Managing Digital Twins of The Test Lab with SystemLink™ Software

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ABSTRACT

Digital twins have become an important part of the systems and software modeling world. Generally, the focus has been on creating digital twins of the item being designed, tested, and produced. However, the test lab itself is important to be part of the modeling lifecycle as the health and calibration of the test systems in use can greatly affect the final product. In this paper we describe SystemLink™ software, a web-based manager of digital twins of the testing resources in a validation lab. We describe the architecture of SystemLink and how having robust digital twins of test systems and assets improves the overall lifecycle of products under test.

CCS CONCEPTS

• **Software and its engineering → Model-driven software engineering**.

KEYWORDS

digital twins, hardware validation labs

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1 INTRODUCTION

Digital twins have become very important in the systems and software modeling world. As we construct more complex systems, the accepted notion is that a shift left through modeling is the right approach to produce a higher-quality end product. Digital twins, since the term was coined by Grieves [2], have become a large part of this shift left, especially in the later stages of manufacturing with the idea of smart factories [11].

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However, while most of the focus has been on creating, maintaining, and testing digital twins of the item being manufactured [4], the validation process must be successful for a manufactured item to leave the factory. Involved in this validation are complex test systems made up of myriad testing assets. These test systems and assets are complicated, and they age as they are used thus requiring maintenance and recalibration. Traditional methods of managing these systems are error-prone and manual involving spreadsheets or pen and paper.

We claim that having digital twins of the test lab itself is crucial to truly shifting left. In this paper we describe SystemLink, a web-based manager of digital twins of the testing resources in a validation lab. We discuss the basic architecture of SystemLink as well as how the software helps test engineers and lab managers.

2 CURRENT PROBLEM

In this section we discuss two problems that can arise with traditional methods of managing the test resources in a validation lab: managing software on the test systems and tracking test asset calibration. While only modeling the test and validation resources may help with the overall design of an item, having digital twins of the resources in the lab and having an efficient way to manage those digital twins (and the resources themselves) is crucial to the success of the validation process.

2.1 Software Management

Test systems require software to run the tests. This software can be as simple as some basic Python scripts or as complicated as a test-sequencing program. There are also software drivers for the individual hardware assets that make up the test system. All these pieces of software have versions to maintain and upgrade, and someone or something must track it all. In a traditional test lab, at best test engineers or lab managers use spreadsheets to track the software versions on the test systems. Keeping track of the large matrix of versions across all the test systems manually in the lab is time-consuming and error-prone. In the worst case, the software versions are not tracked at all.

The key problem is that it is easy to let the different test systems be in different states. The version of a driver or a test program on a system can indeed alter the results of the test itself. Consistency and reproducibility are key in validation. Usually, a lab manager

spends large amounts of time tracking these versions instead of testing more devices.

In SystemLink, the versions of all software installed on a test system are tracked in the digital twin of the system. The lab manager can see at a glance what software is installed on each system and push out updates to the software stack on all systems. Using a feature called states, the lab manager can save off known approved sets of software and versions to save time when creating new digital twins or when restoring to a known good state.

2.2 Calibration

The test assets that make up a test system are the heart of the testing process. Whether the device is an oscilloscope, a power supply, an SMU, or a high-speed RF transceiver, the test assets are only useful if they are still within in their calibration time window. Knowing when a test asset is due for calibration has generally been a manual process that the test lab manager was burdened with. While the devices themselves often report when they will need to be recalibrated, the lab manager traditionally needs to go to each machine to record these dates and then use some method for reminding themselves that an asset is out of calibration.

If a test asset is out of calibration, the results of the tests are invalid. With low-complexity devices, this validity may not be a big concern for the manufacturer. However, with high-complexity devices such as modern semiconductors or ECUs for an electric-vehicle, these erroneous tests can cost money or lives.

