

# BUILD SOFTWARE TO TEST SOFTWARE

The Deliberate Practice of Software Testing

# EXACTPRO AT A GLANCE

Exactpro is an independent provider of AI-enabled software testing services for financial sector organisations. Our clients are exchanges, post-trade platform operators, and banks across 20 countries. Our area of expertise comprises protocol-based testing of matching engines, market data, market surveillance, clearing and settlement systems, payments APIs. We help our clients to decrease time to market, maintain regulatory compliance, improve scalability, latency and operational resiliency. Exactpro is involved in a variety of transformation programmes related to large-scale cloud and DLT implementations at systemically important organisations.



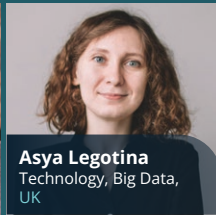
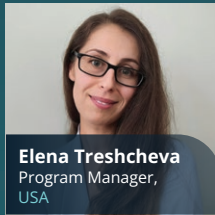
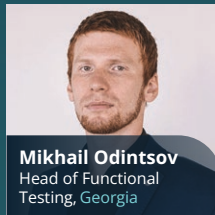
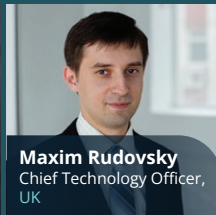
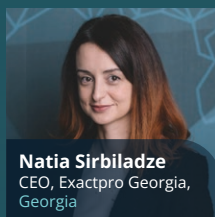
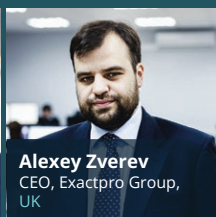
Founded in 2009, the Exactpro Group is headquartered in the UK and operates delivery centres in Georgia, Sri Lanka, Armenia, Lithuania and the UK and representative offices in the US, Canada, Italy and Australia.



Exactpro was part of the London Stock Exchange Group (LSEG) from May 2015 until January 2018, when the Exactpro management went through the buyout of the company from LSEG.



# MEET THE GLOBAL TEAM



# EXACTPRO OFFICES



Toronto, Canada



Cincinnati, USA



London, UK



Adelaide, Australia



New York, USA



Vilnius, Lithuania



Tbilisi, Georgia



Colombo, Sri Lanka



Yerevan, Armenia



Milan, Italy

# AI TESTING : DELIVER BETTER SOFTWARE, FASTER

Software testing is an information service. Its goal is to provide stakeholders with objective information about the defects persisting in their system. A software defect is anything in the code, configuration, data or specification that can decrease the value of software to its stakeholders. The effectiveness of an information service can be assessed based on its accuracy, relevance and accessibility. Improving software testing implies making it progressively better at detecting and interpreting defects, whilst reducing the timeframes and costs.

With the growth of available digital data and computational capabilities, we are seeing the use of subsymbolic artificial intelligence (AI) deliver improvements in autonomy and efficiency across many industries. In software testing, using AI can help harness the power of big data analytics to enhance the generation of test ideas and the interpretation of test results – both tasks traditionally thought to be highly cognitively demanding. These can also be complemented by advanced execution capabilities.

Using AI algorithms introduces new levels of automation and system exploration. At Exactpro, the use of AI algorithms combined with the principles of model-based testing form the **AI Testing** approach. It is designed to strengthen the operational resilience of client infrastructures and, by association, the entire financial technology landscape.

Exactpro's AI-enabled cross-asset and technology-agnostic approach is gaining industry adoption. Each instance of the technology transformation facilitated by Exactpro is supported by a custom-made test framework leveraging our corresponding domain expertise, industry-tested system modelling capabilities and test libraries.

**AI Testing** ensures that a test framework can fully match the complexity of the system under test. Helping account for massive amounts of parameter permutations unique to the system being tested, AI-enabled automation provides increased versatility of the test library, compared to manual or more formal test generation methods.

Leveraging AI and machine learning, Exactpro transforms the quality evaluation service by providing more extensive, highly-performant yet resource-efficient testing of the functional and performance aspects of financial technology platforms. The approach ensures more effective test coverage via better detection of potential vulnerabilities.

# AI TESTING INVESTMENT BANKING SYSTEMS\*

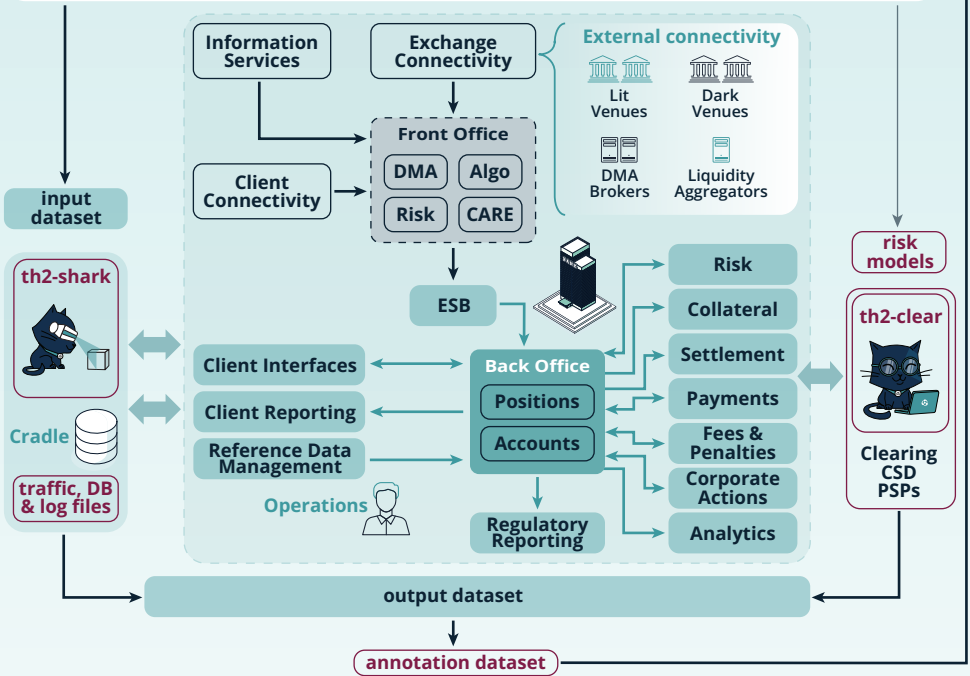
## CASE STUDY

### test basis

- ✓ Reference data – participants & account structure permutations
- ✓ Instrument specifics
- ✓ Market data & transactional data simulation rules
- ✓ Protocol specifications, machine-readable dictionaries
- ✓ Daily life cycle (DLC) & exceptions
- ✓ Various input actions check lists
- ✓ Market & asset class specifics
- ✓ Risk and stress-testing models

- ✓ Information obtained from testing
- ✓ Model refining
- ✓ Improving automation coverage, stability & verifications

weights dataset



\* Visit our website to see examples of AI Testing implementations for [trading](#) and [clearing & settlement](#) systems.

