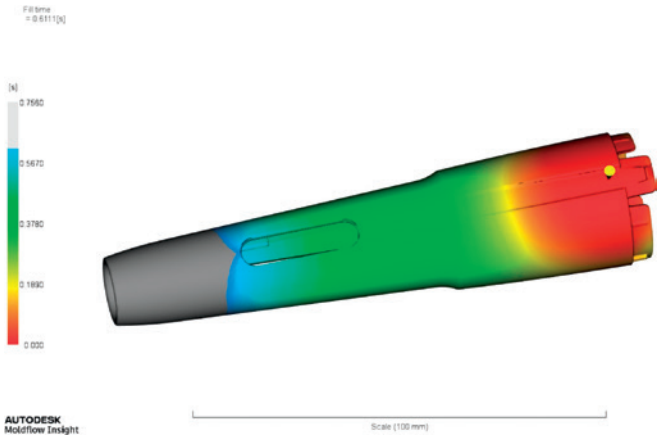


Figure 3: Filling simulation, identification of weld lines.

Furthermore, cycle times can be simulated to estimate production speed and support more refined cost-per-part calculations.

SUMMARY

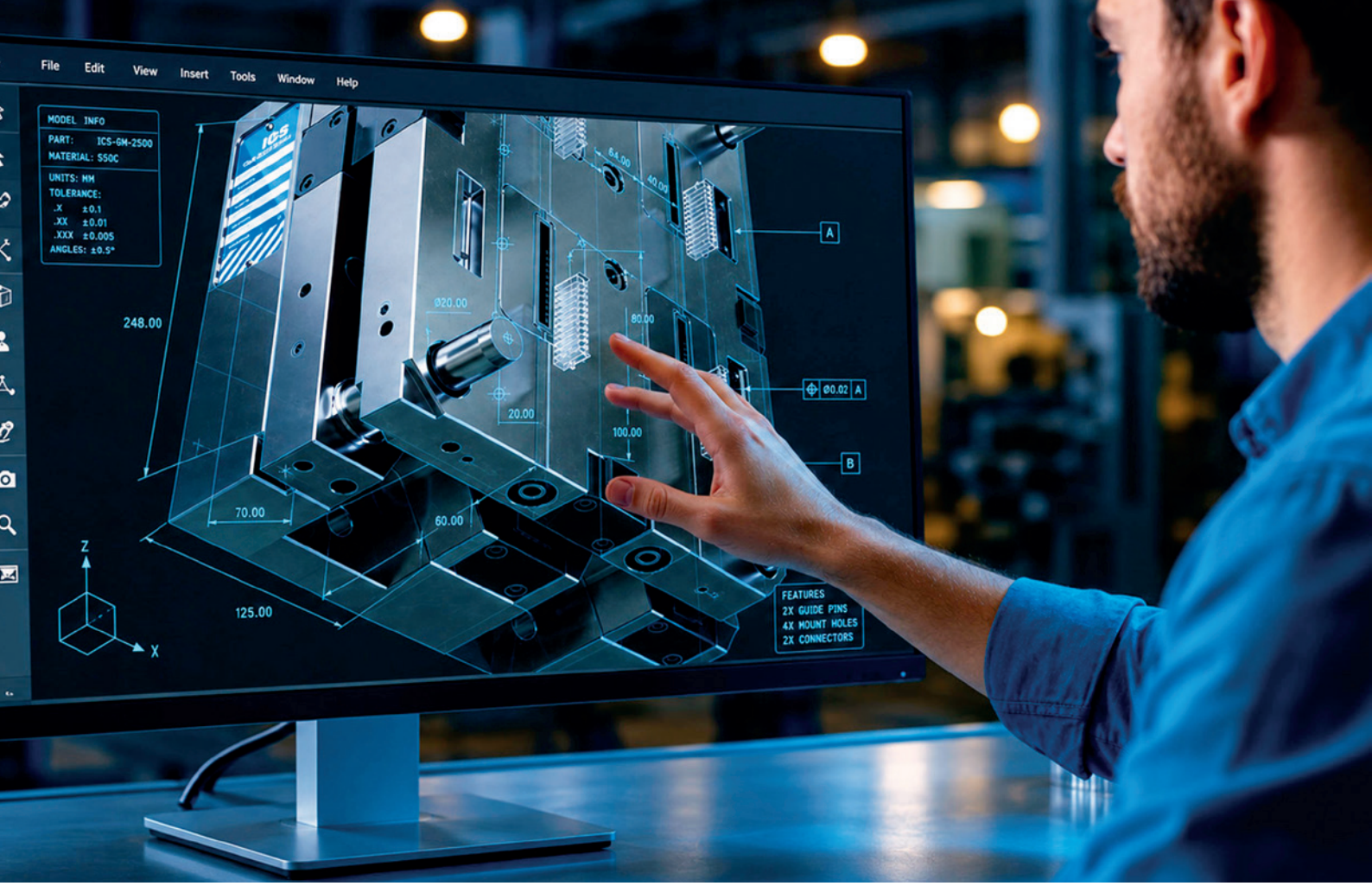
The application of digital twin methodologies to the development of polycarbonate components for autoinjectors presents significant technical, economic and sustainability advantages. By integrating injection-moulding simulations, structural analyses and dynamic impact assessments within a unified framework, design iterations can be evaluated virtually, reducing tooling loops, scrap and manufacturing costs, as well as accelerating time to market.

The predictive capability of digital twins is reinforced through systematic physical validation. Mechanical testing under representative service loads allows direct comparison between simulated and experimental results, enabling calibration of the virtual model and increasing confidence in subsequent design iterations. This approach significantly reduces the cost and time spent on physical tests while maintaining compliance with demanding safety and reliability requirements.

The effectiveness of this methodology relies on the availability of accurate and comprehensive material data. Covestro can provide validated material cards for injection moulding, structural and impact simulations. Where application-specific or extended datasets are required, missing material parameters can be measured and generated in-house, ensuring consistency across all simulation domains and enabling a high level of predictive accuracy.

Overall, digital twins present a comprehensive and sustainable engineering framework for autoinjector development, supporting thinner, lighter and more complex polycarbonate components without compromising safety or reliability, while simultaneously reducing development costs, material usage and environmental impact.

Covestro AG
Kaiser-Wilhelm-Allee 60, 51373 Leverkusen, Germany
E: bernd.garska@covestro.com
www.solutions.covestro.com



HOW MODERN PROTOTYPING ACCELERATES DRUG DELIVERY DEVICE DEVELOPMENT

Erwin van Huijksloot of **IGS GeboJagema** and **Joe Melton** of **FRP** discuss the importance of early prototyping, ensuring a strong understanding of production efficiency and possible variability is grasped before large-scale manufacture begins.

The role of prototyping in drug delivery device development is evolving. Traditionally, the early stages of development focused almost exclusively on demonstrating a concept's functional viability as quickly as possible, with considerations around manufacturability and production efficiency left for later phases, when the product had proven itself and volumes justified the investment.

However, this sequential approach comes at a cost. When production considerations are deferred to the scale-up phase, device developers often discover that their proven, tested design is difficult or expensive to manufacture at volume. The result: redesigns, new validation cycles and potentially a new submission to the EMA or US FDA. Ironically, the time and costs saved by deferring production thinking in the early stages are often lost many times over in later phases.

> "WHEN PRODUCTION CONSIDERATIONS ARE DEFERRED TO THE SCALE-UP PHASE, DEVICE DEVELOPERS OFTEN DISCOVER THAT THEIR PROVEN, TESTED DESIGN IS DIFFICULT OR EXPENSIVE TO MANUFACTURE AT VOLUME."

Therefore, a different approach can be argued: a forward-thinking strategy where production expertise is integrated into the earliest stages of development, ensuring that the device not only works but can also be manufactured efficiently at scale. This approach draws on lessons learned during the long-term collaboration between FRP, a UK-based specialist in prototyping and low-volume injection moulding for medical devices, and IGS GeboJagema, a high-precision production mould maker focused on industrialisation and high-volume production tooling. As of early 2026, the two companies operate under one roof, offering an integrated path from concept to full-scale production. Together, they demonstrate how a forward-thinking approach to prototyping can shorten time-to-market, reduce costs and minimise risk across the entire development journey (Figure 1).

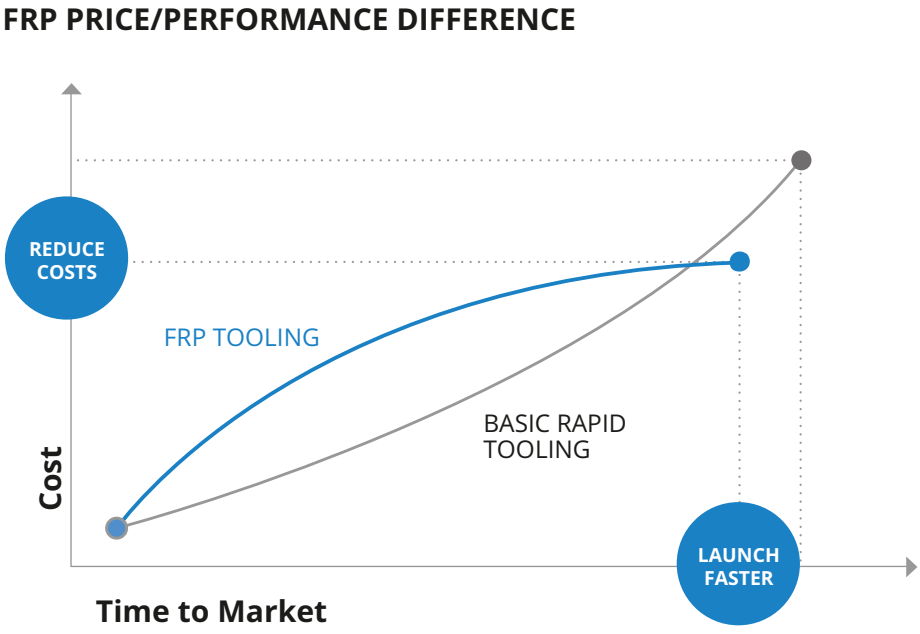


Figure 1: A modern prototyping approach reduces costs and shortens time-to-market.

THE FOUR PHASES OF MOULD DEVELOPMENT

The development of an injection mould for a drug delivery device typically follows four main phases (Figure 2):

1. **Concept**: Early prototypes and a first injection mould (a proto-tool) aim to prove the device's functional viability.
2. **Pilot**: Pre-production moulds are used to produce the parts needed for clinical trials and regulatory submission.
3. **Launch**: After approval, original equipment manufacturers (OEMs) invest in multicavity production moulds to meet market demand.
4. **Full Production**: Production capacity is scaled further through repeat moulds or higher cavity counts.

This development pathway is well established. However, the way these phases connect to each other, and the decisions made in the earliest two phases in particular, can have a profound impact on the cost, speed and overall success of the entire project. The following sections explore how a production-aware approach to prototyping can optimise each transition and compress the path from concept to market launch.

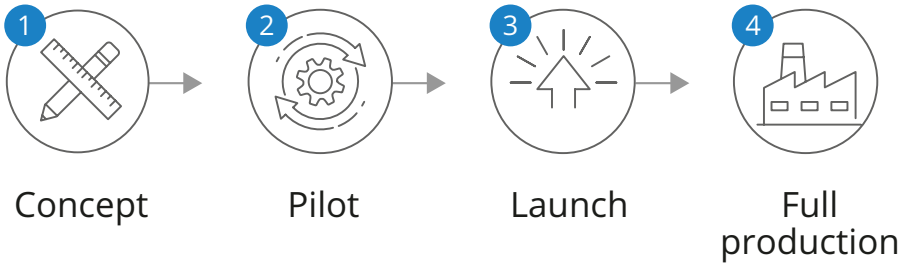


Figure 2: The four main phases of mould development.

THE RIGHT PROTOTYPING TECHNOLOGY

The first phase of development has a clear goal: prove that the device works. However, the choice of how to get there is not always straightforward. A range of manufacturing methods are available, each suited to different volumes and objectives. For injection moulding specifically, FRP distinguishes four levels of tooling, from bronze to platinum, each matched to a phase of development (Figure 3).

The choice between these methods depends on the stage of the project, the number of parts needed and the goals they intend to serve. A company that needs five functioning devices to demonstrate the concept to investors faces a very different decision than one preparing to produce 50,000 units for clinical trials. Matching the right method to the right stage avoids both over-investment and unnecessary compromise.

FRP offers a full range of prototyping technologies: 3D printing, CNC machining, vacuum casting and low-volume injection

"THE FIRST PHASE OF DEVELOPMENT HAS A CLEAR GOAL: PROVE THAT THE DEVICE WORKS. HOWEVER, THE CHOICE OF HOW TO GET THERE IS NOT ALWAYS STRAIGHTFORWARD."

Method	Volume	Lead time	Phase
3D Printing	1-5	Days	Concept
CNC Machining	1-50	Days-weeks	Concept
Vacuum Casting	10-50	Weeks	Concept
Bronze Level Mould	Up to 5,000	3-4 weeks	Concept
Silver Level Mould	Up to 50,000	4-5 weeks	Pilot
Gold Level Mould	Up to 500,000	6-10 weeks	Launch / Full production
Platinum Level Mould	1 million+	26+ weeks	Full production

Figure 3: Four levels of tooling for different product development phases.

moulds. The company considers this technological independence to be critical for a modern prototyping organisation, as it allows clients to make the best possible choice for their project.

Without full visibility into the available options, mismatches between the prototyping method and a project's actual requirements are common. Some device developers get quoted for silver or gold-level tooling when their project's volume only requires a bronze-level mould, which can lead to unnecessary investment. Conversely, developers who have only been exposed to higher-level tooling quotes may conclude that injection moulding is out of reach altogether, and default to a lower-volume method, such as vacuum casting. In practice, this can prove more expensive: producing 200 parts through vacuum casting may require multiple cast tools, whereas a single bronze-level steel mould would deliver the same quantity at a lower total cost and with a more representative part quality. This is why FRP considers technological independence to be a cornerstone of its approach: the right recommendation starts with the project's needs, not the supplier's capabilities.

GETTING THE DESIGN RIGHT FROM DAY ONE

Regardless of which manufacturing method is chosen, one principle should guide the process from the very start: the part design should work in a high-cavity production tool.

This is where design for manufacturing (DfM) makes the critical difference. In the concept phase, DfM ensures that the part design is suitable for injection moulding. This may sound obvious, but it is not uncommon for devices to be designed and prototyped through 3D printing or computer numerical control (CNC) machining by parties without injection moulding expertise, resulting in geometries that need to be fundamentally reworked before they can be moulded. Applying DfM principles from the outset can prevent this, ensuring that the part design can transition smoothly into injection moulding without needing changes to its core geometry.

However, ensuring that a design is mouldable is not the same as ensuring that it will work efficiently in a multicavity production environment. This requires a deeper level of expertise: an understanding of how gating strategies scale, how cooling behaves when cycle times are pushed to their limits and how tolerances accumulate when dozens of cavities must produce identical parts. Without this expertise in industrialisation present during the early stages of development, problems tend to surface later on. It is not uncommon for device developers to arrive at the production tooling phase with a part design that has been successfully prototyped, tested and submitted for regulatory approval, only to discover that it cannot be efficiently manufactured at volume. Re-engineering entails further costs, time, risk and may even trigger a new regulatory submission cycle.

To avoid this exact scenario, FRP involves IGS GeboJagema's production engineering team from the pilot phase onwards. When a silver or gold tool is ordered, the IGS GeboJagema team designs the heart of the mould: the cavity layout, cooling strategy, gating approach and ejection method. The team ensures that the mould design is not only suitable for the silver and gold phase, but that it will also scale effectively to high-cavity production moulds. From regulatory submission to high-volume production, the design never has to change.

ONE UNBROKEN LEARNING CURVE

It is rare for a single organisation to offer both rapid prototyping capabilities and industrialisation expertise for high-volume

"FRP CONSIDERS TECHNOLOGICAL INDEPENDENCE TO BE A CORNERSTONE OF ITS APPROACH: THE RIGHT RECOMMENDATION STARTS WITH THE PROJECT'S NEEDS, NOT THE SUPPLIER'S CAPABILITIES."

"ENSURING THAT A DESIGN IS MOULDABLE IS NOT THE SAME AS ENSURING THAT IT WILL WORK EFFICIENTLY IN A MULTICAVITY PRODUCTION ENVIRONMENT. THIS REQUIRES A DEEPER LEVEL OF EXPERTISE."

production moulds. However, modern prototyping increasingly demands exactly this combination because it unlocks a further advantage: an unbroken learning curve from the earliest prototype through to full-scale production.

In the traditional development model, OEMs work with different partners at different stages. A prototype moulder handles the early tooling, while a larger, industrialisation-focused mould manufacturer takes over for production. Each partner brings their own approach, and the knowledge gained during earlier phases – including process settings, material behaviour and dimensional performance – can be difficult to transfer from one organisation to another. In practice, the learning curve resets every time a new partner picks up the project.

With FRP and IGS GeboJagema now part of the same group, this handover disappears (Figure 4). Because the production engineering team designs the cavity concept from the silver stage onwards, the mould architecture is consistent across every subsequent phase. The mould process optimisation performed on a silver tool carries forwards to gold. The process data from a silver or gold tool can be documented and applied directly to

ONE UNBROKEN LEARNING CURVE

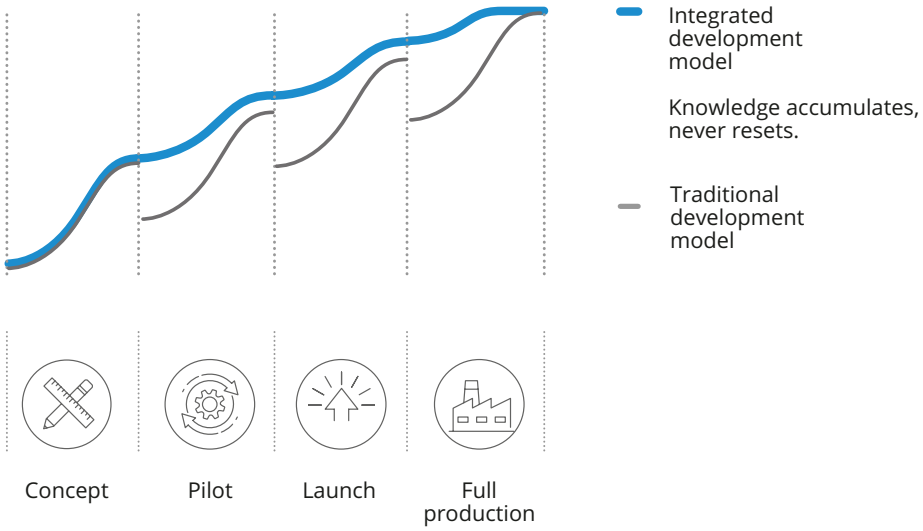


Figure 4: Continuous product development when companies are integrated.

the platinum tool without re-validation. The result is a project where no valuable information is lost between stages.

A FORWARD-THINKING APPROACH

The role of prototyping in drug delivery device development is no longer limited to proving that a concept works. Modern prototyping lays the foundation for everything that follows, from clinical trials and regulatory submissions through to market launch and high-volume production.

When these practices come together, the impact on a development project is significant. When DfM principles are applied from the concept phase, the part design does not need to change as it moves through clinical trials, regulatory submission and into production. When the mould architecture is designed for production from the pilot phase onwards, the transition to high-volume tooling requires no re-engineering. When both are developed under one roof, knowledge can be retained across every phase rather than being lost at each handover. Finally, when neither the part design nor the mould architecture has changed, there is no need for a new regulatory submission to the EMA or FDA.

There is also a practical advantage in terms of time-to-market. Gold-level tooling is production grade, with a shot life of up to 500,000 parts. This means that OEMs can begin selling devices while the high-volume platinum tool is still being manufactured, generating early revenue and further compressing the path from approval to commercial launch.

For OEMs navigating an industry where time-to-market is an increasingly important differentiator and regulatory pathways leave little room for avoidable redesigns, this integrated approach to prototyping is becoming not just an advantage but a necessity.

"FOR OEMs NAVIGATING AN INDUSTRY WHERE TIME-TO-MARKET IS AN INCREASINGLY IMPORTANT DIFFERENTIATOR AND REGULATORY PATHWAYS LEAVE LITTLE ROOM FOR AVOIDABLE REDESIGNS, THIS INTEGRATED APPROACH TO PROTOTYPING IS BECOMING NOT JUST AN ADVANTAGE BUT A NECESSITY."

Erwin van Huijksloot

Erwin van Huijksloot is Senior Sales Manager at IGS GeboJagema, responsible for the company's commercial relationship with healthcare customers, with a focus on partnerships and long-term customer relations. He has over 20 years of experience in sales in the injection-moulding industry and has worked for IGS GeboJagema since 2010.

T: +31 40 264 7500
E: erwin.vanhuijksloot@igsgebojagema.nl

IGS GeboJagema
Esp 430, 5633 AJ Eindhoven, The Netherlands
www.igsgebojagema.nl

Joe Melton

Joe Melton serves as an Account Manager at FRP with over 25 years' experience supporting customers in the medical and automotive industries to bring products to market quickly and efficiently. He specialises in helping clients find the right solution for their early-stage manufacturing requirements, ensuring that projects are set up for success from the outset. With a strong background in project and account management, Mr Melton works closely with customers and internal teams to deliver practical, production-ready components. His focus is on quality, reliability and fast turnaround times, helping clients to stay competitive in demanding and highly regulated markets.

E: joe.melton@frp.co.uk

FRP
Units 4 & 5, Evergreen Venture Park, Barton Road, Wisbech, Cambridgeshire, PE13 4TP, United Kingdom
www.frp.co.uk

CPHI by informa

MILAN
6-8 OCT 2026

Pharma's biggest event is back.

Bigger, bolder, and more fun.

Join the experience

62,000+ Attendees

2,900+ Exhibitors

170+ Countries

Expert View

DE-RISKING POST-MARKET CHANGE THROUGH PILOT PRODUCTION

Jon Powell of Cambridge Design Partnership explores how pilot production, delivered through integrated design, development and manufacturing capabilities, can be used to de-risk change in commercial-scale drug delivery devices, highlighting how such approaches can improve confidence in decision-making while reducing overall time and cost.

