A Cloud-based platform Reference Model for Remote Control and Monitoring for Laboratories of Inspection and Certification Companies

Master Thesis

Siyuan Liu
MSc Business Information Technology

UT Supervisors:
Prof.dr. Maria. E. Iacob
Dr.ir. Marten J.van Sinderen

September 7th, 2022

Faculty of Electrical Engineering,
Mathematics and Computer Science
P.O. Box 217
7500 AE Enschede
The Netherlands

University of Twente

A Cloud-based platform Reference Model for Remote Control and Monitoring for Laboratories of Inspection and Certification Companies

Abstract

Manual operations currently dominate the testing and certification industry, and there are problems such as low efficiency, high costs, and data islands. The research found that the Testing as a service (TaaS) reference model characterized by remote monitoring and remote control has been widely used in other industries, mainly the education industry, and has achieved good results. This study aims to provide inspection and certification companies with a cloud-based platform that enables remote monitoring and remote control by studying the existing TaaS reference model in academia. The study found some reference models of cloud-based platforms that can be used by inspection and certification companies. Next, this study summarizes the needs of stakeholders for the cloud-based platform through literature searches and real-world observations. However, research finds previous reference models do not fully meet stakeholder needs. Afterward, this study designs a cloud-based platform reference model and a cloud-based platform control model based on the reference model mentioned in the literature and the needs of stakeholders. Finally, this report applies the Technical Action Research (TAR) research method to verify the cloud-based platform reference model in the context of the data of SGS company and the case of TeREES. In order to evaluate the reference model, this report also conducts expert interviews as an evaluation process that confirms that the cloud-based platform reference model's design meets this report's main research objectives.

Keywords:
Testing as a service, cloud-based platform, reference model, ArchiMate

Siyuan Liu
s.liu-6@student.utwente.nl

Acknowledgment

This research marks the end of my bumpy but meaningful postgraduate career. In 2019, I was full of expectations for a study program in a foreign country taught in a non-native language. However, there have been so many accidents and misfortunes in the past period that I almost gave up on continuing the project. Fortunately, with the help of my friends, teachers, family, and some people willing to support me, I persisted until the program's successful conclusion. In addition to knowledge and skills, I have also learned a belief that each of us is not alone in facing difficulties. Please believe this.

Firstly, I would like to express my thanks to my supervisor Maria and Marten, for their valuable suggestions and ideas that guided me through the final project. Secondly, I would like to send a special thanks to my cousin Na, Fan, my study advisor Bibian, and all those who helped me through my darkest time. You have given me a lot of strength. Furthermore, I would like to express my gratitude to Cloud, Peng, and all his teammates for their high level of trust and selfless help. Finally, I would like to thank all my friends at UT for your generous help and encouraging conversation.

Thank you all for being with me on this journey!

Siyuan Liu
Suzhou, June 2023

Table of contents

1. Introduction

1.1 Problem Statement

Testing is evaluating a system or its component(s) to determine whether it satisfies the specified requirements. Cloud-based testing is a means of testing cloud-based applications that use resources found in the cloud. By leveraging a cloud computing solution for testing, organizations can shorten provisioning time because the cloud enables the provisioning of test servers on demand. Applying a cloud computing platform helps ensure unused servers are not sitting idle[1].

In educational fields, especially in STEM (Science, Technology, Engineering, and Mathematics), remote practical activities are extended and modified to be accessible online anytime from any device connected to the Internet. In computer science, education, virtualization tools, and technologies are gaining popularity over classical ones [2][3] as they significantly facilitate the conception of realistic, complex, controllable, and repeatable computer networking experiments [4]. The same advantages are also needed in the testing inspection and certification industry for the same purpose. The industry provides testing and inspection services for consumer products manufactured mostly in mainland China for overseas buyers and certification services for such products, as well as for relevant quality management systems.

Inspection and certification laboratories' equipment monitoring and control are still mainly operated by on-site manual operations. It has been observed that these experiments are time-consuming, especially temperature tests, which often take hours and rarely require human intervention. Due to the limited number of experimental equipment, the equipment often runs overnight to catch up with the project schedule. For the experiment to proceed normally, laboratory staff also need to stay on the experimental site to monitor the progress of the experiment. This kind of monitoring work often requires only a few instruction interventions, and automation can replace night shift work entirely.

On the other hand, customers who commission an inspection and certification company to conduct experiments want to obtain the results of laboratory tests to improve the customer's product. However, the staff and laboratory operators communicating with customers within inspection and certification companies are usually in different departments. Their knowledge backgrounds are also quite different. These factors may lead to misunderstandings in data sharing or even damage the reputation of inspection and certification companies. At the same time, the company's confidentiality policy may also affect the data sharing process. Therefore, there is an urgent need for a platform that can efficiently and compliantly realize data sharing.

1.2 Research Context and Motivation

1.1.1 Scientific context

Today we discuss “Online laboratory,” “Laboratory as a Service (Laas),” or “ Cloud-based testing,” which are usually under the context of educational purposes and the construction of laboratories in universities. However, in industry, the intelligent transformation of laboratories to improve management efficiency and better serve customers is being carried out simultaneously. On the one hand, deploying an online laboratory could realize remote control of the laboratory, which can effectively and reasonably set the testing instruments to maximize efficiency. On the other hand, online laboratory experiments can be adapted to experimental projects that require harsh external environments, high-density manual control, and rapid data provision. However, the current “online laboratory” models are usually designed for educational purposes. Its architecture does not provide better scalability for users outside the service organization.

