



Kinetic River Advances Nanoparticle Analysis and Time-Resolved Flow Cytometry with JKI

1,000 events/sec

for NanoCytometer commercialization





Challenge

Delivered production-grade flow cytometry software with real-time nanosecond processing across **FPGA, GPU, and PXI hardware**—achieving orders-of-magnitude performance gains without sacrificing accuracy.



Solution

A scalable, hardware-accelerated architecture built in custom LabVIEW, combining FPGA real-time acquisition with NVIDIA GPU signal processing and an integrated framework for instrument control, analysis, and visualization delivering production reliability with future platform flexibility.



Impact

Reduced processing from overnight batch analysis to real time, achieving up to 1,000 events per second and enabling commercialization of the **Delaware Flow NanoCytometer**.

Kinetic River Advances Nanoparticle Analysis and Time-Resolved Flow Cytometry with JKI

How JKI helped transform prototype algorithms into production-ready software, accelerating data processing by orders of magnitude

By Jamie Smith and Henry Sillin

Industry

Life Sciences / Biotech

Objective

Develop production-ready software for two breakthrough flow cytometry platforms: the Delaware Flow NanoCytometer® for nanoparticle analysis and the Arno Time-Resolved Flow Cytometer, requiring real-time signal processing at nanosecond timescales.

The Systems

- Delaware Flow NanoCytometer with 5-laser optical system (375, 405, 488, 561, and 640 nm)
- Arno Time-Resolved Flow Cytometer with pulsed laser excitation
- FPGA-based real-time data acquisition
- NVIDIA GPU acceleration for signal processing
- Custom LabVIEW software by JKI

Pushing the Boundaries of Flow Cytometry

Flow cytometry has been a cornerstone of biomedical research for over 60 years, enabling scientists to analyze cells and other particles by funneling them single-file at high speeds through laser beams. The technology became indispensable during the AIDS crisis when it provided the gold standard for CD4 T-cell counting, and has since evolved to detect 40 or more fluorescent markers simultaneously.

Kinetic River, founded in 2010 by Giacomo Vacca, Ph.D., has spent 15 years developing advanced technologies for particle analysis. After leaving Abbott Labs, Vacca built a company focused on solving problems that conventional flow cytometers simply cannot address. The result: two groundbreaking platforms that required equally innovative software solutions.

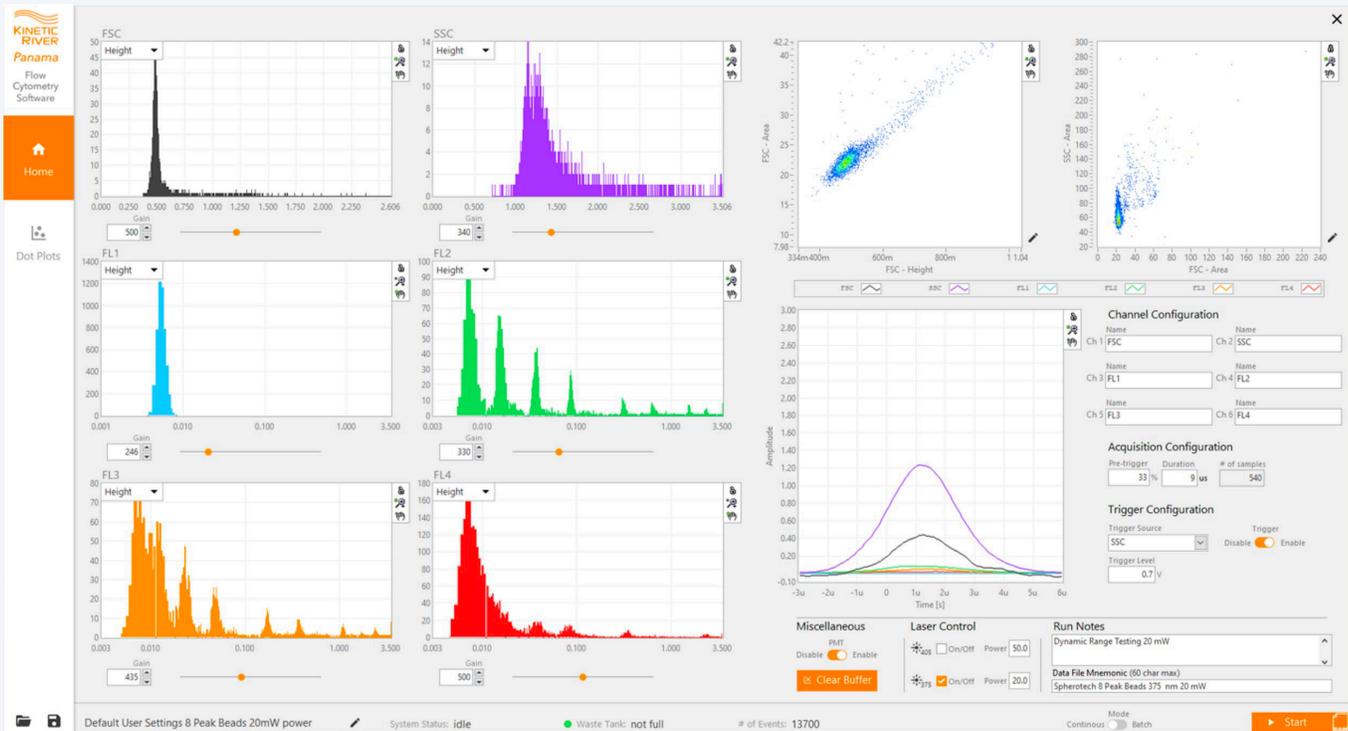
“We needed somebody to turn that code into a production version,” says Vacca. “A production level of reliability and robustness. We worked with a couple of competent consultants, but nobody was able to walk that path down with us until we found JKI.”