## TEST LIBRARY GENERATION AND OPTIMISATION

Would you like to see the benefits of AI-enabled test library generation and optimisation for yourself? Watch our latest AI Testing demo by following this QR code.



# EXACTPRO WINS

'MOST INNOVATIVE THIRD-PARTY TECHNOLOGY VENDOR - INFRASTRUCTURE, OUTSOURCING, AND MANAGED SERVICES' IN THE AMERICAN FINANCIAL TECHNOLOGY AWARDS 2023



## American Financial Technology Awards Winner 2023

Most innovative third-party technology vendor – infrastructure, outsourcing & managed services  
**EXACTPRO**

*To remain competitive and compliant, we are constantly fine-tuning our test data generation, test execution, and test results analysis algorithms to find more effective ways to keep our clients' systems robust and resilient in the face of constant regulatory, geopolitical, infrastructure- or user-driven change. We recognise that realising the potential of AI is critical in achieving greater efficiency. We very much appreciate this recognition as we continue to respond to our clients' need to innovate – without compromising quality.*

**Iosif Itkin,**  
CEO, Exactpro Group

Read the full press-release  
via the QR code



## PARTNERS AND INDUSTRY ASSOCIATIONS

**FIX TRADING COMMUNITY™**  
INDUSTRY-DRIVEN • INDEPENDENT • NEUTRAL

**wfe** WORLD FEDERATION OF EXCHANGES

**Zero Outage**  
INDUSTRY STANDARD

**ISTQB** Platinum Partner  
International Software Testing Qualifications Board



**FIA**

**STANY**  
The Security Traders Association of New York, Inc.

**r3.c.rda**

# ISTQB®-ACCREDITED CERTIFIED TESTER AI TESTING (CT-AI) TRAINING COURSE

Exactpro's training course will aim to help individual and corporate clients to understand the complexities involved in:

- using the AI toolkit to automate workflows and everyday project tasks, enhancing their efficiency, and
- testing AI-based systems – including self-learning functionalities – from the functional and performance perspectives, mitigating issues such as biases, ethics, non-determinism, and the challenges related to transparency and explainability.

The course will follow the ISTQB® CT-AI v1.0 syllabus structure and feature both theory and practice materials on topics including:

- Machine Learning (ML)
- Neural Networks and Testing
- Testing AI-based Systems
- Test Environments for AI-based Systems
- AI for Testing



**200+ practice  
questions**



**Customised  
course length**



**Q&A  
sessions**



**Hands-on Python  
workshops**



**Listen, Watch,  
Read formats**



**Mock Exam**



To find out more about the training course or register your interest, please visit our Careers website at [careers.exactpro.com](https://careers.exactpro.com).



Access our ISTQB® Certified Tester AI Testing explainer series available freely on YouTube. The video series provides a comprehensive introduction to the ISTQB® syllabus.



# CONFIDENT INNOVATION: DIGITAL TWINS FOR OPERATIONAL RESILIENCE IN EXCHANGES AND CCPs

The article was first published in the *September 2023 issue of the World Federation of Exchanges Focus Magazine*.

focus

Monthly insight from the WFE and our member exchanges

'Digital twins' are known to be a reliable means of system simulation across industries: automotive, space, manufacturing – used to obtain valuable insights about a system's quality, analyse its performance, and even prevent or remediate breakdowns. However, building digital twins for modelling complex transaction-processing systems such as exchanges, payment, clearing and settlement systems for the purpose of assessing their quality is an area explored less extensively. This article aims to shine the well-deserved spotlight on the significance of simulation in fintech systems delivery.

Any given exchange environment can require one to two hundred servers to stay operational. A model of the same environment may require just two servers to run the simulations covering all of the system's quality assessment needs. Significantly optimised resources cut down the associated hardware footprint and costs.

Sufficiently thorough regression testing can require substantial time and effort. Using a model, however, would provide a highly efficient version of the regression test library that leverages computing capabilities to produce and analyse diverse scenarios. Increased testing speed enables faster delivery as well as promotes risk-informed decisions and better delivery strategies.

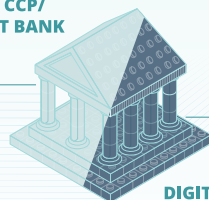
It is possible for a model to be built as the system matures, which, in line with agile software development methodologies, enables stakeholders to receive objective information about the system early in the development lifecycle and resolve most issues long before they become critical.

Due to its ability to unlock greater control over system components and functions, system modelling provides a fundamentally deeper extent of system analysis, compared to SLA-outlined requirements traceability matrices – more so with the use of AI.



Continue reading about [The Synergy of System Modelling and AI](#) on our website.

EXCHANGE/ CCP/  
INVESTMENT BANK



DIGITAL  
TWIN

# AI'S CREATIVITY FOR COMPREHENSIVE TEST COVERAGE



The article was first published in the *Sibos 2023 issue of The Fintech Magazine*.

In the fast-evolving landscape of financial technology, many industry players find themselves facing the question of whether they need to respond to the latest trends and harness the power of artificial intelligence (AI) to keep their competitive edge. In the financial services domain, data plays a crucial role, and the abundance of data makes a strong case for leveraging AI in most of the numerous use cases. Whether it is transactional data, market data, customer data, or other financial datasets, AI can extract valuable insights and boost efficiency in the associated tasks.

What exactly can GenAI improve in testing? If we expect to improve something (i.e. make it better), a first step is to settle on the definition of “good.”

Some industry practitioners envision an ideal test process as possessing such characteristics as full automation, easy maintenance, speed, consistency, system-agnosticism, vendor independence, transparency, and low cost. But aiming to meet these criteria alone carries the danger of goal misalignment – a concept that, in the AI domain, is associated with reward hacking: the objective function is formally achieved without actually delivering the intended outcome. In other words, one will always find a way to satisfy the above criteria of “ideal” testing, with the most evident one being not performing any testing at all.

The true objective function of software testing is finding defects and communicating them to the stakeholders in the most effective manner, and that’s the main purpose of testing as a complex cognitive activity, a deliberate effort. “Good” software testing is an information service, and its effectiveness is measured by the accuracy, relevance, and accessibility of the information about system behaviour. Making the case for Generative AI to improve testing, we would expect it to significantly augment the ability of the testing effort to provide such information.

