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Best Practices for Scaling Production Using a Platform-Based Testing Approach

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- 25+ Years Specifying T&M Systems
  - 20 Years at NI
  - 6 Years at Konrad Technologies

What Makes a Testing Approach “Platform-Based”?

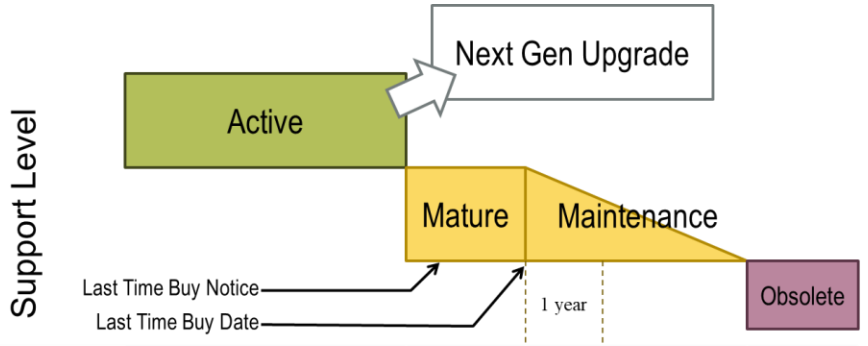
- Modular and Scalable Hardware
- Defined Infrastructure
  - Racks, compute platforms, connectivity, automation
- Standardization
    - ADEs, test executives, HALs
    - Consistent user experience, interfaces, data formats
- Software-Defined Measurements
- Specified Data Management Architecture

The Value of a Standard Platform in Production Test

- The focus of this presentation is production, but there is standardization value in R&D, V&V, and HiL as well
- Generalizations can be made within industries, but the value propositions are application-specific

Platform Value in Aerospace / Defense and Medical Devices

- Long product lifecycles; production / depot testing for decades
- Obsolescence management and sparing strategies are critical considerations
- Preference for stable vendors and consistent instrumentation



	Active	Mature	Maintenance		Obsolete
Buy new products	Yes	Yes	No	No	No
Repair services	Yes	Yes	Yes	Yes	No
Calibration services	Yes	Yes	Yes	Yes	No
Service Agreements	Yes	Yes	Yes	Yes	No

Platform Value in Aerospace / Defense and Medical Devices

- Lower production rates but demanding measurement performance
- Typically, 100% test coverage, high precision / high frequency measurements, complex switching, high channel / pin count
- Often a “family” of standard tester hardware platforms will be adopted to scale based on logical breaks in capital investment

Platform Value in Higher Velocity Industries

- Rapid product turnover (Automotive, Consumer Electronics)
  - Critical time to market; test as final gate to product release
  - Consistent platform accelerates test system development and validation
  - Modular / scalable hardware and consistent software for quick deployment

Platform Value in Higher Velocity Industries

- ROI over shorter periods; lower capital / development budgets
- Drive down cost of test by maximizing throughput, minimizing footprint, right-sizing performance and channels

The Costs of a Standard Tester Platform Approach

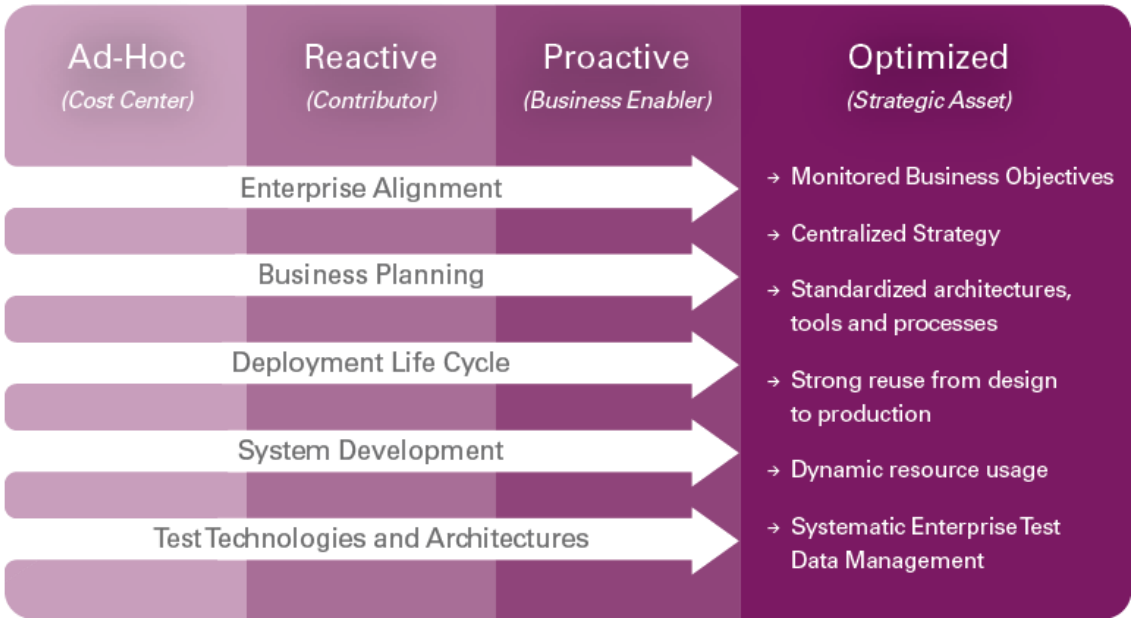
- Why Don't All Companies Standardize? Why Do Some Fail?
- Standardization has significant costs that must be weighed carefully against the benefits
- Standardization typically requires:
  - A higher initial investment in designs
    - Need to accommodate all anticipated variants
    - Documentation and drawings must be thorough
    - Software architectures need to be carefully selected to capture all anticipated use cases and to allow for future expansion (test executive, HAL, standard data formats, *etc.*)