The Delaware: Analyzing What Others Cannot See

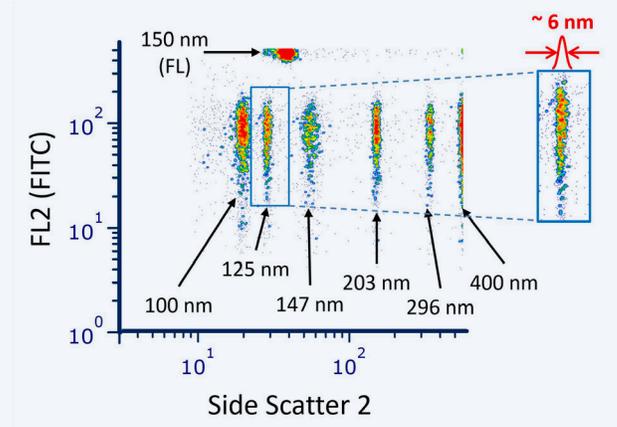
The **Delaware Flow NanoCytometer** represents Kinetic River’s solution to an unmet need in the marketplace: sensitive, high-throughput analysis of nanoparticles, particularly extracellular vesicles (EVs) and exosomes. These tiny biological particles, much smaller than cells, hold tremendous promise for disease diagnosis and therapeutic development.



“If you take just a very good, top-of-the-line flow cytometer today and try to run an EV sample on it, you’ll see a few EVs, maybe more than a few, but you only see the largest ones,” Vacca explains. “The vast majority, which are in the range of 50 to 150 nanometers, flow completely under the radar.”



The Delaware overcomes this limitation while offering something no competitor can match: the largest dynamic range of any analyzer in this space. While other nanoparticle analyzers clog when encountering particles larger than 300-500 nanometers, the Delaware handles everything from nanoparticles < 30 nm in size to full-sized cells (5–25+ μm) without issue.

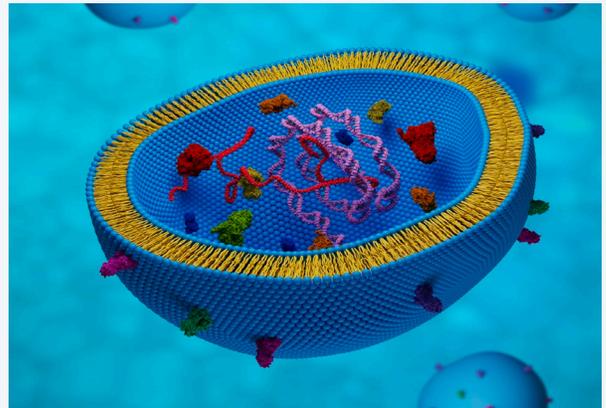


“Most real-world samples are very dirty, full of proteins, junk, and aggregates,” says Vacca. “If you throw a typical sample at one of these other machines, you’ll instantly clog them. Our Delaware is designed to run nanoparticles, but it won’t clog even if you have cells in the sample, which is something nobody else can say.”

Real-World Impact: Detecting Disease Earlier

The Delaware's capabilities are already enabling breakthrough research. Professor Chris Ward at the University of Kansas has been using the system for over two years to study polycystic kidney disease, a genetic condition that can be lethal in its later stages.

