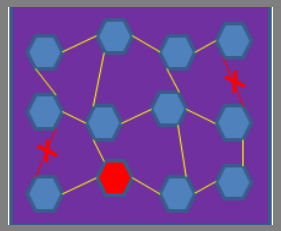
Virtual Software Systems

Extended Resilience Architecture (xRA)



Use Cases

xRA Use Cases: Table of Contents

xRA Use Case Descriptions

- **Process Control Systems Protection**
  xRA process control applications detect and isolate control system failures and enable continued control operations in spite of a failure.
- **Autonomous, Fault Tolerant Control Systems**
  xRA applications distribute control functions to multiple control elements (“replicas”) that operate independently yet appear as one logical unit. These xRA replicas may be spatially distributed ensuring that operating control is maintained in spite of any failure or disruption of a single replica, without loss of transactions or operating ‘state’.
- **Simultaneous Multi-platform Software Testing**
  xRA-enabled testing simultaneously tests a software release on multiple heterogeneous platforms. It also can test two software versions on the same platform. In both cases xRA confirms that all copies of the software execute identically.
- **Hardware Testing**
  xRA-enabled testing of electronic circuit boards, under both hardware-only as well as executing software conditions enables quality control personnel to test for and expose problems that might otherwise not be detected until field deployment.
- **Gray Failure Analytics**
  xRA’s replication, comparison, and fault detection properties could create new methods of solving the pervasive problem of differential observability, an underlying reason gray failures are so hard to detect.

xRA: Process Control Protection

APPLICATION: xRA protects IoT Process Control Systems by detecting and isolating failures while providing continued operations

Improved protection of industrial IoT/ SCADA applications for control systems

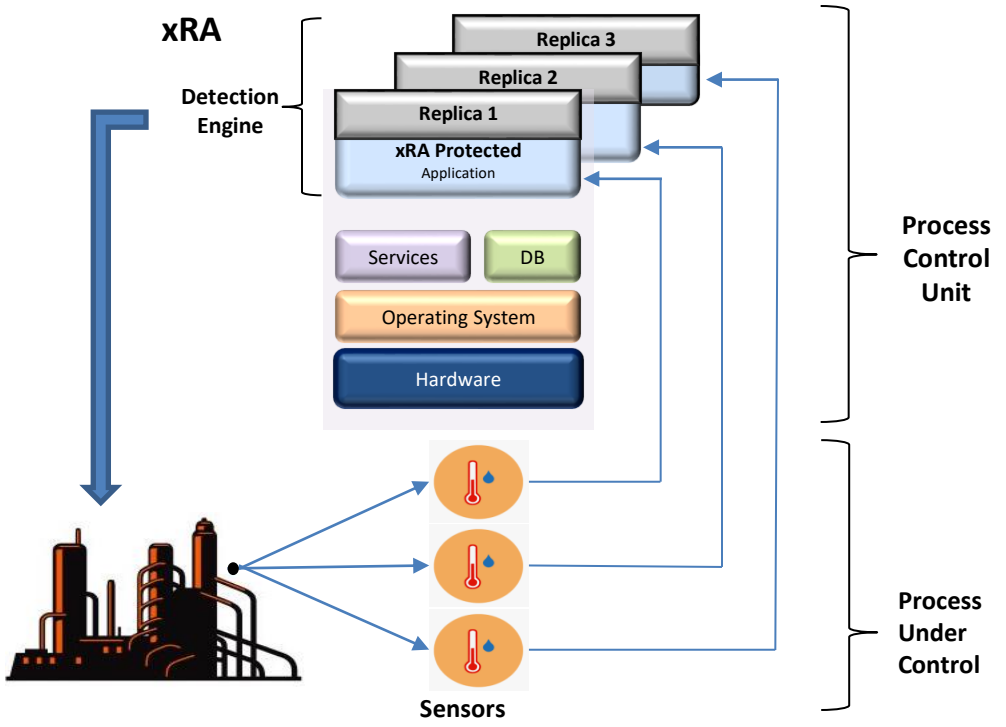
Continued Process Operation

(Illustrative)

xRA can be used to provide resilient monitoring and control for critical processes.

In this example, xRA is used to measure and control temperature in a critical chemical process using multiple sensors and multiple xRA control replicas.