The Costs of a Standard Tester Platform Approach

- A higher initial investment in capital expenses
  - More channels, more precision, higher sample rate, more switching, larger rack size, *etc*. than a purpose-specific test system
- A higher initial investment in software development
  - More experienced / expensive developers and architects to implement abstraction
  - Development hours to create and document test executive, reuse libraries, hardware abstraction layers, *etc.*

The Costs of a Standard Tester Platform Approach

- A higher level of leadership and organizational discipline
  - Sponsored, communicated, and consistently executed by a leader that spans the entire area of effect
  - Must overcome natural desires of engineers to innovate and those of managers / purchasing agents to select lowest price
  - Effective change management and expectation management



Best Practices – Hardware

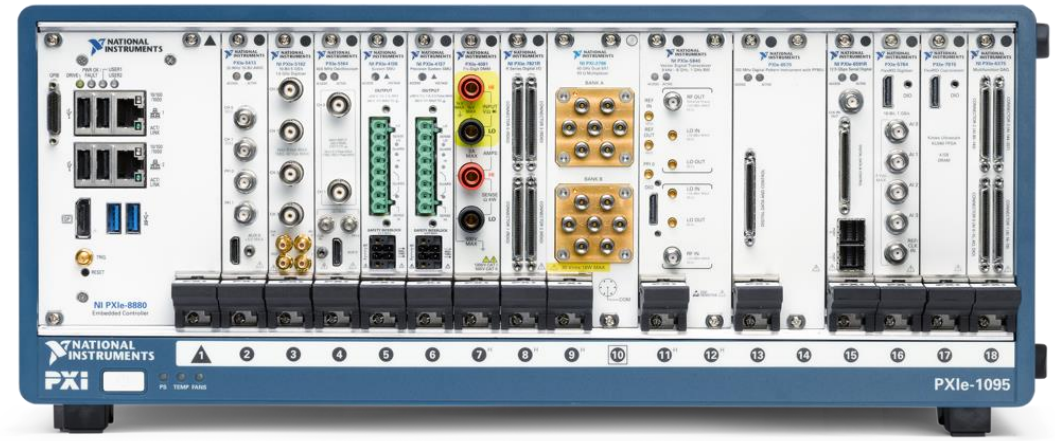
- COTS wherever possible
- Standard rack designs
  - Cooling, ventilation, cable management, power distribution
  - Minimizes long-term investment in design
  - Fewer “surprises” during build and wiring
  - Consistent build quality
- Standard compute platforms
  - From industry-leading vendors with defined product life cycles developed in conjunction with the relevant supply chain (ADI, Intel, NVIDIA, *etc.*)
  - Stable bill of materials with known and consistent hardware interfaces, BIOS, OS, driver stack, *etc.*
  - Interchangeable to facilitate sparing strategies

