QUALITY ENGINEERING IN THE NEW
A vision and R&D update from Accenture Labs and Accenture Testing Services
In recent years, traditional approaches to application testing have been significantly disrupted with the advent of DevOps and intelligent automation, as well as proliferation of digital applications. As delivery timelines have shrunk from months to weeks and now days, testing has shifted both left and right in the software development lifecycle. DevOps and agile have merged development and testing into a single continuous activity. Testing has evolved to quality engineering that begins upfront as part of initial application planning and establishes a continuous feedback loop to anticipate and act on the unknown.

But to truly understand the scale of evolution from testing to quality engineering, we need to recognize how data has changed software development itself. The power of data goes well beyond fueling automation use cases and AI learning datasets for repetitive development and testing tasks. The massive amounts of data users generate every day is now elevating quality engineers to predict risk, identify opportunities, increase speed and agility and minimize technical debt. With this vast influx of data, the quality engineer’s role has become far more exciting but also complex. It will further evolve as we move towards AI, edge computing and the massive IoT end datasets which require machine-to-machine (M2M) communications with complete autonomy and failsafe protection.

Accenture has long been at the forefront of testing innovation, and now we are leading our clients into the world of quality engineering at scale. Our R&D group, Accenture Labs, works closely with Accenture Testing Services to redefine the possible, incubate and prototype new concepts, and find unique technology solutions to improve the way businesses operate. Together, we bring innovation at scale to our clients. Accenture has 250+ patents and patent pending applications across the quality engineering lifecycle.

In this paper, we present some of our Labs’ unique patents and innovations in quality engineering and offer our vision for the future in an increasingly complex technological environment.
Building on the period of intense disruption that application testing has been through in the last decade, in which delivery timelines have shrunk from months to just days, in which DevOps and agile approaches have merged, and in which the rise of shift left has deeply embedded testing in application planning from the outset, a series of new shifts are now set to radically change Quality Engineering (QE) all over again.

The first is a shift in quality. Sky-high customer expectations demand a new level of disruption in application development. In fact, we need to unlearn most of what we think we know about QE. Today, quality as a function cannot simply be limited to ensuring that the software works but also ensuring that the application provides differentiated user experiences in highly competitive, always-on digital markets.

The second is a shift in technology. As new technologies evolve at ever faster rates, the complexity of applications accelerates exponentially—so much so that it can become hard to fathom. To adapt, QE as a function must ensure continuous application monitoring as cutting-edge industrial technologies are introduced across scalable architectures, with increasingly complex layers of technology abstraction. As new technology paradigms emerge—such as testing for blockchain—QE must acquire the agility to adapt to frequent and sudden shifts in core technologies now also involving edge computing, Industry X.0 technologies (intelligent automation combining AI, the IoT and digital technologies), machine-to-machine communication, and vast IoT datasets.

Figure 1 details the various business and technical challenges faced by the QE function today.

**FIGURE 1. The challenges in QE today**

<table>
<thead>
<tr>
<th>BUSINESS CHALLENGES</th>
<th>TECHNICAL CHALLENGES</th>
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<tbody>
<tr>
<td>Miscommunication between client, account teams, and developers</td>
<td>Unclear and frequently changing requirements</td>
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<tr>
<td>Always-on businesses, deployed across multitude of devices, platforms and technologies</td>
<td>Developing and deploying applications at speed for omnichannel environments, even at the edge</td>
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<tr>
<td>Shorter time to market, frequent updates, and engaging user experience</td>
<td>Keeping developer experience relevant across the test environments</td>
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<tr>
<td>New business metrics—from Performance-based to Purpose-based</td>
<td>Identifying performance issues and generating focused test data for purpose</td>
</tr>
<tr>
<td>Focus on customer’s business, industry and market</td>
<td>Aligning technical priorities with business purpose</td>
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</tbody>
</table>
Traditional static script and tool-based approaches are unsuited to this new multi-device, multi-platform, scalable application engineering landscape. Instead, businesses must ensure they are maximizing the use of intelligent technologies, and machine learning in particular, to anticipate performance issues and future disruptions. They must evolve their use of continuous monitoring and integration to develop a self-managing, self-learning, and self-adapting testing function. They must use continuous load testing simulations in conjunction with predictive datasets to enable real-time decision-making.

