FIRST CONSULTING CASE STUDY | TEST AUTOMATION & REQUIREMENTS VERIFICATION

Automated Verification and Backward-Compatibility Testing for a Redesigned Rail Safety Communications Radio

PART 1

The Engagement at a Glance

Executive Summary

A global industrial technology manufacturer engaged First Consulting to support the redesign of a narrowband data radio that carries positive train control (PTC) communications for North American railroads and transit agencies. The new radio has to be a drop-in replacement for a product already fielded across multiple railroads: it has to fit the same mounting, accept the same connectors and power, and interoperate over the air with legacy units that will remain in service for years.

Over a two-year engagement that operates much like a managed service, First Consulting supplies a development team alongside a three-person test team and a dedicated project manager. The test team is building a Robot Framework automation suite to replace manual test procedures, verifying the redesigned product against its requirements, and reporting defects wherever requirements are not met.

The central difficulty was that the legacy product had little to no formal testing or documentation, so much of the expected behavior had to be established from the fielded product itself before the new design could be verified against it.

Background and Context

The client

The client is a global industrial technology manufacturer whose communications business has supplied rugged wireless equipment to railroads and other critical-infrastructure operators for decades. Its rail radios are installed on locomotives, at wayside locations along the track, and at base stations, and are used by Class I freight railroads, commuter railroads, and transit agencies.

The product under test

The product is a licensed narrowband packet data radio that forms the communications link in a PTC system. It carries messages between locomotives, wayside equipment such as signals and switches, and the railroad’s back office, using a time-division protocol on a shared channel. The same radio family is

deployed as onboard, wayside, and base-station units, and is managed through a configuration menu, a serial console, SSH, and SNMP.

The redesign replaces the radio's core hardware platform, including a processor approaching end of life, while keeping its external form, fit, and function. The table below summarizes the main requirement areas the redesigned radio has to satisfy.

Requirement area	What the redesigned radio has to do
Backward compatibility	Interoperate over the air with legacy radios already in the field, and behave the same way to the systems connected to it
Physical and electrical	Same mounting footprint and envelope, same connector types, and the same operating voltage range as the legacy unit
RF performance	Transmit power, receiver sensitivity, adjacent-channel and blocking rejection, and spurious emissions at least equal to the legacy unit
Configuration and management	Consistent configuration menus and toolchain, SNMP monitoring, logging, and statistics
Security	Encrypted remote access in place of legacy clear-text access, and multi-tier user authentication
Timing	Synchronization from GPS and precision time sources, with fallback between them
Environmental and compliance	Rail industry standards for environmental performance, shock and vibration, and electromagnetic compatibility, plus radio licensing rules

Main requirement areas for the redesigned radio.

Why the redesign needed structured testing

Railroads cannot replace every radio at once. For years, redesigned radios will operate alongside legacy units on the same channels, and a locomotive equipped with one generation will run past wayside sites equipped with the other. Every redesigned radio therefore has to work with every legacy radio it might meet, and look the same as the legacy radio to the onboard computers, wayside controllers, and network management systems connected to it.

Requirements come from several railroad and transit agency customers as well as the client's own engineering team. Many of them are written by reference to the legacy product, such as "same as the current radio," which makes the legacy product's actual behavior the specification.

The regulatory driver

PTC is required by federal law. The Rail Safety Improvement Act of 2008 mandated PTC on main lines that carry passengers or certain hazardous materials, and the Federal Railroad Administration (FRA) regulates PTC systems under 49 CFR Part 236, Subpart I. A PTC system can enforce speed limits and stop

a train before a collision, an overspeed derailment, an incursion into a work zone, or movement through a misaligned switch. It depends on reliable communications to do so.