Continue reading on our website as we make [The Case for Generative AI](#) and discuss creativity and responsibility in the context of AI applications in fintech.

HAVE WE ACHIEVED FULL AUTONOMY AND AUTOMATION?

100% OBJECTIVES MET



# TRADING TECHNOLOGY TESTING

## CASE STUDIES

### **EXACTPRO - JSE COLLABORATION TO TEST THE MILLENNIUM EXCHANGE™ PLATFORM**



The case study highlights the Exactpro deliverables in setting up automated functional and non-functional testing of the Millennium Exchange™ trading platform provided to the Johannesburg Stock Exchange (JSE) by LSEG Technology.

### **ATHENS STOCK EXCHANGE (ATHEX) TRADING SYSTEM FIX MIGRATION**

*OASIS Upgrade Testing & Coverage  
Analysis*

The case study is a reference use case for supporting trading system migrations to FIX-enabled technology, it also highlights the role of passive testing approaches in performing and automating regression testing and improving test coverage.



### **MEMX-EXACTPRO COLLABORATION ON EXCHANGE QUALITY ASSURANCE**



The case study reviews the extensive functional testing and test automation delivered by the Exactpro team.

### **MARKET SURVEILLANCE**

The case study highlights the challenges and the complexity of testing market surveillance systems connected to trading platforms, market data providers, involving various data mining processes, alerting mechanisms, and having different degrees of process distribution complexity. The case study is based on the experience of testing a number of market surveillance systems across different markets and locations.



### **TRADING TECHNOLOGY TESTING WITH th2**

The case study and demo review a set of test methods that trading technology providers and their clients can benefit from, to decrease the chances of missing business-critical defects and avoid frequent outage incidents. The methods allow us to develop a comprehensive and efficient test library and achieve exhaustive test coverage.



# POST-TRADE TECHNOLOGY TESTING

## CASE STUDIES

### POST TRADE: FUNCTIONAL AND NON-FUNCTIONAL TESTING

In times of high market volatility, CCPs are one of the finance infrastructure links that are hit the hardest. This case study focuses on the Exactpro approach to testing large-scale post-trade infrastructures with emphasis on enhancing system resilience and increasing the level of process automation. The latter is achieved via leveraging the latest data mining and machine learning techniques.



### RISK MANAGEMENT

The case study focuses on the challenges of testing risk management systems and Exactpro's test automation and testing approach developed and implemented for our client, a central counterparty responsible for clearing and risk management of CCP-eligible transactions on a leading European exchange.



### COLLATERAL MANAGEMENT

The case study features scenarios for testing of collateral and liquidity management systems for a leading global rates and multi-asset clearinghouse and a multi-national central counterparty.



### CONFORMANCE CERTIFICATION

Conformance certification (also known as conformance testing) is a mandatory step in ensuring that customer systems comply with the officially declared exchange/broker certification rules. Conformance certification is conducted in order to prevent the occurrence of compatibility issues between the trading platform and the systems of the trading participants connecting to it. The list of parties conducting conformance certification includes but is not limited to exchanges, alternative trading systems (ATSS), multilateral trading facilities (MTFs), Swaps Execution Facilities (SEFs), broker and post-trade systems. The case study describes Exactpro's passive-testing-based solution for streamlining customer conformance testing automation.



# ENTERPRISE DATA WAREHOUSE CLOUD MIGRATION

CASE STUDY

## THE SOFTWARE TESTING PERSPECTIVE

By Artem Grechishnikov, Senior QA Project Manager, Exactpro

Transitioning operations to a cloud infrastructure is a challenge that firms face on their digital transformation journey. Cloud-driven modernisation in the financial services space involves migrating core parts of the enterprise-grade IT infrastructure, such as the data repository. It entails fundamental changes in the system's business logic and architecture, data flows, the Database Management System (DBMS) functionality, warehouse operation, as well as the dependencies. The process demands alignment, coordination and careful planning within the organisation.

It is crucial to thoroughly assess and understand the technology characteristics of your preferred cloud provider, as there are differences between operators. This step helps shape the underlying

processes going forward and give an understanding of the level and extent of software testing able to support the transition.

However, setting up the right migration strategy is only getting half way – implementing it with no data loss or redundancies and with minimal performance issues in production is what a trading, clearing/settlement or core banking platform operator is looking to achieve. Developing end-to-end software testing expertise at an early stage of the cloud migration design and planning helps ensure the quality and reliability of the new cloud infrastructure. It helps remediate architectural and documentation-related issues, as well as ensure a more optimal cloud setup.

*Why do some cloud migrations not achieve the required results and what are the ways to avoid data loss during a data warehouse migration?*

*What are some of the crucial functional and non-functional aspects of a technology migration to the cloud?*

*Find out from our case study that contains our proposed cloud migration testing strategy and a sample technology stack at [exactpro.com](https://exactpro.com).*



**Artem  
Grechishnikov**

Senior QA Project Manager,  
Exactpro

# RELYING ON THE CONTEXT – INDUSTRY DYNAMICS, TECHNOLOGY ADVANCEMENTS, RESEARCH



**Elena  
Treshcheva**

*Program Manager,  
Exactpro USA*



*I am thrilled to be part of the momentum in aligning Exactpro's AI Testing approach with the unique regulatory environment and diverse technological landscape of the US financial market.*



Ensuring resilience in critical financial market infrastructures worldwide, Exactpro is renowned for its comprehensive expertise in the financial services domain. Supporting our software testing practice with extensive research has always been imperative for us.

In the dynamic landscape of the US financial market, where emerging technologies are rapidly adopted, Exactpro remains committed to staying ahead. To meet the demands of increasing processing speeds and growing data volumes, our team continuously enhances our AI-driven approach to software testing. We focus on developing innovative techniques to generate test ideas and

glean insights from vast arrays of test data, empowering our clients to "Deliver Better Software, Faster."

As a part of our experienced team dedicated to advancing cutting-edge software testing methodologies, I am thrilled to contribute to research and documentation on our latest tools and methods as well as to the common effort of aligning Exactpro's AI Testing approach with the unique regulatory environment and diverse technological landscape of the US financial market. I firmly believe that our AI testing paradigm will catalyse a transformative shift, revolutionising how quality and resilience are ensured in financial systems.

# THE VALUE OF UNDERSTANDING YOUR TECHNOLOGY ASSETS

*"Never invest in a business you cannot understand," - the famous quote attributed to Warren Buffett also holds true for fintech innovation and may suggest that lack of knowledge about your technology assets can put your digital transformation budgets at substantial risk.*

The healthy way to own an asset is to know what is inside and what governs it. If this is the case, you will be able to put this asset to work and get returns on your investment.