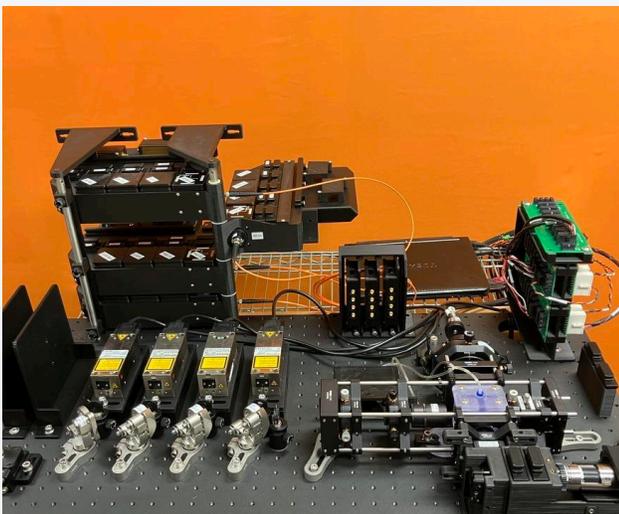
By analyzing tiny EVs exuded by kidney cells in urine samples, researchers can now distinguish between healthy individuals and those with the disease, potentially years before symptoms appear. "By simply taking a sample of urine, which is easy to get and non-invasive, and analyzing it with minimal processing on our Delaware, you can actually see the difference, quantitatively" Vacca notes.



This approach exemplifies how the Delaware opens new possibilities: using these tiny particles as proxies for internal organs that would otherwise be inaccessible.

The Arno: A Reinvention of Flow Cytometry

While the Delaware excels at nanoparticle analysis, the Arno represents something even more ambitious: a complete reinvention of flow cytometry principles using time-resolved measurements.



Traditional flow cytometers use continuous laser excitation and measure the steady-state fluorescence of particles. The Arno instead uses extremely short laser pulses, tens of nanoseconds, and captures the fluorescence decay that follows each pulse. This decay, measured at nanosecond timescales, reveals the fluorescence lifetime of each fluorophore. “Fluorescence lifetime imaging has been used in microscopy for many years,” explains Vacca. “We took that idea and applied it to flow cytometry, where it’s a thousand times harder to do because the sample is gone the moment you look at it, just a few microseconds, and that’s it.”

The implications are profound. Two fluorophores with identical emission spectra but different fluorescence lifetimes, say, 4 nanoseconds versus 10 nanoseconds, appear identical to every flow cytometer on the market except the Arno.

“Those two fluorophores are indistinguishable by any commercial flow cytometer except our own,” says Vacca. “A single detector can detect both emissions at once and distinguish them. That’s something no other flow cytometer on the market today is able to do.”

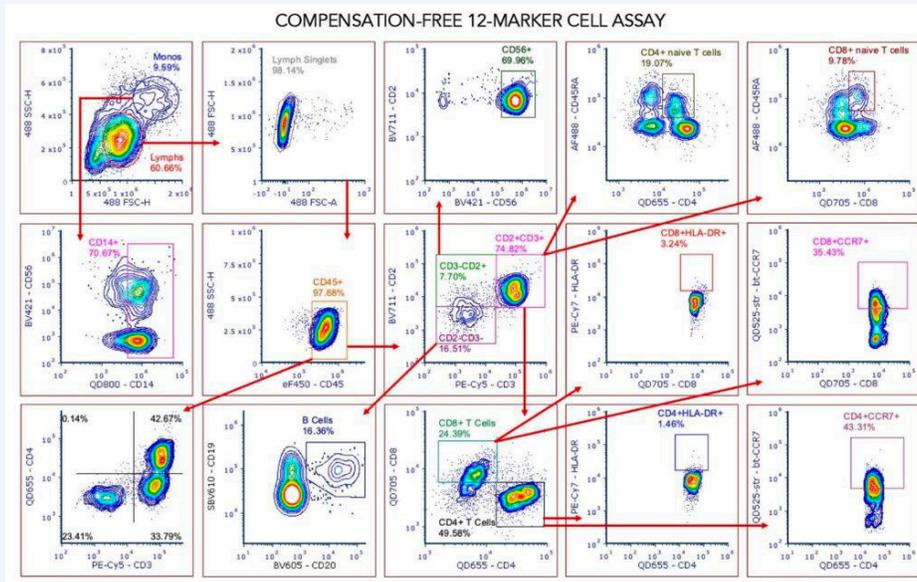
The Promise of Compensation-Free Flow Cytometry

One of the most compelling applications of time-resolved flow cytometry is the elimination of compensation—a burdensome requirement that costs major research facilities millions of dollars annually in reagents and operator time.

In conventional flow cytometry, spectral spillover causes fluorescent signals to spread into multiple detection channels, requiring a complex mathematical correction called compensation. This process demands specialty control materials, repeated calibration for each experiment panel, and significant computational overhead.