- **Federal rail safety regulation:** railroads operate PTC under FRA-approved safety plans, and changes to safety-related components need to be justified with evidence
- **Interoperability:** trains of one railroad routinely operate on another railroad's territory, so PTC equipment has to work across railroads and across equipment generations
- **Radio licensing:** the radio operates in licensed spectrum under Federal Communications Commission rules, which govern transmit power, bandwidth, and emissions
- **Industry standards:** railroad customers require compliance with American Railway Engineering and Maintenance-of-Way Association (AREMA) recommended practices for environmental performance, electromagnetic compatibility, reliability, and configuration management

Scope of the engagement

- **Development:** a First Consulting development team working on the redesigned product
- **Test automation:** automation code, built in Robot Framework, to streamline manual test procedures and verify product requirements
- **Requirements verification:** verifying the redesigned product against its requirements and reporting defects when requirements are not met
- **Program management:** a First Consulting project manager responsible for planning, reporting, and coordination with the client

Constraints

- **A fielded product as the reference:** compatibility has to be proven against real legacy radios, so tests have to run against physical hardware, not just simulations
- **Moving target:** the redesigned product is under active development, so tests have to keep pace with frequent firmware builds
- **Lab hardware:** radios, RF test equipment, and test benches are shared across development and test
- **Schedule:** a two-year engagement

Key Challenges

- **No documented baseline:** the legacy radio had little to no formal testing or documentation, so the team had to establish how it actually behaved before the redesign could be verified against it
- **Requirements defined by the legacy product:** many requirements simply said "same as the current radio," so each one needed a measurable definition, a test that could produce evidence, and a known legacy result to compare against

- **Backward compatibility across a mixed fleet:** the new radio had to work with every legacy unit it could meet in service, and because compatibility problems often appear only in specific combinations, every combination had to be retested whenever the firmware changed
- **Manual testing that could not keep pace:** manual procedures were slow and hard to repeat, and with frequent firmware builds across many interfaces, a full regression by hand would have taken longer than the time between builds
- **What was at stake:** the radio is a link in a federally mandated safety system, so a compatibility regression could disrupt PTC communications in the field and be costly to fix across an installed fleet

Is This Relevant to You?

First Consulting's approach fits organizations facing any of the following:

- A redesign of a fielded product that must remain compatible with units already in service
- A legacy product with little formal testing or documentation
- Manual test procedures that cannot keep up with the pace of development
- Regulated or safety-critical systems that need traceable verification evidence

To discuss a test automation or verification program, contact First Consulting.

> **Continue to Part 2 for the details.** Part 2 covers the challenges the engagement had to overcome, the V&V objectives, the team structure and phased methodology behind the work, and why this approach matters.

PART 2

Inside the Engagement

This part goes deeper into the engagement: what made it difficult, what the team set out to verify and validate, and how the work is staffed, automated, and managed.

The Challenge

Redesigning a radio that is already in service is harder than designing a new one. The new design has to match everything the old one does, including behavior nobody wrote down, and the team has to prove it does.

No documented baseline

The legacy radio had been in the field for years with little to no formal testing or documentation. There was no existing test suite to run against the new design, no set of documented expected results, and in many areas no written description of how the radio actually behaved. Before the team could verify that the redesigned radio matched the legacy one, it had to establish what the legacy one did.

Requirements defined by reference to the legacy product

A large share of the requirements described the redesigned radio relative to the existing one: the same performance, the same menus, the same logging, the same connectors. These requirements are easy to write and hard to verify. Each one needed a measurable definition, a test that could produce evidence, and a known legacy result to compare against.

Backward compatibility across a mixed fleet

The redesigned radio had to interoperate over the air with legacy units and present the same interfaces to connected equipment. Compatibility problems often appear only in specific combinations of radio generation, role, configuration, and message traffic, so a single pass of testing was not enough. Every combination that could occur in service needed to be covered, and covered again whenever the firmware changed.

Manual testing that could not keep pace

Manual procedures were slow, depended on the knowledge of whoever ran them, and were hard to repeat exactly. With frequent firmware builds across many interfaces, including the configuration menu, serial console, SSH, SNMP, and over-the-air messaging, full regression testing by hand would have taken longer than the time between builds.

What was at stake

The radio is a link in a federally mandated safety system. A compatibility regression could interrupt PTC communications in the field, causing enforcement events, delays, and lost confidence among railroad customers. Defects found after deployment would be expensive to fix across a fleet of installed radios, and the railroads relying on the product need to be able to show that the redesigned radio is safe to put into service.

V&V Objectives

The test effort has two jobs: to verify that the redesigned radio meets each of its requirements, and to show that it will work in service alongside the legacy radios it replaces.