Imagine you decide to renovate your own home. This may play out as a nice demonstration of your craft skills and, at the same time, help you save on costs. However, if you choose to pour your creativity onto the walls without knowing where exactly the electrical wiring runs, the outcome of hammering a nail into the wire is likely to spoil both perceived benefits.

Similarly, the feasibility of investing in a technology transformation project depends on the depth of your understanding of the platform in question.

## **The financial benefits of knowing what you own**

Consider two examples.

The first example is around large-scale technology migration within a market infrastructure being handed over to a new parent entity. The current technology is thoroughly tested, its functionality is exhaustively modelled through an end-to-end regression test library equipped with automated execution capabilities. What is more, the team has extensive knowledge of the technology platform, as well as an understanding of its correct and incorrect behavior. The migration is planned with this knowledge in mind.

The second example features a financial institution who started their technology replacement efforts by engaging a third



**Mikhail Kurkov,**  
*Head of the European  
Markets Division, Exactpro*

party to create a requirements specification for a new system based on the organization's business need and then asking them to develop one. The resulting system, though impeccable from the functional specification point of view, however, turns out to be unable to function through multiple interfaces connecting it to the surrounding infrastructure components. In this case, the organization has only a few people familiar with the original system from performing superficial manual tests against it.

Given the two situations, it will not come as a surprise that the first project proved to be a much better investment than the second one, which achieved the only transformational goal of turning an impressive budget into a waste of time and human effort.

Let us try to understand what is involved in "knowing what you own."

## **Understanding: the process of knowledge acquisition**

What is knowledge from an epistemological point of view? Knowledge is different from just an opinion in that it requires evidence to support it. In other words, the process of understanding deals with building a model of reality and subsequent assessment of this model against the reality itself.

Any technology platform is a fragment of the world designed to perform specific meaningful functions. To understand how it works means to build its model and challenge it.

From the knowledge acquisition perspective, this approach is implemented through rigorous testing as opposed to a box-checking exercise, which in the financial technology world is a very common activity accompanying regulatory reporting tasks. The main difference between the two lies in the mindset: to get a good understanding of the system under test we need to challenge our assumptions about it rather than try to prove that they simply comply with the requirements and stakeholders' expectations.

## **Models: reflecting the reality**

An important point about understanding is that it is a process rather than a static snapshot of current reality.

To make this process effective, mere mind power is not enough – it is important to support knowledge acquisition with tools. The deeper the needed degree of confidence in the system under test is, the more complexity would be required from the tool that we use to assess it.

A tool that is fit to the task is essentially a model of the system under test, which rivals it in terms of complexity and degrees

of freedom. Such a tool is capable of modelling all of its possible interactions, both internal and external, and capturing the data flow. Analysis of this data can be leveraged for the model improvement.

## **Test oracles vs. human judgement**

As any technology project evolves, the accompanying testing activities result in building a comprehensive model of the system under test in the form of a large regression testing library. This is a valuable artifact per se, as it significantly improves our knowledge acquisition capabilities.

However, if not subjected to constant improvement, such a model will inevitably decline, losing the ability to serve its main purpose – to drive the evolution of what we know about our technology platform.

According to common understanding, the ability to tell right from wrong, correct from incorrect is considered to be the essence of the test oracle concept. However, when this reasoning capability is cast in stone (i.e., built into a finalized test library) it means that we are delegating our judgement functions to the machine.

An alternative view on the test oracle suggests that its purpose is to serve as an alert mechanism prompting humans to intervene rather than taking over their decision-making responsibility. This perspective is in line with the principle of constant model evolution: to ensure it, we need the people component to be a part of the equation. Moreover, knowledge by its essence is a social concept, so the understanding of the system under test cannot evolve without humans: people act as a collective distributed database

*To be justified in terms of time/money investment, any transformational initiative needs to be assessed in terms of understanding of one's own technology assets. The knowledge about them rests on three pillars – processes, platforms and people, with all three being part of any rigorous software testing approach. Invest in software testing. Build a more resilient future.*



# DLT TESTING

## CASE STUDIES

### Testing Distributed Ledger Technology Platforms and Infrastructures

The case study discusses the development of new techniques for testing distributed ledger technologies (DLT) such as Corda, Hyperledger and DAML – in particular, for their application to mission-critical financial market infrastructures. The case study reviews the technological characteristics specific to DLT systems and highlights the associated requirements imposed on test harnesses validating their quality. It also zooms in on the functional and non-functional aspects of DLT platform testing.



### Functional Testing of CBDCs in the R3 Sandbox for Digital Currencies

The case study and accompanying demo focus on the testing and test automation approaches for functional testing of a Corda-based Central Bank Digital Currencies (CBDCs) solution. The Sandbox for Digital Currencies provides an environment for users to explore the possibilities of a distributed ledger technology solution in a wholesale setting. The test framework used in the implementation is th2 – Exactpro's next-generation framework for automation in testing.



# DEMOS

Formal Verification of Smart Contracts with the th2 Framework for Automation in Testing



P8 NFT Marketplace Functional Testing with the th2 Framework for Automation in Testing



th2 Implementation for Reconciliation Testing of the P8 Marketplace Built by Yaala Labs



# GEVAMU PAYMENT SOLUTION



Enter the age of interoperability, fully equipped to accommodate your customers' technology needs



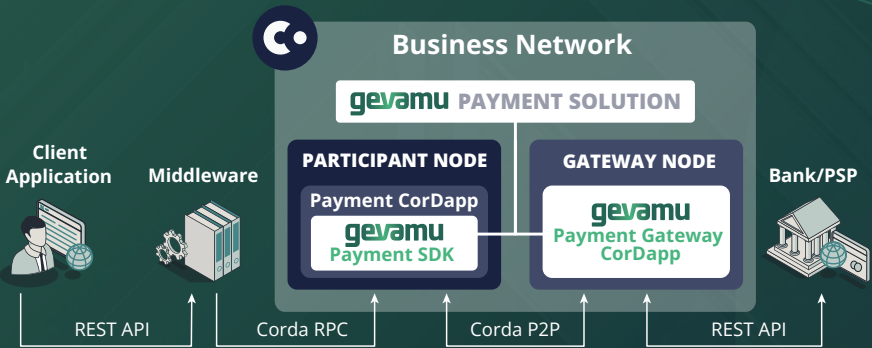
Enhance your domestic and cross-border payments infrastructure with greater speed and transparency



Connect your payments platform and the blockchains of your choice to set up a frictionless workflow and benefit from full ISO 20022 support



Enable integrated ecosystems where users can send and collect cryptocurrencies, CBDCs and fiat money across technologies



Gevamu Payment Solution is developed as two components – a payment SDK and a payment gateway. The current implementation is to be deployed in a Corda business network managed by a Corda Business Network Operator (BNO). Both components are developed based on R3 Corda 4.x. A separate gateway is configured for each bank/PSP.