In this report, “online laboratory” and “smart laboratory” are defined as a set of physical instruments controlled by the client following the predefined functionalities and services stored in the server. The definition follows [5, 6] Salzmann & Gillet and Tawfik’s paradigms to enable interoperability between server and client. According to a study by M. A. Bochicchio and A. Longo[3], in the last 20 years, the classic “laboratory” concept has been technologically extended according to four main dimensions, and remote laboratories are one of them[7, 8, 9, 10, 11, 12]. However, the existing remote laboratory models rarely focus on inspection companies, which have special requirements within themselves and with their stakeholders.

1.1.2 Practical context

SGS provides a context in which this research project takes place. SGS is a company that provides testing, inspection, and certification services. There are about 2,600 laboratories distributed in more than 100 countries and regions, delivering testing, inspection, and certification services to industrial manufacturing, public affairs, chemicals, health and safety, architecture, agriculture, energy, and many other related industries. Their value to society enables a better, safer, and more interconnected world.

Better; SGS enables a better world by helping businesses everywhere work efficiently, deliver quality, and trade with integrity and trust.

Safer; SGS enables a safer world by ensuring that the environment where you work and live is secure and clean and that the products you use or consume are safe.

More interconnected; SGS enables a more interconnected world by helping new technology reach consumers quickly and affordably, ensuring IT and data security, and using AI and IoT to develop smart cities[13].

This article was inspired by observations while working at the SGS Suzhou branch. The equipment in this division's laboratory is divided into the electromagnetic compatibility (EMC) test group and the safety test group. The electromagnetic compatibility (EMC) test group includes a 10-meter anechoic chamber, two 3-meter anechoic chambers, a radiated immunity test system, a set of automation Bluetooth/Wi-Fi regulation test systems, a set of millimeter wave test facility, and a set of Specific Absorption Rate (SAR) test system. The safety test group includes several programmable AC/DC variable frequency power supplies, several constant temperature/humidity chambers, a group of temperature shock chambers, a group of rapid temperature change chambers, and ten ovens. Typically, experiments involving groups of EMC experimental equipment are shorter, about 2 to 3 hours. Except for the SAR experimental equipment, which only one person can carry, other equipment requires two or more people to operate. Only one person is required to experiment with the voltage-related equipment in the safety test equipment group. The experiment duration varies from 1 to 3 hours; the temperature-related equipment requires one to two people, and the experiment lasts at least 5 hours.