“For some high-end labs, it’s literally millions of dollars a year in reagents just to do compensation,” Vacca notes. “Operators have to constantly buy compensation controls, use up expensive antibody reagents, collect compensation data, apply the corrections to their data, and redo this for every different reagent panel.” Even spectral flow cytometry, a modern evolution of the technology that offers finer slicing of the fluorescence spectrum and the ability to analyze more fluorophores simultaneously, must perform the same kind of spectral compensation (called “unmixing”), with even heavier burdens in terms of costs and complexity.

The Arno's compensation-free approach uses widely separated spectral channels combined with lifetime differentiation to provide inherently clean measurements. "Users don't have to worry about that," says Vacca. "They just run the system. That makes it much easier to run, much cheaper to run, and inherently more robust."



JKI's Role: From Seconds to Microseconds

The technical challenges facing both platforms spanned optical, electronic, fluidic, and algorithmic domains. But the most demanding challenge was software: transforming Vacca's working algorithms into production-ready code capable of real-time performance.

"The algorithms I developed went through a lot of iterations, and we were able to hone them quite well already, but they weren't fast enough," Vacca recalls. "It took us sometimes overnight to take the results from one experiment and reduce them to something a cytometrist could use."

Kinetic River's TRFC technology is implemented on a PXI platform with custom LabVIEW code and advanced signal processing algorithms. The architecture distributes processing across specialized hardware: the FPGA handles front-end signal conditioning and high bandwidth, low-latency I/O, while the GPU performs parallel processing on datasets too large or complex for the FPGA alone, and faster than a CPU could manage. Offloading these tasks allows the CPU to focus on core application tasks such as data logging and user interface control.

JKI tackled this challenge in two phases: first accelerating the algorithms in software, then implementing hardware acceleration using FPGAs and NVIDIA GPUs.

“Most of the time, the JKI team knew exactly how to do what we needed. And if they didn’t know, they knew exactly where to look to find out.”

Giacomo Vacca, Kinetic River founder and president

The results were dramatic. By combining GPU and FPGA components in a Real-Time system, Kinetic River’s Time-Resolved Flow Cytometer can now characterize thousands of cells per second. The system acquires and analyzes time-resolved flow cytometry data in real time at up to 1,000 events per second, comparable to conventional instruments, while processing an underlying data stream captured at gigahertz speeds. This gives experimenters real-time feedback on their experiment and eliminates the need to store large datasets or wait until post-processing delivers results.

“We went from overnight processing to real-time,” says Vacca. “JKI helped us achieve orders of magnitude improvement in processing speed.”

A Framework for the Future

JKI’s work on the Arno created a software framework that Kinetic River has leveraged across its entire product line. The Delaware, which came later in development, benefited directly from the architectural work already completed.

“We were able to essentially repurpose some of the same work that had already been done and use it for product launch,” Vacca explains. The framework encompasses laser control, flow parameter monitoring, photodetector management, real-time data analysis, and an intuitive user interface that presents complex data without overwhelming users.

Beyond the core functionality, JKI helped create software that is truly production-worthy: robust error handling, corner case management, and the polish expected from commercial instruments.

“The JKI-developed Panama software has elevated the Potomac [precursor of the Delaware] to be more than just a lab instrument. Some version of JKI code will likely go into every other product that we sell.”

Giacomo Vacca, Kinetic River founder and president

Status and Next Steps

The Delaware is now a released product with several instruments installed at customer sites. Kinetic River continues to engage directly with customers, running demos and refining the technology based on real-world feedback.

The Arno is approaching commercialization. A pre-production prototype will be completed within weeks, with a beta unit planned for customer testing by year's end. The platform will serve applications including compensation-free flow cytometry and autofluorescence elimination.

Kinetic River has received seven NIH SBIR grants across multiple phases to support this development, including a recent Commercialization Readiness Program grant. The company has been awarded 27 patents covering its innovative approaches.

“JKI was definitely right there with us, in the trenches, working through the problems firsthand,” Vacca reflects. “They helped us accelerate our R&D, which has been critical to the successful development of our platforms.”



Project Summary

The JKI engineering team helped Kinetic River transform prototype algorithms into production-ready software for two groundbreaking flow cytometry platforms. By implementing sophisticated real-time signal processing with FPGA and GPU acceleration, JKI enabled processing speeds that improved by orders of magnitude—from overnight batch processing to real-time analysis at millisecond timescales. This work has positioned Kinetic River to bring revolutionary new capabilities to researchers studying everything from kidney disease to cancer immunology.

Kinetic River Corp.

897 Independence Avenue, Suite #4A
Mountain View, CA 94043
www.KineticRiver.com
info@KineticRiver.com

JKI

3687 Mount Diablo Blvd, Suite 208
Lafayette, CA 94549
888.891.7821
jki.net
info@jki.net

**Schedule 30 min
Consultation**