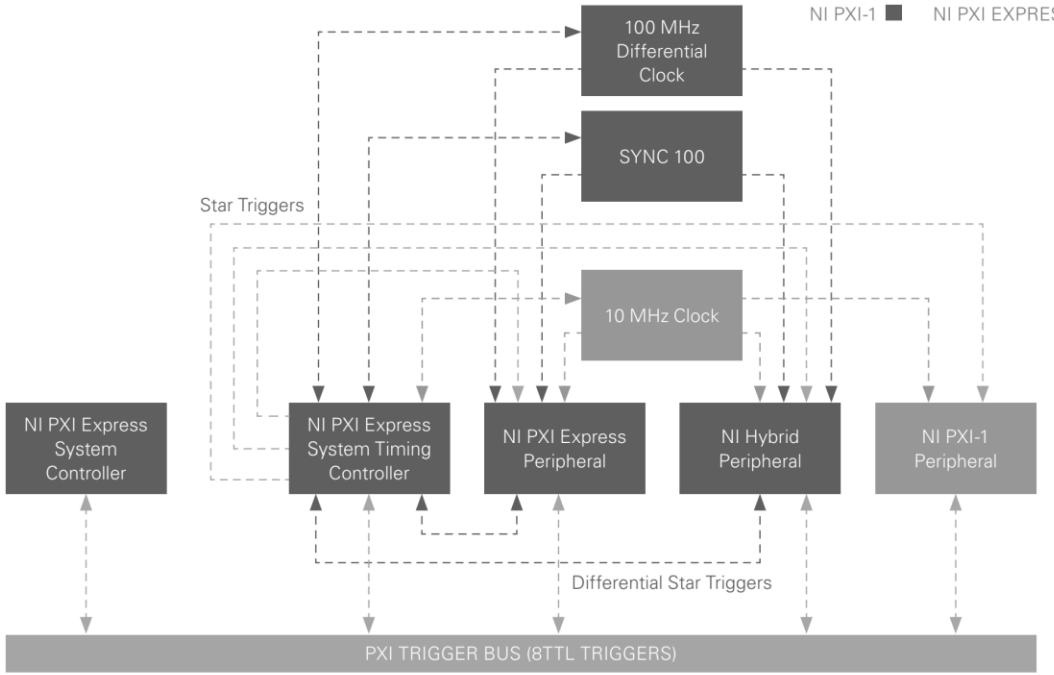
Best Practices – Hardware

- Standard connectivity
  - Rugged interface test adapters are often appropriate for high-value test systems that need to accommodate a high mix of devices under test
  - Careful consideration to the selection of switch vendors to ensure consistent configuration, software development, and predictable product life

Best Practices – Hardware

- Modular instrumentation platforms
  - PXI, LXI, and (legacy) VXI platforms are designed for scalability and interoperability
  - Often have platform-level capabilities for asset health monitoring, timing, triggering, and synchronization





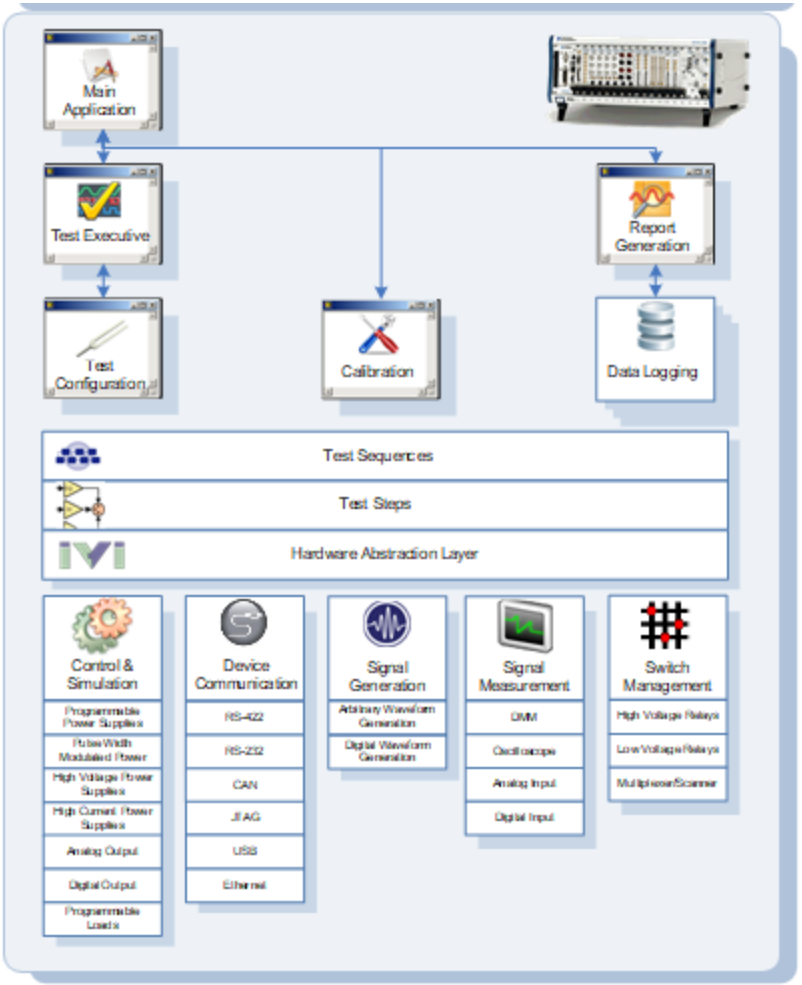
Best Practices – Software

- Standard operator / user experience
  - Minimizes errors and inconsistent test workflow
  - Simplifies training and re-training requirements
  - Privileges scale to different personnel as needed

- Standard test executive
  - Consistent implementation of test sequencing, conditional looping, branching, and loading / unloading of test pass / fail limits
  - Uniformity in data presentation via standard file formats and reports
  - Ownership of test executive can often be more easily outsourced to integration partners with a development cycle that is decoupled from product-specific test code
  - Selection of COTS / integrator-customized COTS test executive allows test engineers to focus on core competencies