Managing change in drug delivery device manufacturing post launch is inherently challenging. Whether driven by regulatory requirements, issues with an existing on-market device, supply chain disruption or design evolution, even small modifications can introduce significant risk to product quality, cost and supply continuity. These challenges are compounded by the practicalities of generating statistically meaningful data from prototype designs without disrupting established, high-volume manufacturing operations.

WHAT DRIVES CHANGE IN DRUG DELIVERY DEVICES?

Even the most comprehensive design verification programmes cannot always accurately predict all failure modes that may emerge once a product is deployed at commercial scale. As production increases from hundreds to millions of units, variability in materials, processes and real-world use conditions can reveal previously unobserved behaviours. In addition to on-market performance considerations, manufacturers must also respond to external and internal drivers, such as:

- Regulatory updates
- Material obsolescence
- Supplier changes
- Cost optimisation initiatives.

Collectively, these factors make change management an essential element in the lifecycle of successful combination products. However, implementing changes without disrupting supply presents a significant challenge – the commercial justification often requires data that can only be gained by transitioning from small numbers of lab-built prototypes to thousands of devices produced using representative manufacturing processes.

> "AS PRODUCTION INCREASES FROM HUNDREDS TO MILLIONS OF UNITS, VARIABILITY IN MATERIALS, PROCESSES AND REAL-WORLD USE CONDITIONS CAN REVEAL PREVIOUSLY UNOBSERVED BEHAVIOURS."

While guidance such as ISO 20069:2019 "Guidance for assessment and evaluation of changes to drug delivery systems" provides a framework for assessing and documenting changes, it offers limited direction regarding exactly how to generate the representative data efficiently without impacting validated production lines.

A COMMON CHALLENGE

Consider an on-market drug delivery device that is currently being manufactured at scale. The production system to make and assemble such a device will be highly optimised. Material handling, in-process quality controls, final packaging, labelling – every step will be designed to reduce variation and ensure quality.

If such a device experienced an issue post-launch, the impact on the manufacturer could be enormous. The decision on how to proceed has significant consequences and could potentially trigger an intervention by the US FDA, the EMA or other regulatory bodies. This is reflected in the number of recalls and corrections reported by the FDA, underlining that the ability to implement changes to marketed products in a controlled way is a strategic need for manufacturers.

Examples from infusion and syringe-based drug delivery systems help to illustrate this challenge. Table 1 presents a selection of recent product recalls and corrections affecting this class of devices. Whilst the specific failure mechanisms differ, the examples highlight recurring challenges associated with fluid handling and sensing functions, such as leak paths and occlusion detection.

Design modifications to address issues such as these require large data sets to generate sufficient statistical confidence that the issue has been resolved; where an issue is not fully understood or only occurs on an infrequent basis, this can potentially entail

Device	Failure Mode	Patient Risk	Date	Remediation
Cardinal Health Monoject Luer-lock syringes	Recognition, compatibility and pump performance issues when used with syringe pumps and patient-controlled analgesia pumps	Overdose, underdose, delay in therapy and delays in occlusion alarms	March 2024	Recall of specific product
B. Braun Infusomat Space Large Volume Pump	On certain models, occlusion alarm may sound when no occlusion exists	Interrupted or failed delivery of medication or fluids	September 2023	Correction of occlusion pressure sensor
Fresenius Kabi Ivenix Infusion System	Fluid leak that causes damage to the electrical system	Delay or interruption to treatment	March 2023	Urgent device recall letter sent to customers
Eitan Medical Sapphire Infusion Pumps	Failure to detect air in line when running on battery power	Risk of serious injury or death from air embolism	September 2023	Recall and customer notification, software update

Table 1: Excerpt of recent product recalls/corrections affecting infusion and syringe-based drug delivery systems.[1]

tens of thousands of units. The requirement for high numbers of finished devices exposes a gap in available manufacturing options:

- Volumes too high for conventional prototyping approaches
- Volumes too low, and timelines too short, to engage commercial-scale CMOs
- Existing production lines may not accommodate the design without significant disruption

This scenario reflects a common industry challenge, where development teams must balance two competing priorities: minimising change to fit with existing manufacturing capabilities versus allowing sufficient design freedom to maximise the likelihood of technical success.

CONTRACT MANUFACTURING CAN BE INFLEXIBLE

In conventional outsourcing models, CMOs are typically optimised for either low-volume engineering support or stable, high-volume commercial manufacture. Small-scale engineering workshops prioritise flexibility and rapid iteration, whereas production facilities are designed around efficiency, repeatability and validated processes (Figure 1). Projects that sit between these two models can create significant operational tension.

In the case of drug delivery systems, the challenge is often amplified by the combination of bespoke automation, tight tolerances and sub-assemblies that contain both rigid and compliant parts. Even relatively small engineering programmes may require dedicated fixtures, custom tooling, automation development and specialised operator training. These investments can be difficult to justify when production volumes remain limited and product designs are still evolving.

Furthermore, these engineering builds often involve a high degree of uncertainty. Device configurations may change frequently, process parameters may still be under investigation and build schedules can fluctuate as development priorities evolve. For a CMO operating under conventional production metrics, such variability can disrupt factory planning, reduce equipment use and negatively impact operational efficiency.

There is also an economic challenge. Low-to-medium-volume engineering programmes rarely achieve the economies of scale associated with high-volume commercial manufacture, yet they may

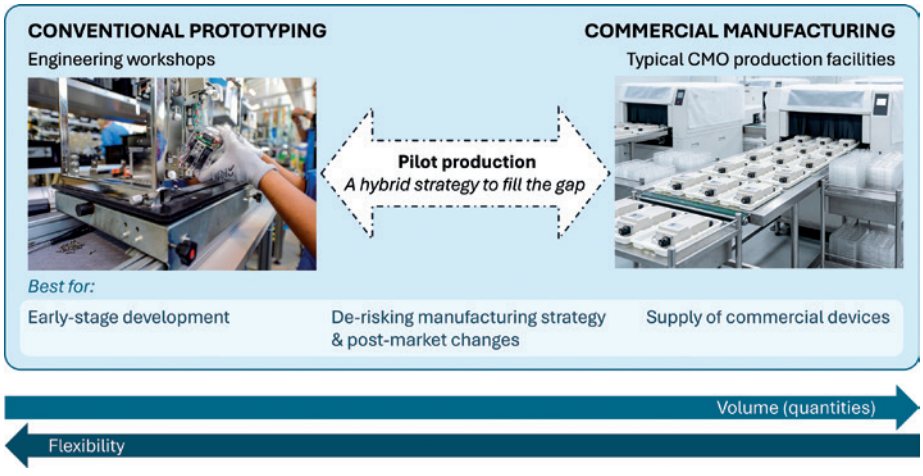


Figure 1: Typical device manufacturing models are optimised either for early-stage design and development or high-volume commercial manufacturing. Alternative models, such as pilot production, bridge this gap by combining the flexibility of engineering workshops with the repeatability and rigour of commercial production facilities.

still demand significant engineering oversight and quality infrastructure. As a result, the commercial model can become unattractive for both the client and the manufacturing partner.

Many CMOs now advertise "Design" as a differentiator – spawning the initialism CDMO – offering design services as well as more traditional manufacturing services. However, as design is often not a core skill for these companies, they can leave clients with a design that only works with their in-house manufacturing approach, or where the IP rights no longer lie with the client.

For these reasons, many organisations may benefit from dedicated pilot production environments operating outside of conventional commercial manufacturing structures, providing a more effective route for executing complex flexible manufacturing.

CONVENTIONAL PROTOTYPING LACKS RIGOUR

Traditional prototyping is typically focused on evaluating functional concepts and demonstrating technical feasibility. Prototype devices are often produced in small quantities using flexible, low-volume methods that prioritise speed and adaptability over repeatability. These builds are valuable during early-stage development, where the objective is to assess usability, confirm mechanical principles or explore initial design architectures. However, prototypes are rarely manufactured under conditions representative of commercial production – as a result, they may not fully reveal the interactions between product design, automation strategy and manufacturing variability.

Pilot manufacturing occupies a different position within the development pathway. Rather than simply proving that a device can function, pilot manufacturing aims to demonstrate that it can be assembled repeatedly, efficiently and robustly under production-representative conditions. This includes consideration of automation compatibility, process capability, quality inspection and operational throughput. The parts themselves are often manufactured by representative processes, such as injection-moulded plastic housings rather than 3D-printed parts.

"RATHER THAN SIMPLY PROVING THAT A DEVICE CAN FUNCTION, PILOT MANUFACTURING AIMS TO DEMONSTRATE THAT IT CAN BE ASSEMBLED REPEATEDLY, EFFICIENTLY AND ROBUSTLY UNDER PRODUCTION-REPRESENTATIVE CONDITIONS."

This distinction is important because many challenges associated with drug delivery systems emerge only when products are built at scale. Tolerance accumulation, fixturing behaviour and automation interactions may appear manageable during low-volume prototyping but can become significant risks during industrialisation. By bridging the gap between prototyping and commercial manufacturing, pilot production enables engineering teams to identify and resolve these issues earlier in development, reducing industrialisation risk and supporting more robust product and process designs.

WHY EXISTING PRODUCTION LINES MAY NOT ACCOMMODATE DESIGN CHANGES

Many manufacturing systems for drug delivery devices rely on bespoke automation, tightly controlled tolerances and carefully sequenced assembly operations, specifically developed for a defined product configuration. Even relatively small design modifications, such as changes to component geometry, material behaviour or assembly orientation, can have cascading effects across the production process.

In automated systems, manufacturing equipment is often programmed around precise assumptions regarding part position, stiffness, insertion forces and component interactions. A seemingly minor design change may therefore require reconfiguration of robotic motion paths, vision system parameters, fixturing, feeding systems, inspection methods or a combination thereof. In some cases, the modification can introduce variability that existing automation is simply unable to accommodate reliably.

"A TARGETED APPROACH CAN BE ADOPTED TO BALANCE FIDELITY WITH FLEXIBILITY AND COST."

These challenges are particularly acute in assemblies containing both rigid and compliant parts. Elastomeric tubes, adhesives or soft materials may behave differently during automated handling when adjacent components are modified, creating interactions that only become apparent at production scale. For example, a section of tubing may curl in one direction 98% of the time based on how it is presented. The low occurrence of the alternative behaviour means it may not be observed in small sample sizes, leading to assumptions being made during automation development that later prove unreliable.

Importantly, commercial manufacturing lines for medical and combination products are usually validated environments operating under strict quality and regulatory controls. Any significant modification to equipment, tooling or process parameters may trigger formal change control activities, required revalidation and production downtime. For manufacturers supplying commercial products, this introduces both operational risk and potential supply chain disruption.

As a result, manufacturers are often reluctant to trial experimental designs directly on operational manufacturing lines, particularly where product demand remains high. This is where pilot production, as a hybrid of prototyping and commercial manufacturing, can provide a practical alternative. By replicating critical manufacturing operations outside the commercial environment, it allows design changes to be evaluated under production-representative conditions without interrupting ongoing supply, nor compromising validated manufacturing systems.

DEVELOPING A HYBRID MANUFACTURING STRATEGY

Replicating the full complexity of the existing high-volume manufacturing system when conducting pilot manufacturing is usually neither practical nor necessary. Instead, a targeted approach can be adopted to balance fidelity with flexibility and cost.

This hybrid strategy, illustrated in Figure 2, involves:

- Mapping the device production process flow
- Identifying critical-to-quality and critical-to-function process steps
- Assessing risk and applying suitable mitigations so that each of these steps is replicated using appropriate technology, for example:
  - A needle insertion step that requires precise needle alignment (high risk) may require a controllable and repeatable automated system, such as a Selective Compliance Articulated Robot Arm
  - Non-critical processes (low risk) could be conducted using manual or semi-automated methods.

As the pilot production system will be operating at a slower rate than a commercial line, a flexible approach to labour organisation and work balancing can mitigate uncertainties in the new, untested line. Even when simulating the new line with digital tools, the pinch points in production flows may not be known without running the system. The use of adaptable fixturing and work-in-process storage, which allows stations to build up inventories, is recommended to cope with these unknowns.

Additionally, it may be possible to redeploy equipment from the existing production lines to maintain process fidelity without incurring unnecessary cost. These valuable pieces of process equipment may be unused spares or repurposed from obsolete lines. However, due care and attention must be observed when bringing them online – they may have different voltages, require repair or maintenance or need production documentation to be translated from other languages.

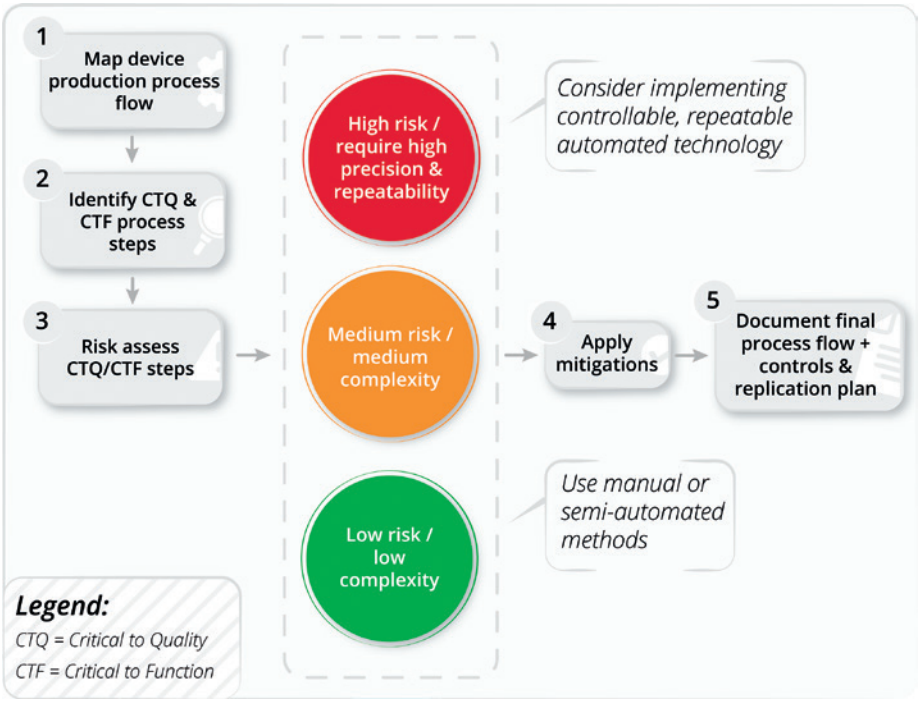


Figure 2: A hybrid manufacturing strategy used in pilot production to achieve a suitable balance between flexibility (allowing modifications) and fidelity (representative of commercial-scale processes).

IMPLEMENTATION AND OUTCOMES

The resulting pilot production line should incorporate a combination of approaches that can be designed and implemented rapidly:

- Automated assembly cells for critical processes
- Manual and fixture-based operations for non-critical steps
- Integrated inspection and functional testing capabilities.

To give a real-world example that puts this into context, a pilot production system such as this was designed, built and operated within a 12-week timeframe, including both factory acceptance testing and site acceptance testing. This enabled rapid deployment into an engineering production environment while design activities continued in parallel. In total, more than 14,000 devices were manufactured across seven design variants. These units supported:

- Engineering performance evaluation
- Accelerated ageing studies
- Ongoing engineering verification testing to prove functional performance.

The pilot production approach therefore provided both the scale and fidelity required to support robust, data-driven decision making.

"TO GIVE A REAL-WORLD EXAMPLE THAT PUTS THIS INTO CONTEXT, A PILOT PRODUCTION SYSTEM SUCH AS THIS WAS DESIGNED, BUILT AND OPERATED WITHIN A 12-WEEK TIMEFRAME, INCLUDING BOTH FACTORY ACCEPTANCE TESTING AND SITE ACCEPTANCE TESTING."

CONCLUSION

For established drug delivery devices, the pressure to change can be driven by performance data, regulatory evolution, supply chain disruption or the ongoing pursuit of improvement. However, the tools available to generate the

evidence needed to support those changes remain poorly matched to the task. Conventional prototyping lacks manufacturing fidelity; commercial-scale CMOs are structured around stability, not experimentation; and validated production lines cannot easily absorb the uncertainty of iterative design work.

Pilot production addresses this gap directly. By replicating critical manufacturing operations in a flexible, lower-volume environment, development teams can generate statistically meaningful data under production-representative conditions, without putting commercial supply at risk. Crucially, it is not a replacement for formal design transfer, but a means of arriving at that stage with greater confidence and fewer unknowns.

As drug delivery systems become increasingly complex, and as expectations for continuous improvement grow, such approaches are likely to play an increasingly important role. By bridging the gap between concept and commercial manufacture, pilot production enables organisations to pursue innovation with greater confidence, while maintaining the reliability and supply continuity that patients depend on.

Jon Powell

Jon Powell, Head of Manufacturing at Cambridge Design Partnership, has over 25 years' experience in manufacturing and operational roles, working across a diverse range of sectors, including medical devices, automotive and aerospace. At CDP, he leads a team of manufacturing engineers who help develop products and processes for the healthcare and consumer sectors. Within drug delivery, he has worked on a range of product types, including parenteral and respiratory devices, as well as intraocular and intrathecal delivery systems.

T: +44 7517 908 347
E: jon.powell@cambridge-design.com

Cambridge Design Partnership
Bourn Quarter, Wellington Way, Cambridge, CB23 7FW, United Kingdom
www.cambridge-design.com

REFERENCE

1. *"Medical Device Safety Communications Database". Web Page, US FDA, accessed May 2026.*

ON diagnostics

Launching 2027

A brand new publication for the global diagnostics industry, connecting diagnostics innovators and manufacturers with clinical and commercial partners.

www.on-diagnostics.com

Issue Topics

- Point-of-Care and Rapid Dx
- Companion Diagnostics & Precision Medicine
- Consumables, Components & Sample Prep
- Immunodiagnostics
- Molecular Diagnostics
- Digital Diagnostics, AI & Connected Diagnostics

In which issue could *your* company appear?

FLYING ON TWO WINGS: YPSOMED'S DUAL-ENGINE STRATEGY FOR SUCCESS IN CHINA

YPSOMED
SELFCARE SOLUTIONS

Hong Cui, **Orfeo Niedermann** and **Shawn James** of **Ypsomed** discuss how their company has succeeded in China, highlighting the importance of integrating into the local market, keeping in stride with the pace of development and maintaining alignment with global quality standards.

MOVING THE NEEDLE: THE EVOLUTION OF CHINA'S INJECTABLE MARKET

China's pharmaceutical market, the second largest in the world, is expected to see spending on medications exceed US$190 billion (£140 billion) by 2029 (Figure 1).[1] But scale alone does not capture what is happening; over the past decade, China's biopharma sector has undergone a structural shift, one that is redefining what the market demands and what it takes to compete within it.

The evidence is striking – in the first half of 2025, 46% of all new drug molecules entering human trials originated from Chinese biopharma companies.[2] Regulatory reforms from the National Medical Products Administration and increasing alignment with ICH standards, which China joined in 2017, have accelerated that trajectory, creating a more sophisticated and internationally connected development environment. In its 2025 report, IQVIA noted that a growing number of originally branded medicines are being introduced by domestic companies rather than multinational firms, a shift that is changing China's pharmaceutical sector and influencing markets both across the region and globally.[1]

Nowhere is this more visible than in injectable drug delivery. China has rapidly expanded its pipeline of subcutaneous therapies across oncology, autoimmune diseases, metabolic disorders and diabetes, with demand for self-injection devices

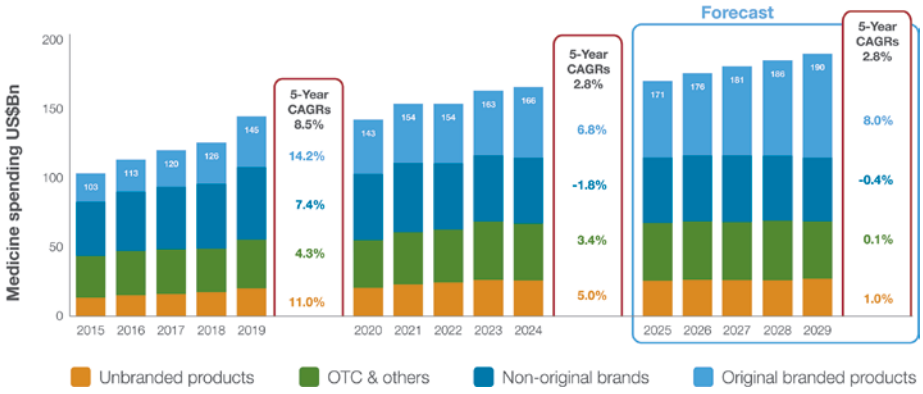


Figure 1: Spending on medications within the Chinese market sorted by product type (2015–2029). Data sourced from IQVIA Institute for Human Data Science. Available from *www.iqviainstitute.org*.[1]

"GROWTH IN PIPELINE COMPLEXITY AND INTERNATIONAL AMBITION CHANGES WHAT PHARMACEUTICAL COMPANIES NEED FROM A DEVICE PARTNER – SIMPLY SELECTING A DEVICE PLATFORM IS NO LONGER THE STARTING POINT IT ONCE WAS."

growing alongside it. Chinese pharmaceutical companies are no longer developing therapies for domestic consumption alone. They are building globally competitive biologics and injectable programmes with serious international licensing and commercialisation ambitions. At the same time, multinational pharmaceutical companies are seeking to enter or deepen their presence in the Chinese market.

Both groups face the same underlying challenge – they need a device partner capable of delivering local manufacturing, local expertise and globally recognised standards from inside China itself. That combination, two capabilities working in concert, is what the next chapter of China's pharmaceutical growth will demand.

GOOD CHEMISTRY: THE NEW FORMULA NEEDED FOR PARTNERSHIP

Growth in pipeline complexity and international ambition changes what pharmaceutical companies need from a device partner – simply selecting a device platform is no longer the starting point it once was. Today's demands are broader and more integrated: speed of development, supply continuity, regulatory fluency across multiple markets and the ability to support programmes from early device selection through to commercial scale.