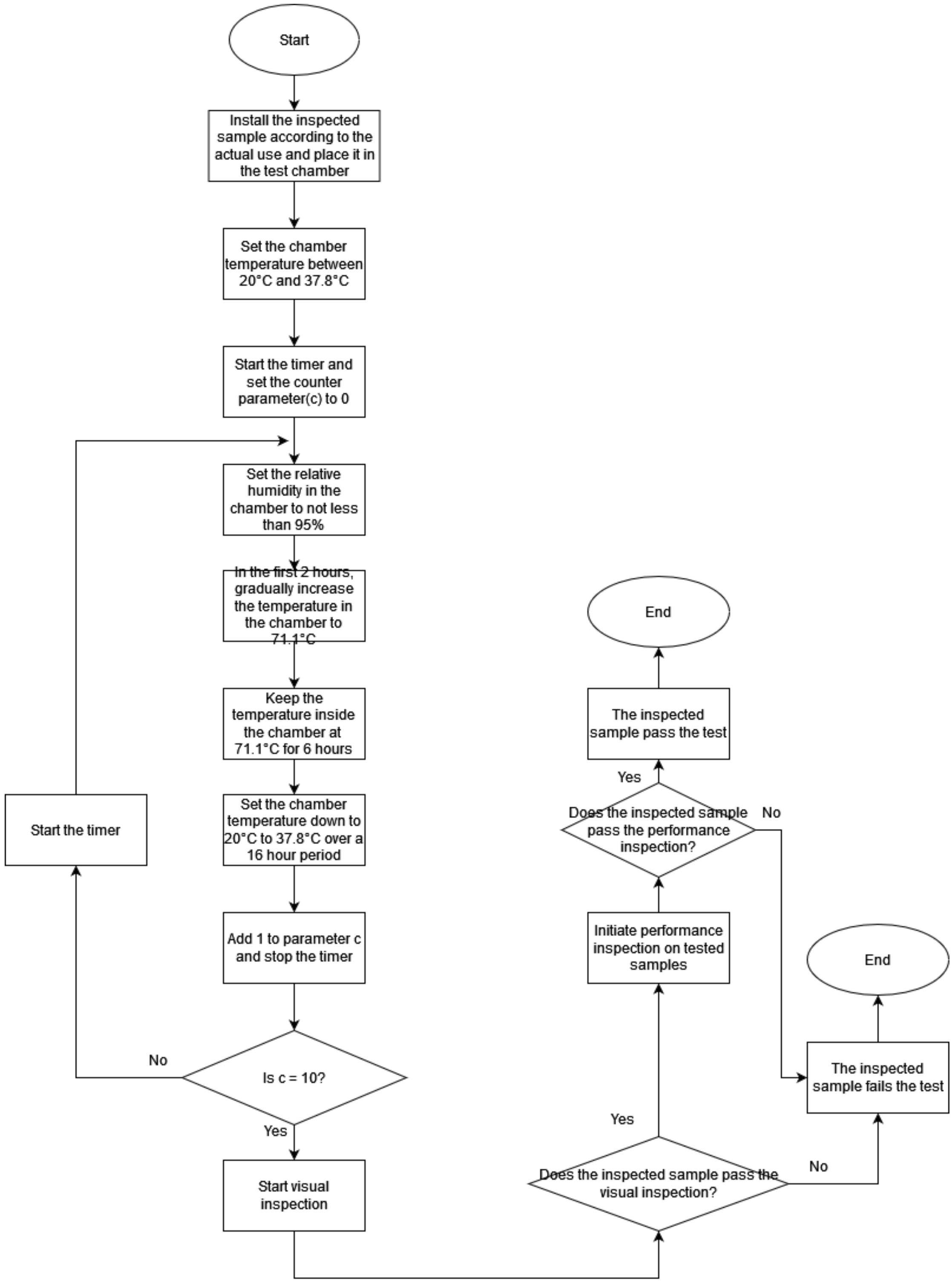


Figure 1 The humidity test in accordance with the Chinese Civil Aviation Technical Standard CTSO-C73; Summarized from http://www.caac.gov.cn/XXGK/XXGK/BZGF/JSBZGD/201511/t20151102_7840.html

Figure 1 shows the flow chart of the humidity test in accordance with the Chinese Civil Aviation Technical Standard CTSO-C73. A humidity test is one of the tasks performed by the equipment of the safety test group. The steps in this flow chart are all implemented manually at present. This process requires at least 240 hours of manual on-site monitoring, consuming a lot of workforce and costs. However, the steps before the visual inspection in the process, that is, the process on the left side of the flow chart, can be realized entirely through remote monitoring, remote control, and automation.

Currently, SGS has applied a few integrated automation platforms based on local server control. It is called Safety Testing Automation Systems (STAS ®). STAS ® is a data acquisition and motion control platform for electrical and another safety testing. It has realized the automation from testing to reporting by translating the test methods into software language by establishing the connection and communication between the control platform and the power supply system, testing instruments, and auxiliary devices. It has now been developed to the fifth generation STAS®-Plus. And the cloud-based platform that realizes remote control and remote monitoring supporting STAS®-Plus has not yet been implemented. SGS has an idea for remote monitoring and remote-control platform, namely Test Resource & Equipment Eco-System (TeREES®). TeREES® is going to be an IoT-based laboratory resource management system. It has the following features:

- Dashboard to monitor the running status of 80 environmental test equipment;
- Experiment online booking & scheduling;
- Online test plan programming
- Data acquisition & processing
- Equipment profile management

Furthermore, SGS would like to allow other stakeholders, like their clients, to access the cloud-based platform. They have reached cooperation intentions with some well-known companies to provide remote online equipment monitoring systems in the future. The system is based on STAS®-Plus and TeREES®. Take the cooperation between SGS and a large wind power group as an example. It is called Oil Condition Monitoring (OCM OnlineTM). The OCM OnlineTM system has the following features:

- Sensors are connected by STAS®-Plus and installed in equipment (E.g., turbines) for oil condition (E.g., contamination, wear, viscosity) monitoring;
- Real-time data to SGS Cloud via 4G/5G;
- Cloud-based platform for data monitoring/ analysis.

SGS expects the OCM OnlineTM system to connect to the client’s diagnosis platform to ensure the operation & maintenance of the wind field. The OCM OnlineTM planned system architecture is presented in Figure 2.