The temperature control example can be extrapolated to any critical temperature control environment such as engines, generators, and reactors, etc. as well as other critical process control environments.



xRA Process Control Application

xRA: Process Control Protection

APPLICATION: xRA protects IoT Process Control Systems by detecting and isolating failures while providing continued operations

Improved protection of industrial IoT/ SCADA applications for control systems

Business Challenge

- **Protect process continuity and safety, increase process availability, as well as reliability**
- **Isolate and diagnose control system failures, in order to decrease costs and operational losses**
- **Detect and locate source of failures for repair and/or remediation**

VS² Contribution

- **Enables developers to create distributed application replicas to detect execution divergence, provide continued operation and aid in the isolation and diagnosis of failures *regardless of their cause***
- **xRA facilitates fault root cause isolation via its fault handler and forensic analysis tools**

Usage

- **Replicate sensors and applications**
- **Create applications, modify applications, or create xRA agents to monitor/measure performance**
- **Combine cloud and edge computing with IoT controllers to provide an extra layer of protection against process control failures**

Benefits Include…

- **Improves application availability and safety in operational systems**
- **Better disruption tolerance, increased speed and reduced cost of problem isolation, reduced operations and maintenance costs**

xRA: Autonomous Control Systems

APPLICATION: xRA increases system resilience using distributed, autonomous command and control systems

xRA-enabled control systems ensure continued operation via multiple, spatially separated, independent and cooperating controllers that preserve state during localized disruptive events

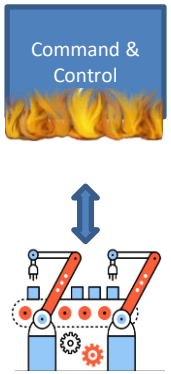
Spatially Distributed Process Resiliency

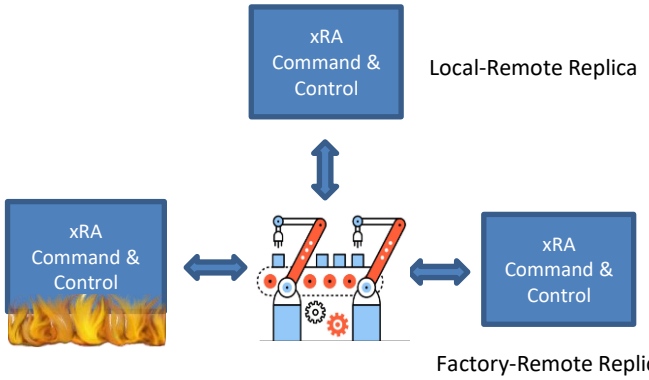
(Illustrative: A Catastrophic Fire in a Plant's C & C System)

Non-redundant
Single Point of Failure

versus

Redundant (xRA)
Autonomous Distributed Resiliency





A single location or single controller control system failure leaves a process without control or visibility - 'flying blind'

To protect against a controller failure, xRA spatially distributes command and control of the complex algorithms that tie together mission- or life-critical sensors and actuators while retaining the state of the control system

xRA: Autonomous Control Systems

APPLICATION: xRA Increases system resilience using distributed, autonomous command and control systems

xRA-enabled control systems ensure continued operation via multiple, spatially separated, independent and cooperating controllers that preserve state during localized disruptive events

Business Challenges

- **Applications that monitor and manage physical life/safety related critical functions are subject to failure or disruption**
- **Efficiently and effectively maintain stateful applications locally and in the cloud**
- **Detect and locate source of failures for repair and/or remediation**

VS² Contribution

- **Automatically distributes an application over multiple loosely coupled, spatially diverse, independently operating elements**
- **Makes protected control systems *both* fault tolerant *and* resilient to major localized disruptions**
- **xRA facilitates fault root cause isolation via its fault handler and forensic analysis tools**

Usage

- **Distributed control of a process across multiple application replicas in various locations within a facility and/or in separate facilities**

Benefits Include

- **Continued availability of an autonomous control application in spite of local failures**
- **Protection of critical processes/infrastructure**
- **Cost effective path to control application fault tolerance**

xRA: Simultaneous, Multi-platform Software Testing

APPLICATION: xRA enables Quality Control to regression test software updates across different hardware/software platforms

xRA-enabled testing makes software testing cheaper and faster, ensuring proper testing can be completed prior to release

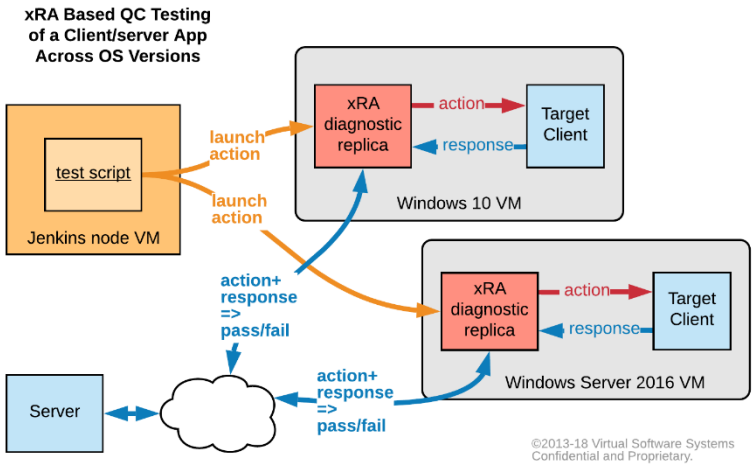
Cross-Platform Testing

(Illustrative)

xRA is a detection engine. When used in testing xRA reveals fine-grained differences in execution of the target software in two cases.