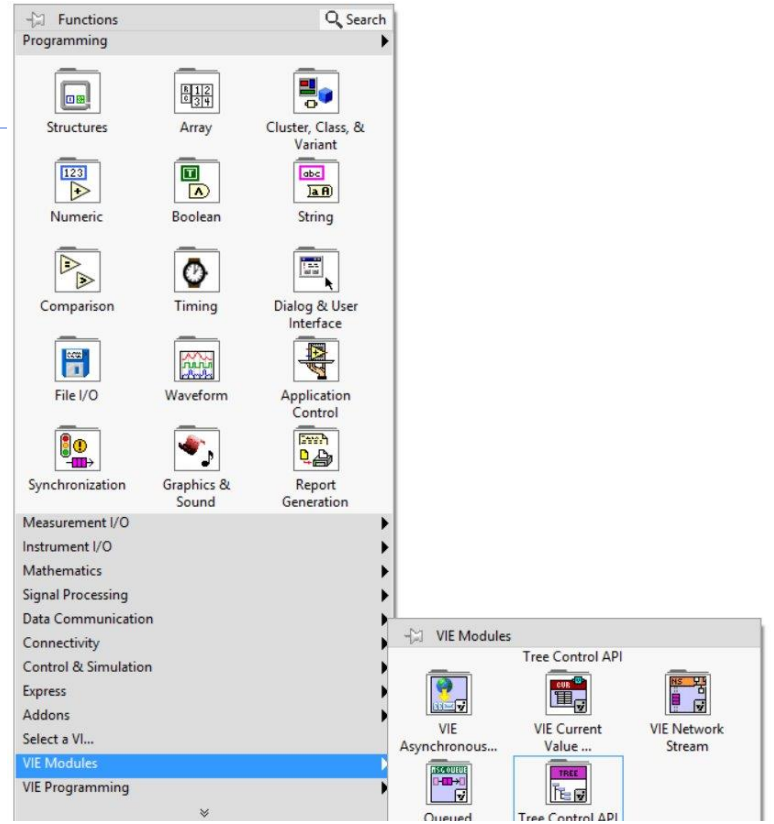
Best Practices – Software

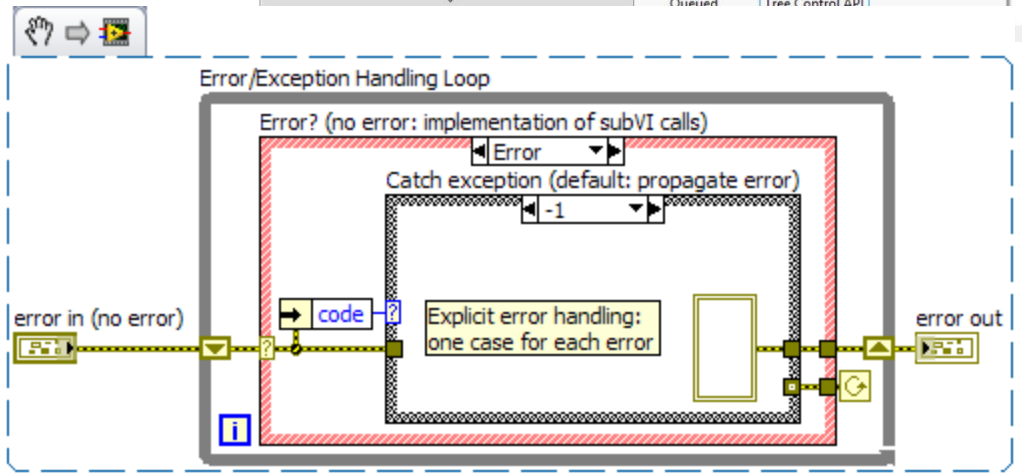
- Standard application development environments
  - Facilitates team-based development and outsourcing
  - Minimizes learning curves and accelerates responsibility transfers
- Implementation of Hardware Abstraction Layer (HAL) and drivers
  - More valuable for larger, long-lived, enterprise-level standardizations
  - Industry initiatives like IVI have relied on HALs to make test code more agnostic to instrument vendors for common functions



Best Practices – Software

- Create, acquire, and leverage design patterns and reuse libraries
  - Don’t reinvent the wheel! – accelerate development with validated code
  - Easier to enforce best practices
  - Simplified code maintenance
- Build Robust Error-Handling into all Code and Implement Exception Logging
- Use Code-Profiling Tools to Optimize Performance and Improve Stability





Best Practices – Software

- Version Control & Configuration Management
  - Using version-controlled systems (*e.g.*, Git) to track changes
  - Using configuration management tools for automated deployment and maintenance
- Implement Automated Software Testing and Continuous Integration
  - Improve code reliability and quality by catching bugs early. CI pipelines automate the build, test, and deployment processes, accelerating software releases
- Don’t Neglect Security and Cybersecurity
  - Input validation, encryption, and authentication

Emerging Trends in Platform-Based Approaches to Testing

- Cloud-Based Platforms:
  - Centralize test resources and enable remote access to testers
    - Particularly beneficial for geographically distributed teams and for managing large-scale test deployments
  - Remote access to test systems
  - Centralized data management
    - Improves access to data & consistency in storage and backup workflows