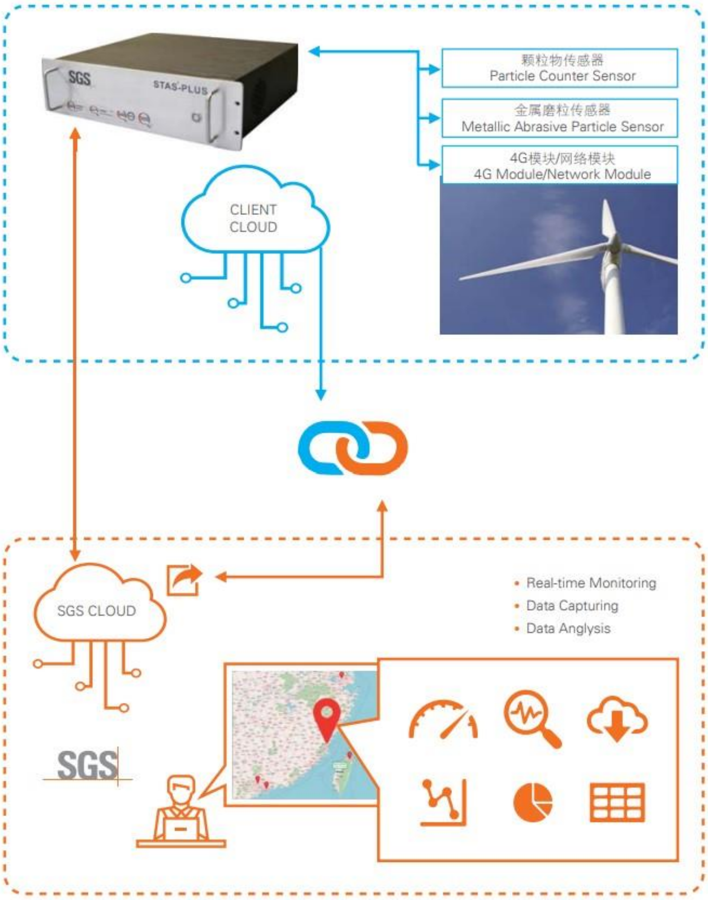


Figure 2 OCM Online™ planned basic architecture

1.3 Research Objectives

The high-level goal of this report is to provide appropriate cloud-based testing for testing and certification companies to improve their business performance and complete complicated tasks. This architecture includes recommendations for an organizational shift from companies using traditional testing models to cloud-based platforms. The high-level goal of this research is translated into the following main research question:

What is an appropriate cloud-based testing reference model for the SGS testing lab, and how should it be implemented?

The main research question is divided into three secondary research objectives according to the logical order of the research. Research must look for relevant cloud test architectures in the published literature and examine and certify company stakeholders' needs for cloud test architectures. Assuming that finding models from the literature can only partially meet the needs of stakeholders for cloud test architecture, this report will design a cloud test architecture that meets the needs of stakeholders based on the cloud test architecture found in literature searches.

Sub – Research Objective 1

To find one or more reference models for the design of the cloud-based testing according to published literature;

Research Question 1(RQ1):
What is the existing reference model for the cloud-based testing?

Sub – Research Objective 2
To find the needs of stakeholders for cloud-based testing and the changes to them after the adoption of cloud-based testing.

RQ2:
Which are the benefits of adopting cloud-based testing platform for the stakeholders?

RQ3:
What requirements are needed to be fulfilled for testing and certification company and their stakeholders when adopting cloud-based testing?

Sub – Research Objective 3
To design/adopt a cloud-based testing reference model for a testing and certification company and give advice on its implementation process.

RQ4:
How should the cloud-based testing reference model be designed?

RQ5:
How to change the laboratory management policy to fit the cloud-based testing system?

RQ6:
How effective is the cloud-based testing reference model?

In order to accomplish these goals, this report will investigate the existing literature in academia to find useful reference models for cloud-based testing and answer RQ1 by summarizing these reference models. This article will answer RQ2 and RQ3 through a literature survey, and stakeholder needs analysis. This article will answer RQ4, RQ5, and RQ6 through treatment design and status survey.

1.4 Research Methodology

This report follows the Design Science Research Methodology (DSRM) defined by Peffers et al. [14].

1. Problem Identification & Motivation; The main objective is to define the specific research problem and justify the solution's value. A literature review is performed in this stage. The aim is to summarize all existing content on research questions and objectives.
2. Define the objectives for a solution; The main research object is defined and broken down into three sub-objectives. The main research object will be fulfilled with an artifact that fits the pre-defined research question.

3. Design and development; This phase includes academia's model reference for the cloud-based testing reference model suitable for verification and certification companies, the existing architecture, and requirements of SGS, and the requirements for the model formed in the case study.
4. Demonstration & Evaluation; SGS provides a practical experimental environment for the model. For the evaluation process, semi-structured interviews were introduced to incorporate expert opinion to assess model effectiveness.
5. Communication; This dissertation exists and aims to provide testing and certification companies with a reference for the communication of cloud-based testing laboratory architecture.

1.5 Thesis Structure

Chapter	Content	Related Sub-RO and RQ	Method
2	Chapter 2 uses the systematic literature review method to search the Scopus database with keywords to find out whether there is a cloud-based reference model for third-party inspection and certification companies to adopt.	Sub-RO1 RQ1	Systematic literature review method
3	Chapter 3 discusses the benefits of using a cloud-based testing platform for inspection and certification companies and stakeholder needs for a cloud-based testing platform by summarizing the results of a systematic literature review and field study.	Sub-RO2 RQ2 & RQ3	Literature review & Field study
4	Chapter 4 uses the relevant cloud test platform model found in the second chapter and combines the needs of stakeholders discussed in the third chapter to design a cloud test platform model suitable for inspection and certification companies.	Sub-RO3 RQ4 & RQ5	Literature review & Field study
5	Chapter 5 uses the case of TeREES from SGS to provide context for the cloud-based platform and interviews three experts to evaluate the example designed against the reference model (figure 24).	Sub-RO3 RQ6	Expert evaluation

1.6 Practical and Scientific Relevance

This section will introduce the relevance from a practical and scientific perspective.

1.6.1 Practical relevance

Industry-related research shows remote laboratory models can effectively improve operational efficiency [15]. The remote laboratory reference model proposed in this report is meant to help inspection and certification companies to improve their efficiency and enhance the client experience. Using the model and the supporting management policies, practitioners can obtain a reference informing them what part should be considered when conducting remote and intelligent laboratories. Although this experimental model is based on the laboratory architecture of SGS, the architecture of this model refers to the architecture of remote laboratory models in academia. This report believes that the laboratories of other testing and certification companies will also benefit from the construction of remote laboratories.