- Differences in *one release* running on two or more different operating systems simultaneously (shown in the example are Windows 10 and Windows Server) or hardware platforms.
- Differences in software functionality *between two release versions* running on the same operating system or hardware platform (ex: Intel and ARM).

xRA diagnostics can be developed without extensive knowledge of the target software. xRA forensics provide detailed information about where the differences first occur.



xRA: Simultaneous, Multi-platform Software Testing

APPLICATION: xRA enables Quality Control to regression test software updates across different hardware/software platforms

xRA-enabled testing makes software testing cheaper and faster, ensuring proper testing can be completed prior to release

Business Challenge

- **Deliver new releases to market faster at lower cost and with better quality**
- **Ensure compatibility with previous software version across different hardware and software platforms**
- **Detect and locate source of errors**

VS² Contribution

- **Real-time, fine-grained comparison engine running on heterogenous platforms**
- **A stimulus-driven testing process, rather than predictive**
- **xRA facilitates fault root cause isolation via its fault handler and forensic analysis tools**

Usage

- **Quality control developers use replicated diagnostic apps to test the same target software over multiple platforms or different target software (e.g. updates) over homogenous platforms**
- **xRA diagnostic replicas run on different hardware and OS platforms simultaneously**
- **xRA replicas detect differences in target software execution**

Benefits Include

- **Inconsistencies are detected and located**
- **Speeds up software testing, Improves quality, and customer satisfaction**
- **Detects Heisenbugs in xRA-enabled applications**

xRA: Hardware Testing

APPLICATION: xRA enables system testing of processor or microcontroller PCBs (printed circuit board) in Manufacturing Quality Control

xRA-enabled PCB system testing reduces cost and lead time for circuit testing

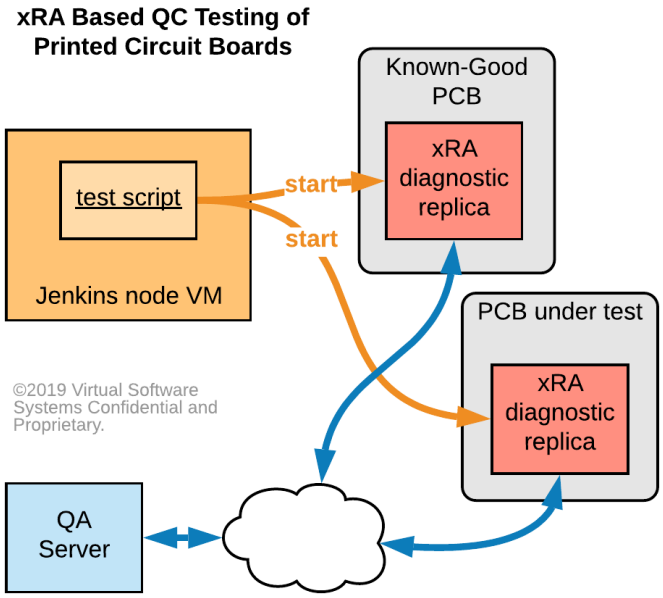
XOR Testing Via Known-Good Parts

(Illustrative)

xRA can be used for hardware quality control, to detect differences in operation of printed circuit boards, by comparing the functionality of a new board against a known good printed circuit board.

xRA technology can be applied further down the quality control path by actually testing the functionality of the circuit board under live software execution conditions via simplified xRA diagnostics.

This level of testing allows the manufacturer to identify faults that cause intermittent failures due to such things as poor connector conductivity, slow gate switching, and execution timing issues such as “heisenbugs”, all of which are very difficult to identify and diagnose.



xRA: Hardware Testing

Application: xRA enables system testing processor or microcontroller PCBs (printed circuit board) in Manufacturing Quality Control

xRA-enabled PCB system testing reduces cost and lead time for In Circuit Testing.