Implementations for other blockchains are possible upon request.

**Watch demo** →



# EXACTPRO AND BNY MELLON WIN SWIFT HACKATHON 2022 IN DIGITAL ASSETS OWNERSHIP AND INTEROPERABILITY CHALLENGES

[18 October 2022, London] – Exactpro, an independent software testing services provider for financial market infrastructures, is honoured to be recognised winner of the Ownership challenge of the Swift Hackathon 2022 alongside BNY Mellon prevailing in the Interoperability challenge.

The Hackathon finale came as part of Sibos 2022, Europe's premier financial services conference. In line with the conference theme of Progressive Finance for a Changing World, the Hackathon's focus was turned to digital assets. Challenge 1 teams tackled the problem of interoperability between ledgers, as well as between traditional and distributed ledger technology (DLT) systems. Challenge 2 addressed the issues of ownership of digitally native assets.

Exactpro's winning solution – Project "Footprint" – is an analytical framework intended to collect and analyse ownership-related information of digital assets and visualise the data in an intuitive way in the form of profiles. The Exactpro team's expertise in software testing helped shape the approach.

*Our test data generation and aggregation capabilities are at the core of the solution. With the technical disparity we are currently seeing in the digital assets space, we've had to come up with an architecture that can accommodate changes to systems and protocols for years to come. We also kept in mind that in the hyper-connected world of today, a solution to tracking ownership should draw from a multitude of channels and go beyond just the trading platforms.*

**Marina Kudriavtseva,**  
Head of DLT, Exactpro

*We have been taking part in large-scale digital transformation projects with our clients over the past few years, and it's nice to see the experience we have gained in the DLT domain carry over to addressing the finance community's most pertinent challenges. We are delighted to win this award, following on from our runner-up position in the Swift Hackathon 2021 challenge on Building 'synthetic' data-sets required for AI-based product development, whilst protecting privacy.*

**Iosif Itkin,**  
CEO, Exactpro Group

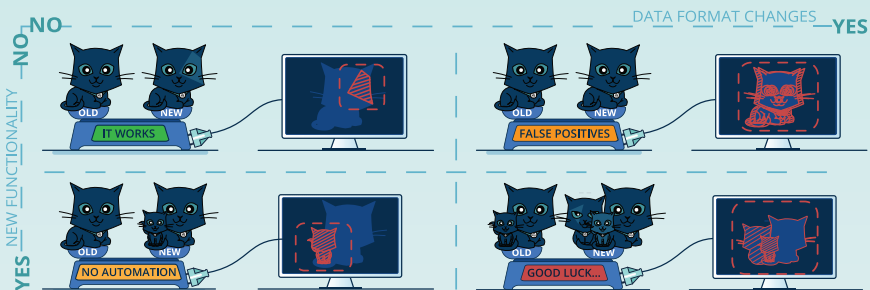
Read the [Swift Hackathon 2022 wrap-up article on swift.com](#) featuring an interview with **Abhay Navale**, BNY Mellon's Global Head of Digital Assets Technology, **Iosif Itkin**, CEO, Exactpro Group.

# TEST AUTOMATION FOR CCPS AND EXCHANGES – OPERATIONAL DAY REPLAY LIMITATIONS

## INTRODUCTION

As regulated entities vital for the financial markets ecosystem, CCPs and exchanges recognise the importance of quality and resilience of their platforms. Thorough software testing is fundamental in identifying problems that can affect system integrity. Software testing encompasses functional testing which ensures that the system works according to specifications and satisfies the compliance requirements, and non-functional testing spanning the assessment of performance, latency, capacity, reliability and operability. Test automation decreases time to market and boosts verification coverage.

A popular verification approach used across the industry – not without some merit – is a parallel run comparing the current production system and a new release, this is also known as ‘production data replay.’ However, overreliance on this method puts firms at a disadvantage when delivering significant changes into live service.

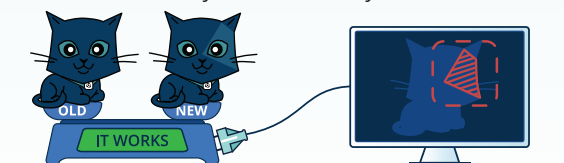


## NO/NO QUADRANT – INSIGNIFICANT DATA FORMAT AND FUNCTIONALITY CHANGES

In test automation based on replay, the same set of input data – that can be taken from production or saved for testing purposes – is replayed against the existing and the next versions of the system. Reportedly, the method allows one to identify and analyse the discrepancies between versions. The output data gets compared at the end of such a run.

The data is expected to either have no discrepancies or have so few that a QA analyst will be able to analyse them and determine whether these are expected or regression bugs.

This approach refers to a certain ‘old’ version of the system as the only test oracle.



Thus, if the system had previously contained outstanding issues, there will be no way to reveal them and expect a different (better) outcome from the comparison. In fact, the correct functioning of the system may be perceived as a bug.

This way, defects can persist in the system for years and not be detected. We can admit, however, that data replay can work well with very limited functional and data format changes.

### YES/NO QUADRANT - SIGNIFICANT DATA FORMAT CHANGES AND MINOR FUNCTIONALITY UPDATES

Let's say that the two versions of the system under test are two different images. Every output data element is a pixel in the picture. Using replay and parallel runs is similar to pixel-by-pixel comparison. At times, it works well: the pixels remain where they are and few discrepancies are detected. But what if, instead of changing, the picture has slightly shifted? Despite the absence of significant changes, we will detect major discrepancies between the two pictures.

In software testing based on data replay, a small change in the data format can cause breaks across the perimeter. The team will have to spend time on the manual introduction of adjustments and reviewing all false positives, while overlooking the actual problems. In our [Trading Day Logs Replay Limitations and Test Tools Applicability](#) research (accessible via the QR code in this section), we demonstrate that a non-deterministic outcome can occur even without differences in the input data, due to the distributed nature of the systems used in trading and clearing.



Read the full research paper on our website



### NO/YES QUADRANT - EXTENSIVE FUNCTIONALITY CHANGES AND MINOR DATA FORMAT UPDATES

When the system's business-as-usual behaviour serves as the only test oracle, it is impossible to apply test automation to new functionality. Since data replay only allows us to check the existing functionality, verification for the new functionality is mostly manual and the testing scope is very limited.

The data replay approach also fails when the new functionality is outside the testing scope. There is no way to detect it or test it.