For Chinese pharmaceutical companies, these demands are particularly acute. Programmes are moving faster, pipelines are more sophisticated and the expectations placed on device partners have never been higher. For multinational companies entering the Chinese market, the challenge is different but related: how does a global organisation maintain seamless alignment with its worldwide development programmes while operating at the pace that the Chinese market demands?

The answer to both questions points in the same direction. What the market now requires is a device partner genuinely embedded in China, one with the global quality standards and regulatory experience to support programmes wherever they are ultimately headed, built on two foundations: manufacturing inside the country and cross-functional expertise on the ground. Neither is sufficient alone.

FAMILIAR TERRITORY: A LONGTIME LOCAL

Ypsomed's presence in China did not begin with the opening of its Changzhou manufacturing facility. It began more than 20 years ago, when the company established its first commercial presence in the Chinese market, at a time when the country's pharmaceutical industry looked very different to what it is today (Figure 2).

The entry point was diabetes care, a deliberate choice given both the scale of unmet need in China and the growing demand for reliable, high-quality injection devices to support long-term therapy adherence. From that foundation, Ypsomed progressively expanded its local presence, moving from an initial commercial footprint to a dedicated office in 2014, steadily building out teams across commercial, technical, regulatory and project management functions.

As the Chinese pharmaceutical market evolved, so did Ypsomed's scope within it. The company expanded beyond diabetes into peptide therapies delivered through pen injectors and autoimmune disease programmes supported by autoinjector platforms, tracking the broader diversification of China's injectable therapy pipeline.

The results of that sustained investment are visible in Ypsomed's track record. The company has realised more than 25 product launches in collaboration with Chinese pharmaceutical customers, across more than 20 years of partnership. Two in three of Ypsomed's Chinese customers have

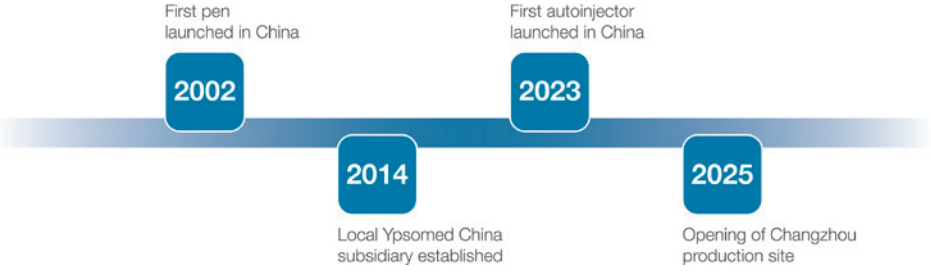


Figure 2: Key Ypsomed China milestones.

partnered with the company on more than one programme. That pattern of long-term, multiprogramme partnerships reflects both the confidence customers place in a partner that has consistently delivered, and the operational credibility that only comes from sustained presence in a market over time.

FACTORY SETTINGS: A CONCRETE COMMITMENT IN CHANGZHOU

In April 2023, Ypsomed broke ground on a new production facility in Changzhou's National Hi-tech District, a high-tech industrial park near Shanghai that is home to more than 10,000 companies (Figure 3). The facility opened in June 2025, representing an investment of over $100 million and a manufacturing footprint of more than 15,000 m², with an additional 30,000 m² secured for future expansion.

The decision to build in China rather than expand exports from Europe was deliberate. Ypsomed was not relocating capacity from its European facilities but adding new capacity, designed from the outset to serve the Chinese market directly. For pharmaceutical companies managing complex development and commercialisation timelines, locally manufactured supply removes a layer of operational risk that cross-border models cannot fully eliminate – customs procedures, import documentation, transportation lead times and exposure to broader supply chain disruption. Bringing manufacturing into China simplifies that picture considerably and secures access to therapies where continuity of treatment is critical, especially for chronically ill patients.

Figure 3: Inside the Changzhou manufacturing site.

Figure 4: The "two wings" framework.

At the same time, local manufacturing supports greater production flexibility. Compared with globally centralised supply models, a manufacturing presence within China allows for closer alignment with local customer needs and faster adaptation to changes in order volumes, accelerated timelines and more efficient logistics. That responsiveness is particularly valuable in a pharmaceutical market that is continuing to evolve at exceptional speed.

The facility has been built to Ypsomed's global standards throughout. ISO 13485 certification for medical devices has been completed by TÜV Süd (München, Germany) and the site has achieved LEED Platinum certification, making it one of the most sustainable industrial buildings in the world. All staff are trained and qualified in line with Ypsomed's global quality framework. The industrialisation of drug-device programmes within China, taking a product from development through to commercial scale, can now be managed locally and reliably, without compromise on the standards set by Ypsomed and that global programmes demand.

FLYING ON TWO WINGS: SPANNING PRODUCTION AND PEOPLE

Local manufacturing and local expertise are each valuable in their own right. But it is their combination that defines Ypsomed's operating model in China, and that combination is deliberate – this is Ypsomed's "two wings" framework (Figure 4).

Ypsomed's Changzhou facility does not operate in isolation. It is supported by a multifunctional team based in China, spanning commercial, technical, regulatory and project management functions. Those two capabilities, manufacturing presence and cross-functional expertise together allow Ypsomed to support

Chinese pharmaceutical customers across the full arc of a programme, from initial device selection and technical compatibility discussions, through regulatory co-ordination and project management, to commercial launch and supply.

For Chinese pharmaceutical companies developing their first autoinjector or pen injector programme, this integrated model removes a layer of complexity that would otherwise require managing multiple partners across different geographies. Local language, local time zones and local currency, combined with reduced complexity around cross-border supply and import processes, mean that day-to-day collaboration is simpler and faster – one partner, operating locally, capable of supporting the entire journey (Figure 5).

For multinational pharmaceutical companies seeking to enter or expand within China, Ypsomed's model serves a different but equally important function. It acts as a bridge between a customer's global development programmes and the specific regulatory, operational and supply requirements of the Chinese market, providing local regulatory fluency, local supply capability and local project co-ordination.

For Chinese pharmaceutical companies with international ambitions, the model also addresses a less obvious but increasingly important consideration. As more Chinese companies pursue global licensing and commercialisation strategies, partner credibility on intellectual property protection becomes a genuine concern. With more than 240 patent families, Ypsomed brings an established IP framework that can help customers prepare their products for international markets with confidence.

> *"Opening our own factory in China is not just a strategic investment – it reflects our long-term commitment and confidence in the Chinese market.*
>
> *Local manufacturing enables us to respond more quickly to customer needs, reduce logistical risks and deliver our products more efficiently and sustainably."*
>
> Simon Michel, CEO of Ypsomed

Figure 5: Quote from Simon Michel, CEO of Ypsomed.

Underpinning all of this is a broader ecosystem approach. Collaborations with partners across primary packaging and automation, combined with ready-to-use final assembly capabilities, allow Ypsomed to co-ordinate across multiple parts of the drug-device value chain, reducing complexity for customers that manage increasingly demanding development programmes.

NO EXPIRY DATE: A POTENT FUTURE

China's pharmaceutical industry is not approaching a plateau. The pipeline of biosimilars, novel biologics and increasingly sophisticated injectable therapies continues to expand, and the international ambitions of Chinese pharmaceutical companies continue to grow along with it. As programmes become more complex and commercialisation strategies reach further across global markets, the demands placed on device partners will only intensify.

Ypsomed's position in China was built with this trajectory in mind, with more than 20 years of local presence, a multifunctional team embedded in the market and a manufacturing facility designed for scale. These are not fixed assets. They are an operating model, one capable of expanding alongside both the complexity of customer programmes and the continued growth of China's pharmaceutical industry. This commitment has not gone unrecognised. At BIO CHINA 2026, one of the most significant industry gatherings in the world, Ypsomed was named Outstanding Supplier of the Year – an acknowledgement of the trust that Chinese pharmaceutical and biotech partners place in the company.

For both Chinese pharmaceutical companies advancing towards global biologics leadership and multinational organisations deepening their presence in the market, Ypsomed's operating model offers something rare: a device partner that is genuinely local in its operations, genuinely global in its standards and genuinely committed to China for the long term.

"YPSOMED'S OPERATING MODEL OFFERS SOMETHING RARE: A DEVICE PARTNER THAT IS GENUINELY LOCAL IN ITS OPERATIONS, GENUINELY GLOBAL IN ITS STANDARDS AND GENUINELY COMMITTED TO CHINA FOR THE LONG TERM."

REFERENCES

1. *"The Global Use of Medicines Outlook Through 2029: Increasing Access, Use, and Spending". Report, p 45, IQVIA Institute for Human Data Science, 2025. Available from www.iqviainstitute.org.*
2. *"China is increasing its share of global drug development". Goldman Sachs, Dec 2025.*

Hong Cui

Hong Cui, General Manager, has worked at Ypsomed since 2015. Prior to joining the company, she worked at the Beijing office of a German consulting firm, where she managed Ypsomed's projects in China. She studied Chemical Engineering and earned an MBA from Peking University's National School of Development (Beijing, China). Over the past 20 years, she has held cross-functional roles in the medtech and healthcare industries, including regulatory affairs, account management, marketing and sales. Since 2024, she has served as a board member of SwissCham Beijing and its Life Science Committee.

T: +86 186 1055 6739
E: hong.cui@ypsomed.com

Orfeo Niedermann

Orfeo Niedermann, Director of Account and Business Development, has worked at Ypsomed since 2005, partnering with pharmaceutical and biotech companies to develop and launch innovative self-injection systems. He holds an MSc in Mechanical Engineering from ETH Zurich and an MBA from Bern University of Applied Sciences (Bern, Switzerland). Over the course of his career, he has held a range of positions in both engineering and sales. He currently leads two teams responsible for account management and business development in Asia-Pacific and Eastern Europe.

T: +41 34 424 39 47
E: orfeo.niedermann@ypsomed.com

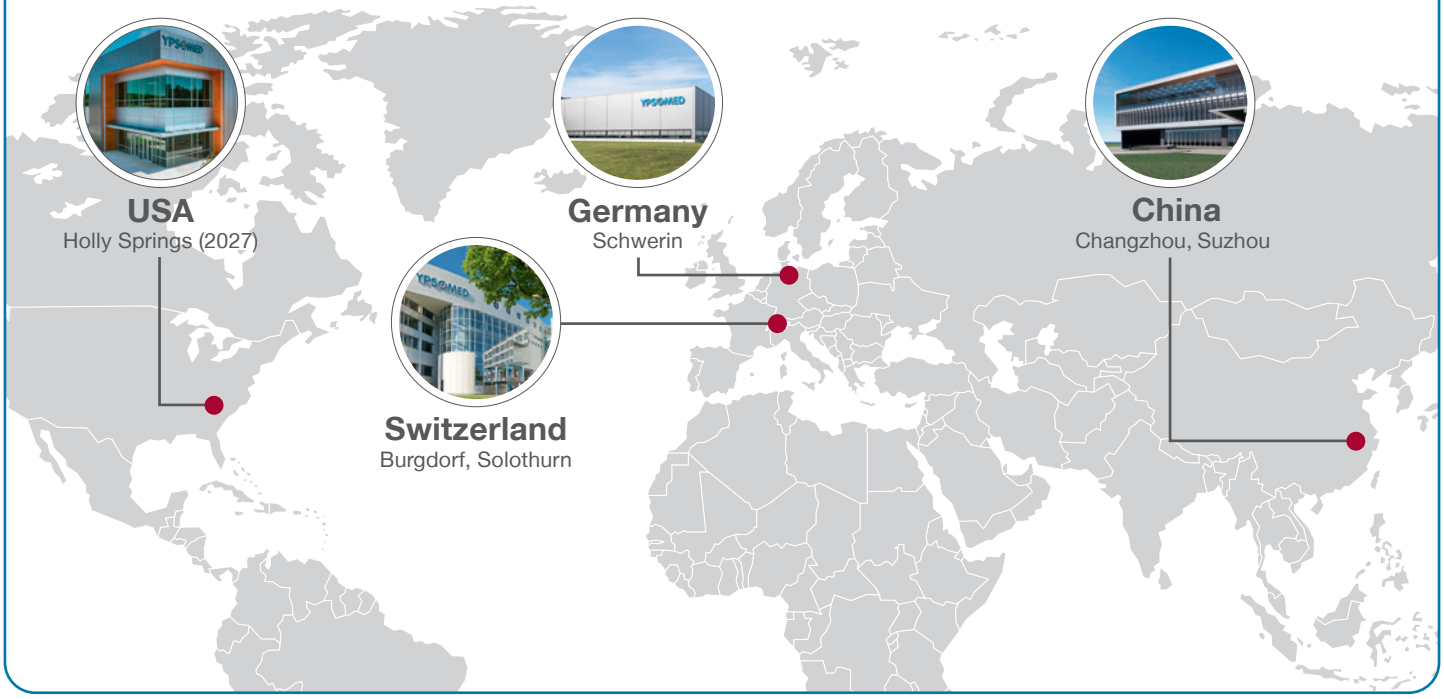
Shawn James

Shawn James is Communication Expert at Ypsomed, where he develops scientific, product and technical content across thought leadership, marketing communications and external publications. He brings more than 15 years of experience in writing, editing and communications, with substantial experience within the medtech industry. Mr James is a member of the European Medical Writers Association and holds a Master's degree in English Literature, Language and Communication from Humboldt University of Berlin (Germany). His background combines strong editorial expertise with the ability to translate complex technical topics into clear, engaging content for professional audiences.

E: shawn.james@ypsomed.com

Ypsomed
Brunnmattstrasse 6, 3401 Burgdorf, Switzerland
www.ypsomed.com

Swiss precision, scaled for the world.



13041870-MSTR-en/V01

Flexible platforms, global production, and trusted partnerships – built to deliver.

- Swiss-engineered platforms manufactured across Europe, Asia, and soon North America.
- Strategic partner network with platforms pre-aligned with world-class container, fill-finish, and assembly partners.
- Flexible platforms built to scale from clinical supply to full commercial volumes.
- Trusted by originator and biosimilar makers for over 40 years.
- Ongoing international expansion, added capacity, and future-proofed global supply chains.

For more information visit www.ypsomed.com or scan the QR code

For more information visit www.ypsomed.com
Ypsomed AG // Brunnmattstrasse 6 // 3401 Burgdorf // Switzerland
T +41 34 424 41 11 // info@ypsomed.com

YPSOMED
SELFCARE SOLUTIONS

INDUSTRIALISING DRUG DELIVERY IN AN UNCERTAIN WORLD

Andy Wertheim of **Quvara Medical** considers how the priorities of drug delivery device industrialisation have shifted in response to the major supply chain shocks of recent years, with companies shifting their focus from purely optimising for low cost and putting much greater emphasis on security and continuity, and what these changing priorities imply for the industry as a whole.

For decades, the pharmaceutical industry has optimised drug delivery manufacturing around three primary variables: cost, scale and efficiency. This model worked; global supply chains expanded, manufacturing networks consolidated and industrialisation strategies increasingly prioritised lean operations, low-cost regions and highly specialised global production hubs.

However, over the past five years, the industry has experienced a succession of shocks that have fundamentally changed the conversation. Covid-19 exposed the fragility of globally extended healthcare supply chains; the war in Ukraine disrupted energy markets, raw materials and industrial stability across Europe (Figure 1); and ongoing instability in the Middle East and disruption surrounding the Strait of Hormuz are once again demonstrating how vulnerable critical healthcare manufacturing networks can become when geopolitical events collide with concentrated global supply chains.

The Strait of Hormuz alone carries approximately 20–25% of the global seaborne oil trade. Recent disruption has already contributed to shipping rerouting, freight inflation and operational uncertainty across global logistics networks. The healthcare sector is not insulated from these pressures.

Modern drug delivery devices depend upon highly integrated industrial ecosystems involving polymers and petrochemicals, precision mouldings, automation systems, electronics, sterile

Figure 1: The war in Ukraine has caused significant disruptions to industrial stability across Europe.

manufacturing environments and specialist logistics networks. When geopolitical instability disrupts freight routes, energy markets or critical raw material flows, the consequences rapidly ripple through pharmaceutical manufacturing operations. The industry is now confronting an uncomfortable reality:

- The challenge is no longer simply how to design innovative drug delivery systems
- Increasingly, the challenge is how to industrialise them reliably, rapidly and resiliently in an uncertain world
- Resilience, strategic manufacturing geography and industrial execution are becoming the defining competitive advantages in drug delivery device manufacturing.

INDUSTRIALISATION IS NO LONGER JUST A MANUFACTURING ACTIVITY

Industrialisation has become one of the most strategically important disciplines within the drug delivery sector. Historically, industrialisation has often been treated as a downstream transfer exercise following device development. Today, that approach is becoming increasingly difficult to sustain.

Drug delivery devices have become significantly more sophisticated over the past decade. Autoinjectors, pen injectors and wearable systems are expected to support increasingly complex formulations, including high-viscosity biologics and large-volume therapies, whilst remaining intuitive, reliable and suitable for patient self-administration. At the same time, global demand is rapidly accelerating.

Glucagon-like peptide-1 (GLP-1) therapies alone are placing extraordinary pressure on worldwide injection-device manufacturing infrastructure. Demand for devices, assembly capacity, tooling resources and cleanroom operations has increased substantially in a relatively short period of time, creating mounting pressure across the industrial ecosystem.

A device that performs effectively in low-volume engineering builds may behave very differently when transferred into automated, high-volume regulated manufacture. Small design decisions can create substantial operational consequences once production scales into the millions of units per year. Industrialisation now directly influences scalability, validation complexity, automation strategy, supply continuity, manufacturing resilience, speed-to-market and long-term commercial flexibility.

Organisations that engage manufacturing expertise earlier in their development programmes are often significantly better positioned to reduce transfer risk, accelerate scale-up and improve supply robustness. Industrialisation is no longer simply a manufacturing activity at the end of development – it is becoming a strategic discipline in its own right.

THE ERA OF "JUST-IN-TIME GLOBALISATION" IS BEING REWRITTEN

For many years, pharmaceutical manufacturing networks prioritised efficiency above almost everything else. The logic was understandable:

- Centralise production
- Minimise inventory
- Optimise freight
- Reduce manufacturing cost
- Consolidate suppliers.

However, the combined effect on global instability of covid-19, Ukraine and the Middle East has exposed the vulnerabilities associated with highly extended and geographically concentrated supply chains. Recent disruption surrounding the Strait of Hormuz has already caused major shipping route changes, increased freight costs and operational uncertainty across global logistics networks (Figure 2).

This matters directly to drug delivery industrialisation. Modern injection devices rely heavily on petrochemical-derived materials, precision manufacturing inputs and globally connected industrial supply chains. Disruption to freight corridors, energy markets or critical component flows can quickly create downstream manufacturing risk.

Figure 2: The disruption in the Strait of Hormuz has increased operational uncertainty across global logistics networks.

The industry is now moving beyond purely efficiency-driven industrialisation strategies towards something more balanced and resilient. Increasingly, organisations are seeking to balance efficiency, resilience, regional flexibility, supply continuity and manufacturing responsiveness – all built around the core of security. This shift is fundamentally changing how pharmaceutical companies evaluate industrialisation partners.

STRATEGIC MANUFACTURING – SECURE GEOGRAPHY MATTERS MORE THAN EVER

Manufacturing geography is now a critical strategic decision. Recent global disruption has demonstrated that manufacturing resilience is not determined solely by technical capability or production cost, it is also increasingly shaped by:

- Geopolitical stability
- Logistics accessibility
- Regulatory maturity
- Engineering capability
- Supply-chain security.

Within this evolving landscape, the UK occupies a uniquely strong and secure position. The UK combines:

- A globally respected life-sciences sector
- Mature pharmaceutical manufacturing infrastructure
- Advanced medtech engineering capability
- Strong regulatory credibility
- Highly skilled technical talent
- Strategic accessibility to both the North American and European markets.

Importantly, the UK also offers a comparatively stable and operationally resilient environment at a time when many global supply chains are experiencing increasing geopolitical and logistics volatility. For pharmaceutical companies seeking to balance resilience, speed, flexibility and commercial scalability, this strategic positioning is becoming increasingly valuable.

"UK-BASED INDUSTRIALISATION CAN THEREFORE PROVIDE FASTER ROUTES TO VALIDATED MANUFACTURE, LOWER TRANSFER RISK AND REGIONAL SUPPLY FLEXIBILITY, AS WELL AS BRIDGE MANUFACTURING CAPABILITY AND ACCELERATE COMMERCIAL SCALE-UP, BEFORE BROADER GLOBAL LOCALISATION STRATEGIES ARE IMPLEMENTED WHERE REQUIRED."

One of the misconceptions emerging within the market is the assumption that resilient manufacturing strategy automatically means "everything must be manufactured in the US" or within a single domestic geography. The reality is considerably more nuanced. For many pharmaceutical companies, the objective is not complete manufacturing isolation; instead, it is the creation of more balanced, resilient and strategically flexible industrial networks. In practice, this often means:

- Reducing overdependence on single manufacturing geographies
- Shortening critical supply chains
- Creating dual region manufacturing strategies
- Improving contingency capability
- Enabling phased localisation over time.

For many organisations, UK-based industrialisation can therefore provide faster routes to validated manufacture, lower transfer risk and regional supply flexibility, as well as bridge manufacturing capability and accelerate commercial scale-up, before broader global localisation strategies are implemented where required. The conversation is increasingly shifting away from, "Where is the absolute cheapest place to manufacture?" towards "Which industrial strategy gives us the best balance of speed, resilience, scalability and operational flexibility?" This distinction matters.

THE MARKET IS REDISCOVERING THE VALUE OF INDUSTRIAL EXECUTION

One of the most important changes taking place across the sector is a renewed appreciation for proven industrial execution capability. For many years, the industry conversation has heavily focused on:

- Innovation
- Device platforms
- New technologies
- Digital capability
- Future manufacturing concepts.

While those areas remain important, recent global disruption has reminded the market that industrial execution itself is a competitive advantage. This is particularly relevant in drug delivery manufacturing, where industrialisation timelines are increasingly shaped not only by technical readiness but also by access to validated infrastructure, cleanroom availability, automation maturity, supply-chain resilience, operational scalability and experienced engineering capability.