That fundamentally changes the role of the SDET (Software Development Engineer in Test). They must evolve to align ever more closely with the business purpose, reskilling as test design experts with cross functional expertise who understand the critical role of customers within the development process. That talent won’t come cheap. Typically, businesses will have to pay a premium to hire scarce cross-domain expertise to cover the multiplicity of platforms, devices, technologies, data, and customers that are inherent to modern application development.

The third shift underway today is a shift in talent. Application users are no longer the pure consumers of old—they’ve become co-developers and co-innovators in a complex, ever-changing development process, producing vast amounts of data to power machine learning and automation opportunities. Moreover, with the advent of edge computing and the IoT, yet more massive datasets will emerge, requiring M2M communications with complete autonomy and failsafe protection.

The final shift is a shift in organizations themselves. As SDET roles evolve, and as QE changes irrevocably, so must the enterprise. Organizations must acquire new levels of agility, flexibility, and responsiveness to manage a distributed, mobile workforce operating across a borderless enterprise, while remaining aligned to a clear business purpose.

To adapt to these shifts, QE must evolve. In short, it’s time to take QE into the New.

TAKING QE INTO THE NEW

To ensure business continuity and business value as these shifts in quality, technology, people, and organizations take hold, QE will evolve into a pervasive, real-time, and insight-driven function, augmented by AI-led autonomous frameworks. Across five dimensions—data, frameworks, process, technology, and the organization—testing will shift away from the traditional approaches towards new ideas and new methodologies fit for the application engineering world of tomorrow:

**Data**
Exponential growth in data volumes and variety, sourced from a huge number of new enterprise channels and devices, will drive a shift from “test data” to “test insights” through applied analytics.

**Frameworks**
QE will increasingly move beyond function/script-driven approaches towards autonomous frameworks that bring developers, customers, and end-users together to align application quality with business needs.
Process
The focus will shift from issues-based resolution to real-time monitoring and integration, using intelligent identity management to enable the integration of any technology stack and creating a new paradigm: “quality everywhere and for everything”.

Technology
Enterprises will create a pervasive AI layer across the organization to first augment testing professionals and then enable truly self-managing QE functions, embedding trust throughout the system to prevent unintended bias.

Organization
SDET roles will evolve, and testing will move outside the four walls of the Center of Excellence, as interconnected virtual teams comprising a range of industry, business, and technology expertise, aligned around common business purposes, create radically different kinds of “borderless enterprises”.

FIGURE 2. QE in the New
Applied analytics will be key to QE in the New. As enterprise applications and channels grow in number and complexity, and as new sources of test data emerge from a multitude of connected devices, platforms and technologies, both the volume and veracity of test data will increase dramatically. Moreover, with the need to integrate log and event data from so many devices, platforms and technologies, and with the coming shift from binary to quantum algorithms, the exponential growth in the number of test data points—and the complexity in processing them—is set to explode. The simple truth: today’s systems won’t be able to keep pace.

To adapt, QE will shift focus from the quantity of data to the quality of data—and the insights that can be derived from it. In place of trying to simply scan all available data, for instance, the focus will now shift to the most insightful data that can offer key insights into performance. Data-driven frameworks and quality platforms will store every test point and insight, enabling the real-time prediction of application defects. And AI-driven “test data as a service” will provide analytics as a function to testing systems, creating a playground for developing new products and services for the enterprise.