Read the full white paper on our website



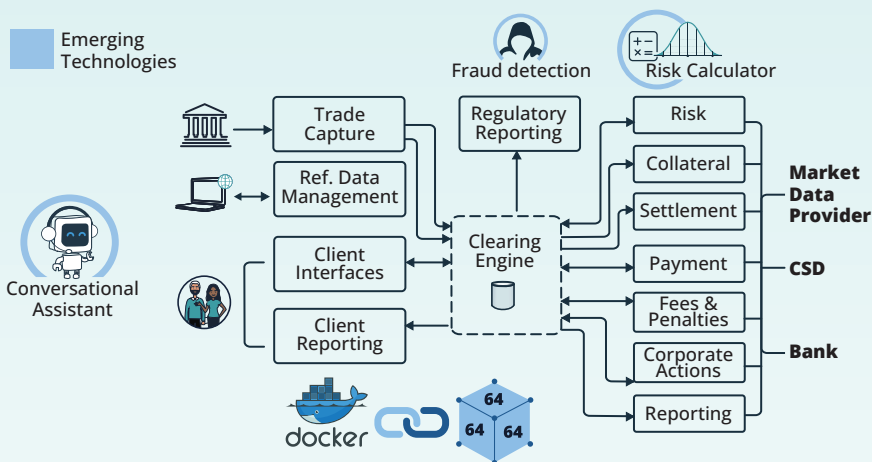
# TOWARDS REDUCING THE OPERATIONAL RISK OF EMERGING TECHNOLOGIES ADOPTION IN CENTRAL COUNTERPARTIES THROUGH END-TO-END TESTING

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This schema of a generalised architecture of a post-trade platform within a CCP enhanced with emerging technologies illustrates the participant structure complexity. A company may be represented by various entities, and these entities may trade in different markets and in different asset classes. Moreover, their margining can be carried out in a consolidated way or in segregated currencies. The links between non-clearing members and clearing members, their changing roles in different markets, the array of accounts – all of this adds challenges to the software testing process.



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## KEY TAKEAWAYS

- Emerging technologies that are widely adopted by financial institutions promise functional efficiency and cost reduction, but also pose a number of risks. Extreme complexity and non-deterministic nature of the existing technology platforms are commonly underestimated and need to be addressed, as they will be imminently inherited by the platforms built with the new technologies.
- Potential risks associated with traditional technology platforms in the financial services industry stem from the challenges posed by their multicomponent structure, large number of endpoints and system interdependencies, participant structure complexity, multitude of asset classes and associated life cycle events and their system schedules, variety of protocols and APIs, complex calculations, and distributed multithreaded architecture.
- The risks induced by the existing complexity of FMIs are amplified by some of the characteristics of the emerging technologies. Infusing traditional CCP technology stack with DLT leads to significant platform transformations and associated interoperability issues at the confluence of traditional technology components and those built with DLT. In its turn, AI transformation, in addition to obvious technical challenges of data collection and preprocessing as well as building a trustworthy model, requires additional attention to avoid biases and ensure regulatory compliance.
- To address these challenges, a robust software testing approach is needed. Stochastic processes related to multi-threaded distributed processing across multiple nodes and uncertainties related to machine-learning models require sophisticated testing methods to ensure resilience and trustworthiness of mission-critical software platforms.
- The proposed approach suggests incorporating both active and passive testing techniques reinforced with the statistical analysis of test execution data. High-volume automated testing of distributed clearing systems helps to expand the test coverage and create production-like conditions.
- Test automation framework described in the paper emulates the nodes in CCP infrastructures, generates API calls, and triggers transaction flows. The verification process of bi-directional message flows suggests that the framework stores all the messages sent or received to/from the non-blockchain parts of the hybrid system alongside the data extracted from the ledger to enable passive testing and property-testing over many random cases. The framework provides a platform for building an extensive regression testing library covering functional and non-functional aspects of clearing platforms of any complexity in order to reduce operation risk involved in their implementation and ongoing exploitation in the live service.

# MEMX-EXACTPRO COLLABORATION ON EXCHANGE QUALITY ASSURANCE

## INTRODUCTION

Members Exchange (MEMX) is a US exchange operator founded in 2019 by the largest U.S. online retail broker-dealers, global banks, financial services firms, and market makers to benefit all investors. MEMX was established to bring new competition into the market to drive three effects: lower fees, provide its members a voice in market dialogue and decisions, and foster innovation.

## MEMX Platform Requirements

From the start, MEMX committed to building an exchange that allowed for continuous enhancement and improvement. MEMX's goal is to use innovation to break free from the past, while maintaining system quality, reliability and customer trust to operate a thriving exchange. Below is a review of MEMX exchange functionalities available today.

MEMX provides its members with a set of connectivity options based on common methods and semantics to type, define, encode and decode message data using the FIX Protocol Standard and Simple Binary Encoding (SBE). The table below outlines the interfaces exposed to the members:

**MEMX-TCP.** A Session Level TCP-based transport protocol for reliable delivery of business messages.

**MEMX-UDP.** A Session Level UDP-based transport protocol for best-effort delivery of business messages.

**MEMO SBE.** The native binary protocol used for order submission.

**MEMO FIX.** The Classic FIX (ASCII Tag/Value) protocol used for the exchange of information related to securities transactions.

**MEMOIR Depth.** A real-time full depth-of-book feed offered directly from MEMX.

**MEMOIR Top.** A real-time top-of-book feed offered directly from MEMX that provides the best bid and best offer on the exchange.

**MEMOIR Last Sale.** A real-time trade feed offered directly from MEMX that provides reporting, cancelation and correction of exchange executions.

**Drop Copy.** A Drop Copy in Classic FIX protocol providing information related to trades executed on MEMX with the option to include order related information.

MEMX supports Pre-Market, Market and Post-Market trading sessions. Both the SBE and FIX MEMO order entry protocols contain an integrated pre-trade risk management service, which includes a mandatory set of configurable controls.

They are designed to protect investors and ensure market integrity by preventing erroneous orders from passing through to the matching engine for execution. Additionally, MEMX offers a configurable batch cancel function allowing participants to cancel all or a subset of orders in one or more symbols with a single command to the exchange over any active session, irrespective of the session(s) over which the original order(s) was submitted. MEMX also supports cancel on disconnect.

Based on industry feedback to reduce complexity and promote fair, transparent, and efficient client interactions, MEMX accepts three order types:

- Market (for time-sensitive traders),
- Limit (for price-sensitive traders), and
- Pegged (including Midpoint Peg and Primary Peg orders that will automatically adjust with changes in the National Best Bid and Offer for traders sensitive to periods of market volatility).