Building entirely new manufacturing operations remains possible, but often involves substantial lead-times associated with:

- Facility development
- Equipment procurement
- Validation activity
- Recruitment
- Operational stabilisation.

"QUVARA WAS NOT CREATED AS A THEORETICAL MANUFACTURING PLATFORM OR A GREENFIELD STARTUP OPERATION – IT WAS BUILT FROM MORE THAN 30 YEARS OF PROVEN REGULATED DRUG DELIVERY MANUFACTURING EXPERIENCE WITHIN ONE OF THE WORLD'S LARGEST MEDTECH ENVIRONMENTS."

In many situations, existing industrialised environments may offer significantly faster and lower-risk routes to commercial manufacture. This is where Quvara offers something distinctive within the market.

WHY QUVARA?

Quvara was not created as a theoretical manufacturing platform or a greenfield startup operation – it was built from more than 30 years of proven regulated drug delivery manufacturing experience within one of the world's largest medtech environments. Today, that operational heritage is concentrated within a highly experienced and deeply integrated manufacturing hub in Swindon, UK.

This focused industrial model is intentional. Resilience is not created simply by accumulating manufacturing sites across multiple geographies; it is created through operational control, manufacturing maturity, engineering depth and the ability to industrialise reliably at scale. Rather than operating fragmented manufacturing networks spread across multiple disconnected sites, Quvara offers:

- Concentrated technical expertise
- Integrated engineering and manufacturing teams
- Established operational culture
- Mature validated infrastructure
- Streamlined decision making
- Consistent quality-system execution
- Faster industrial alignment.

Quvara's Swindon hub combines:

- More than 7,500 m² of manufacturing space
- Extensive controlled manufacturing and cleanroom capability
- Established automation infrastructure
- High-volume assembly expertise
- Advanced engineering support
- Validated quality systems
- 24/7 operational capability
- Immediate industrialisation readiness.

This matters in a market where many organisations are facing:

- Cleanroom shortages
- Long automation lead times
- Industrial transfer delays
- Constrained manufacturing capacity
- Growing supply-chain risk.

For many pharmaceutical companies, the priority is therefore not simply the number of manufacturing locations available – increasingly, it is the ability of a manufacturing partner to provide:

- Reliable execution
- Operational continuity
- Scalable infrastructure
- Responsive decision-making
- Industrial depth
- Strategic focus.

This is where Quvara's model becomes highly differentiated.

BEYOND THE TRADITIONAL CDMO MODEL

A common assumption within the market is that organisations must choose between speed-to-market via integrated CDMO platform providers or manufacturing flexibility via independent industrialisation partners. The future market is unlikely to be that binary. Integrated platform providers undoubtedly offer advantages in certain scenarios, particularly where development acceleration is prioritised. However, platform ownership alone does not eliminate the industrialisation challenge.

Regardless of device platform selection, drug delivery device development programmes still require:

- Validated industrial transfer
- Scalable manufacturing systems
- Automation strategy
- Operational robustness
- Quality-system integration
- Long-term supply continuity.

"A COMMON ASSUMPTION WITHIN THE MARKET IS THAT ORGANISATIONS MUST CHOOSE BETWEEN SPEED-TO-MARKET VIA INTEGRATED CDMO PLATFORM PROVIDERS OR MANUFACTURING FLEXIBILITY VIA INDEPENDENT INDUSTRIALISATION PARTNERS. THE FUTURE MARKET IS UNLIKELY TO BE THAT BINARY."

BOX 1: A PRACTICAL INDUSTRIALISATION RESILIENCE CHECKLIST

Organisations should increasingly be asking themselves a broader set of strategic manufacturing questions:

- Do we fully understand the scalability limitations of our current device architecture?
- How dependent are we on single-source suppliers or single manufacturing geographies?
- What would happen if one of our critical supply routes became disrupted for 30–90 days?
- Are our manufacturing timelines dependent upon new facility construction or greenfield validation?
- How resilient is our tooling and automation supply chain?
- Can our industrialisation partner support both rapid scale-up and long-term commercial continuity?
- Do we have sufficient regional manufacturing flexibility to support future localisation requirements?
- Are we over-optimised for lowest cost at the expense of resilience?
- How quickly could we transfer production if market conditions changed?
- Does our manufacturing partner have proven experience operating at sustained commercial scale?
- Are our device and manufacturing strategies aligned from the earliest stages of development?
- Have we considered how geopolitical instability could affect freight, energy costs or material availability?

These are no longer theoretical questions. They are increasingly becoming board-level operational risks capable of affecting programme timelines, market supply and long-term commercial performance.

These areas are becoming increasingly important as commercial volumes rise and supply-chain resilience becomes more strategically critical. Importantly, many pharmaceutical companies are also seeking to avoid excessive dependency on single proprietary ecosystems over the full commercial lifecycle of a product.

As a platform-agnostic manufacturing partner, Quvara offers organisations greater flexibility in how they structure industrialisation pathways, supply strategies, regional manufacturing models and long-term commercial scalability (Box 1). The market is increasingly favouring collaborative industrial ecosystems combining innovation, device expertise, flexible manufacturing capability and resilient industrial execution rather than purely vertically integrated models alone.

THE INDUSTRY MAY BE UNDERESTIMATING THE SCALE OF CHANGE AHEAD

The drug delivery sector is still in the early stages of a broader industrial transformation. The combined effects of the following are creating structural changes that may persist for many years:

- Growing demand for GLP-1s
- Biologics expansion
- Geopolitical instability
- Freight disruption
- Energy volatility
- Supply-chain regionalisation
- Increasing healthcare resilience requirements.

The industry may still be underestimating future cleanroom demand, automation capacity constraints, tooling lead-times, supply-chain fragility, industrial transfer complexity and the strategic value of existing validated manufacturing infrastructure. This is precisely why experienced industrialisation partners, such as Quvara Medical, will play an increasingly important role within the next generation of drug delivery manufacturing. The challenge is no longer simply innovation; increasingly, it is resilient industrial execution at commercial scale.

THE FUTURE OF INDUSTRIALISING DRUG DELIVERY

Technical innovation will remain central to the future of drug delivery. However, the next decade will increasingly be defined by the organisations capable of combining innovation with resilient industrial execution. Covid-19 demonstrated the fragility of global healthcare supply chains, Ukraine exposed the vulnerability of industrial energy and raw-material dependency, and the ongoing instability surrounding the Strait of Hormuz is reinforcing the risks associated with globally concentrated freight and manufacturing

Figure 3: Covid-19 and other major global supply shocks have led pharmaceutical companies to reassess how they think about supply chains and industrialisation.

networks. Together, these events are fundamentally reshaping how pharmaceutical companies think about industrialisation strategy (Figure 3).

Resilience, regionalisation, manufacturing maturity and supply continuity are becoming increasingly important considerations alongside traditional metrics, such as cost and scale. Ultimately, the organisations best positioned for long-term success are likely to be those capable of combining:

- Technical capability
- Operational maturity
- Scalable infrastructure
- Resilient supply networks
- Regulatory excellence
- Strategic manufacturing flexibility.

For organisations currently reassessing supply-chain resilience, evaluating industrialisation pathways or facing increasing cleanroom and capacity constraints, the conversation is changing rapidly. The question is no longer simply: "Who can manufacture our device?" – it is: "Who can help us industrialise reliably in an uncertain world?" That is the challenge Quvara was built to solve.

Andy Wertheim

Andy Wertheim is Chief Commercial Officer at Quvara Medical, a CMO specialising in autoinjectors, pen injectors and precision medical device components. He leads global commercial strategy, business development and marketing, focusing on expanding capacity partnerships for pharmaceutical and medtech customers. Prior to joining Quvara Medical in 2025, Mr Wertheim held senior commercial and portfolio leadership roles at Owen Mumford, where he led strategic growth initiatives for drug delivery devices and combination products. His experience spans device industrialisation, partner selection and scaling regulated manufacturing platforms that support complex injectable therapies.

T: +44 1793 714500
E: info@quvaramedical.com

Quvara Medical
Faraday Road, Dorcan, Swindon, SN3 5JH, United Kingdom
www.quvaramedical.com

Expert View

INDUSTRIALISING DRUG DELIVERY DEVICES: INSIGHTS FROM 40 YEARS OF GETTING TO MARKET

Chris Hurlstone of Team Consulting looks at the process of developing drug delivery systems through the industrialisation phase and explores ways to address the challenges that arise along the way. Drawing on Team's 40-year track record of supporting drug delivery device innovation, the insights are intended for teams involved in developing drug delivery systems, particularly those responsible for design, engineering, industrialisation and manufacturing transfer.

"THE DRUG DELIVERY DEVICE REGULATORY FRAMEWORK IS CONSTANTLY CHANGING AND THE LONG-RUNNING NATURE OF DEVICE DEVELOPMENT PROGRAMMES MEANS THAT APPLICABLE STANDARDS, REGULATIONS AND GUIDANCE MAY SHIFT DURING THE DEVELOPMENT PROCESS."

Tools, technologies and processes may have changed over the decades, but many of the fundamentals of developing a drug delivery system (DDS) and taking it through the critical industrialisation phase remain unchanged. A DDS is defined as a given combination of a medical device and a medicinal product – whether provided as separate products or integrated as a single product – intended to deliver the medicinal product.

During DDS development, a lot depends on establishing the foundations for success from the outset. This involves ensuring a clear and viable product strategy, capturing requirements effectively and realistically, choosing concepts grounded in core engineering and scientific principles, and focusing strongly on design for manufacture and assembly from the word go.

UNDERSTAND AND BE GUIDED BY THE REGULATORY PATHWAY

Classifying a device or combination product and establishing its required regulatory pathway can often be straightforward. There are occasions however, particularly for innovative devices and technologies, where ambiguities arise, sometimes with multiple possible pathways to consider. Examples include whether or not to file as a substitutable generic, how to demonstrate bioequivalence or whether the device software is classified as Software as a Medical Device.

Similarly, it is important to establish which standards and guidance will be applied. The drug delivery device regulatory framework is constantly changing and the long-running nature of device development programmes means that applicable standards, regulations and guidance may shift during the development process. Examples include updates to ISO 11608 for injection systems, ISO 10993 for biocompatibility, US FDA guidance for "five nines" reliability and, more recently, Essential Drug Delivery Outputs (EDDOs).

The implication of changing regulatory standards on the industrialisation phase is that strategies and requirements for design verification and validation (V&V), stability programmes and clinical studies can evolve during development. This can strongly influence the requirements for pre-launch supply of components and devices and, therefore, the specifications and capabilities of manufacturing systems, such as tooling, assembly and inspection equipment. These are long lead-time items where specification or implementation changes mid-stream can have major implications.

UNDERSTAND AND DOCUMENT THE DRUG DELIVERY SYSTEM DESIGN

Having a strong understanding of the device's performance – its sensitivities and the limits of the design envelope – is highly recommended (Figure 1). Without it, characterisation, optimisation, implementation and troubleshooting become inefficient and problematic.

For a DDS, this understanding and the documentation of it becomes a regulatory imperative. For example:

- The European Medical Device Regulation, which has increased focus on the device constituent part compared with the Medical Device Directive, requires that manufacturers ensure that all general safety and performance

requirements are demonstrated as being met, and that manufacturing processes are appropriate.

- The design transfer section of ISO 13485 stipulates a number of requirements for manufacturers, including ensuring that design outputs are suitable for manufacturing before becoming final production specifications and that production capability can meet product requirements.

- The requirements set out by the recent FDA EDDO guidance extend to the need for documented manufacturing control strategies that demonstrate that essential outputs are understood and fully controlled.

Insufficient planning of how to meet these requirements can significantly impact the industrialisation and scale-up phases of a development programme. Having to build the necessary levels of device understanding late in the day – for example, to support final optimisation, tooling qualification or specification of test and inspection regimes – is a common cause of inefficiency and delay.

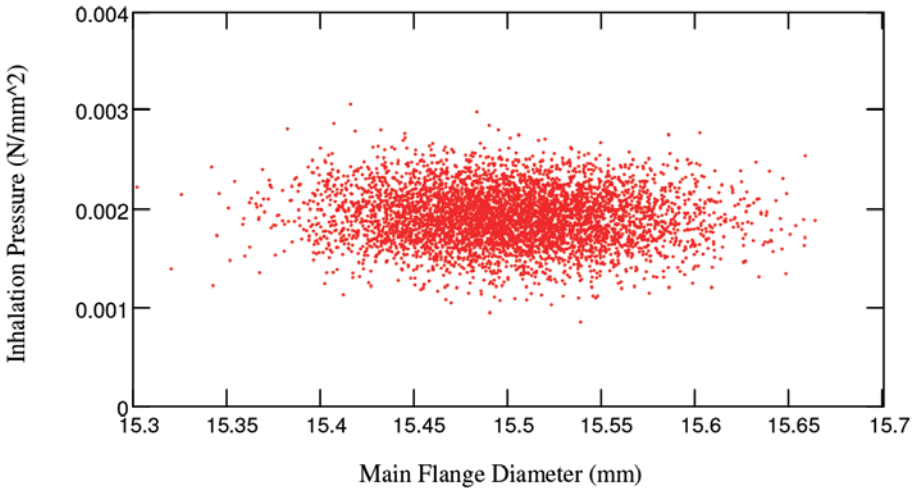
WORK WITHIN INDUSTRY STANDARDS AND ACCEPTED NORMS, OR BE PREPARED WHEN YOU CANNOT

The drug delivery industry is built on many well established, standardised elements. These include drug product primary packs, such as syringes, cartridges, vials, stoppers, needles, pressurised metered dose inhaler (pMDI) canisters and powder capsules, as well as materials, filling processes, etc. This standardisation brings benefits such as consistency, interchangeability and efficiency, but it does have a downside – device or technology innovation programmes that rely on making changes to any of these standards and norms can become more difficult.

In cases where these constraints can stifle innovation and result in suboptimal solutions for patients, there may be a strong argument for pushing back on them. When taking this route, it is important to go into the development programme with eyes wide open. It is possible to develop concepts and prototypes using non-standard elements, and doing so can present new opportunities.

However, engagement with CMOs and the supply chain at the start of industrialisation is not the time to discover that you are trying to swim against the flow. Establish this early on in the programme and make appropriate adjustments.

$$P_i := \left[\frac{SF + vS01 + F_{invert} - F_{res} - F_{prime}}{\frac{\pi}{4} \cdot (vC04^2)} \right]$$



$$MCpcin(P_i) = \begin{pmatrix} \text{"Process Capability Indices (Normal)"} & \text{"LMC"} & \text{"Mid"} & \text{"MMC"} \\ \text{"----------"} & \text{"------"} & \text{"-------"} & \text{"-------"} \\ \text{"Limits for Cpk = 1.33 (64 ppm)"} & 0.00081 & 0.00193 & 0.00305 \\ \text{"Limits for Cpk = 1.66 (0.5 ppm)"} & 0.00053 & 0.00193 & 0.00333 \\ \text{"Limits for Cpk = 2.00 (0.002 ppm)"} & 0.00025 & 0.00193 & 0.00361 \\ \text{"Extremes in Data Set of 5000"} & 0.00086 & 0.00193 & 0.00307 \end{pmatrix}$$

$$PPM\left(\begin{pmatrix} P_i \\ 0.0030 \end{pmatrix}\right) = \begin{pmatrix} \text{"PPM below Limit"} & \text{"PPM above Limit"} \\ \text{"----------"} & \text{"----------"} \\ 999933.593 & 66.407 \end{pmatrix}$$

Figure 1: Sensitivity analysis: one tool to help establish and demonstrate design understanding.

ADOPT A SYSTEMS ENGINEERING APPROACH

Drug delivery systems such as autoinjectors and pMDIs may seem relatively simple compared with large, complex systems. However, taking a systems engineering approach from the outset is still strongly recommended, as it can yield benefits and prove particularly helpful at avoiding – or resolving – issues that arise during industrialisation and scale-up. Such benefits include the use of sub-system verification, which can support efficient troubleshooting of late-stage issues, and the involvement of all disciplines throughout development to help prevent late-stage issues arising in the first place due to a perspective being overlooked early on.

Primary Pack Functionality

Consideration of sub-systems, interfaces and interdependencies is especially important for DDSs that incorporate existing primary packs that must meet additional levels of functionality beyond their original requirements. For example:

- A breath-actuated inhaler that relies on attributes of the pMDI canister (e.g. geometry and tolerances, force characteristics through life, valve opening characteristics)

- An autoinjector that relies on attributes of a prefilled syringe, such as geometry and tolerance to control timing of needle cover release, glide force to avoid excessive delivery times and glass robustness to avoid impact breakage.

These primary packs were not originally designed to be part of such systems, and hence are not optimised or controlled for this purpose. Suppliers will not necessarily be willing – or able – to hold and/or adapt key quality attributes to meet specific device needs (Figure 2).

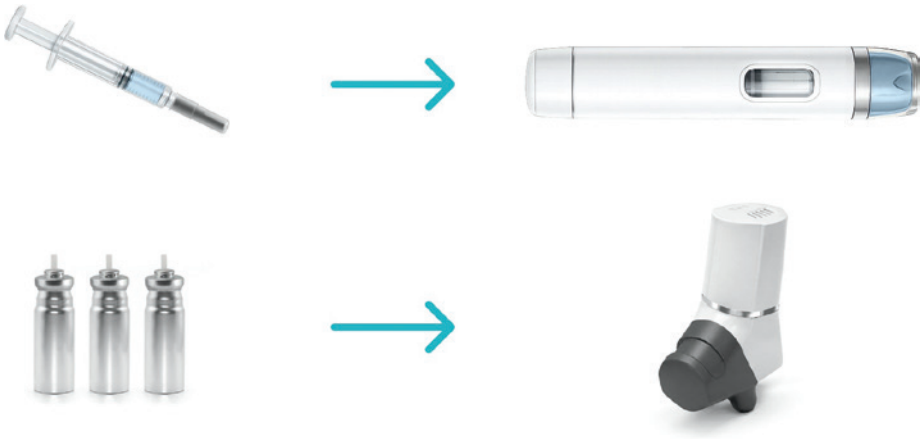


Figure 2: Primary packs as sub-system elements.

User/Drug Interaction

For novel DDSs, the user/drug interaction is assessed through clinical trials. Early studies check for safety and initial efficacy, with some flexibility on which device is used. In Phase IIb and especially Phase III, however, where dosing and delivery performance is finalised, devices need to be more closely representative of the commercial product. This means that the industrialisation phase is often concentrated between pilot stage verification and the Phase III study. Delays to these stages bring a very heavy cost; therefore, it is critical to get the next two interactions right.

Drug/Device Interaction

Early demonstration of drug/device interaction is often carried out on development formulations, or surrogate liquids or powders, in prototype or pilot devices. Availability of representative drug can be either impossible or heavily limited due to cost.

Design verification through performance testing of a truly representative combination of drug and device can only occur following the industrialisation stage, when commercial production systems are approaching final qualification. If there are sensitivities in performance (e.g. delivered dose, particle size distribution, injection time, injection depth), this is not a good time to find out.

To mitigate this risk, development work should identify and investigate potential sources of variation. These can include temperature (viscous drugs), settling over time (suspensions), contact material and environment (drug stability), formulation robustness to delivery conditions (high stresses, due to pressure or vibration, e.g. ultrasonics), moisture ingress (dry powders) and electrostatics (powders and fine mists). Implications for system elements such as power sources, needle gauges, airflow characteristics and powder handling can then be resolved.

For platform systems, the full range of formulations intended for delivery needs to be considered when capturing input requirements. Decisions on what to include and what to exclude may be difficult but are necessary.

User/Device Interaction

Many DDSs rely on interaction with naive patients and, therefore, need to be robust to variation. For example, it is advisable to base a device's user interface on users' pre-existing mental models and the different ways in which they may interact with the device. This emphasises the importance of good human factors/usability engineering (HF/UE), but also of applying good engineering design principles.

It is advantageous for the developer that these interactions can be investigated and de-risked well before the industrialisation phase. User populations are known and prototype devices of a reasonably high fidelity can usually be sufficient to support assessment through HF/UE studies and expert review.

The user/device interaction needs to be considered in both directions, however. Not only must the user be able to successfully prepare and operate the device, but the device itself must be able to withstand interaction with the user, such as gripping, dropping and foreseeable abuse. It is during industrialisation that device features critical to success are finally fully representative (e.g. snaps, clips, wall thicknesses, mass, material properties) and that units are available in large enough quantities for sizeable test programmes and actual use studies to be carried out.

"RISK MANAGEMENT, ENGINEERING ANALYSIS AND TESTING IN EARLIER PHASES MUST BE APPLIED RIGOROUSLY TO ENSURE AS FAR AS POSSIBLE THAT UNIDENTIFIED POTENTIAL FAILURE MODES DO NOT PRESENT THEMSELVES AT LATE STAGES OF DEVELOPMENT."

Risk management, engineering analysis and testing in earlier phases must be applied rigorously to ensure as far as possible that unidentified potential failure modes do not present themselves at late stages of development.

CONSIDER THE ENTIRE DRUG DELIVERY DEVICE 'ECOSYSTEM'

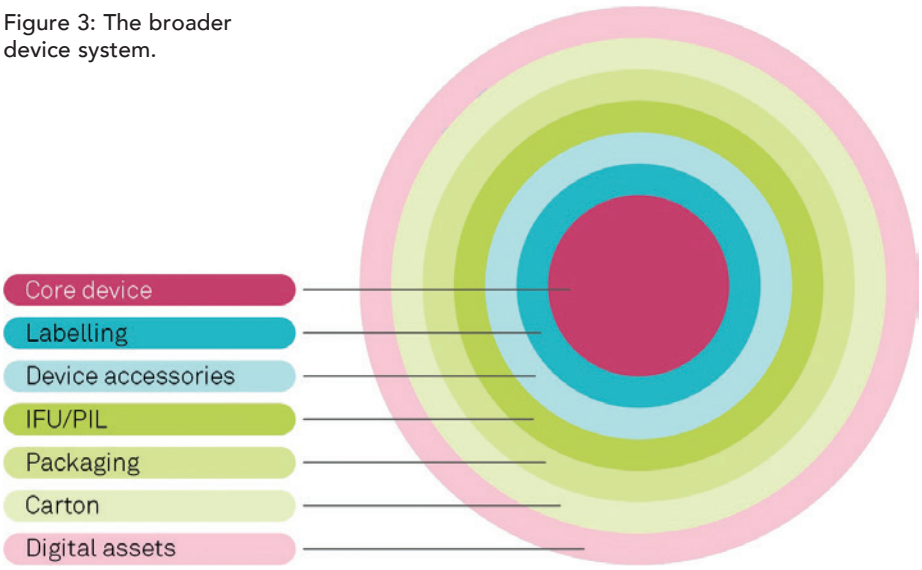
For medical products such as a DDS, the "device" element extends beyond the core device itself, to include items such as labels, instructions for use and tertiary

packaging, as well as any supporting applications or other digital assets (Figure 3).