**RELEVANT PATENTS**

Accenture’s patented and patent-pending innovations help drive QE value in a data-driven future

**SYNTHETIC DATA VAULT (SDV)**

*Joint collaboration with MIT*

SDV is a first-of-its-kind generative modeling system for relational databases that synthesizes realistic test data from samples. A set of underlying algorithms compute statistics of the sample test data points using a state-of-the-art multivariate approach to model the entire database. (Inventors: Kalyan Veeramachaneni, Neha Patki, Kishore P. Durg, Sunder R. Nochilur, Jeffrey S. Wilkinson)

**LATENT DEFECT IDENTIFICATION**

This method of determining test data for use in testing software involves identifying software that is known to have one or more bugs and which has a similar structure to software under test previously, using knowledge of those one or more bugs to create test data for the software under test. (Inventors: Basil Eljuse)

**MINING APPLICATION REPOSITORIES**

This system improves software quality using static analysis to extract information about patterns, dependencies, and constructs from application source code. After compiling the extracted information, the system determines statistics about language constructs in many different applications and uses those statistics to improve software quality. (Inventors: Qing Xie, Mark Grechanik, Chen Fu)

**CONSTRAINT EXTRACTION FROM NATURAL LANGUAGE TEXT FOR TEST DATA GENERATION**

This innovation takes the natural language text contained in requirements documentation and identifies the constraints for each input field (such as a password). It then generates test case data for each possible combination of constraints, reducing the manual effort in the software design phase. (Inventors: Janardan Misra, Milind Savagaonkar, Neville Dubash, Sanjay Podder, Sachin Hanumantappa Waddar)
FRAMEWORKS: Beyond DevOps

In the New, QE will look beyond DevOps towards the autonomous frameworks that enable a true focus on business needs. Most enterprises have already adopted the agile DevOps frameworks that use shift left testing, specialized automation testing tools, and continuous integration to break the application development process into smaller incremental builds, testing early and often.

As DevOps continues to evolve, testing for security (DevSecOps) will become ever-more embedded in application engineering. This will bring a high level of automation and monitoring to the QE function to ensure that the application returns from failure. With a growing emphasis on metrics like user behavior and business value, frameworks will evolve again to bring AI-enabled automation to bear on end-to-end business test cases (BizDevOps).

RELEVANT PATENTS
Accenture’s patented and patent pending innovations bring autonomy to the test environment

EVALUATING AND ENFORCING SOFTWARE DESIGN QUALITY
This system computes a quality index for the design of a software application by analyzing the application against a set of software design rules to detect quality violations. The system computes the design quality index as a combination of performance, security, and rigidity metrics. (Inventors: Vikrant Kaulgud, Santonu Sarkar)

TESTING FRAMEWORK FOR POLICY-BASED WORKFLOWS
This framework for the comprehensive testing of workflow applications (including policy-based workflows implemented in XML) represents a workflow in a control flow graph and identifies the required entry conditions or characteristics in order to traverse each possible execution path. (Inventors: Kunal Taneja, Teresa Sheausan Tung, Mijung Kim)

TEST DATA SUPPLY CHAIN MANAGER FOR AN INTEGRATED TEST PLATFORM
This next-generation testing system is used by an organization or software development house to test and verify the function and operation of a large software package or application (or set of applications), such as an accounting system, an invoicing system, an operating system version release, or any other software system. The platform analyses the various test scripts and assigns a priority value to each one depending on many weighted factors. (Inventors: Julian Brown, Peter John Smith, Stephen Williams, Jason Steele)
Ultimately, application development frameworks will become highly autonomous, identifying failure points proactively and pervasively across the entire complex application environment, bringing developers, customers, and end users together to ensure applications always adhere to actual business needs.