Emerging Trends in Platform-Based Approaches to Testing

- Continuous Integration / Continuous Deployment (CI/CD)
  - Accelerates software release cycles with automated testing and deployment processes
- Data Analytics and Insights
  - Real-time monitoring
  - Artificial Intelligence and Machine Learning (AI/ML) Algorithms
    - Test data analysis
    - Anomaly detection
    - Predictive maintenance of test equipment
    - Generating test cases

Metrics to Assess the Impact of Platform-Based Approaches

1. **Test Coverage**
   - Definition: Percentage of the product that is tested.
   - Best Practices: Aim for high test coverage to ensure product quality. Use automated tools to measure and report on coverage.
2. **Test Cycle Time**
   - Definition: Time taken to complete one test cycle.
   - Best Practices: Monitor and optimize cycle times to reduce bottlenecks. Implement parallel testing where possible.
3. **First Pass Yield (FPY)**
   - Definition: Percentage of products that pass testing without requiring rework.
   - Best Practices: Higher FPY indicates better quality control and fewer defects.
4. **Mean Time to Detect (MTTD)**
   - Definition: Average time taken to detect a defect.
   - Best Practices: Use real-time monitoring and advanced analytics to reduce MTTD.
5. **Mean Time to Repair (MTTR)**
   - Definition: Average time taken to repair a defect.
   - Best Practices: Streamline repair processes and maintain an inventory of critical spares.

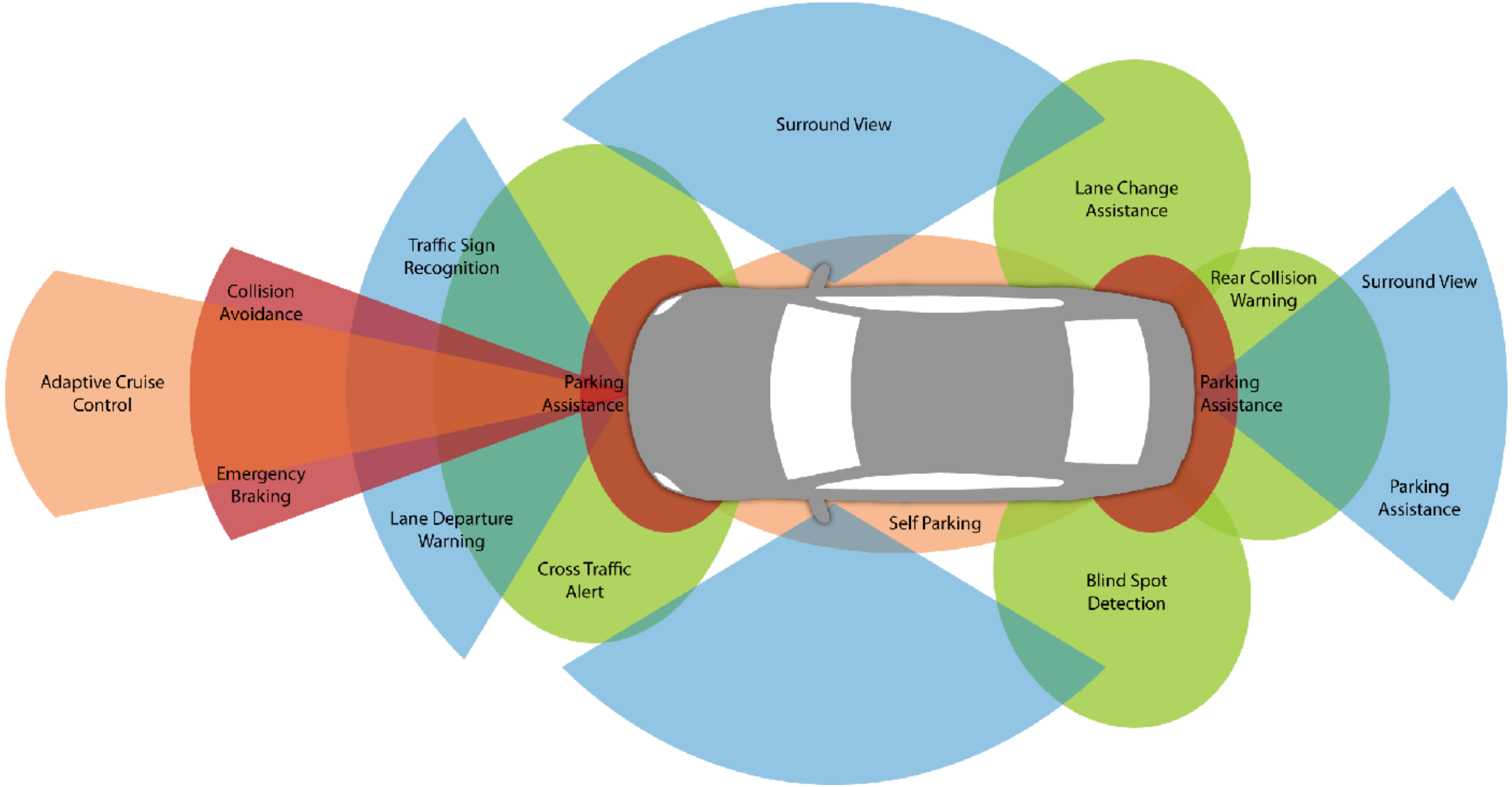
Metrics to Assess the Impact of Platform-Based Approaches