Final design V&V of the DDS must be carried out on commercially representative versions of all these elements. However, experience shows that some are not given the necessary attention early enough in the development, or with sufficient focus. This can lead to delays, such as to design verification testing or summative HF/UE studies or – at best – extra loading and stress into what is often already an intense and demanding phase of work.

All elements of the DDS need to be progressed in parallel. It is bad enough for the device to find itself on the critical path without it being due to delays in the availability of, for example, labelling equipment or carton inserts.

Figure 3: The broader device system.



Another good reason for parallel development of the entire system is that it can facilitate the incorporation of features into the device design, which can then be referred to, directly or indirectly, such as in the instructions for use ("remove the blue cap"). This can help to ensure that the overall package (including packaging) is optimised to support safe, effective and intuitive use. Leaving development of the ecosystem until later can close the doors on potential easy wins.

BASE DEVELOPMENT AROUND ROBUST RISK MANAGEMENT ACTIVITIES

Some DDSs have higher risk profiles than others, but there is always an imperative to ensure safe and effective use. Starting early with rigorous risk management activities, combined with an effective HF/UE programme, ensures that this can be demonstrated during design V&V.

The path to achieving low residual risk should become clear during detailed design, based on optimisation of the design and specification of production systems and control strategy. Any need for late-stage

risk reduction, such as through design modification or additional inspection/test measures, can have a significant adverse impact on industrialisation. This should be a phase featuring implementation of known risk mitigation measures, not identification of new ones.

CAREFULLY PLAN AND MANAGE THE SHIFT FROM DEVELOPMENT TO MANUFACTURING ORGANISATIONS

The tools, processes and mindsets present in organisations specialising in rapid design development often differ from those in commercial manufacturing. Both are appropriate, and CMO partners are ideally involved in development during detailed design phases so that collaboration can start early. However, significant transfer of activities and responsibilities between organisations usually occurs during the industrialisation phase, and this can be a source of challenge.

Systems being transferred need to be compatible, decision-making processes need to be clear and effective and the collaboration in previous phases needs to have ensured joint buy-in and "ownership" of the design. Careful selection of the right partners is critical, as is generation of effective transfer plans, including definition of roles and responsibilities. Effective collaboration across functions is critical throughout DDS development programmes, but the stakes and risks are often highest during the industrialisation phase.

MANAGING INDUSTRIALISATION OF DRUG DELIVERY SYSTEMS

One of the challenges with DDSs is that delays at the industrialisation phase can be extremely costly. Late-stage programme milestones often drive critical activities, including supply of devices for clinical trials, sign-off to build registration batches or filings to hit important dates, such as an exclusivity window.

There are many potential causes of delay during industrialisation or scale-up, including poor planning, resourcing challenges and contractual negotiations with supply partners. Another is the need to resolve late-stage technical issues that are preventing performance requirements being met successfully. Specific challenges require specific mitigations, but a good general rule of thumb is to allow for as much "headroom" as possible while remaining commercially competitive. Examples include:

- Not specifying over-constraining or over-optimistic input requirements – do not turn "wants" into "musts" or "shoulds" into "shalls" if not necessary
- Understanding the performance window and keeping away from the edges, especially early on, to avoid problems arising later on
- Being more pessimistic than optimistic in working assumptions, such as for engineering analyses or worst-case test conditions
- Building in as much clearance as practicable between the process capability at which the design meets requirements and the process capabilities achievable from manufacturing systems, typically featuring high cavitation tooling and automated assembly
- Avoiding any processes that are on a knife-edge or highly sensitive to input variables
- Avoiding concepts that deviate from established principles and technologies or that depend on multiple levels of innovation, such as having more than one core technology that is at a low technology readiness level.

"EFFECTIVE COLLABORATION ACROSS FUNCTIONS IS CRITICAL THROUGHOUT DDS DEVELOPMENT PROGRAMMES, BUT STAKES AND RISKS ARE OFTEN HIGHEST DURING THE INDUSTRIALISATION PHASE."

SUMMARY

While all DDS development programmes are different, bringing their own challenges and opportunities, over time, it becomes clear that some late-stage issues occur more often than others. Anticipating them early, or putting measures in place to address them efficiently when they do arise, can help to ensure a path to successful industrialisation.

Chris Hurlstone

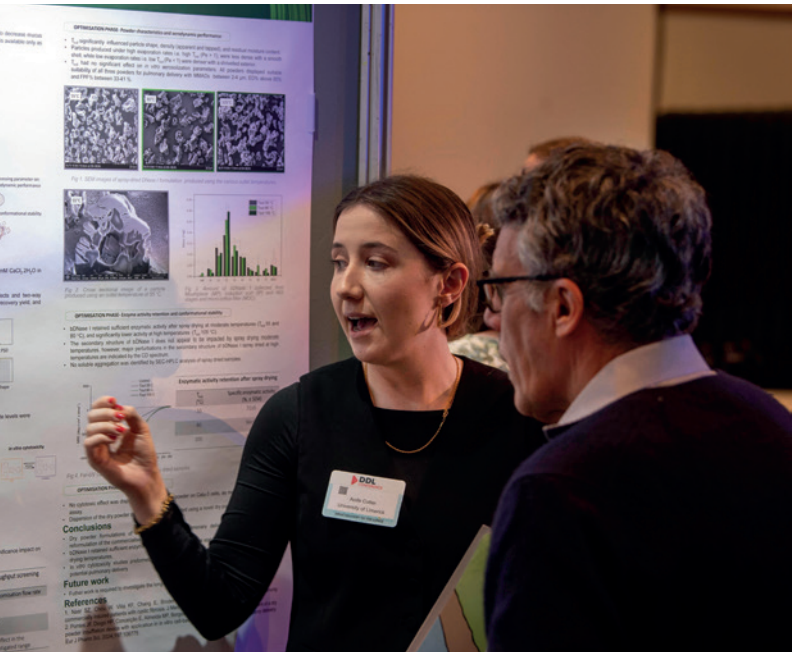
Chris Hurlstone, Director of Drug Delivery at Team Consulting, has more than 25 years of experience in developing technologies and devices for healthcare markets, with a particular focus on drug delivery systems. He has successfully brought products to market in technical lead and project management roles, including inhalers, injectors and an award-winning ophthalmoscope. A named inventor on numerous patents, Mr Hurlstone has a strong track record in delivering innovative and robust engineering solutions. He is a regular contributor at key industry conferences and is also a member of the ISO TC84 standards committee covering devices for administration of medicinal products and catheters.

T: +44 1799 532700
E: marketing@team-consulting.com

Team Consulting
Abbey Barns, Duxford Road, Ickleton, Cambridge, CB10 1SX, United Kingdom
www.team-consulting.com

DDL2026

DRUG DELIVERY TO THE LUNGS



Edinburgh International Conference Centre & Virtual

9/10/11th December 2026

The Premier International Conference Covering All Aspects Of Respiratory Drug Delivery

- 3 days of expert lectures
- 1000+ attendees expected
- Large Industry exhibition
- 100+ scientific posters
- Free registration for students
- Networking opportunities
- Awards and grants for young researchers

www.ddl-conference.com

info@ddl-conference.com

DESIGNING FOR SCALE: RELIABLE MANUFACTURING OF PEN INJECTOR PLATFORMS

Phillips Medisize
a molex company

Henrik Leisner of **Phillips Medisize** discusses the reliable scaling of pen injector programmes, considering how high-quality, high-volume manufacture depends on experience and collaboration.

Many pen injector programmes begin with established designs. The key question is whether or not those devices can be delivered reliably at scale. This is why manufacturing experience and collaborative ways of working play such an important role in the success of such a programme.

Pen injector programmes frequently build on established device formats that are already widely used for chronic self-administration, including therapies such as insulin and glucagon-like peptide-1. In these programmes, development typically centres on behaviour that aligns with existing platforms and established user expectations. In some cases, a different approach is taken, usually in response to specific therapy requirements or a deliberate choice to differentiate.

One of the most widely deployed formats is the variable multidose pen injector. In this format, dose selection, confirmation and delivery follow interaction patterns that have been deployed at scale for many years. These devices

> "INTERACTION PATTERNS MAY BE WELL ESTABLISHED, BUT THAT DOES NOT REMOVE THE CHALLENGE OF DELIVERING CONSISTENT PERFORMANCE AT SCALE."

"AS PROGRAMMES MOVE TOWARDS HIGH-VOLUME PRODUCTION, THE QUESTION BECOMES HOW WELL QUALITY AND YIELD HOLD UP AT SCALE."

support dose adjustment before injection, provide confirmation of dose delivery and can be adapted to fixed dose configurations through changes to the dosing mechanism. As these formats are well established, expectations around their performance requirements and use characteristics are typically well understood.

Interaction patterns may be well established, but that does not remove the challenge of delivering consistent performance at scale. Every unit needs to perform as expected, across production volumes, over time and across geographies. Human factors validation remains essential to confirm that real-world use aligns with intended function, but once interaction patterns are well established, attention tends to move towards how those patterns are maintained through repeatable manufacturing processes.

The same expectations apply to regulatory preparation, where consistency in product performance and intended use is fundamental to achieving efficient and predictable registrations. Established device formats provide a valuable reference point; however, regulatory success is primarily driven by the strength of development work – specifically the ability of research and development to generate robust, well-documented verification and validation evidence. Demonstrating that the design performs to state-of-the-art pen injector standards, meets intended use expectations and is supported by rigorous testing reduces uncertainty, builds reviewer confidence and enables smoother, more streamlined regulatory approvals across markets.

In practical terms, these benefits come down to whether or not the device can be produced reliably, repeatedly and at the volumes needed for long-term supply. This approach underpins pen platform programmes, such as Phillips Medisize's Envoi™, which is designed to preserve expected user behaviour while supporting consistent quality at commercial scale.

WHERE DIFFERENTIATION REALLY SHOWS: DESIGNING FOR HIGH-QUALITY, HIGH-VOLUME MANUFACTURE

As programmes move towards high-volume production, the question becomes how well quality and yield hold up at scale. For experienced teams, this is a familiar consideration, largely shaped by manufacturing capabilities and how operations run day to day. Beyond prototype or pilot builds, issues that were relatively contained earlier on can start to have a much bigger effect at higher volumes if not actively managed.

Small sources of variation play a big part here. Part tolerances, material batches, tool wear and gradual process drift during extended production runs can start to affect assembly yield. As such, early design choices need to factor in how variability behaves under sustained high-volume manufacture.

This is where device development and design-for-manufacture experience become particularly important. Programmes that design with manufacture in mind from the outset tend to be better placed to scale predictably, maintain quality and support reliable commercial supply.

WHAT MANUFACTURING EXPERIENCE CHANGES IN A PLATFORM PROGRAMME

Decisions made early around design for manufacture help shape readiness for scale. How well the programme then performs over time depends just as much on how manufacturing is run day to day.

Programmes that succeed at scale tend to draw on experience in high-quality, high-volume manufacture. That includes long-standing expertise in areas such as tooling, automation, inspection and process control, all of which help keep manufacture stable and repeatable as volumes grow.

This kind of operational experience can make a difference later in the product lifecycle, reducing rework, avoiding delays and limiting cost escalation. It also highlights the importance of a manufacturing footprint that can support global programmes, with consistent processes, aligned quality systems and continuity of supply across regions.

Together, these foundations can help pharma companies to meet the challenge of delivering treatments to patients worldwide, turning a design into a product that can be supplied reliably over the long term.

TRUST AND STEERING PROGRAMMES OVER TIME

Manufacturing capability is only one part of the picture. Trust is another, and it tends to build over time through listening and a clear understanding of the programme context. When teams share information openly, potential risks often surface earlier in the programme, when they are easier to address. That kind of visibility can help make it easier to work through trade-offs together as requirements evolve.

This way of working supports pharma teams through the journey to market, particularly as priorities shift. Ongoing adjustment is a normal part of scale-up, as programme needs, constraints and manufacturing realities are refined along the way.

When development, commercialisation and supply planning are closely aligned, teams are generally better placed to make timely decisions as conditions change, without compromising long-term manufacturability. Many of these decisions play out over years, shaping how capability, supply and risk are managed across the product lifecycle.

"WHEN TEAMS SHARE INFORMATION OPENLY, POTENTIAL RISKS OFTEN SURFACE EARLIER IN THE PROGRAMME, WHEN THEY ARE EASIER TO ADDRESS."

Ultimately, it is during commercialisation that established formats are tested most thoroughly. Reliability is closely tied to whether designs can be manufactured with consistent quality, at scale and over time. Familiarity may shape early confidence, but sustained performance depends on thoughtful design choices, manufacturing experience and collaborative ways of working across the commercial lifecycle.

Phillips Medisize works with pharma partners to deliver established pen injector formats at commercial scale, drawing on experience built over multiple programmes. That experience includes transferring new designs into manufacture, scaling volumes as demand grows and maintaining consistent quality across a global manufacturing footprint. The company's position as part of Molex, a Koch company, supports a long-term view on capability building and supply continuity across the product lifecycle.

Envoi™ is a trademark of Phillips Medisize.

"ULTIMATELY, IT IS DURING COMMERCIALISATION THAT ESTABLISHED FORMATS ARE TESTED MOST THOROUGHLY. RELIABILITY IS CLOSELY TIED TO WHETHER DESIGNS CAN BE MANUFACTURED WITH CONSISTENT QUALITY, AT SCALE AND OVER TIME."

Henrik Leisner

Henrik Leisner is Director of Platform Management at Phillips Medisize, where he leads innovation and platform development for medical device solutions. He brings extensive experience in R&D leadership, product management and commercialisation from roles at global companies such as Phillips Medisize and Coloplast. Mr Leisner specialises in translating technical innovation into commercially viable platforms, with a strong focus on business case modelling, product strategy and cross-functional execution.

E: pmcinfo@molex.com

Phillips Medisize

2202 Carmichael Road, Hudson, WI 54016, United States

www.phillipsmedisize.com

WHERE CONTENT MEETS INTELLIGENCE

ON drugDELIVERY

SCAN TO SUBSCRIBE FREE

PHARMASHELL – AN ALD NANOCOATING TECHNOLOGY FOR ONCE-MONTHLY INJECTABLES

Dr Anders Johansson, **Dr Polla Rouf** and **Dr Oliver Hedge**, all of **Nanexa**, introduce the company's PharmaShell® technology and discuss how, in combination with nanotechnology, it can achieve previously unattainable dosing intervals with standard formulations.

Long-acting injectable therapies are transforming chronic disease management by reducing dosing frequency and improving patient adherence. PharmaShell® is a drug delivery technology designed to enable once-monthly injections for drugs that currently require frequent dosing. Developed by the Swedish company Nanexa, PharmaShell is centred on ultra-thin nanocoatings applied to drug microparticles using atomic layer deposition (ALD) – a precision technique adapted from the semiconductor industry.[1]

By encapsulating injectable drug particles in a nanometre-thick, biocompatible, inorganic coating, PharmaShell creates a controlled-release depot formulation. After injection, the coating dissolves at a tuned rate, providing a sustained therapeutic release over weeks to months.[2] This approach enables high drug loading in a small-volume injection, eliminating the need for large implants or frequent dosing. In practice, formulations using PharmaShell can be delivered through thin needles (30G) with conventional syringes or autoinjectors, maximising patient comfort while ensuring prolonged drug action.

PHARMASHELL TECHNOLOGY & RATIONALE

The core principle of PharmaShell is to combine nanotechnology with pharmacotherapy to achieve dosing intervals unattainable with standard formulations. Particles of pure drug substance, typically in the range of a

"PHARMASHELL COATINGS ARE INORGANIC AND DO NOT RELY ON ANY SPECIFIC DRUG-POLYMER CHEMISTRY, SO THE PLATFORM CAN BE APPLIED TO A WIDE RANGE OF MOLECULES – FROM SMALL-MOLECULE THERAPEUTICS TO LARGE PEPTIDES AND BIOLOGICS."

few microns, are enveloped with an extremely uniform PharmaShell coating (approximately 10–50 nm thick) using ALD. This atomic-level process provides unparalleled control over the coating thickness and composition, which, in turn, determines how quickly the drug is released once inside the body.

By adjusting parameters such as coating material (e.g. oxide type) and thickness, Nanexa can "dial in" a desired release profile; for example, this could be a near-linear release over 30 days or a slower three-month release for quarterly dosing. The impermeable coating initially protects the drug from immediate dissolution after injection, and then, as the coating gradually dissolves or becomes porous under physiological conditions, the drug is steadily released. This controlled dissolution mechanism contrasts with traditional poly(lactic-co-glycolic acid) (PLGA) microsphere depots, which often rely on polymer degradation, enabling formulators to avoid the high initial burst and unpredictable tail-off that can occur with those systems.[3]

The rationale for PharmaShell is clear: by flattening the pharmacokinetic curve and extending it, therapeutic drug levels can be maintained with one injection per month or potentially one injection every three months, instead of daily or weekly administration. This has major implications for patient convenience and compliance – fewer injections means reduced discomfort and increased adherence to treatment, particularly for chronic conditions such as diabetes, obesity or other diseases requiring long-term injectable therapies.

Furthermore, a more stable drug concentration (lower peak-to-trough variation) can translate to reduced side effects, as many adverse events are linked to peak plasma levels. Finally, reduced dosing frequency can potentially mitigate the effects of a missed dose, such as reducing the risk of therapeutic failure. PharmaShell's ability to achieve stable, low-fluctuation drug levels over extended periods is therefore a key advantage in improving safety and tolerability.[4]

Another key aspect of the technology is its broad applicability. PharmaShell coatings are inorganic and do not rely on any specific drug-polymer chemistry, so the platform can be applied to a wide range of molecules – from small-molecule therapeutics to large peptides and biologics. The coating process occurs at near ambient temperatures and has been shown to preserve the stability and activity of sensitive biomolecules, including peptides such as glucagon-like peptide-1 (GLP-1) analogues.

In addition, the inert nature of the ALD coating materials and their low mass fraction (often less than 10–20% of the total particle weight) means that they add minimal injection-site burden. The aluminium content in a PharmaShell dose (e.g. in a monthly semaglutide product) would be only a few hundred micrograms – far below the established safety thresholds for parenteral aluminium exposure[5] and even less than typical dietary aluminium intake. This gives confidence that the coating materials serve their purpose as a delivery vehicle without introducing safety concerns.

ONCE-MONTHLY SEMAGLUTIDE DEPOT

Nanexa's internal project on PharmaShell-coated semaglutide is a compelling example of PharmaShell's potential in action. This project aims to develop a once-monthly depot formulation of semaglutide (a GLP-1 receptor agonist) for the treatment of type 2 diabetes and obesity. Semaglutide is currently marketed as Novo Nordisk's Ozempic (for diabetes) and Wegovy (for obesity) in a once-weekly injection format – a significant improvement over daily injections, yet still requiring 52 injections per year. A monthly formulation would reduce this to just 12 injections per year, offering patients an even more convenient regimen while maintaining efficacy.[6]

The PharmaShell platform is particularly well-suited to semaglutide for several reasons. First, semaglutide is a relatively large peptide (~4 kDa), and the combination of its albumin-binding property and high bioavailability makes it a good candidate for extended release using PharmaShell. Second, its therapeutic mechanism (glucose control and appetite suppression) benefits from maintaining steady, basal levels rather than sharp peaks and troughs, which aligns perfectly with the profile delivered by a controlled-release depot.[7] Finally, clinical use of semaglutide involves a dose-escalation phase (patients start at a low dose and gradually increase to mitigate side effects). A long-acting formulation can accommodate this by adjusting the initial dosing schedule (e.g. either administering a smaller PharmaShell-coated dose for the first one or two months before the full maintenance dose or a less frequent initial dosing regimen), which early simulations have shown to be feasible without compromising the smooth release profile.

Nanexa initiated development of PharmaShell-coated semaglutide in 2025, using knowledge from an earlier PharmaShell GLP-1 project. This earlier project provided a critical proof-of-concept in humans: a Phase I study using PharmaShell-coated liraglutide (in metformin-stable, GLP-1 naive, type 2 diabetic patients) demonstrated successful prolonged release and tolerability, with results presented at the American Diabetes Association Scientific Sessions in June 2025.[8] In that first-in-human trial, a single injection of PharmaShell liraglutide achieved exposure over 36 days, effectively converting a daily injectable into a monthly dose.

This encouraging outcome laid the groundwork for switching to semaglutide, as the project with liraglutide strongly indicated that the PharmaShell approach could be translated into clinical practice. For semaglutide – a more potent and longer-acting molecule than liraglutide – the team anticipated that a once-monthly dose could potentially match or even surpass the clinical performance of weekly Ozempic/Wegovy.

"EARLY ON, NANEXA IDENTIFIED THAT MODIFICATION OF THE COATING COMPOSITION AND THICKNESS COULD DRAMATICALLY REDUCE THE INITIAL 'BURST' RELEASE THAT WAS OBSERVED WITH A PRIOR FORMULATION."

RECENT PRECLINICAL RESULTS – ADVANCING A BETTER FORMULATION

The development has already yielded significant progress in Nanexa's labs and preclinical studies. A key focus has been to optimise the PharmaShell coating and formulation specifically for semaglutide's properties. Early on, Nanexa identified that modification of the coating composition and thickness could dramatically reduce the initial "burst" release that was observed with a prior formulation. In a comparative experiment, an optimised semaglutide-coated formulation showed a much flatter release profile *in vivo* than the earlier version used in the first liraglutide trial. Approximately 50% of the semaglutide dose was released over the first two weeks with the new formulation (roughly 25% per week), whereas the older formulation released ~50% of its payload in just the first week. This improvement means a more consistent drug level throughout the critical first month, and a lower peak concentration immediately post-dose.