Business Challenge

- Fine grain testing and diagnosing capability without a physical bed of nails fixture
- Detection and isolation of intermittent failures in system testing
- Improve visibility into complex chips via software "test points"

VS² Contribution

- Real-time, fine-grained comparison engine running on heterogenous platforms
- A stimulus-driven testing process, rather than predictive
- xRA facilitates fault root cause isolation via its fault handler and forensic analysis tools

Usage

- Quality control developers use replicated diagnostic apps to test a fresh lot PCB under test against known-good PCBs
- Execution differences are detected in real time at system call granularity
- xRA system test diagnostic replicas detect intermittent errors caused by unreliable hardware

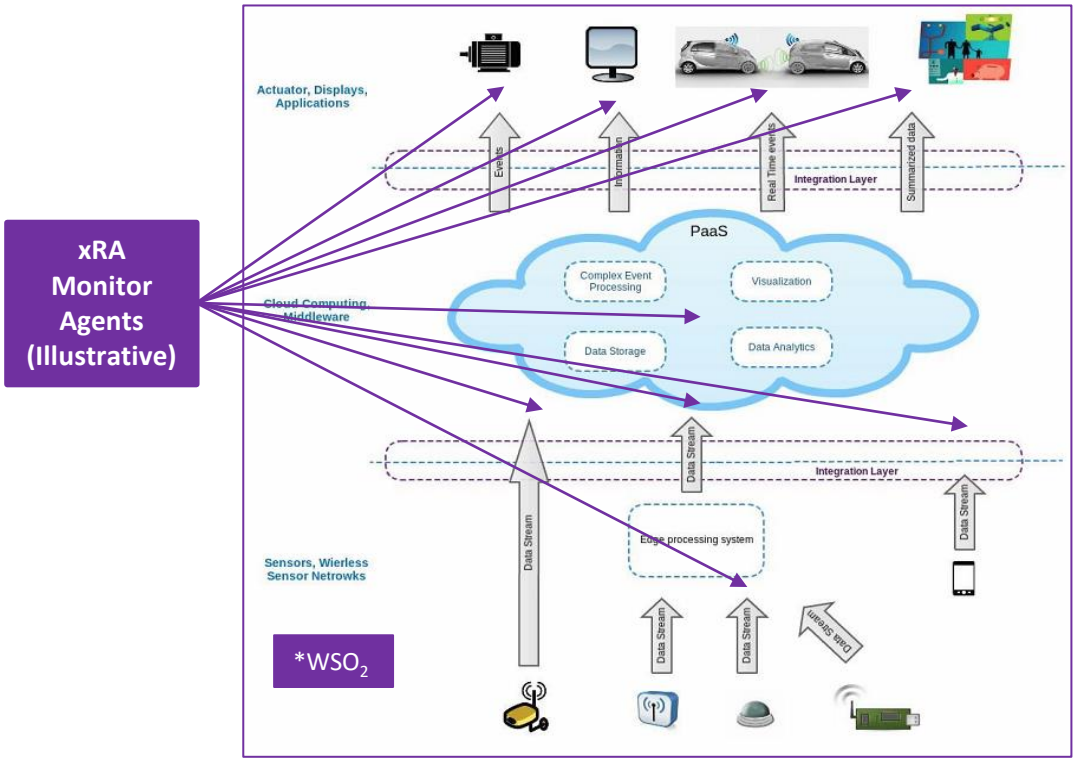
Benefits Include

- Improved quality
- Reduced Quality Control cost
- Reduced field repair & support cost

xRA: Gray Failure Analytics

APPLICATION: xRA holds the potential to help detect and isolate causes of gray failures in complex cloud and edge computing networks

xRA's replication, comparison, and fault detection properties could create new methods of solving the pervasive problem of differential observability, an underlying reason gray failures are so hard to detect



xRA monitoring agents (xRA replicas) may be placed throughout a complex cloud/edge system to extend system observability, enabling operations personnel to compare the performance of various parts of the system.

Differential performance indicators can be combined with other existing detection methods and analyzed to locate and isolate performance issues that can lead to gray failures.

*WSO_2 - conceptual view of the cloud centric model (https://wso2.com/library/articles/2014/05/connecting-the-real-world-and-world-of-computing-with-a-complete-cloud-centric-iot-model/)

xRA: Gray Failure Analytics

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xRA's replication, comparison, and fault detection properties could create new methods of solving the pervasive problem of differential observability, an underlying reason gray failures are so hard to detect.

Business Challenges

- **Gray Failures are recognized as a major impediment to the evolution of complex cloud and edge computing**
- **Gray Failures cause lost revenue and lost productivity for both cloud service providers and their customers**

VS² Contribution

- **xRA's patented user-level application replication and comparison engine may enable developers to create monitoring agents to measure and report on gray failure metrics**
- **xRA facilitates fault root cause isolation via its fault handler and forensic analysis tools**

Usage

- **xRA technology can create, distribute, and tie together monitoring replicas**
- **Replicas-can be implemented across different cloud hardware and software platforms**
- **Monitoring of replicas can be shaped to meet specific requirements**

Benefits Include

- **Reduced time to identify, locate and repair complex performance issues**
- **Reduced revenue loss for both providers and their customers**
- **Improved customer satisfaction**

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