In SystemLink, the digital twin of the test asset includes the last calibration date as well as the calibration due date. This feature makes it easy for lab managers to set alarms and reminders for when an asset is due for calibration.

3 SYSTEMLINK SOFTWARE

SystemLink is a web-based software tool that comprises multiple different applications that give different perspectives on a test and validation lab. All these applications present a view of digital twins of the test systems and their assets. SystemLink allows a test engineer or lab manager to see their test systems, the assets in these test systems, the calibration state of the assets, and the software installed on each system. Test engineers can extend SystemLink through the use of Jupyter notebooks. These notebooks are used to analyze the digital twins themselves (e.g., to predict when maintenance may be needed as Lee et al. [6]) or test results.

In this section, we describe the architecture of SystemLink and the user experience of a few key workflows.

3.1 Architecture

SystemLink is a Kubernetes-based web application of microservices that we designed to scale automatically with the number of test systems that it manages. We have performed one-off performance and scalability analysis for particular customers. However, we are currently working on a holistic scalability study across all services. We have not yet completed and published the results of that work. A lab manager can manage systems from multiple labs, and keep track of the versions of software installed on each system as well as the calibration state of the assets in each system. Furthermore, each test system can upload the test results from any tests that the system runs to SystemLink for the test engineer to analyze. We show a high-level view of SystemLink's architecture in Figure 1.

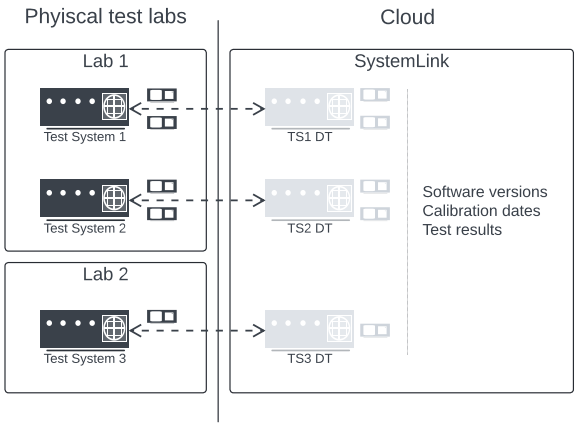

Figure 1: Conceptual architecture of the digital twins in SystemLink, including the test systems and assets, and the relevant properties of those entities

Each digital twin of a test system is a uniquely instanced digital entity. SystemLink keeps track of the key attributes of each system that makes the digital instance both unique and matched to its physical counterpart. These attributes include:

- The software installed on the system in addition to versions of each piece of software.
- The calibration state of each asset in the test system.
- The tests that have been run on the system, and possibly the results of those tests.
- The physical location of the system and assets in the lab (for example, the asset may have been moved to a different system or to storage).
- The serial numbers of systems and assets issued by the manufacturer.

As the physical system ages and performs tests, the digital twin is updated as well. If a test manager moves a test asset from one system to the next, the digital twin shows this in SystemLink. Even if an asset is put in storage, SystemLink can still track the asset.

SystemLink provides a live connection to the physical test system through a feature we call tags. These tags allow the digital twin to reflect real-time system health data, such as CPU utilization or temperature. The test engineer or lab manager interested in these physical properties can set alarms to be notified when they are out of bounds.

An important note is that SystemLink maintains digital twins of both the test systems and the test assets. While from the systems view of the digital twins, a test engineer or lab manager will see all the assets currently in that system, they can also look at the digital twin of just a single asset. For example, a lab manager may want to see all the assets that are getting close to needing a recalibration.

SystemLink will show all the assets, even the ones in storage and not currently installed in a test system.

SystemLink transparently uses multiple different data stores to represent the digital twins.