In practical terms, the refined PharmaShell semaglutide achieves a near-linear release over at least one month, providing what is essentially a constant infusion profile from a single injection. Indeed, internally conducted rat pharmacokinetic studies (using a three-month model to assess long-term release) indicated that the plasma concentration of semaglutide can be maintained in a tight range for the full four- to five-week period with the new formulation. Notably, by minimising early release, the formulation is expected to reduce initial side effects, such as nausea and flushing, which are often dose- and C_{max}-related for GLP-1 therapies.

Another significant finding comes from pharmacokinetic simulations and animal models regarding plasma concentration fluctuations. With monthly dosing, drug levels must not dip too low at end-of-interval or spike too high after each injection. Using data from preclinical studies, Nanexa simulated human plasma profiles for monthly semaglutide dosing.[9] The results are highly promising: a peak-to-trough ratio of roughly 1.2 was predicted for steady-state monthly dosing and 1.5 for three-monthly dosing (depending on dose level). For context, a weekly semaglutide therapy itself has a peak-to-trough ratio of around 1.7–1.9 at steady state, as even with a weekly injection, levels rise and fall.

Thus, the PharmaShell monthly depot can achieve plasma level stability comparable with the current gold-standard weekly injection. Figure 1 illustrates this equivalence: the concentration-versus-time profile of the once-monthly PharmaShell semaglutide closely shadows that of once-weekly Wegovy (semaglutide), without extreme peaks or troughs. Simulations were made using an established model described by Overgaard *et al.*[10] This flat profile is not only efficacious but also clinically important for safety – lower fluctuation means that the body is not subjected to high transient concentrations, likely translating to a lower incidence of side effects, such as the gastrointestinal events associated with GLP-1 agonists (data for Wegovy taken from publicly available information and overlaid on Nanexa's data for comparison).[6]

Supporting these pharmacokinetic achievements, Nanexa has also addressed the formulation's real-world usability. One significant advance in 2026 has been the development of a ready-to-use suspension formulation of PharmaShell-coated semaglutide particles. Earlier PharmaShell clinical trials used a two-vial system (dry coated powder reconstituted in a liquid at the time of injection). However, a single-vial or prefilled syringe system is far more convenient for the end user. By selecting a suitable non-aqueous vehicle and optimising the particle dispersion, Nanexa created a suspension that remains stable over time.

Ongoing stability studies have shown at least six months of real-time stability at room temperature and at 40°C for non-aqueous suspensions of PharmaShell-coated GLP-1 analogues, without any agglomeration of the particles or loss of performance or quality. Kinetic modelling indicates that a shelf life of 36 months at room temperature is feasible. In other words, the product can potentially be supplied in a prefilled syringe or cartridge,

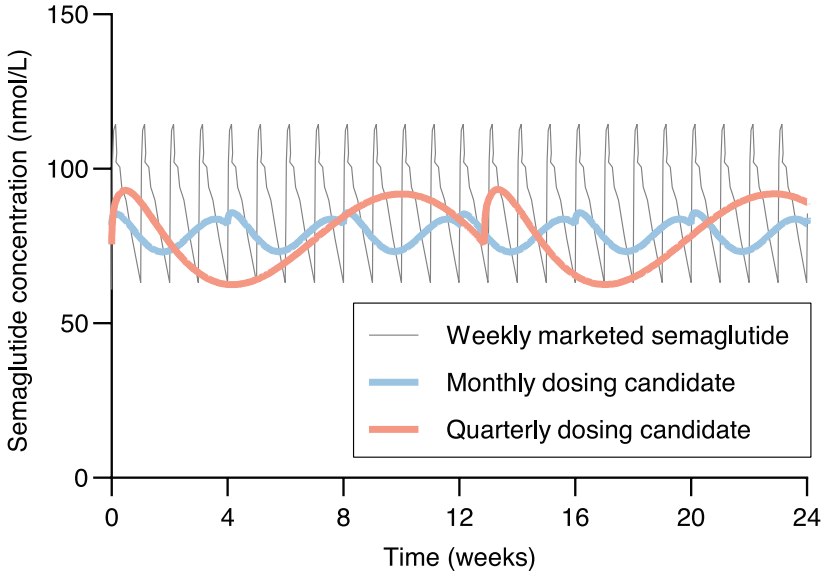


Figure 1: Predicted pharmacokinetic profiles for monthly PharmaShell semaglutide dosing, indicating a stable plasma concentration with lower peak-to-trough fluctuations comparable with weekly dosing of semaglutide (e.g. Wegovy).

stored at ambient conditions and used directly by patients – a major practical advantage.

Additionally, the rheological properties of the suspension (e.g. viscosity) have been adjusted so that it can be administered through a fine-gauge needle. For an optimal patient experience, the use of a spring-powered autoinjector is envisioned – this would easily accommodate the slightly higher injection force and ensure a smooth administration even with a more viscous suspension. Other marketed long-acting injectables (e.g. AstraZeneca's exenatide Bydureon® BCise™ autoinjector) have successfully implemented similar solutions, so the path for device combination is well established.

Nanexa has begun exploratory work with device partners to confirm compatibility of the PharmaShell semaglutide suspension with typical prefilled syringes and autoinjector systems, with no issues identified to date (e.g. no clogging, consistent dose delivery).

UPSCALE AND MANUFACTURING CONSIDERATIONS

As PharmaShell semaglutide advances toward clinical trials and commercialisation, a parallel effort is underway to scale up the PharmaShell manufacturing process.

"NANEXA HAS BEGUN EXPLORATORY WORK WITH DEVICE PARTNERS TO CONFIRM COMPATIBILITY OF THE PHARMASHELL SEMAGLUTIDE SUSPENSION WITH TYPICAL PREFILLED SYRINGES AND AUTOINJECTOR SYSTEMS, WITH NO ISSUES IDENTIFIED TO DATE."

Unlike conventional drug formulation methods, ALD coating requires specialised equipment and process expertise. Nanexa is working to ensure that PharmaShell can transition from laboratory scale (grams of coated particles) to clinical and commercial scale (multi-kilogram batches) efficiently.

The coating process itself is modular and can be run in larger ALD reactors or in parallel across multiple reactor chambers. In fact, a dedicated scale-up installation for PharmaShell production is currently being explored. Plans include implementing a "1/10 scale" pilot ALD tool in Nanexa's GMP facility in Uppsala as an intermediate step, which would demonstrate the ability to produce coated particles at one-tenth of the full commercial batch size. This pilot tool will inform the design and operation of a subsequent full-scale production ALD machine, capable of handling the quantities needed for global product supply. The ultimate goal is to have the PharmaShell semaglutide manufacturing process and equipment "launch-ready" in time for late-stage clinical trials and market introduction in the next few years.

Beyond the coating itself, other manufacturing aspects are also being scaled and optimised. Upstream, the drug particle engineering (micronisation or spray drying of semaglutide to the desired particle size) is conducted in partnership with CMOs experienced in pharmaceutical spray drying. Downstream, the fill-finish processes for the suspension are being adapted from existing practices used for depot injections. For instance, filling systems and appropriate container closure solutions are under evaluation to ensure that the final product can be filled, sterilised and packaged reliably. By proactively addressing scale-up challenges now, well ahead of product launch, Nanexa is de-risking the path to market.

SUMMARY

In summary, PharmaShell is an enabling technology that can reshape how injectable therapies are delivered. The example of PharmaShell semaglutide demonstrates how the platform can take a weekly biologic and convert it into a monthly treatment, with equal (or improved) therapeutic coverage and potentially fewer side effects. The technology's recent preclinical successes – achieving linear month-long release and matching or outperforming the pharmacokinetics of the current standard of care – underline the viability of this approach.

Coupled with a clear strategy for manufacturing scale-up and device integration, commercially available PharmaShell-based products are moving steadily towards reality. If successful, they hold the promise of greatly simplifying treatment regimens for patients and unlocking new possibilities in chronic disease management. With its combination of nanotechnology precision and biomedical innovation, PharmaShell exemplifies the next generation of drug delivery systems, where one injection per month could soon replace a dozen injections or more – improving patients' lives through smarter technology.

REFERENCES

1. *Kessels E et al, "Atomic layer deposition". Nat Rev Methods Primers, 2025, Vol 5, art 66.*
2. *Hellrup J et al, "Nanoshells prepared by atomic layer deposition – long acting depots of indomethacin". Eur J Pharm Biopharm, 2019, Vol 140, pp 60–66.*
3. *Butreddy A et al, "PLGA/PLA based long acting injectable depot microspheres in clinical use: production and characterization overview for protein/peptide delivery". Int J Mol Sci, 2021, Vol 22(16), art 8884.*
4. *"Product Quality Review: Exenatide extended release, non aqueous (BYDUREON BCISE)". US FDA, 2017.*
5. *"Draft Guidance for Industry: Small Volume Parenteral Drug Products and Pharmacy Bulk Packages for Parenteral Nutrition: Aluminum Content and Labeling Recommendations". US FDA, Jul 2025.*
6. *Yang XD, Yang YY, "Clinical pharmacokinetics of semaglutide: a systematic review". Drug Des Devel Ther, 2024, Vol 18, pp 2555–2570.*
7. *Gorgojo Martínez JJ et al, "Clinical recommendations to manage gastrointestinal adverse events in patients treated with GLP 1 receptor agonists: a multidisciplinary expert consensus". J Clin Med, 2022, Vol 12(1), art 145.*
8. *Devries H et al, "1975-LB: A Single Ascending Dose Study of a Once-Monthly Liraglutide Formulation in Participants with Type 2 Diabetes". Diabetes, 2025, Vol 74(Suppl 1), art 1975-LB.*
9. *Hellrup J, "PharmaShell®: Atomic layer deposition enabling once monthly and once quarterly semaglutide depots, with clinical proof of concept from liraglutide". DDF Summit, 2026, Berlin, Germany.*
10. *Overgaard RV et al, "Population Pharmacokinetics of Semaglutide for Type 2 Diabetes". Diabetes Ther, 2019, Vol 10(2), pp 649–662.*

Dr Anders Johansson

Anders Johansson, PhD, serves as Head of Intellectual Property, Senior Scientist and Co-Founder at Nanexa, where he has been employed since 2009. Dr Johansson holds an MSc and a PhD in Chemistry from Uppsala University, Sweden. Prior to joining Nanexa, he gained experience as a patent consultant at the intellectual property firm Bjerkéns KB in Sweden.

E: anders.johansson@nanexa.se

Dr Polla Rouf

Polla Rouf, PhD, is Head of ALD R&D at Nanexa. Dr Rouf leads the development of atomic layer deposition (ALD) coatings that enable controlled drug release, contributing to programmes such as NEX-22. He earned a PhD in Materials Chemistry from Linköping University (Sweden) specialising in the ALD technology, and he holds a MSc in Chemical Engineering from Uppsala University.

E: polla.rouf@nanexa.se

Dr Oliver Hedge

Oliver Hedge, PhD, is a Senior Formulation Scientist at Nanexa. Dr Hedge works in formulation development and is Chief Designer (formulation) for the PharmaShell liraglutide and semaglutide projects at Nanexa, working with the overall drug product functionality and quality related aspects for these projects. He holds a PhD in Pharmaceutical Sciences and an MSc in Pharmacy from Uppsala University.

E: oliver.hedge@nanexa.se

Nanexa AB

Virdings Allé 2, SE-75450, Uppsala, Sweden

www.nanexa.com

2026/27 Editorial Calendar

Each issue of ONdrugDelivery focuses 100% on one specific topic *within* drug delivery.

SEP Wearable Injectors DEADLINE: **Aug 6, 2026**	**SEP/OCT** Dual Chamber Delivery Systems DEADLINE: **Aug 20, 2026**	**OCT** Prefilled Syringes & Injection Devices DEADLINE: **Sep 3, 2026**
OCT/NOV Sustainability in Drug Delivery DEADLINE: **Sep 17, 2026**	**NOV** Pulmonary & Nasal Drug Delivery DEADLINE: **Oct 1, 2026**	**DEC** Delivering Gene & Cell Therapeutics DEADLINE: **Nov 5, 2026**
JAN 2027 Prefilled Syringes & Injection Devices DEADLINE: **Dec 10, 2026**	**FEB** Oral Drug Delivery DEADLINE: **Jan 7, 2027**	**MAR** Ophthalmic Drug Delivery DEADLINE: **Feb 4, 2027**
APR Pulmonary & Nasal Drug Delivery DEADLINE: **Mar 4, 2027**	**APR/MAY** Sustainability in Drug Delivery DEADLINE: **Mar 18, 2027**	**MAY** Delivering Injectables: Devices & Formulations DEADLINE: **Apr 1, 2027**
MAY/JUN Dermal, Transdermal & Microneedles DEADLINE: **Apr 15, 2027**	**JUN** Industrialising Drug Delivery DEADLINE: **May 6, 2027**	**JUL** Oral Drug Delivery DEADLINE: **May 20, 2027**

LYOPHILISATION VIALS: QUICK AND EFFECTIVE SOLUTIONS TO REDUCE FOGGING

NIPRO
Live Longer. Live Better.

Diane McCormick and **Clément Condouret** of **NIPRO** discuss lyophilisation fogging, explaining its negative downstream effects and presenting NIPRO's thermal treatment, VIALEX™, to minimise this issue.

Today, around half of all biopharmaceuticals and about 40% of all parenteral medications rely on freeze drying as a critical part of their manufacturing process (Figure 1). With this widespread use comes a major challenge – the freeze-drying process must accommodate an ever increasing diversity of complex formulations. New excipients, new drug modalities and higher product sensitivities all add layers of complexity.

VIAL FOGGING: A CONTINUOUS CHALLENGE DURING THE LYOPHILISATION PROCESS

One of the most persistent and challenging phenomena encountered during the lyophilisation process is vial fogging, also referred to as lyophilisation fogging (Figure 2). This phenomenon not only affects aesthetics, it can directly impact

> "ONE OF THE MOST PERSISTENT AND CHALLENGING PHENOMENA ENCOUNTERED IN LYOPHILISATION IS VIAL FOGGING, ALSO REFERRED TO AS LYOPHILISATION FOGGING."

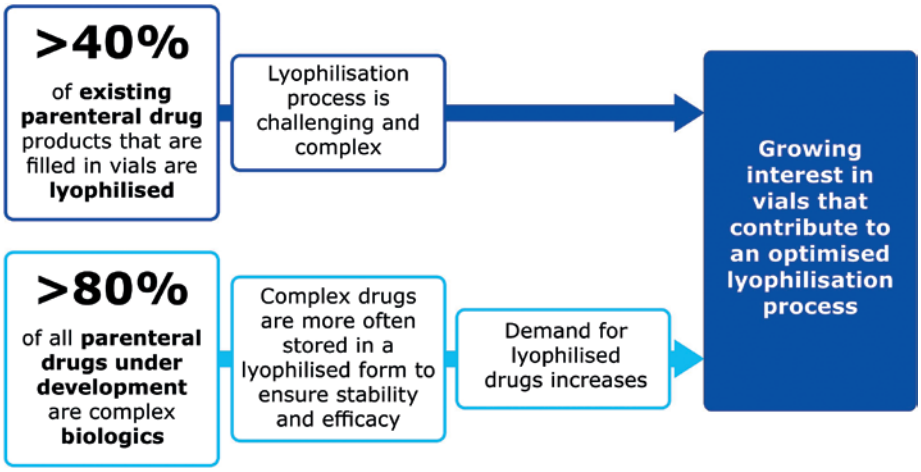


Figure 1: A growing need for lyophilisation.

manufacturing performance and quality control. Vial fogging increases reject rates during final camera-based inspection, reducing overall equipment efficiency and, in critical cases, compromising container closure integrity.

Occurrence of Lyophilisation Fogging During the Freeze-Drying Process

A closer look at the lyophilisation process helps to understand where and how vial fogging occurs (Figure 3).

Step 1: Filling

The vial is filled with the drug product in liquid formulation. This formulation typically contains several excipients in addition to the API. Many of these components reduce the surface tension of the liquid, which plays a crucial role later in the process.

Step 2: Water Evaporation

Immediately after filling, a small amount of water from the formulation begins to evaporate. This evaporated water condenses and deposits on the inner walls of the vial, forming a thin film.

Step 3: Marangoni Flow Setup

At this stage, two liquids co-exist: the drug formulation with lower surface tension and the condensed water with higher surface tension. This contrast creates ideal conditions for Marangoni flow, causing the drug product to begin moving up the inner wall of the vial.

Step 4: Freeze Drying

During freeze drying, the temperature at the vial wall differs from the temperature at the centre of the vial. This temperature gradient then further increases the surface tension gradient, intensifying the Marangoni

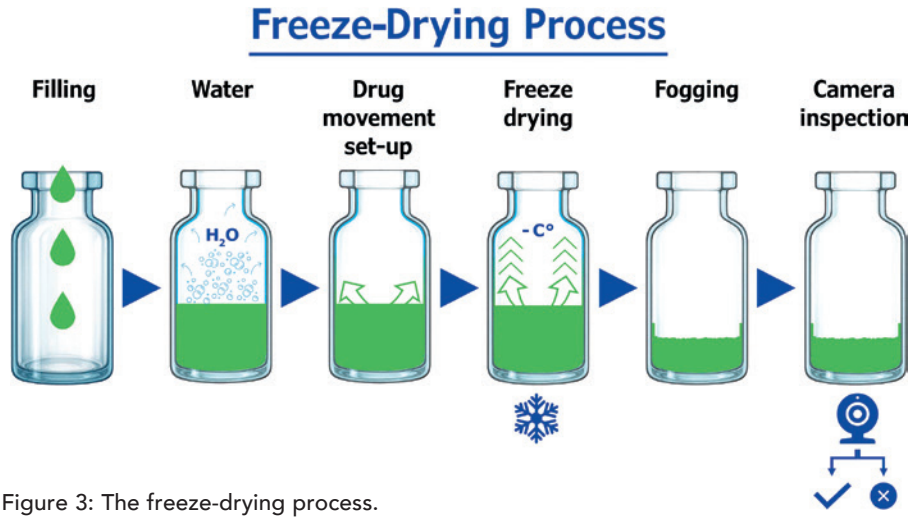


Figure 3: The freeze-drying process.

Figure 2: Vial/lyophilisation fogging.

effect, so the drug product continues to travel up the wall. At this stage, the product on the wall remains invisible because it has not yet dried.

Step 5: Vial Fogging

Once the freeze-drying cycle is complete, the product deposited on the wall dries. Only then does it become visible, appearing as a cloudy, fog-like residue – vial fogging.

Step 6: Impact on Visual Inspection

Once fogging appears, automated visual inspection systems struggle to distinguish it from true defects. As a result, acceptable vials may be rejected, leading to increased scrap rates and unnecessary loss of valuable API.

PRIMARY APPROACHES TO MITIGATE LYOPHILISATION FOGGING

Approach One: The Formulation

This approach focuses on reducing the difference in surface tension between the condensed water and drug formulation. This can be achieved by removing or reducing surfactants or by modifying the formulation, such as by selecting different lyoprotectants or excipient combinations.

However, this approach has a major limitation: vial fogging is often identified late in the drug development phase, when the formulation is nearly finalised. At this stage, changes are difficult to implement and may require further costly stability studies and regulatory assessments. For this reason, formulation changes are rarely the preferred solution.

Approach Two: The Vial

This approach aims to prevent the formation of the water layer during the filling process. One method is applying a coating to the inner surface of the vial to ensure that the surface is hydrophobic. However, coated vials typically require additional regulatory documentation and validation, lengthening project timelines and increasing complexity.

A more straightforward option is the NIPRO thermal treatment (Figure 4). This treatment creates a hydrophobic inner surface without adding any external material. It is a fast, simple and effective solution that avoids regulatory complications while strongly mitigating vial fogging.

NIPRO'S PROPRIETARY SOLUTION FOR REDUCING VIAL FOGGING

NIPRO applies a proprietary thermal treatment (VIALEX™) to the inner surface of the glass vial without using additional materials such as a coating. This requires no change to the glass chemistry – manufacturers can continue using standard Type I borosilicate glass. A 100% inline thermal inspection process confirms that the treatment has been conducted properly and the resulting inner surface is comparable with that of glass tubing or moulded vials.

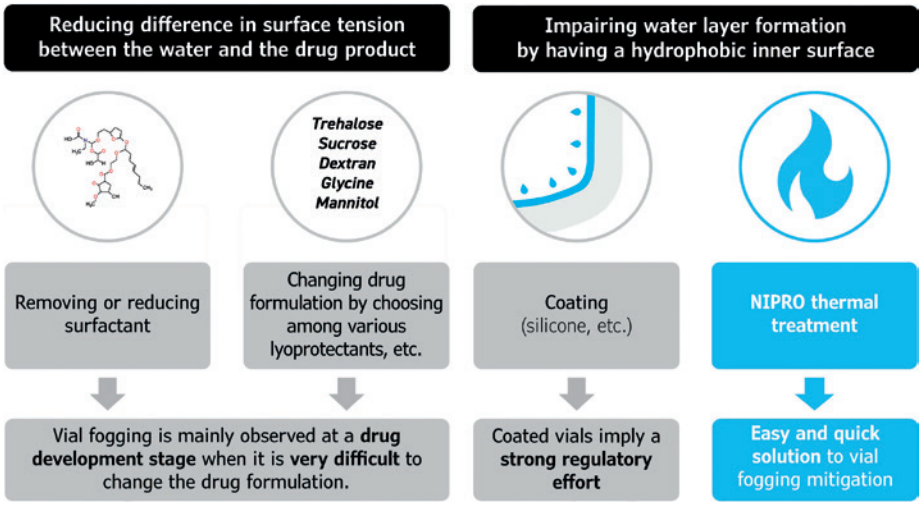


Figure 4: NIPRO's thermal treatment solution to mitigate vial fogging.

As a result, the vials feature:

- Low levels of extractables and leachables
- Reduced surface alkalinity
- Enhanced chemical durability
- A more hydrophobic inner surface.