1.6.2 Scientific relevance

Due to the influence of Industry 4.0, more enterprises and organizations are gradually paying attention to automation to increase their efficiency and enhance customer experience. However, based on our research, there isn't much attention drawn to this direction. The current "online laboratory" models are usually designed for educational purposes. This research gathers, integrates, and analyzes the current method and reference model from selected sources and proposes an online laboratory reference model to automate inspection and certification companies.

To sum up, the paper makes two contributions of scientific relevance. First, we contribute a reference model for inspection and certification companies to reform their current laboratory architecture into a remote laboratory architecture. Second, we propose a case demonstrating how the architecture works in an inspection and certification company that helps it form its remote laboratory architecture. We also believe that follow-up research is needed to improve its adaptability to different projects of different companies in the inspection and certification industry.

2. Literature Review

This chapter conducts a systematic literature review. 2.1 Introduces research methods and keywords for literature search. 2.2 summarizes the evaluation criteria for the quality of literature. 2.3 summarize the results of the literature search. This chapter is related to Sub-Research object 1 and Research question 1.

2.1 Methodology

I applied the basic systematic literature review method described by Kitchenham [16]. The primary searching method is automated search using complex keyword combinations via Scopus. These keywords are split into three groups:

1. "Laboratory as a service" OR "Testing as a service" OR "Smart testing" OR "Smart Inspection" OR "Remote laboratory";
2. "Architecture" OR "Model" OR "Reference Model";
3. "Cloud" OR "Cloud-based" OR "Distributed";

Since SCOPUS allowed the construction of complex searches and reducing the number of searches reduces the problem of integrating search results, the SCOPUS search was based on a complex search query:

Search: TITLE-ABS-KEY ("Laboratory as a service" OR "Testing as a service" OR " Smart testing" OR "Smart Inspection" OR "Remote laboratory") AND TITLE-ABS-KEY ("Architecture" OR "Model" OR "Reference Model") AND TITLE-ABS-KEY ("Cloud" OR "Cloud-based" OR "Distributed")

The automated search found 164 studies through the search.

I re-checked China national knowledge infrastructure(CNKI), and these two papers are still missing. However, I found that any other papers do not cite these two papers, so I concluded that I hadn't missed any other mainstream paper and did not need to take more detailed searches for missing studies.

2.2 Performance Criteria

The main object of the paper was to discuss whether there are cloud-based reference models for third-party inspection and certification companies to adopt. This inclusion criterion defines the basic scope of the study I reviewed.

The selection of papers is divided into two steps. The first selection process was designed to exclude irrelevant, duplicate papers based on title, abstract, keywords, and papers that cannot be found. Each paper is screened to identify papers that can be rejected based on abstract and title. This step led to the exclusion of 38 papers.

These papers do not present a remote laboratory model nor identify the critical infrastructure of cloud-based testing technology (e.g., [16] presented an evaluation method against the ability of a knowledge management cloud without discussing the critical components of a cloud management system.)

The second step is to select papers from the remaining papers based on the inclusion and exclusion criteria below:

- The paper is complete (not a preface or an introduction to a proceeding).
- At least a model is presented in the paper (not an introduction to recent development or comprehensive literature review).
- The model should have specific application scenarios, such as educational scenarios.

This step resulted in the exclusion of 17 papers. After this step is completed, there are 110 articles left for reference.

To assess the quality of the paper, I conducted a few questions based on the review questions and research goals. Sample answers to a list of assessment questions are also provided to help understand the assessment form for the essay.

Q1: Did the paper report the critical infrastructures for building a remote laboratory model? If it did, what are they?

This question is set to answer RQ1 and to complete Sub-Research Object 1. This question is to find a suitable cloud-based testing reference model for designing a cloud-based testing model suitable for testing and certification companies.

Q2: Did the paper report the benefit and drawbacks of adopting cloud-based testing technology/remote laboratory system? If it did, what are they?

This question is set to answer RQ2 and RQ3 and to complete Sub-Research Object 2. To answer RQ2, Q2 is asked to find the requirement of stakeholders from the paper introducing a cloud-based testing reference model in a different industry. Since the benefits of cloud-based testing are often categorized as benefits to different stakeholders in other industries, this question can infer the benefits of cloud-based testing for stakeholders in testing and certification companies. I will analyze the SGS stakeholders' requirements using the results as a reference. Similarly, in order to find answers for RQ3, Q2 can also find out the benefits of cloud-based testing models to other industry stakeholders, allowing this report to deduce the benefits of cloud-based testing to stakeholders of testing and certification companies.

Q3: Did the paper report the implementation process and steps need to be taken during the adoption?

This question is set to answer RQ4. Suppose the referenced paper mentions the detailed process of the implementation phase of the cloud-based testing reference model in other industries. In that case, it is easy to apply it to the implementation phase of the cloud-based testing model in the testing and certification company.

The questions are scored as follows:

Question 1: Yes(Y), the paper reports every infrastructure and identifies its use; Partly(P), the paper reports only part of the infrastructures and their use; No(N), the paper reports nothing about the composition of the remote laboratory model.

Question 2: Yes(Y), the paper reports a few benefits and drawbacks of adopting cloud-based testing technology/remote laboratory system; No(N), the paper doesn't report any benefit or drawbacks of adopting cloud-based testing technology/remote laboratory system.