6. **Equipment Utilization**
   - Definition: Percentage of time testing equipment is actively used.
   - Best Practices: Aim for high utilization rates by optimizing scheduling and reducing downtime.
7. **Test System Uptime**
   - Definition: Percentage of time the test system is operational.
   - Best Practices: Regular maintenance and predictive analytics can help improve uptime.
8. **Cost Per Test**
   - Definition: Total cost divided by the number of tests performed.
   - Best Practices: Track and optimize costs by improving efficiency and reducing waste.
9. **Defect Escape Rate**
   - Definition: Number of defects that escape to the next stage of production.
   - Best Practices: Implement stringent testing protocols and root cause analysis to reduce escape rates.
10. **Scalability Metrics**
    - Definition: Metrics that assess the ability to scale testing systems (e.g., time to integrate new test units, system performance under increased load).
    - Best Practices: Regularly stress-test systems and plan for scalability from the outset.

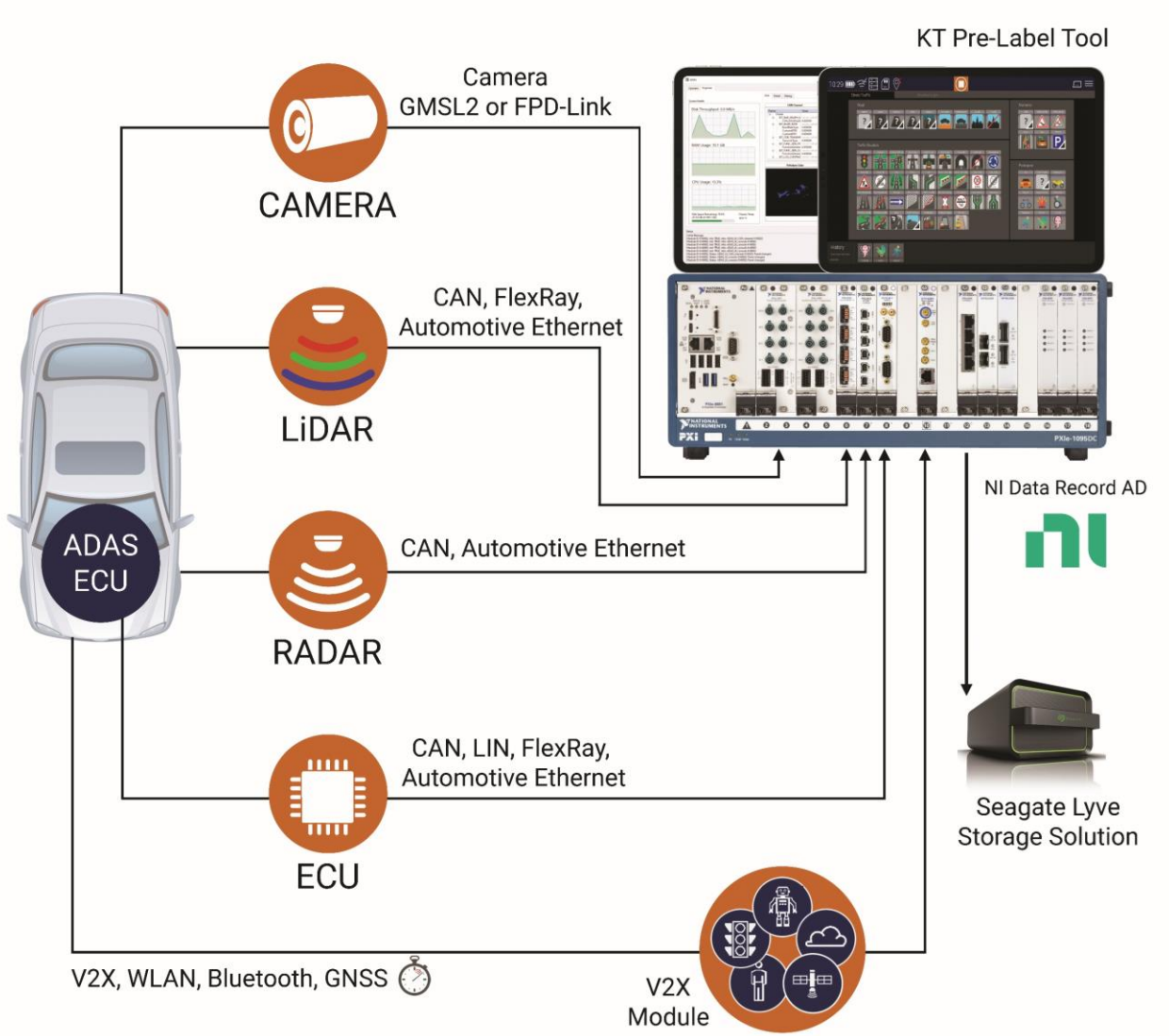
Sustaining Standardization – Industry Best Practices