This can lead to:

- Significantly less lyophilisation fogging
- Reduced container-drug product interactions
- Lower pH shift
- Reduced risk of glass delamination.

To explain further, vial fogging is typically considered a cosmetic defect of the lyophilisation cake. In severe instances, when fogging extends into the neck region of the vial, it may compromise seal integrity and thus drug properties. This phenomenon is related to interfacial energy between the glass, liquid and gas interfaces. A hydrophobic vial surface has been shown to reduce these interactions and mitigate fogging.

"NIPRO APPLIES A PROPRIETARY THERMAL TREATMENT (VIALEX™) TO THE INNER SURFACE OF THE GLASS VIAL WITHOUT USING ADDITIONAL MATERIALS SUCH AS A COATING. THIS REQUIRES NO CHANGE TO THE GLASS CHEMISTRY – MANUFACTURERS CAN CONTINUE USING STANDARD TYPE I BOROSILICATE GLASS."

Vial	Type
Vial 1	Standard
Vial 2	Altered geometry
Vial 3	Altered geometry with thermal treatment

Table 1: Vial selection for fogging study.

NIPRO LYOPHILISATION VIALS: TESTED BY AN EXTERNAL LABORATORY

The benefits of NIPRO lyophilisation vials were demonstrated in a 2025 case study, conducted at LyoHub, a research facility at Purdue University (West Lafayette, IN, US).[1] This study aimed to reproduce a typical vial fogging situation using demanding freeze-drying conditions with typical test solutions.

Three sets of vials were selected to evaluate the effect of inner surface hydrophobicity on fogging during the lyophilisation process (Table 1). All vials were 10R/10 mL Type I borosilicate glass with a thermal expansion coefficient of 51×10^{-7} K^{-1}.

Each vial was washed according to USP <660> and filled at room temperature with 3 mL of a model formulation:[2]

- 4% (w/v) mannitol
- 2% (w/v) sucrose
- 1.55 mg/mL histidine
- 0.1 mg/mL polysorbate 80 (PS80)
- 5 mg/mL pyranine (fluorescent tracer).

This was followed by a regular freeze-drying cycle, performed in a MicroFD system (Table 2).

Surface Free Energy

Droplets were measured using a DSA25 Basic Device (KRÜSS, Hamburg, Germany). The surface energy of each material was determined using Owens-Wendt-Rabel-Kaelble method:[3]

$$2\sqrt{r_{sv}^{d}r_{sl}^{d}} + 2\sqrt{r_{sv}^{p}r_{sl}^{p}} = r_{lv}(1+\cos\theta)$$

Using this model, the surface energy of a material can be calculated by measuring the contact angles of two liquids, a polar liquid (water) and a non-polar liquid (diiodomethane), as shown in Figure 5.

Surface energy depends on both vial geometry and inner surface condition, so a smaller contact angle means stronger attraction to liquids and hydrophilic behaviour and a larger contact angle means lower attraction and hydrophobic behaviour. Vials 2 and 3 showed reduced surface energy, confirming the effect of surface treatment and geometry (Figure 6).

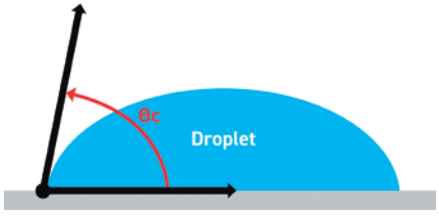


Figure 5: Measuring the contact angle of two liquids to calculate surface energy.

Freezing Phase	• Hold at 20°C • 20°C to -40°C • Hold at -40°C	• 10 min • 1°C per min • 120 min
Primary Phase	• -40°C to 10°C • Until (PVG/CM) < 7 mTorr	• 0.5°C per min • 100 mTorr
Secondary Drying	• 10°C to 40°C • Hold at 40°C	• 0.5°C per min • 6 hrs at 100 mTorr
Post-Drying Hold and Stoppering	• Hold at 25°C • Stoppering	• Shelf temp • Under vacuum

Table 2: Freeze-drying outline as part of vial fogging study.

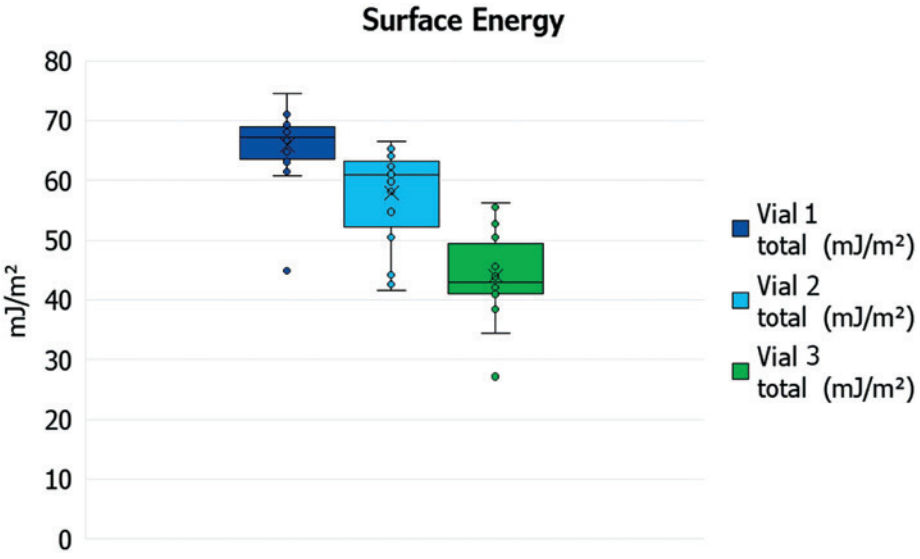


Figure 6: Surface energy calculated for each vial.

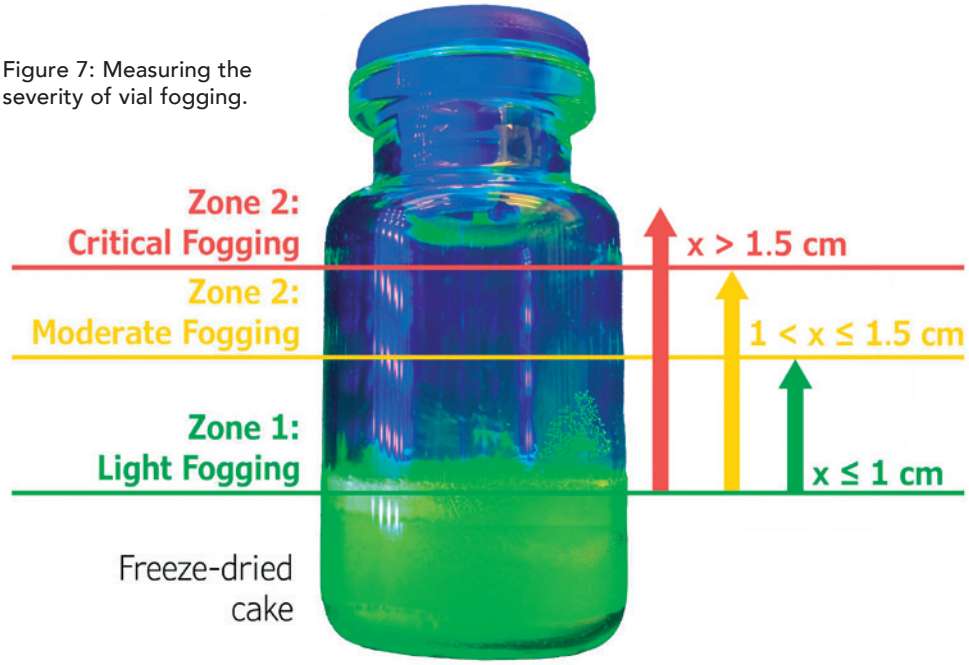


Figure 7: Measuring the severity of vial fogging.

Fogging Data

Fogging was assessed using a scoring system (Figure 7 & Table 3):

- No fogging: 0 points
- Light fogging: 1 point
- Moderate fogging: 2 points
- Critical fogging: 3 points.

Vial 3 showed an approximately 70% reduction in its overall fogging score compared with a standard vial. These data demonstrate that applying this surface thermal treatment to NIPRO's lyophilisation vials lowers their surface energy, thereby reducing fluid creep and inherent fogging during the lyophilisation process.

Vial	No Fogging	Light Fogging	Moderate Fogging	Critical Fogging	Fogging Score
Vial 1	0	0	3	50	**156**
Vial 2	0	6	26	18	**112**
Vial 3	16	22	11	1	**47**

Table 3: Fogging score for tested vials.

Diane McCormick

Diane McCormick is a Product Development & Laboratory Engineer at NIPRO PharmaPackaging, with a degree in Chemical Engineering and a specialisation in pharmaceutical packaging and lyophilisation technologies. Based in Millville (NJ, US), Ms McCormick leads R&D efforts focused on optimising glass container performance under extreme processing conditions. Her work integrates material science and drug delivery, with a particular emphasis on improving inner glass surface integrity to enhance product stability. Ms McCormick collaborates across multidisciplinary teams to translate laboratory insights into scalable solutions for the biotechnology and injectable pharmaceutical sectors.

E: diane.mccormick@nipro-group.com

Clément Condouret

Clément Condouret is a Product Portfolio Manager at NIPRO PharmaPackaging, where he has led the vials, cartridges and ampoules portfolios for the past five years. He notably contributed to the development of NIPRO's lyophilisation vial range. Mr Condouret holds a Master's degree in Packaging Sciences from ESIReims (Reims, France). Prior to joining NIPRO, he gained experience in moulded glass packaging for the cosmetics and luxury sectors at Gerresheimer in Belgium. His expertise spans pharmaceutical packaging development, product innovation and glass container technologies.

E: clement.condouret@nipro-group.com

NIPRO PharmaPackaging
Blokhuisstraat 42, 2800 Mechelen, Belgium
www.nipro-group.com

"APPLYING THIS SURFACE THERMAL TREATMENT TO NIPRO'S LYOPHILISATION VIALS LOWERS THEIR SURFACE ENERGY, THEREBY REDUCING FLUID CREEP AND INHERENT FOGGING DURING THE LYOPHILISATION PROCESS."

NIPRO LYOPHILISATION VIALS: LESS FOGGING FOR AN EFFECTIVE LYOPHILISATION PROCESS

Existing lyophilisation vials feature a specific bottom geometry that supports heat transfer. NIPRO Type I borosilicate vials are further enhanced through a proprietary thermal treatment that requires no additional materials. This treatment reduces the sodium concentration at the glass surface and improves surface quality. As a result:

- The inner surface is restored and becomes more hydrophobic
- Marangoni flow is reduced
- Lyophilisation fogging is significantly decreased.

Performance improvements include:

- Up to 70% overall reduction in fogging
- Up to 98% reduction in critical fogging (previous studies have demonstrated an 85% reduction)
- Optimised bottom geometry that supports consistent and efficient heat transfer
- Improved overall equipment efficiency through reduced reject rates
- Easy implementation with no changes required to existing processes or materials.

With this treatment, NIPRO can improve the reliability of lyophilisation at a time where its demand continues to grow, de-risking the production of lyophilised drugs and permitting their smoother entry onto the market.

REFERENCES

1. *"Fogging Study: NIPRO-PURDUE Collaboration". Research Summary Report, Purdue University & NIPRO, Jul 2025.*
2. *"Introduction to Vial Fogging and Mitigation Strategies". Webinar, Millrock Technologies, Mar 2022.*
3. *Shu S et al, "Impact of surface energy and surface tension on vial fogging within lyophilized drug products". Eur J Pharm Sci, 2025, Vol 207, art 107040.*

Expert View

EFFICIENCY, DATA INTEGRITY AND QUALITY ASSURANCE IN THE PRODUCTION OF INSULIN PENS

Based on an article originally published in British Plastics & Rubber Magazine.

Stephan Vogel of Kistler Group discusses the role of advanced monitoring technologies in high-volume medical device manufacturing, considering the key role they play in ensuring quality and compliance with regulatory requirements and how analysing data centrally can support consistency across lines and sites.

In recent years, medication formulations and drug delivery systems, such as insulin pens and autoinjectors, have become more effective and patient-friendly, ushering in a new era of self-administered treatments. However, their spread has presented manufacturers with major challenges – they have to meet extensive quality and sustainability requirements while still being able to ramp up production quickly. Advanced measurement technology and process monitoring solutions help manufacturers to efficiently master these challenges and count on advanced process control, robust data integrity and reliable quality assurance (Figure 1).

The medical technology industry is growing worldwide, particularly in the field of diabetes care, where growth is estimated to exceed 10% by 2029. Beyond the rise in self-administered insulin therapies, the demand for autoinjectors is also driven by improved drug formulations that now enable subcutaneous delivery of medications for a variety of other diseases.

Previously, such drugs were limited to slow intravenous use due to their high viscosity or the volume required. The shift to self-administered therapies via mechanical insulin pens and other autoinjectors offers substantial benefits to healthcare systems, reducing treatment costs and helping to address medical staff shortages – provided that the pens are safe, easy to use and equipped with appropriate safety features, such as covered needles or on-demand dosing.

Though pens are relatively inexpensive to produce, manufacturers of disposable or reusable pens are faced with manifold

"MONITORING THE CAVITY PRESSURE IN-LINE DURING PRODUCTION IS AN EFFECTIVE SOLUTION – BY MEASURING CAVITY PRESSURE AND MOULD TEMPERATURE IN REAL TIME, MANUFACTURERS CAN VISUALISE EACH SHOT AS A COMPLETE PROCESS CURVE."

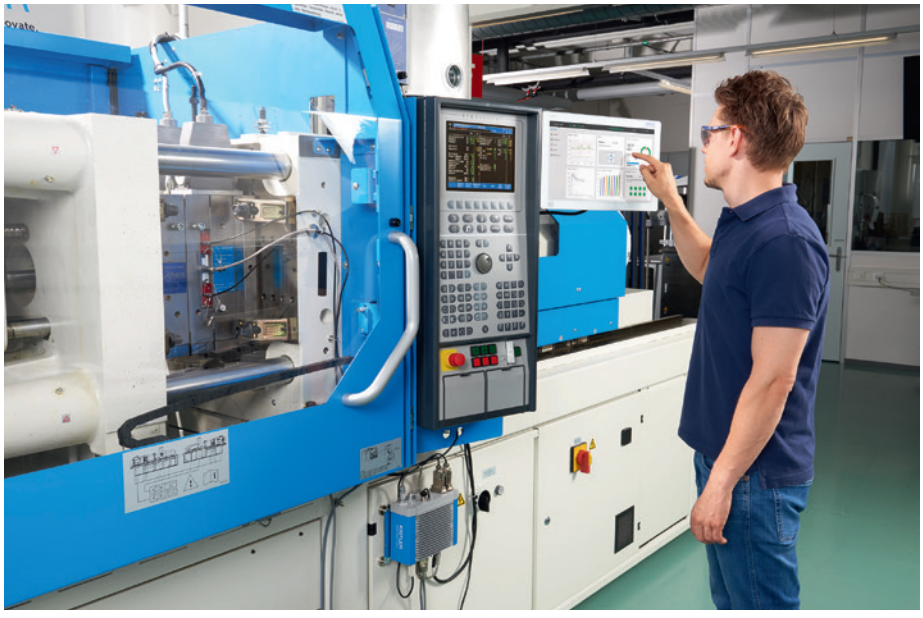


Figure 1: The evolution of medical production, fuelled by innovations such as autoinjectors and insulin pens, requires enhanced process control and data integrity to meet stricter quality assurance and regulatory demands while also increasing efficiency.

challenges. These include increasingly detailed global regulations, such as the EU Medical Device Regulation, and rising pressure to reduce waste, accelerate time-to-market and lower costs. High quality standards further increase cost pressures, as manufacturers must sort out possible faulty parts at every stage of the production process without losing good parts.

ADVANCED MEASUREMENT TECHNOLOGY AND PROCESS CONTROL FOR PEN PRODUCTION

Manufacturers can pull several levers to overcome these challenges. In the production of plastic components, for instance, two issues are crucial:

- The rapid ramp-up of production capacities
- Cost-efficient and reliable processes for part release.

Monitoring the cavity pressure in-line during production is an effective solution – by measuring cavity pressure and mould temperature in real time, manufacturers can visualise each shot as a complete process curve (Figure 2). Direct cavity pressure sensors with melt contact can deliver high-resolution data and are ideal for fine-grained process feedback, while indirect sensors can enable quality monitoring without affecting the surface of the part. When combined with intelligent process monitoring systems, this approach can make it possible to trace each part individually and document a variety of quality-relevant parameters.

> "APPROPRIATE REAL-TIME MONITORING DRASTICALLY REDUCES RAMP-UP TIME FOR NEW TOOLS AND INCREASES OVERALL EFFICIENCY BY STABILISING THE PROCESS AT AN EARLY STAGE."

Figure 2: Continuous process control through real-time monitoring systems supports efficiency enhancement and precise quality assurance for reliable production of complex medical devices.

This allows manufacturers to detect deviations early on and accurately predict part quality during the moulding cycle. Appropriate real-time monitoring drastically reduces ramp-up time for new tools and increases overall efficiency by stabilising the process at an early stage. Furthermore, advanced measuring technologies are precise enough that the pressure curves can be used to draw conclusions about the dimensional accuracy of the manufactured parts, eliminating the need for time-consuming remeasurements.

VISION SYSTEMS CLOSE THE GAPS IN QUALITY MONITORING

Despite the advantages and efficiency of cavity-pressure and temperature monitoring, certain product characteristics require additional inspection, such as surface quality, colour fastness, dimensional tolerances and the absence of burrs on metallic parts like needle tips. Vision systems can use 2D, 2.5D and 3D imaging technologies to deliver high-resolution data on a wide range of critical features, including precise measurements of geometric dimensions, verification of assembly integrity and the detection of surface defects on both plastic and metallic components.

Real-time vision systems can operate in-line, ensuring that every single part meets defined quality standards without interrupting the production flow. They are able to assess an abundance of visual characteristics, compress the resulting data efficiently into records and forward it to higher-level systems for seamless documentation and analysis. The result is a consistent quality assurance concept that covers nearly all autoinjector components, even in high-volume, cross-continental production scenarios.

CHALLENGING FORCE MEASUREMENT IN HIGH-SPEED ASSEMBLY

While optical systems are essential to close remaining quality gaps left by process monitoring, particularly for visual and surface-related features, they cannot provide information about the forces acting within the assembly process itself. This is a critical gap in monitoring high-volume production settings, where cameras often assess component height before and after press-fit operations without monitoring the actual joining process or verifying compliance with force tolerances.

Measuring these forces in high-speed environments presents a technical challenge. When sensors are mounted on rapidly

moving actuators, the effects of acceleration and deceleration interfere with the force signal, making accurate measurements nearly impossible, especially with the tight force tolerances required to protect the glass syringe within the autoinjector.

One approach to a fully integrated solution is to combine a high-speed magnetic drive with synchronised force and acceleration sensors, controlled by a process monitoring system. This form of setup would need to compensate dynamically for inertial influences, isolating the true joining force in real time and directly comparing it with specified tolerance windows. This could enable users to reduce cycle times and detect faulty parts without needing to conduct extra testing on a smaller and more effective machine design (Figure 3).

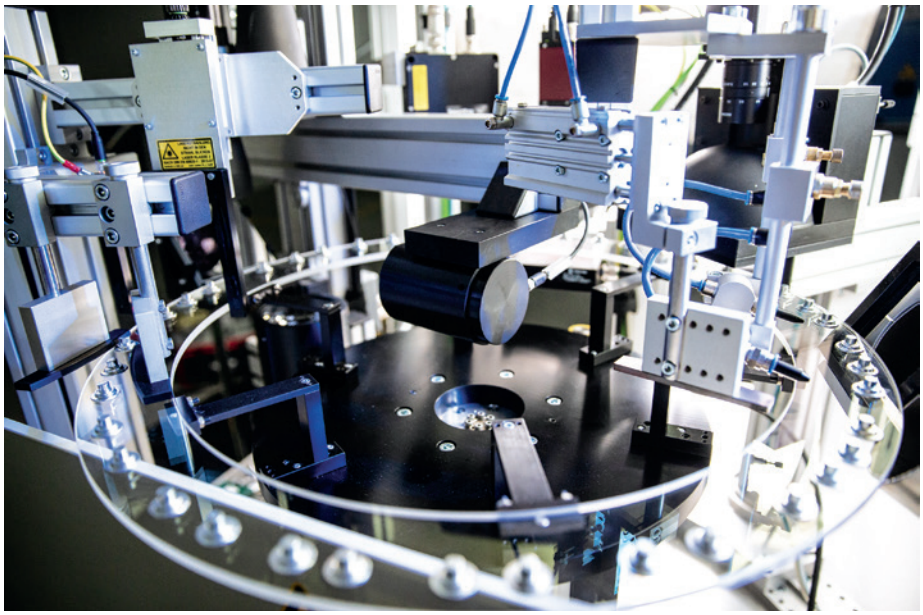


Figure 3: Advanced, camera-based measurement technology enables thorough visual inspection, ensuring data integrity and quality assurance when manufacturing medical devices in high volumes.

DATA INTEGRITY AS A FOUNDATION FOR RELIABLE MANUFACTURING

Outputs from real-time monitoring can be saved, analysed and compared across sites and production lines, enabling consistent quality data management worldwide and rapid process validation. Closed-loop control can enable straightforward integration into existing programmable logic controller environments, which can provide precise, direct feedback at the part level, allowing for immediate sorting of faulty components without disrupting overall throughput.

Complete data integrity is a core requirement in medical device production.

> "OUTPUTS FROM REAL-TIME MONITORING CAN BE SAVED, ANALYSED AND COMPARED ACROSS SITES AND PRODUCTION LINES, ENABLING CONSISTENT QUALITY DATA MANAGEMENT WORLDWIDE AND RAPID PROCESS VALIDATION."

Each component must be traceable, verifiable and reproducible across all production lines and sites to meet regulatory requirements. A key approach to this is to transfer data collected during manufacturing and assembly processes to an effective quality management system. Data should be centrally stored and analysed to transform it into usable information according to customers' needs.