Question 3: Yes(Y), the paper reports every implementation step, including validation in detail; Partly(P), the paper reports part of the implementation steps with some steps defined; No(N), the paper doesn't mention anything related to implementation.

The scoring procedure is Y = 1, P = 0.5, N = 0. The scoring results are shown in the table (Table 8) under reference.

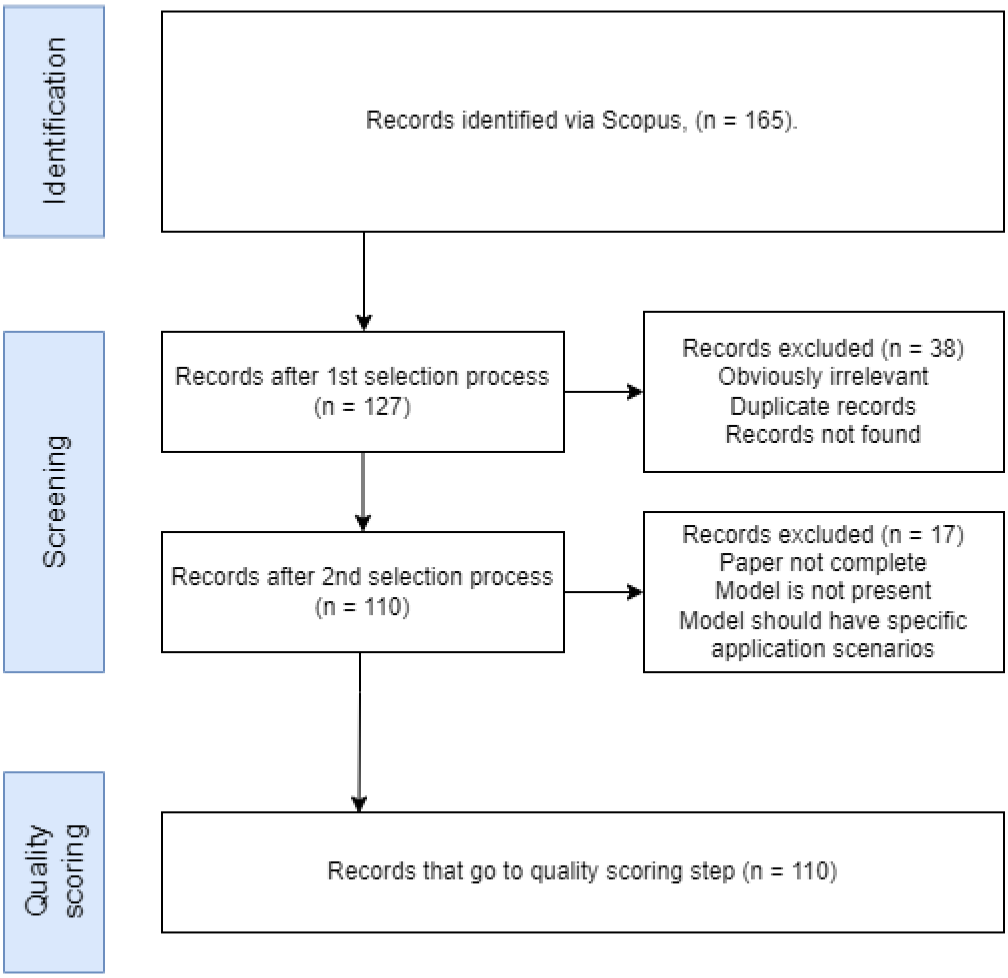


Figure 3 Flow chart of literature selection steps

2.3 Review Results

2.3.1 Key infrastructures for remote laboratory models

In summary, Q1 asked about the critical infrastructures of the remote laboratory model. It's clear that on the infrastructure level, there are four key components: measurement instrument, lab server, management system, and client [7]. However, there are two different types of models for constructing the network. Gao et al. [18] proposed the difference between traditional cloud server platforms and SOA-oriented cloud servers. They believed that SOA-oriented cloud servers have advantages in testing objectives and focus, testing environment, testing techniques, systematic tool composition and integration, large-scale test simulation, service delivery, and test support service.

Physical Mashups is an Internet of Things software architecture based on REST-style Web services proposed by researchers at the Swiss Federal Institute of Technology in Zurich [19]. Its reference model is shown in Figure 4. This model builds the device side as a web service built on the smart gateway. This web service is provided in the form of Pull/Push. Two modules in the cloud are provided: an event hub and physical mashups. The event hub distributes the events triggered by the gateway Web service to the corresponding applications. The physical mashups module aggregates the smart gateway's web service with the cloud's web service to quickly create user-defined applications. In addition, each application can also directly access the Web service provided by the intelligent gateway.