**FIGURE 3.** Rise of autonomous frameworks, beyond DevOps

<table>
<thead>
<tr>
<th>AGILE</th>
<th>DEVOPS</th>
<th>DEVSECOPS</th>
<th>BIZDEVOPS</th>
</tr>
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<tbody>
<tr>
<td>Breaking the product into small incremental builds &amp; testing individually</td>
<td>Shift left testing with automation tools and continuous integration</td>
<td>Embedding security in software design to recover application from failure</td>
<td>AI enabled automation with key focus on business requirements</td>
</tr>
</tbody>
</table>

**BEYOND BIZDEVOPS**

RISE OF AUTONOMOUS FRAMEWORKS

Identifying failure points proactively and pervasively

2020 Maturity Horizon

Beyond 2020

Enforcing design quality, identifying design workflows and decisions support systems will enable quality engineering to focus on business conditions beyond the 2020 horizon
PROCESS: Real-time AI-driven monitoring and integration

With access to test data at high speed, accelerated by the adoption of new technologies, QE in the New will enable the AI-based real-time continuous integration and monitoring of applications. New forms of enterprise interaction will amplify testing-as-a-service with virtual and augmented reality collaboration to transform testing professionals into design engineers. Sensor technologies will enable virtualizations, digital twins, and deeper test simulations. Intelligent identity management using technologies like blockchain will embed smart contracts to provide distributed test teams with individual test identifiers, as well as supporting real-time root-cause analysis and seamless handovers for distributed applications.

As edge computing takes ever greater hold across the enterprise, extensive new datasets will create a new “quality everywhere and for anything” paradigm—one in which true end-to-end data monitoring and logging and decentralized API-based test integration supports plug-and-play application testing for a potentially limitless number of device types and algorithms. What’s more, as quantum computing creates unprecedented levels of processing power, QE will have access to accelerated machine learning capabilities and new platforms for optimizing test planning and execution. Indeed, quantum computing will act as an enabler of the quality platforms of the future by providing the speed and accuracy required for next-generation QE algorithms.
**TECHNOLOGY: Self Managing**

AI will enable ‘QE in the New’ to evolve towards a self-managing function. In the near term, that means using machine learning to augment the test professional’s ability to identify bugs/system defects, to enable automated environment provisioning, to clean and sanitize test data, and to generate requirements analysis data.

**RELEVANT PATENTS**

**Accenture’s patented and patent-pending innovations bring AI to self-managing quality systems**

**AUTOMATED TESTING OF INTERACTIVE VOICE RESPONSE SYSTEMS**
The implementation of this system assists in the automated testing of IVR systems, including validating IVR responses and end-to-end call flows. Before an IVR system is implemented or updated, a tester can test it to ensure, for example, that it correctly interprets user input (e.g., tester input) and provides correct IVR responses. (Inventors: VijayChandar Natesan, Rajesh Sarangapani, Surajit Chatterjee)

**USING SIMILARITY ANALYSIS AND MACHINE LEARNING TECHNIQUES FOR TEST CASE INFORMATION**
Testing large enterprise applications is inherently difficult owing to the complexities involved with respect to design of applications and the variety of interrelated functionalities and ambiguities in test requirement specifications. Due to these complexities over time as test suites start to grow, underlying information landscape starts to fragment and unintended redundancies start getting added onto the test suites. Redundancies in test suites result into increased costs in maintenance of test suites and execution of similar tests brings reduced value to testing outputs. This invention fills this gap and business need to have similarities known among test cases so that test suites can be compacted with reduction in overall cost and test design coverage can be improved. (Inventors: Janardan Misra, Divya Rawat, Neville Dubash, and Sanjay Podder)