This approach not only ensures full traceability in line with regulations, but it also forms the basis for predictive improvements, faster line validation and resource-efficient production. Instead of manually verifying quality through random sampling, manufacturers can access real-time performance data to evaluate output rates, dimensional accuracy and compliance before a single unit leaves the machine.

Additionally, new production lines can be benchmarked against existing reference curves to ensure consistent product quality worldwide. Thus, data integrity becomes more than a documentation requirement – it becomes a driver of product safety, cost efficiency and technological scalability.

EMPOWERING THE VALUE CHAIN

Sustainable success in medtech manufacturing requires a fully connected value chain that translates process data into actionable knowledge, links decentralised production stages via standardised quality logic, and ensures that every unit produced anywhere in the world complies with internal targets and external regulations. This integration should begin during tool validation and part release, continue through in-line monitoring and force-

> "SCALABLE HARDWARE AND SOFTWARE SOLUTIONS ARE ESSENTIAL, BUT ARE ONLY EFFECTIVE WHEN PAIRED WITH THE CORRESPONDING HUMAN EXPERTISE, MAKING APPLICATION-SPECIFIC CONSULTING AND HANDS-ON TRAINING KEY TO UNLOCKING THE FULL POTENTIAL OF MEASUREMENT SYSTEMS."

controlled assembly, and culminate in data-driven documentation and continuous process refinement.

Scalable hardware and software solutions are essential, but are only effective when paired with the corresponding human expertise, making application-specific consulting and hands-on training key to unlocking the full potential of measurement systems. When technology and know-how converge across the value chain, manufacturers gain more than process control – they create resilient, globally consistent production systems that can reliably and rapidly deliver high-quality, patient-safe devices at scale.

ABOUT THE COMPANY

Kistler Group is a provider of dynamic pressure, force, torque and acceleration measurement technologies, serving both industry and scientific research, enabling it to optimise its products and processes so as to secure sustainable competitive edge. Kistler's sensor technologies help to shape future innovations not only in automotive development and industrial automation but also in many emerging sectors. The company has over 2,000 employees at more than 60 facilities across the globe and is dedicated to the development of new solutions.

Stephan Vogel

Stephan Vogel is Head of Global Industry Development and Industry Lead MedTech/Pharma at Kistler. After university, he worked in Australia in industrial filtration before attending an international management trainee programme, followed by positions in technical product management. Since 2015, he has worked as Business Development Manager and Industry Development Manager, focusing on manufacturing and automation, especially in the medical device industry. He leads a group of global industry development managers, driving strategic focus for the Kistler Group.

T: +41 52 224 11 11
E: info@kistler.com

Kistler Group
Eulachstrasse 22, 8408 Winterthur, Switzerland
www.kistler.com

INJECTION-MOULDED PROTOTYPES FROM 3D-PRINTED TOOLING: ACCELERATING DRUG DELIVERY DEVICE DEVELOPMENT

H&T PRESSPART

David Valencia and **Martí Giralt** of **H&T Presspart** discuss the value that 3D-printed tooling can bring to prototyping injection-moulded components for drug delivery devices, enabling rapid turnaround and iteration of designs while remaining functionally representative of the final commercial parts.

Industrialisation timelines for drug delivery devices are tightening, while regulatory expectations and human factors evidence requirements are increasing. Bridging early design intent with production-realistic mechanical performance is therefore critical for de-risking decisions and compressing time to market. 3D-printed mould inserts for injection moulding provide a direct path to functional polymer parts within days, enabling faster learning and earlier verification.

H&T Presspart now combines 3D-printed cavities, cores and inserts with laboratory injection moulding to produce prototype components in production-intended polymers within days, under production-like process conditions (Figure 1). This closes the gap between appearance models and functionally representative parts, de-risking critical design decisions for drug delivery device components while complementing the capabilities of the company's Global Technology Centre.

DESIGNING FOR REALITY: MECHANICAL FIDELITY IN DRUG DELIVERY DEVICES

Drug delivery devices live at the intersection of human factors, stringent performance requirements and regulatory scrutiny. Early 3D-printing is invaluable for fit, form and user studies, yet printed materials rarely replicate the mechanical behaviour of the final application-specific polymers. When decisions hinge on snap-fits that must

Figure 1: Whole cavity printed in ceramics, mounted in a frame tool and ready for moulding run.

"EARLY 3D-PRINTING IS INVALUABLE FOR FIT, FORM AND USER STUDIES, YET PRINTED MATERIALS RARELY REPLICATE THE MECHANICAL BEHAVIOUR OF THE FINAL APPLICATION-SPECIFIC POLYMERS."

survive multi-use cycles, torque transmission in dose counters, hinge durability in caps or creep- and dimensional stability-related concerns, teams typically wait weeks for machined steel tooling, incurring long lead times, high costs and increased risk.

PRODUCTION-REALISTIC PARTS, EARLY

Cavities, cores and inserts can be additively manufactured in high-temperature technical resins and used to mould short prototype runs in the same polymer grades that are intended for commercial production (Figure 2). Even with the limited lifespan of these printed tool components, the resulting parts provide:

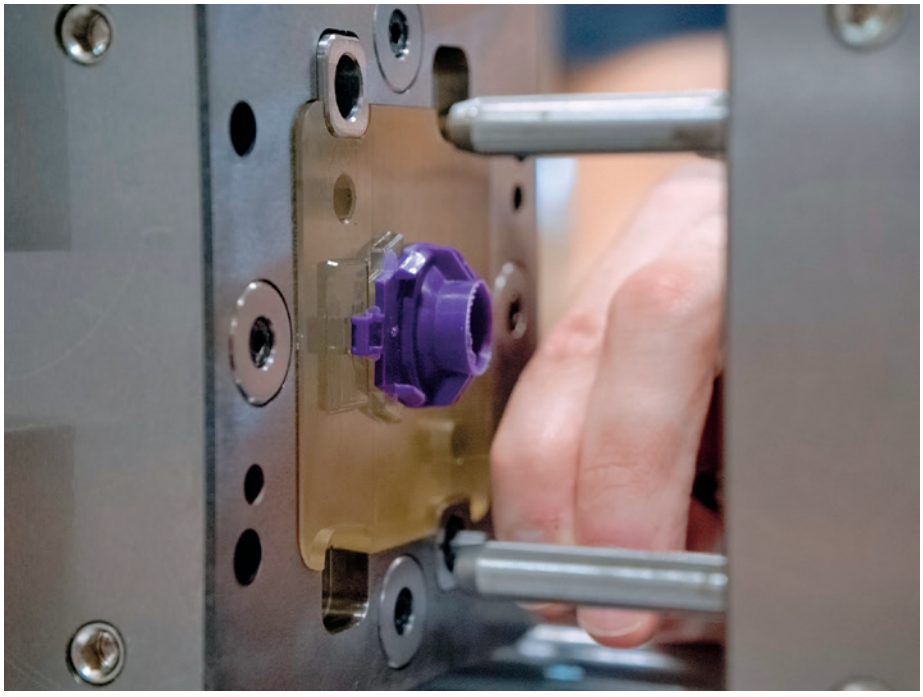


Figure 2: Lilac moulded part in a cavity printed with high temperature resin.

- **Expanded Material Exploration:** Affordable, parallel evaluation of multiple polymer grades can be enabled by printing insert variants, enabling data-driven selection of material-geometry combinations early.
- **Representative Mechanics:** Parts reflect the true behaviour of final polymers processed by injection moulding.
- **Faster Iteration:** Insert designs, gate geometries and vent strategies can be reprinted overnight.
- **Better Design for Moulding and Assembly:** Weld lines, sink marks and warpage can be observed early, allowing part and tool designs to be optimised before production tools are started.

Modular Tooling with Specialist Support

In partnership with Cronomol SL (Barcelona, Spain), specialists in small components and micro-moulding, H&T Presspart has developed a modular mould base that can accept printed inserts. This architecture allows rapid swapping of resin cavities or inserts to match geometric and mechanical requirements, as well as enabling localised changes to specific features without rebuilding the full tool. The workflow is illustrated in Figure 3.

Printed Insert Materials

- **Ceramic-Filled Resin:** Very high stiffness (~10 GPa) and heat deflection temperature (HDT) of > 280°C. Printed on a Stratasys (Minnetonka, MN, US) Origin+.
- **High-Temperature Resin:** HDT ≈ 240°C, with greater toughness than the ceramic-filled options. Printed on a Formlabs (Somerville, MA, US) Form4.
- **Water-Breakable Resin:** Withstands up to 300°C and dissolves or breaks down in water after moulding. This allows single-shot parts with complex geometries, avoiding costly and time-consuming sliders or other active mould mechanics. Even geometries not achievable with conventional injection moulding are possible. Printed on a Formlabs Form4.

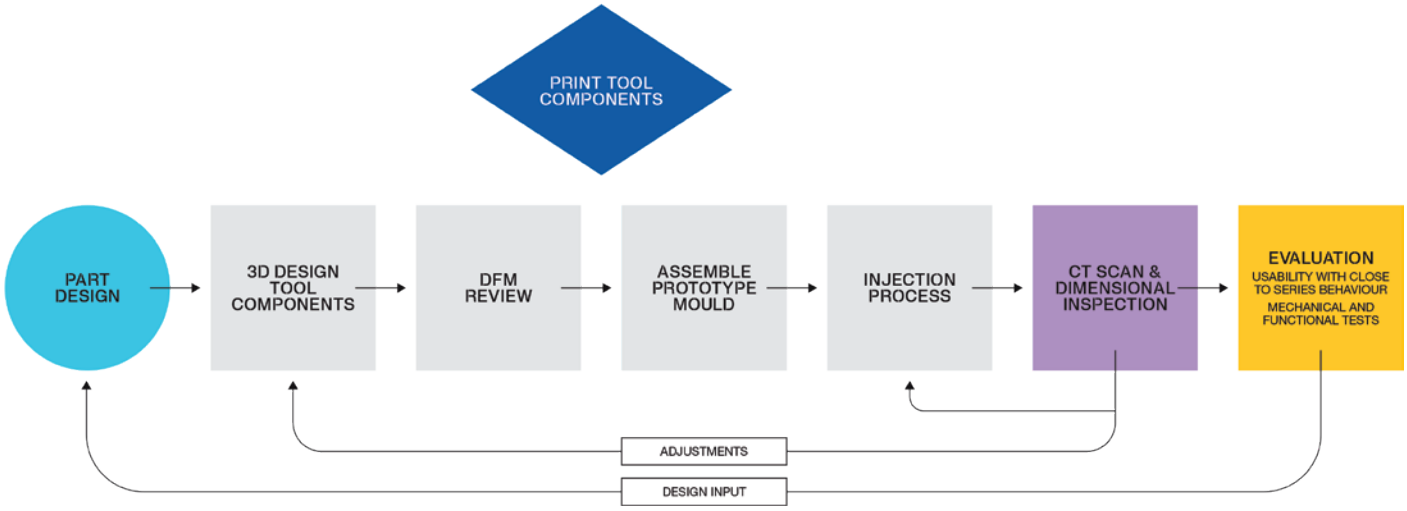


Figure 3: Workflow diagram.

LABORATORY MOULDING UNDER CONTROLLED CONDITIONS

Prototype moulding is conducted on a BOY (Northants, UK) injection-moulding machine in a controlled laboratory environment. Target production parameters – melt and mould temperatures, injection and holding profiles, and cooling – are mirrored to bracket the future manufacturing window. By using the target plastic grades, mechanical responses – such as stiffness, impact and creep – can be closely aligned with those of the production parts, enabling credible functional tests and early verification activities (Figure 4).

"BY USING THE TARGET PLASTIC GRADES, MECHANICAL RESPONSES – SUCH AS STIFFNESS, IMPACT AND CREEP – CAN BE CLOSELY ALIGNED WITH THOSE OF THE PRODUCTION PARTS, ENABLING CREDIBLE FUNCTIONAL TESTS AND EARLY VERIFICATION ACTIVITIES."

Typical insert lifespans range from the tens to the low hundreds of shots, depending on resin, part geometry, gating, venting and cycle parameters. The lifespan can be extended by optimising gate and vent design, reducing melt and mould temperatures within spec, smoothing radii, improving cooling profiles and applying hybrid finishing where critical features require durability.

Figure 4: Prototype parts and cold runner sprue, moulded in first test run with high-temperature resin mould (some flashes and details to be optimised in subsequent loops).

Accuracy, Finishing and Metrology

While printed polymer inserts do not equal steel in precision or wear resistance, several measures can help to narrow the gap:

- **CT-Driven Iteration:** Computed tomography (CT) metrology can guide dimensional corrections and rapid reprints
- **Hybrid Refinement:** Local milling or grinding of printed inserts where tight tolerances matter
- **Surface finishing:** Polishing and structuring of cosmetic or functional surfaces.

What This Enables in Device Programmes

- Early functional reliability with accurate dimensions, realistic snap-fits, flexible hinges, threads, gears and actuation mechanisms – by using the same material intended for the final product, the mechanical properties are effectively equivalent

- Moulded prototypes are suitable for formative human factors studies where tactile feedback and mechanical behaviour can influence results
- Early insights into gate and vent strategy, ejection and handling can provide input for mould and assembly design
- Reduction of development risks and more mature part understanding can reduce the need for tool reworks and facilitate faster convergence on robust designs.

Practical Boundaries

- Shot counts are limited by the insert resin, part geometry and process conditions
- Tolerances are wider than those of hardened steel, so critical features may require hybrid finishing
- The thermal conductivity of ceramic or resin inserts differs from an all-steel mould, often requiring longer cycle times due to reduced cooling to protect the inserts and achieve a stable process.

Process Steps

- Determine inputs, including computer-assisted design files, target polymers, estimated shot counts and critical features regarding quality and function
- Review part requirements against constraints of current setup and define any mould frame adjustments or hybrid metal features, if needed
- Select the insert material, the gate and vent strategy, and an iteration plan aligned with the verification needs and timelines
- Design and optimise the 3D prints to deliver reliable and consistent mould components, drawing on the expertise of the 3D-printer manufacturer and resin supplier
- Run prototypes under controlled parameters, capturing CT and functional data to drive rapid iterations.

CONCLUSION

By merging additive tooling with real-polymer injection moulding, production-realistic parts can be introduced into the earliest design loops. This approach accelerates learning, strengthens evidence for design development and human factors work, and reduces the risk of costly, time-consuming errors on the path to production tooling and market entry.

David Valencia

David Valencia is an R&D Engineer at H&T Presspart, where he has worked in the Global Technology Centre since 2017. He is involved in the development of innovative drug delivery devices, contributing to the design and advancement of next-generation inhalation technologies. Mr Valencia holds a Bachelor's degree in Industrial Design Engineering from ELISAVA School of Design and Engineering (Barcelona, Spain). Prior to joining H&T Presspart, he worked as a Project Engineer at Nifco Products España SLU, where he gained experience in product development and engineering before moving into the pharmaceutical drug delivery sector.

E: david.valencia@presspart.com

Martí Giralt

Martí Giralt is the R&D Laboratory Team Leader at H&T Presspart, leading inspection, testing and prototyping for inhalation, injectable and parenteral drug-delivery devices. Mr Giralt holds a Bachelor's degree in Industrial Engineering from the UPC-ETSEIB (Barcelona, Spain). He brings 10 years of multi-disciplinary testing experience across the automotive and pharmaceutical industries. He has been involved in DPI development, supporting end-to-end characterisation and performance verification.

E: marti.giralt@presspart.com

H&T Presspart

Avda del Foix, s/n, Parque Empresarial "El Foix", 43720 L'Arboç, Tarragona, Spain
www.presspart.com

SHL ADVANTEC SHL MEDICAL

OUTSTANDING SPONSORS

SHL Advantec is a global provider of high-performance, advanced manufacturing equipment solutions for MedTech, pharma, diagnostics and other highly demanding industrial applications. As the manufacturing equipment subgroup of SHL Medical, SHL Advantec offers fully integrated precision tooling and advanced automation to deliver flexible and scalable solutions that ensure quality, efficiency and reliability for its customers' production needs and global supply strategy.

Christy Chen
christy.chen@shl-advantec.com
www.shl-advantec.com

SHL Medical designs, develops and manufactures self-injection solutions, such as autoinjectors, pen injectors and specialty delivery systems for large-volume and high-viscosity formulations. By partnering with leading pharma and biotech companies, SHL Medical continues to develop and supply products and services to support, engage and oversee patients whose quality of life relies on innovative self-administered therapies.

Alberto Flores
alberto.flores@shl-medical.com
www.shl-medical.com

To learn more, see **Page 10**

BESPAK

enquiries@bespak.com
www.bespak.com

Bespak is a specialist inhalation CDMO with established capacity and ongoing expansions to enable the development and manufacture of pMDIs with low-GWP propellants. The company provides a fully integrated service encompassing early-stage feasibility, analytical and formulation development, product development and clinical supply, through to full-scale cGMP batch production.

See **Page 08**

covestro

Amy Weyant
amy.weyant@covestro.com
www.covestro.com

Covestro is a supplier of high-performance materials for the healthcare industry, with over 50 years serving medical device manufacturers globally. For drug delivery systems, surgical instruments, electromedical equipment and wound care, Covestro offers a comprehensive portfolio including polycarbonates, polycarbonate blends and thermoplastic polyurethanes.

To learn more, see **Page 16**

DCA

Sarah Horton
medical@dca-design.com
www.dca-design.com

DCA is a product design consultancy with a wealth of experience developing leading drug delivery devices for global markets, including all types of injection, infusion, inhalation, intranasal, oral and topical devices. DCA provides comprehensive, expert support for device design and development, including strategy, usability, connectivity, engineering, electronics, medical device software and industrialisation.

See **Page 02**

FRP

Joe Melton
joe.melton@frp.co.uk
www.frp.co.uk

FRP is a UK-based rapid manufacturing specialist with over two decades of experience serving the medical device industry. The company holds ISO 13485 certification and offers a range of capabilities including prototyping, 3D printing, CNC machining, injection moulding and in-house CT scanning. The company's medical devices team of 20 professionals operates from Wisbech. As of early 2026, FRP operates as part of the IGS GeboJagema group.

To learn more, see **Page 18**

H&T PRESSPART

David Valencia
david.valencia@presspart.com
www.presspart.com

H&T Presspart is a manufacturer of drug delivery devices and components with more than 50 years of industry experience. The company's Global Technology Centre supports its customers in developing new products and delivering strategic innovation. H&T Presspart operates five manufacturing sites in Germany, Spain, Switzerland, the UK and the US.

To learn more, see **Page 68**

IGS GeboJagema

Erwin van Huijksloot
erwin.vanhuijksloot@igsgebojagema.nl
www.igsgebojagema.nl

IGS GeboJagema is a high-precision mould maker that designs, manufactures, validates and maintains moulds for products where extreme precision is vital, from glasses and contact lenses to asthma inhalers, insulin pens and blood diagnostic devices. IGS GeboJagema specialises in collaborating with medical original equipment manufacturers early in the product lifecycle, allowing its exceptional engineering team to develop innovative moulding solutions.

To learn more, see **Page 18**

nanexa

Dr Anders Johansson
anders.johansson@nanexa.se
www.nanexa.com

Nanexa AB is a Swedish drug delivery company focused on long-acting injectables. Founded in 2007 and headquartered in Uppsala, Sweden, Nanexa has developed the proprietary PharmaShell technology, using ALD nanocoatings to create ultra-long-acting depot formulations. The company partners with global pharma firms to apply PharmaShell across various therapeutic areas, aiming to improve patient adherence and treatment outcomes through reduced dosing frequency.

To learn more, see **Page 52**

NIPRO
Live Longer. Live Better.

Diane McCormick
diane.mccormick@nipro-group.com
www.nipro-group.com

Established in 1954, **NIPRO PharmaPackaging** is a global manufacturer of comprehensive pharma packaging solutions for the pharmaceutical industry. From glass tubing to finished products, the company commits its expertise and services to carefully master drug product requirements.

To learn more, see **Page 58**

Phillips Medisize
a molex company

Henrik Leisner
pmcinfo@molex.com
www.phillipsmedisize.com

Phillips Medisize, a Molex company, collaborates with leading medical technology, pharmaceutical and *in vitro* diagnostic companies to design, engineer and manufacture lifesaving innovations. As a CDMO, the company leverages 60 years of expertise and capabilities and a global presence to help millions live healthier, more productive lives.

To learn more, see **Page 48**

Quvara Medical

Andy Wertheim
info@quvaramedical.com
www.quvaramedical.com

Quvara Medical is a UK-based CMO specialising in precision medical devices for injectable drug delivery. With over 30 years of heritage, Quvara combines validated cleanroom capacity, regulatory expertise and scalable manufacturing to support pharma and biotech partners from development through to commercial supply, delivering quality, compliance and speed to market.

To learn more, see **Page 36**

team

Chris Hurlstone
marketing@team-consulting.com
www.team-consulting.com

Team Consulting is a fee-for-service consultancy that works with pharma and medtech clients to design and develop medical devices, in particular drug delivery devices. In the field of drug delivery, Team Consulting's focus is on administration via the respiratory and parenteral routes.

To learn more, see **Page 42**

YPSOMED
SELFCARE SOLUTIONS

Hong Cui
hong.cui@ypsomed.com
www.ypsomed.com/yds

With over 40 years of experience, **Ypsomed**'s comprehensive drug delivery device platforms consist of autoinjectors for prefilled syringes, disposable pens, reusable pen injectors, ready-to-use prefilled wearable patch injectors and injection devices for drugs in dual chamber cartridges. Ypsomed is well equipped to tackle digital healthcare challenges and has strategically invested in the development of connected solutions and therapy-agnostic digital device management services.

To learn more, see **Page 30**

When the world gets uncertain...
Your manufacturing strategy shouldn't be.

Secure Capacity Now

- Hormuz
- Ukraine
- Pandemics

Global supply chains remain exposed.
We have UK-based validated manufacturing capacity - available now.

Scan Here

- ISO 13485 Certified Quality Systems
- GMP-Aligned Manufacturing
- Precision Injection Moulding
- Cleanroom Assembly - Class 7 & 8
- Autoinjector & Pen Injector Expertise
- 30+ Years Regulated Manufacturing

Book a capacity discussion to protect your programme timeline.

Quvara Medical

info@quvaramedical.com