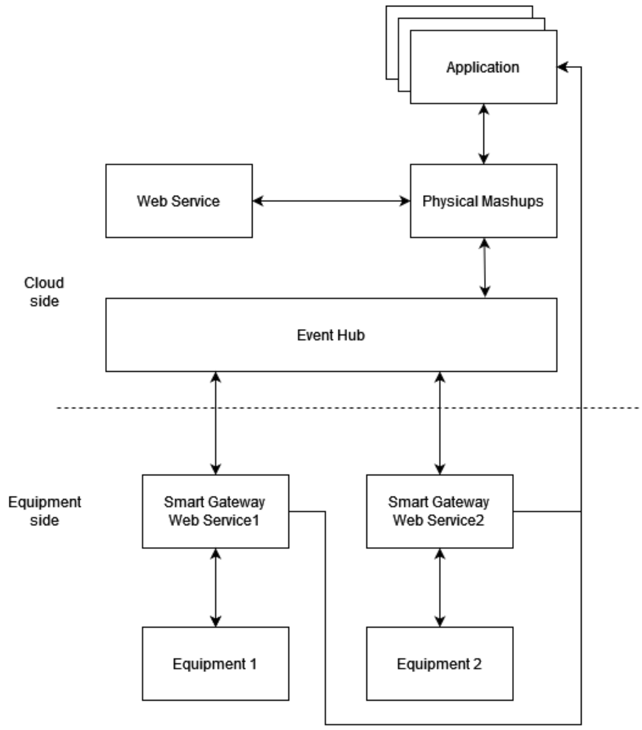


Figure 4 Physical Mashups architecture

Aguru et al.[20] introduced three kinds of architecture that give a protocol for defining the standards and techniques.

The simplest is the Three-Layer Architecture(a). It consists of a perception layer, a network layer, and an application layer. The perception layer gathers data through physical devices. The network layer collects data from the perception layer for storage and distribution. The application layer maintains communication with the user for accessing applications and data from specific resources.

The middleware-based architecture(b) contains an application layer, coordination layer, backbone network layer, edge & access layer, and middleware layer. The middleware layer is responsible for information communication between the network and application layers. Middleware supports access to real-time information within and between systems in an IoT network.

The service-oriented architecture (c) includes objects, object abstraction, service management, service composition, and application layer. This architecture focuses on adapting applications to different tasks. The application will call the service in the network to be suitable for the task.

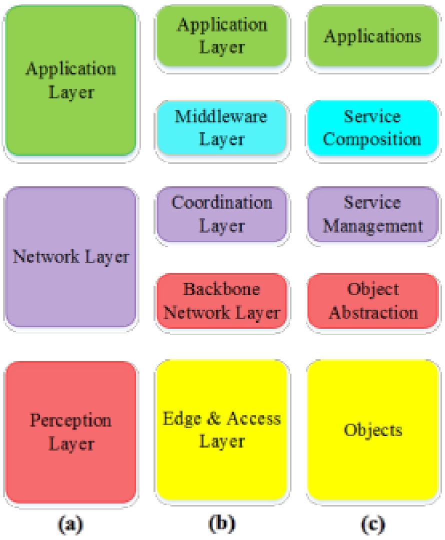


Figure 5 Three-Layer Architecture(a), middle-ware based architecture(b) and service -oriented architecture (c)

As [21], 2014 proposed in MIDAS SOA-oriented cloud-based platform, the projects were launched under two cases: a Healthcare services pilot for managing patients affected by chronic diseases and a GS1 Logistic Interoperability Model supply chain pilot. These SOA-friendly usage environments usually consist of a series of processes rather than a single-point event. In the face of point events and the different outcomes of events, especially when complex experimental conditions are involved, semi-automated systems do not allow operators to identify problems quickly. In the electromagnetic compatibility (EMC) experiment, due to the position and distance of the sample from the signal, whether the ground reflection is considered or not, and the dynamic change of the experimental site, the SOA-oriented platform is not as easy as the traditional cloud-based platform to find out the problem of the experiment. Thus, SOA-oriented platforms are not necessarily more advantageous than traditional platforms regarding the experimental environment and adaptation to conditions.

2.3.2 Benefits of remote laboratory model

Q2 asked about the benefit of using a remote laboratory model. The SOA-oriented remote laboratory model helps to resolve the IoT-specific testing issues regarding coordination and scalability semi-automatically. However, considering the complexity of the actual experimental environment, the traditional cloud-based platform suits an actual testing environment well. The cloud allows systems to dynamically provide the computing resources their users need, thus reducing expenses and energy consumption as well as improving their scalability [22, 23]. Regarding the needs of stakeholders, since the articles surveyed in this literature review can be divided into reference models built for remote laboratories in the field of education or engineering, the needs of stakeholders also need to be appropriately adjusted according to different fields. The following is a stakeholder analysis in education[24].

- Students need to use experimental equipment regardless of time and place so that they can flexibly arrange their study plans;
- Universities hope to make full use of laboratory resources to realize cross-regional and cross-organizational sharing of valuable experimental equipment;
- Finance wants to reduce lab maintenance costs;
- Lab management wants to reduce lab maintenance.

The following is a stakeholder analysis in the engineering field:[25]

- The legal department and IT department are concerned that the confidential experimental data will not be disseminated indiscriminately, and every sharing is recorded;
- The laboratory department and other related department cares about the performance parameters of the new platform, such as access time, runtime, capacity, latency, etc., that are good enough not to affect work efficiency;
- Customers care about the stability of the system and information sharing, hope that the new platform will not affect the correctness of the test results, and hope to understand some experimental data to understand and improve the product;
- IT departments expect new platforms to be highly maintainable, testable, modular, and modifiable to complete maintenance work better and faster.