3.2 User Experience

SystemLink presents various table-based views of the digital twins it manages to the user, based on what job the particular user is trying to complete. For users who are interested in managing the software stack on their fleet of test systems, they can start with the Systems Application, seen in Figure 2, which shows a list of digital twins corresponding the physical test systems SystemLink is managing. Systems are grouped into workspaces, and users can only view the systems that are in workspaces they are members of. The user can configure the table to display whatever system metadata is important, and these custom views are saved to the user's profile. While there is standard metadata, such as IP address or serial number, users can also add custom metadata that becomes part of the digital twin of the system.

Figure 3 shows the detailed view of a digital twin of a particular system. In this detailed view, there are two sections of note. The first is the top section, which shows critical information about the specific system. The bottom half of the screen shows the various views into the digital twin of the system. The user can see the assets associated with this system, the test results that have been uploaded from this system, as well as the software installed on this system. All this information mirrors the physical system and changes as the physical system changes (e.g., a new test completes or software is updated).

Figure 4 shows the digital twin for a particular asset within a test system. A similar user experience (UX) pattern is used where details about the specific asset appear at the top of the screen with a table of updates to the asset in the bottom half. This pattern is common in all SystemLink applications. Two key pieces of data in the top half are the last calibration date and calibration due date. There are also tabs that will show the test results associated with this test asset as long as any files that have been uploaded and associated with this asset.

The consistent UX of SystemLink makes it easy for the users to quickly understand the state of their test lab [7]. The systems and assets applications use a consistent UX that makes often repeated tasks such as updating an asset location or pushing out an update to a software version straightforward.

4 RELATED WORK

	SystemLink	Wats	PathWave
Software Management	✓	✓	✓
Asset Calibration	✓	✓	✓
Test Results	✓	✓	✓
SaaS		✓	
On premise	✓		✓

Table 1: Comparison of features of SystemLink, Wats, and PathWave

There are two other main competing commercial tools: Wats [10] and Keysight's PathWave [8]. Both have similar features and capabilities to SystemLink. SystemLink, in our opinion, is the best solution for NI-based test systems. In the world of digital twins, all three products have similar features (see Table 1), though there seems to be no published work classifying these tools with a digital twins lens.

Grieves [2] coined the term "digital twin." Kritzinger et al. produced a thorough survey of the state of the art in digital twins [4]. Our work with SystemLink falls in the area of software defined manufacturing (SDM) [3, 5]. However, while SystemLink is definitely used in manufacturing, most customers use SystemLink in validation labs.

Borodulin et al. [1] introduce a digital twin cloud platform — microservice-based "Digital Twin as a Service" for smart factories. SystemLink is an instantiation of that idea, but focused on the test systems not the factory or devices themselves.

5 CONCLUSION

In this paper we describe SystemLink, a web-based manager of digital twins of the testing resources in a validation lab. We describe the architecture of SystemLink and how having robust digital twins of test systems and assets improves the workflows for test engineers and lab managers in the day-to-day management of the test lab.

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A APPENDIX

NI has created a library of videos explaining several aspects of using SystemLink [9].