- Automated Data Collection and Analysis
  - Ensures accuracy and reduces manual workload
  - Use advanced analytics to derive insights from test data, identify trends, and predict potential issues
- Continuous Monitoring and Improvement
  - Regularly review KPIs to identify areas for improvement
- Benchmarking
  - Compare metrics against industry standards and competitors to identify gaps / improvement vectors
  - Participate in industry groups and forums to stay abreast of best practices and trends
- Training and Development
  - Ensure staff are trained on the latest technologies and methodologies and that they are aware of the business drivers for standardization

PXI Case Study: In-Vehicle Data Logging & Replay HiL



In-Vehicle ADAS Recording



From Data Record System AD to Your Integrated Solution

konrad ···technologies··· + NI

Standard on Every System

- PXI System Controller and Chassis
- Data Record AD Software and Configuration
- APIs and Examples for Customization

Configuration Based on Test Requirements

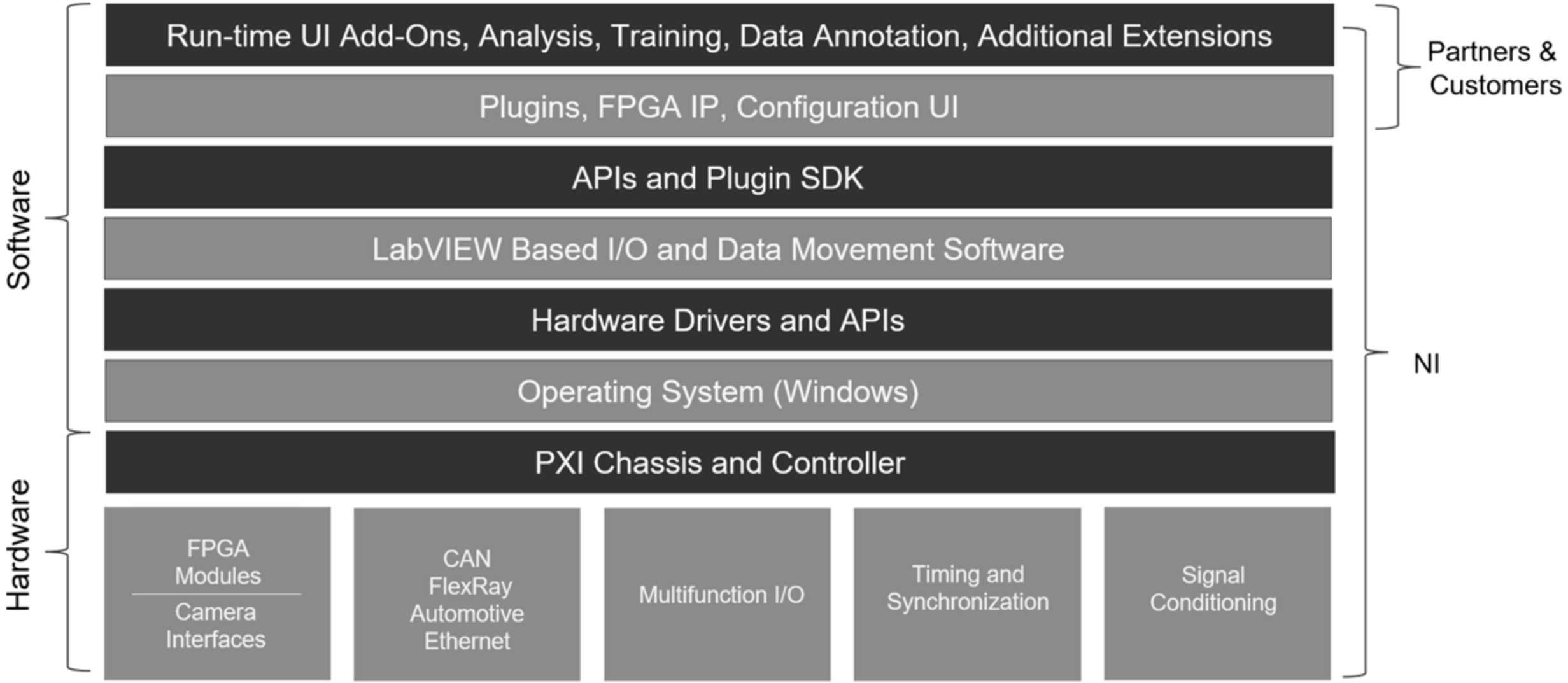
- I/O Matching to Sensor Needs
- Storage Capacity
- System Performance
- Power Consumption