MEMX supports a set of modifiers, including:

- Intermarket Sweep Orders,
- Reserve Quantity (with multiple replenishment options including randomized size and time),
- Re-Pricing to comply with Reg NMS, Reg SHO, and Limit-Up/Limit-Down,
- Non-Displayed,
- Minimum Quantity,
- Post Only,
- Book Only.



MEMX routes orders to away markets displaying protected quotations to comply with Reg NMS. A combination of exchange proprietary data feeds and CQS/UQDF data feeds from the Securities Information Processors (SIPs) are used for the handling, execution, and routing of orders. MEMX required a test solution to properly cover all these areas to ensure proper behavior and function.

### The Implemented Solution

To achieve the objective and facilitate the delivery of the exchange, MEMX's testing team was enhanced with the assistance of the established professional testing services provider – Exactpro – known for its long-term partnerships with some of the leading global exchange groups and a thorough test approach leveraging a bespoke automation test tool suite.

### Processes: the MEMX-Exactpro Operating Model

Being a customer-centric market operator, MEMX engaged Exactpro at the early stages of the program for review of the client-facing specifications in order to deliver clear and transparent documentation to the participants.

Exactpro worked in close collaboration with the MEMX team starting from the initial analysis of the test scenarios and specifications, through the test design, to the model-based and the discovery-based implementation, test planning and monitoring.

MEMX uses a modified waterfall development methodology and rapid prototyping, which resulted in frequent builds. Exactpro not only designed a detailed functional automated library covering all the required functionalities, but also worked continuously to enhance the quality and speed of the regression testing through the CI/CD process. The test coverage was analyzed by both MEMX and Exactpro teams based on problems and objectives to ensure the thoroughness of the executable test model.

### Platforms: th2 Test Automation Framework for MEMX

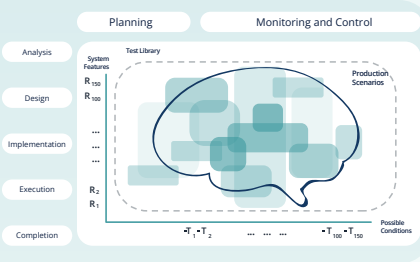
In collaboration with MEMX, Exactpro introduced its new next-generation test automation framework – th2 – into the testing process not only for active testing, but also for passive data consistency checks and reconciliation. In addition, th2 – integrated into the CI/CD testing pipeline – provided a set of stubs and drivers including the away markets simulator, which enabled deep testing of the related features.

The test platform uses a microservices-based architecture. It is cloud-native, and uses Kubernetes orchestration to schedule test containers across a cluster, scale those containers, and manage their health over time.

The th2 platform consists of 3 types of blocks:

- Core and Infrastructure Components
- Basic Building Blocks
- Custom Logic Components

The Core and Infrastructure components for th2 are available as open source software under the Apache 2.0 license. They are responsible for test component deployment, inter-service communication over Rabbit-MQ, as well as the processing and storage of messages and events in noSQL – a distributed compliance Cradle database based on Apache Cassandra.



*We have been delighted to partner with MEMX on such an ambitious and innovative project, a natural fit for Exactpro's services and our continued expansion into North America.*

**Thomas Toller,**  
Managing Director, Exactpro USA

## Basic building blocks used by MEMX are of several types:

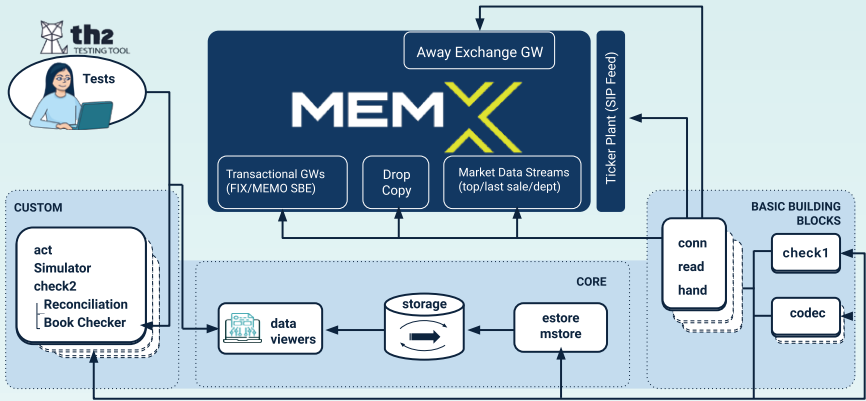
1. **conn** components represent connections to the respective MEMX endpoints and are responsible for active communication with the system under test (SUT) in accordance with the available specifications.

2. **read** components acquire data as passive subscribers. They are needed to apply data consistency and reconciliation checks across different data streams, irrespective of the inbound traffic. Examples of such checks

include MEMO FIX/SBE transactions vs. MEMOIR last sale/drop copy, MEMOIR top vs MEMOIR depth/last sale.

3. **codec** blocks process transactional data from conn and read components. They are responsible for encoding and decoding the messages. Multiple blocks allow support for different protocols and their versions.

4. **check1** contains simple verifications.



## Custom logic components were configured to reflect the specifics of the MEMX platform:

1. **act** is responsible for the active test scenario logic.

2. **check2** contains advanced verifications such as:

- a) **Reconciliation** which is used to widen the test cover age of the executed transactional tests by reconciling the data streams coming into and going out of the SUT.
- b) **Book checker** which builds order books based on market data output and checks the.

3. **simulator** was designed for the emulation of the away exchange for MEMX and was configured based on the specific business logic. The aim of the sim component is to support the designed test library of routed orders.

The platform enables the implementation, execution and analysis of a wide variety of test concepts.

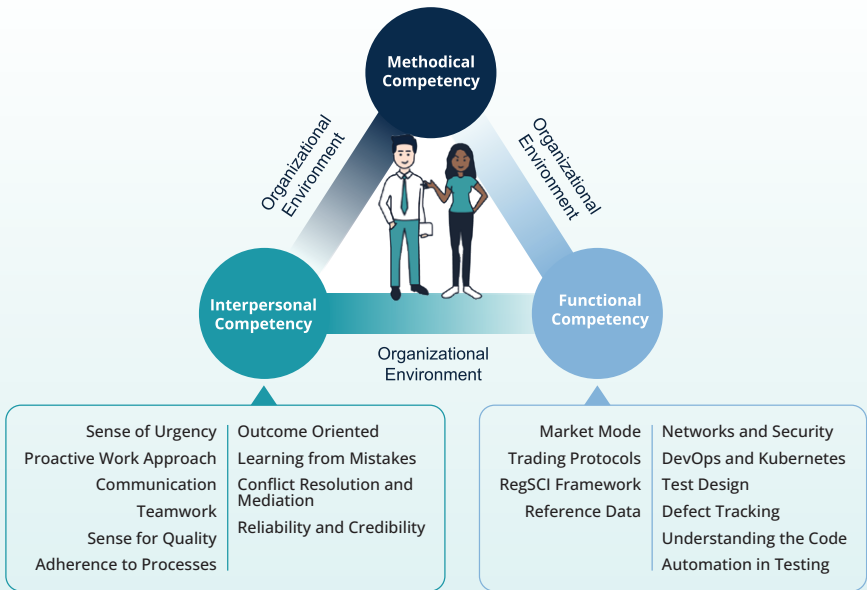
*Working with MEMX, the fastest-growing US equities exchange, has proved to be an invaluable experience as we continue to deploy our next-generation test automation framework, th2. With this new offering, Exactpro was able to support MEMX's rapid deployment schedule whilst simultaneously providing the highest levels of system quality assurance.*