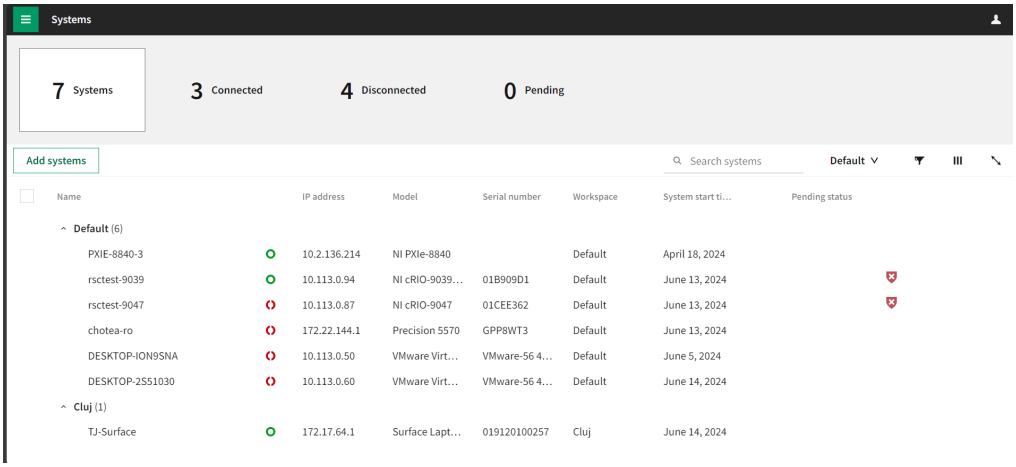

Figure 2: The UX of the Systems Application

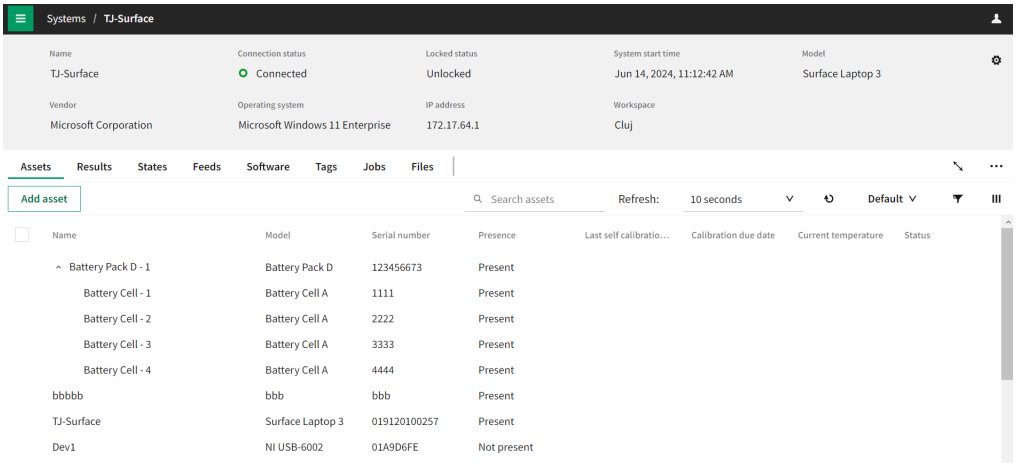

Figure 3: The UX of the detailed view of the digital twin of a particular test system

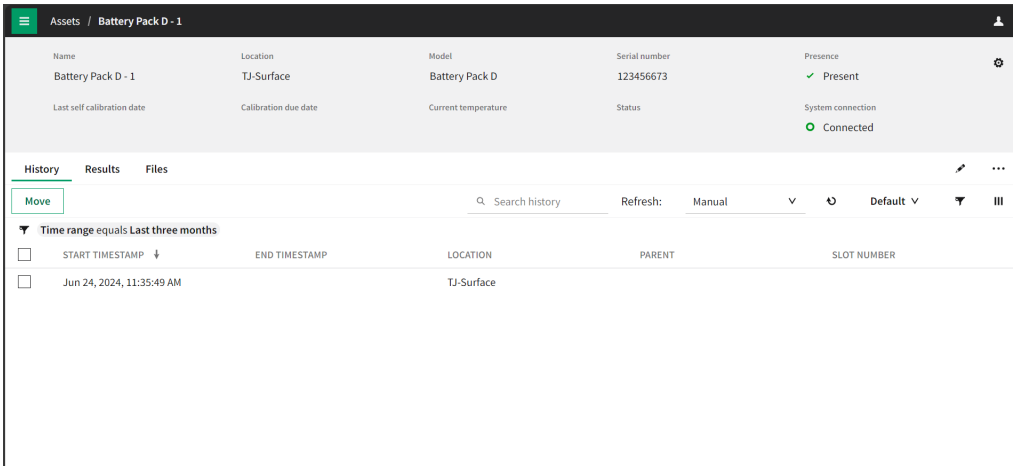

Figure 4: The UX of the assets within a specific system in SystemLink