Verification objectives

- **Requirements coverage:** every requirement linked to at least one test, with a recorded result
- **An established legacy baseline:** the legacy radio's behavior captured as documented expected results wherever requirements referred to it
- **Repeatable regression testing:** automated tests that can be rerun on every firmware build and give the same result each time
- **Documented defects:** every unmet requirement reported with the evidence and steps needed to reproduce it, and retested once fixed

Validation objectives

Passing individual requirements does not guarantee the radio will work in a railroad's network. The team therefore also tests the redesigned radio in mixed configurations that represent field conditions, with redesigned and legacy units operating together in onboard, wayside, and base-station roles.

Program objectives

Objective	Measure	Target
Requirements coverage	Requirements with a linked test and result	100%
Defect reporting	Unmet requirements with a logged defect	100%
Completion	End of engagement	Two-year term

Program objectives and targets.

Approach and Methodology

First Consulting's approach is to turn the legacy product's undocumented behavior into documented, automated tests, and then use those tests to verify each new build of the redesigned radio. Every

manual procedure that is repeated becomes a candidate for automation, and every requirement becomes traceable to a test.

Team structure

Role	Focus
Project Manager	Planning, status reporting, risk management, and coordination with the client's engineering and product teams
Test Engineers	Automation development, requirements verification, and defect reporting
Development Team	Development work on the redesigned product
Client Engineering	Product ownership, requirements decisions, and defect resolution

Team composition.

A phased methodology

Phase	Timing	Key activities
1. Legacy baseline	Early in the engagement	Exercise the legacy radio across its interfaces and roles; record its actual behavior as expected results
2. Requirements analysis	Early in the engagement	Turn each requirement, including "same as legacy" requirements, into a measurable pass/fail criterion; build traceability
3. Automation framework	Early in the engagement	Set up Robot Framework, shared keyword libraries, and lab connections to radios and test equipment
4. Test development	Ongoing	Convert manual procedures to automated tests, prioritized by risk and how often they are run
5. Build verification	Each build	Run the regression suite on new firmware; compare redesigned and legacy results
6. Defect management	Ongoing	Report unmet requirements with evidence; retest fixes; track to closure
7. Completion and handover	End of engagement	Final verification and handover of the test suite and documentation to the client

Program phases.

Using the legacy radio as the reference

Because the legacy product is largely undocumented, the team uses the legacy radio itself as the reference for expected behavior. Tests are run against legacy units first to record how they respond, and the results become the expected results for the redesigned radio. Wherever the requirements say "same as the current radio," the test compares the two side by side. When the legacy behavior is

ambiguous or appears to be a defect, the team raises it with the client for a decision instead of copying it into the new design by default.

Test automation with Robot Framework

Robot Framework was chosen because its keyword-driven test cases read like plain-language procedures, which makes them easy for engineers and reviewers to understand. The team builds shared keyword libraries for the radio's interfaces so that individual tests stay short and readable while the details of connecting to and controlling the hardware live in one place.

- **Interfaces covered:** configuration menus, serial console, SSH, SNMP, and over-the-air messaging between radios
- **Traceability:** each test case tagged with the requirement IDs it verifies, so coverage can be reported directly from test results
- **Evidence:** Robot Framework logs and reports kept for every run as a record of what was tested, on which build, with what result
- **Repeatability:** automated setup and teardown so every test starts from a known radio configuration

Requirements verification and defect reporting

Each requirement is verified on the redesigned radio and its result recorded. When a requirement is not met, the team logs a defect with the requirement it violated, the build and configuration, the steps to reproduce it, and the supporting logs, then retests the fix on a later build. Defects that reflect an unclear requirement instead of a product fault are raised as requirement questions, so they can be resolved at the source.

Governance and communication

The First Consulting project manager runs planning and status reporting with the client and tracks risks, defects, and test coverage across the program.

Why It Matters

Many long-lived products in rail and other critical infrastructure were built before formal test practices were standard, and the people who knew how they behave have often moved on. When those products are redesigned, the hardest part is often proving that the new version still does everything the old one did. First Consulting's approach is built to do exactly that: capture the legacy behavior, turn it into automated tests, and verify every build against it.

What this demonstrates

- **Test automation:** replacing slow, inconsistent manual procedures with repeatable, readable automated tests
- **Verification of legacy replacements:** establishing a baseline for an undocumented product and proving backward compatibility against it
- **Safety-critical context:** testing communications equipment that railroads depend on to meet federal rail safety requirements
- **Managed delivery:** development, test, and project management from one provider, accountable over a multi-year engagement