**People: Human Competencies for Delivering Mission Critical Systems**

Exactpro builds software to test software to be able to verify complex systems that underpin global financial markets. To ensure the required level of services is being met, the company follows the Zero Outage Industry Standard in its human capital development strategy. The standard is a collection of best practices enabling IT professionals to plan, build, deliver and run end-to-end IT solutions suited for the most critical business functions and processes. Exactpro shares the Standard's holistic view on going beyond technology and emphasizing that not only are platforms, processes, and security essential to IT services, but that people are the backbone of every organization and every project (please refer to the picture).

**CONCLUSION**

The extensive functional testing and test automation delivered by the Exactpro team contributed to the successful launch of the MEMX U.S. equity market in September 2020, followed by trading of all NMS symbols in October 2020. Today, MEMX continues to be the fastest growing U.S. equities exchange. Its success is a testament to the participants' desire for an exchange focused on fostering innovation and competition, as well as on the quality and efficiency of its platform.

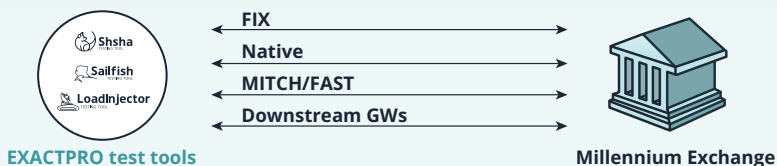


*MEMX's close collaboration with Exactpro provided additional operational resilience and contributed to the exchange's seamless launch, rollout and, ultimately, live trading in all NMS symbols. We greatly appreciate Exactpro's partnership in working to ensure the exchange's technology was ready to perform at full capacity from day one.*

**Dominick Paniscotti,**  
MEMX Chief Technology Officer

# EXACTPRO – JSE COLLABORATION TO TEST THE MILLENNIUM EXCHANGE™ PLATFORM

This case study highlights the Exactpro deliverables in testing the Millennium Exchange™ trading platform for the Johannesburg Stock Exchange (JSE). The testing activities were part of JSE's Integrated Trading and Clearing (ITaC) multi-year programme focused on the implementation of world-class, multi-product solutions to enhance the exchange's trading and clearing functions. To emulate JSE's client activity and the system responses, Exactpro used its bespoke test tools:



Exactpro successfully automated and tested the following functionalities of the trading system:

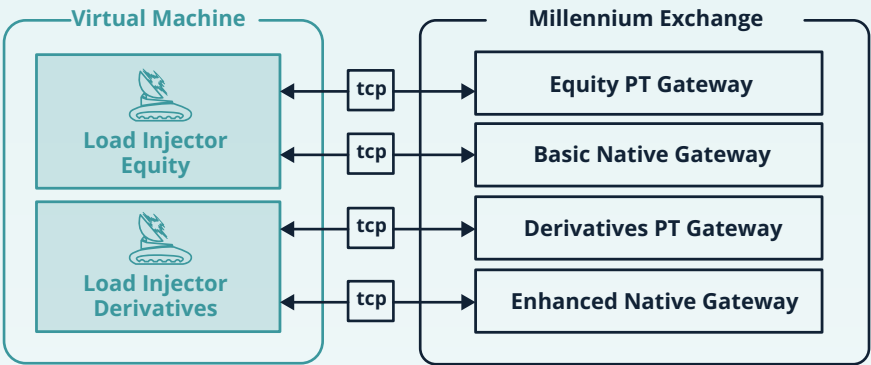
- Equity and Derivative Order/Quote Management
- Order Matching and Price Monitoring
- Order Book Reconstruction and Trade Publication
- Request for Quotes (RFQ) Management
- Trade Reporting
- Daily Life Cycle
- Client Connectivity and Authentication
- Reference Data Management

Within the JSE ITaC programme, Exactpro also successfully delivered a high frequency Order Generation Tool. The JSE business analysts needed the ability to generate a versatile and flexible load of messages and had specific requirements for trades/order ratio, order/quote types, instruments, markets and rates.

To meet these requirements, the Load Injector tool was enhanced with the following features:

- Support of message templates and functions in templates to generate all required types of messages with specific values
- Support of different rates for different markets (Equities and Derivatives)
- Support of multiple order types for different types of instruments
- Support of multiple order/trade ratio across different segments
- The option to shuffle the generated messages and send them into the system according to a predefined load profile

The Order Generation Tool allowed us to create a complex load for the trading system and execute a comprehensive set of non-functional tests.



The test automation tools (Sailfish, Shsha, Load Injector – for test automation of trading, and ClearTH – for test automation of clearing) delivered to the JSE by Exactpro as part of our collaboration in the trading test automation area were successfully used by the JSE team and helped with the successful implementation of the multi-year ITaC programme into production on 29 April 2019. The introduction of new, internationally recognised systems means the JSE will strengthen its position as a global market player providing more stable and efficient trading and clearing services to its clients.

"I have been receiving very positive feedback from my JSE teams about their work with Exactpro. The automated testing solutions allow us to perform in-depth testing to ensure software quality before deploying into live service," says Hendrik Kotze, Chief Information Officer, JSE.

"We will continue our collaboration with Exactpro who help us with quality deliverables to ensure that the JSE continues offering reliable, secure and efficient capital markets across a diverse range of instruments, supported by cost-effective services."

Exactpro's clients innovate. With testing services provided by us, they can adopt innovative technology with confidence and improve the resiliency, performance and quality of their systems and platforms. Our company achieves this through deep testing performed by our teams using our innovative tools developed in accordance with our test automation principles. We are empowered by experience gained over the years and embrace a culture of relentless learning and dedication to our clients.

*I have been receiving very positive feedback from my JSE teams about their work with Exactpro. The automated testing solutions allow us to perform in-depth testing to ensure software quality before deploying into live service.*

**Hendrik Kotze,**  
Chief Information Officer, JSE

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