**TOUCHLESS TESTING PLATFORM**
Touchless Testing is a platform that enables QE by providing automation, optimization, pattern mining, and visualization capabilities. The platform allows testing teams to easily integrate tools from leading players such as Conformiq, Hewlett Packard Enterprise, Intel Saffron, Sauce Labs, Tableau, Tricentis, and Worksoft, along with key Accenture innovations, to bring new enterprise software solutions to market faster and with higher quality. (Inventors: Mahesh Venkata Raman, Mallika Fernandes, Girish Kulkarni, Ranjan Jena Chinnaya, Jothi Gouthaman, Venugopal S Shenoy, Srinatha Mulugund Sreedhara, Sivasankar Ramalingam, Kishore P Durg, and Matthias Rasking)
Further ahead, it means using AI’s evolving capabilities with unstructured/complex data to create self-monitoring systems capable of performing script-less real-time error checking and failsafe analyses, as well as identifying failure cases and generating test simulations. Eventually, intelligent technologies will support DevOps test planning (including time and effort estimations), continuous monitoring and defect prediction, and natural language interactions. One day, AI systems will understand user requirements using natural language processing and write machine code for the intended purpose without human intervention.

A key part of developing an AI-supported testing environment: testing the AI itself to ensure it is delivering the desired outcomes, behaving responsibly, and avoiding unintended bias. User adoption of AI quality systems depends on trust and transparency in AI decision-making. So, in testing the quality of an AI’s decisions, delivering correct results is not enough—delivering them responsibly is also key. This creates both functional and non-functional testing requirements.

The AI will need to be analyzed to ensure its decisions are consistent, fast, and accurate, while adhering to the functional requirements of the enterprise. While performance is paramount, AI will need to be reliable, responsible, and scalable to infrastructure or dataset, while accounting for ethical considerations. And it will need to handle the increased personalization of future interactions, products, and services.

However, the AI will also need to be tested for a much broader set of requirements. It will need to comply with the regulatory and legal environment, while avoiding gender, ethnic, and other biases and ethical risks. It will need to align with the business strategy and brand reputation, offering a transparent test process to verify its decisions. And it will need to learn from its environment to respond to changing social constructs, demonstrating an ability to distinguish “right” from “wrong”.

**FIGURE 4: Evolution of QE as a self-managing function**

- **AI AUGMENTED TEST PROFESSIONAL**
  - Short Term
  - Test cases and processes automated by an AI system to assist QE professionals.

- **AI SCRIPT-LESS TESTING**
  - Medium Term
  - Self-monitor algorithms for real-time error checking and failsafe analysis.

- **AI BASED DEVOPS**
  - Long Term
  - AI working across the SDLC to synthesize vast amounts of test data for predicting and preventing failures.

- **AI CODE GENERATION**
  - Exploratory
  - Using NLP for understanding user problem and writing machine code for intended purpose.
FUNCTIONAL REQUIREMENTS
Consistency, Speed, Accuracy, Reliability, Scalability, Personalized and Reduced Mean Time to Recover (MTTR)

NON FUNCTIONAL REQUIREMENTS
Ethical, Compliant, Unbiased, Safe, Transparent, and Adaptable to changing social and human constructs

KEY REQUIREMENTS FOR TESTING AI SYSTEMS

TEST MODELS

TEST DATA

AI TESTING PLAYGROUND TO ENSURE

RELEVANT PATENTS
Accenture’s patents and patent-pending innovations create transparency in machine decision-making

VERIFYING MACHINE LEARNING THROUGH METAMORPHIC TESTING
A typical machine learning (ML) application has an extremely large number of scenarios to test, which can make testing ML applications extremely expensive. This patent presents a new approach to testing ML-based applications through the concept of Metamorphic Testing. Our methodology, based on the underlying mathematical principles of ML algorithms, needs only a few test cases (or even just one) to identify bugs in ML applications, thereby reducing the cost of testing significantly. (Inventors: Anurag Dwarakanath, Manish Ahuja, Samarth Sikand, Raghotham M Rao, R.P. Jagadeesh Chandra Bose, Neville Dubash, Sanjay Podder, Kishore Durg)

TESTING AI SYSTEMS: PROVIDING TRANSPARENCY WITH HOLISTIC AI
Integrating Knowledge Representation and Reasoning (KRR) with machine learning, “Holistic AI” provides transparency into the logic behind algorithmic decision-making, helping the enterprise reduce business risk and ensure regulatory compliance. It not only facilitates the work of testers, it also helps gain the trust of other stakeholders. (Inventors: Teresa Escrig, PhD, Kishore P. Durg, Mallika Fernades)