Konrad Technologies Provides

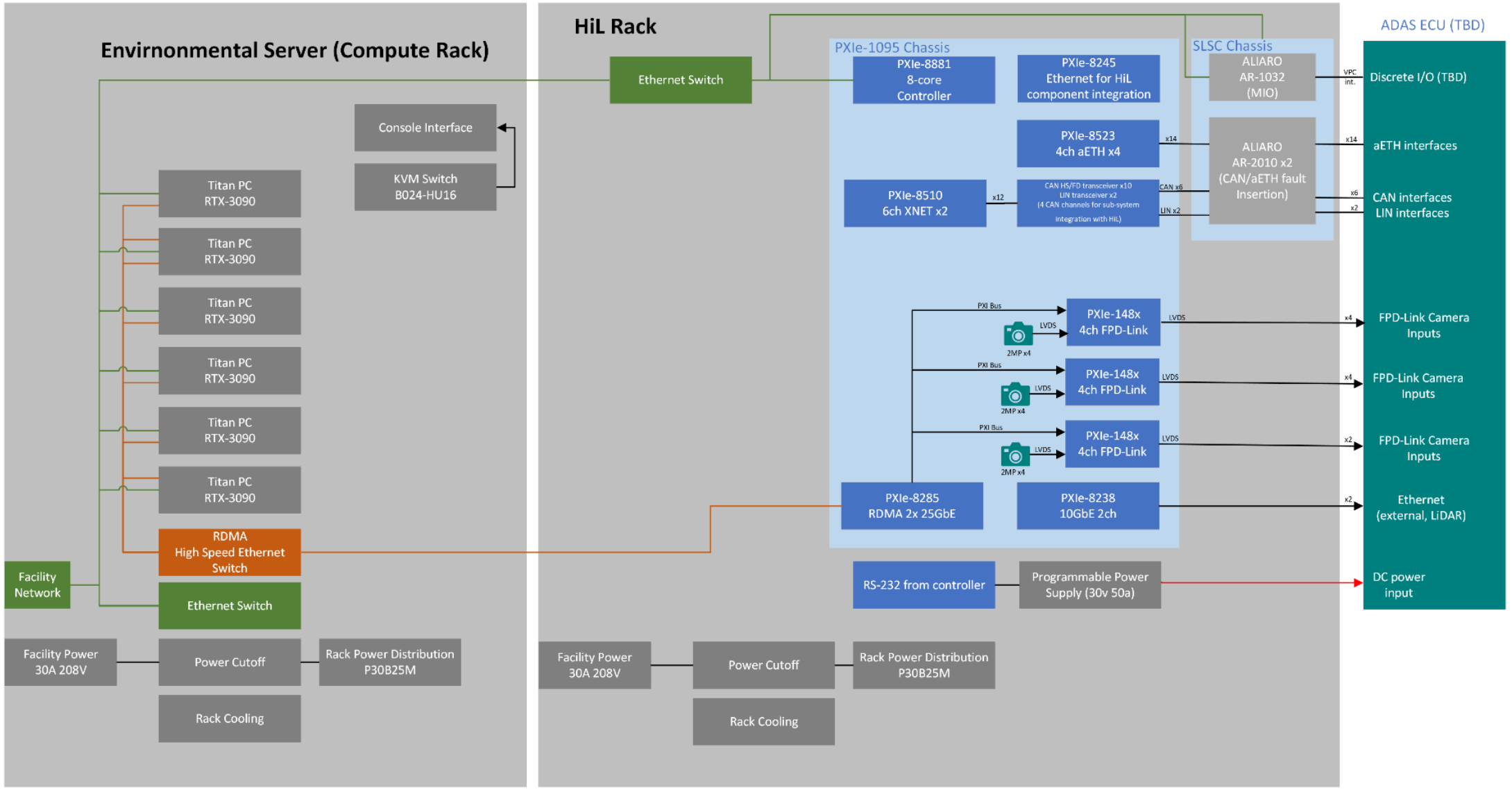
- Runtime and GUI customization
- Custom data processing and sensor interface customization
- System Installation
- System Debug and Troubleshooting

NI Certified Partner

NI Data Record System AD Architecture



Sensor Fusion XiL System Diagram



Konrad PXI Case Study: High-Throughput Production Test

- Medical Device Manufacturing
- https://www.youtube.com/watch?v=td_H27e2wHY

Case Study: Pacemaker Automated Functional Test System

- Functional testing of low-power and high-power hybrids (PCBs)
- Scalable testing of 1–16 hybrids per pallet, and parallel testing of up to 4 hybrids
- Two identical and switchable Test Interfaces in a Dual PXIe Test Interface Cage
  - Can be removed individually or as a single assembly
- Test Interface Cage contains 34 PXIe instrumentation modules with MAC Panel connectivity
- DUT pre-heated and tested at 37 °C

Summary

- Platform-based Testing
  - Modular, scalable, and standardized
  - Consistent user experience and software-defined measurements
- Value of Standardization
  - Requires careful consideration of costs and benefits in each scenario
- Best Practices
  - COTS hardware, standard connectivity, modular instrumentation, powerful ADEs
- Emerging Trends
  - Cloud-based platforms, CI/CD, data analytics, AI/ML algorithms
- Challenges
  - Resistance from engineering and management
  - Need for sponsorship and management from the top

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