RANDOM UTILITY GENERATOR TECHNOLOGY
This software system generates random benchmark programs for evaluating program analysis and testing tools. It uses random graphs and stochastic parse trees to generate random programs. Language grammar production rules are assigned probability distribution functions to specify the frequencies with which instantiations of these rules will appear in the generated programs. In this regard, a user can tailor the types of programs they would like to use for testing and generate random benchmark programs that do not suffer from human programming bias. (Inventor: Mark Grechanik)
As QE drives into the New, the business will be evolving alongside, breaking down barriers and creating a new kind of borderless enterprise. Conducting business at the pace required in the economies of tomorrow means involving all the stakeholders across the enterprise and enabling “zero delay” decisions. For QE, that means creating interconnected multidisciplinary design teams, including a mix design of engineers, business clients, and end customers, that can focus on truly meeting enterprise needs.

RELEVANT PATENTS
Accenture’s patented and patent-pending innovations accelerate the borderless enterprise

SOFTWARE TESTING CAPABILITY ASSESSMENT FRAMEWORK
This testing and assessment tool is directed toward particular testing areas based on the Testing Maturity Model hierarchy. The tool allows both for individualized and directed testing of particular individuals in particular testing areas as well as a full comprehensive assessment of a large group. (Inventors: Henk Fliek, Scott Wayne Christensen)

EXCHANGEABLE APPLICATION COMPONENTS
This application testing system limits downtime during the testing of complex applications. It facilitates the switching in and out of any desired version of any of the multiple application components that implement the application functionality. As a result, application test personnel can work quickly to find, debug, and test the complete application functionality, without causing significant periods of application unavailability. (Inventors: Marco Montesissa, Luca Salvaneschi, Jonny Lavorato)

PLATFORM FOR SUPPORTING MULTIPLE VIRTUAL AGENTS
A user device may include applications (“virtual agents”) that provide assistance to the user of the device in performing particular actions, such as sending messages, placing calls, providing recommendations, accessing content, etc. A virtual agent may perform these actions by interacting with other applications, searching local information (i.e. that stored by the user device) and/or by delegating a request to another device (e.g. a web server). (Inventors: Roshni R. Ramnani, H Wabgaonkar, Shubhashis Sengupta, Sanjay Podder, Neville Dubash, Tirupal Rao Ravilla, S Ganapat Patil, Rakesh Thimmaiah, Reeja Jose, Chaitra Hareesh, Priyavanshi Pathania)
In this environment, both robo-workers and broad-skilled human resources will move seamlessly across the business, ensuring continuous integration/monitoring, QE metrics, and quality lifecycle management. Virtual employees, bots, Machine to Machine edge agents, and “intelligence as a service” will combine with employees, crowd-sourced resources, industry and technology expertise, and client/consumer “citizen testers” to align the entire QE process around the future success of the business.

**FIGURE 6.** Borderless enterprise aligned around a common purpose

![Diagram of Borderless Organization and Seamless People Mobility](image-url)
FROM APPLICATION-FOCUSED TO PURPOSE-DRIVEN

Today’s fast-paced evolution of enterprise application testing environments shows no sign of abating. As it continues to evolve, QE will be defined less by its focus on the applications themselves, and ever more by its alignment with business purpose. That means using real-time testing, monitoring, and fixes to ensure the business “works” as well as the code. And it means developing self-learning, self-adapting systems supported by machine learning and advanced analytics.

This is a future that Accenture is actively preparing for. With over 250 patents and pending patent applications globally across the entire QE lifecycle, we are driving QE into the New with innovations in holistic QE strategy, embedded cognitive and machine learning capabilities, and end-to-end automation. These are transforming everything from test planning and test case development to test execution and environment setup, and helping QE reimagine its role in the future enterprise.
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