According to Gao [13] and Aziz [50], the remote laboratory model has the following benefits:
1. It allows sharing of testing resources among many users and programs, which could keep a high overall rate of utilization. Therefore, the hardware cost is better amortized.
2. On-demand automated testing service in 365/7/24. While the testing process is automated and distributed, the experimental tasks can be distributed at any time.
3. While more information is shared with the cloud-based platform, the information could be shared with clients and other stakeholders for better customer service.
4. SOA architecture includes test environment construction and configuration, tool selection, configuration and deployment, and test solution composition and integration [13]. This feature is suitable for customized testing.

According to Troger & Rasche [133], Gao [67], and Yu [144], using an Enterprise Service Bus (ESB) has the following advantages:
1. Standardized SOAP protocol, clients, and infrastructure can depend on different platforms; This allows client and infrastructure implementation can rely on different platforms [133].
2. State interaction with the Service is provided to the client in an interoperable and standardized way; Standardized data allows the data to be processed and reused within the company and with customers.
3. Leverage existing testing tools to build a configurable test environment to support large-scale user-facing testing and Internet data traffic stress [67].

2.3.3 Implementation of remote laboratory model

Q3 asked about the implementation steps of a remote laboratory model. The implementation steps follow the design cycle: Problem investigation, model design, model validation, model implementation, and implementation evaluation. About 25% of the reviewed paper have advised on implementation. For those paper that introduces the implementation process, they mainly implement the architecture following the step: preparing hardware; preparing the basic engine of software; preparing middleware; constructing cloud instruments; software testing. The implementation process introduced by Yan [37] is the most typical. They divide the whole cloud-based system into five parts:

1. Web Service LoadTester : LoadTester is responsible for receiving load test tasks from testers and displaying their test results.
2. Test Task Manager; Test Task Manager is the core module. It oversees test task dispatching, test results gathering, and preliminary trim. Test Task Manager receives the test task from LoadTester and starts the test process.
3. Test Engine; TestEngine receives the test request, then prepares the corresponding number of test threads and reply Test Task Manager with the 'ready' response. When ordered to start the test process, TestEngine activates all the ready threads to invoke the target service simultaneously.
4. SA Manager; SA Manager is a middleware manager. It is in charge of registering and querying service applications and decides the deployment and undeployment of all types of service applications.
5. Local Agent; Local Agent assists SA Manager with managing software applications in a computing node. It is also used to support the operation of TestEngine deployment, undeployment, registration, etc.

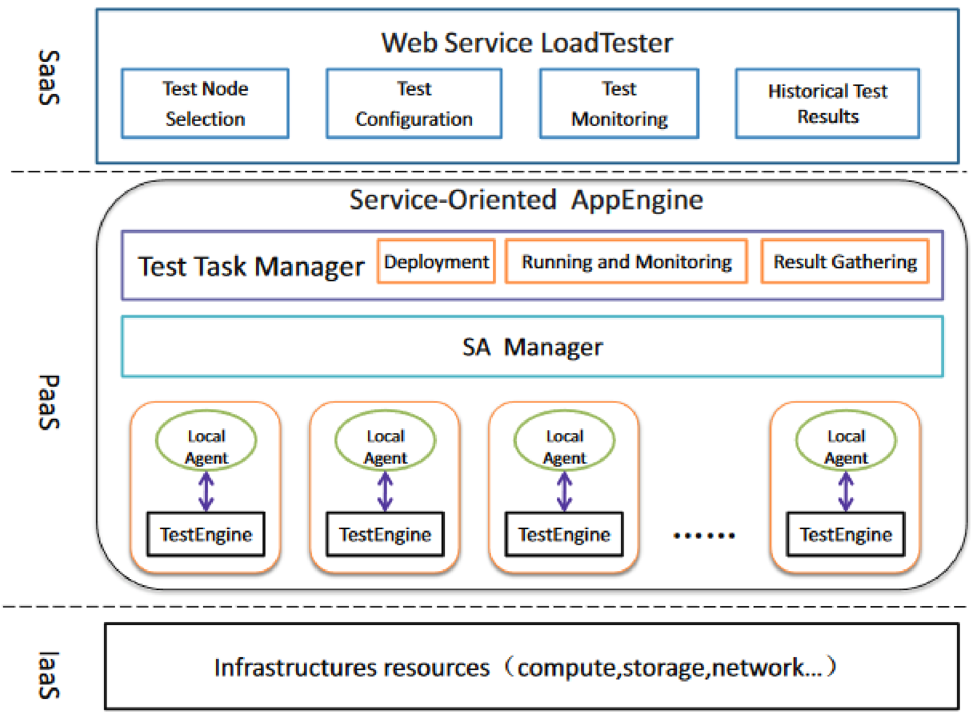


Fig. 3. System Architecture of WS-TaaS

Figure 6 five implementation parts introduced by Yan [37].

However, after comparing the mentioned remote testing architecture, several differences between the models in the literature and this case could be seen. First, most of the mentioned architecture is for software testing. The testing environment requirements are completely different in software testing from physical testing. Compared with virtual labs, remote labs retain many key characteristics of physical labs, such as authenticity, complexity, uncertainty, errors, and psychology of presence[140]. Similarly, due to the particularity of physical testing, the complex process of calling components on the virtual experiment platform cannot be implemented in physical testing. Therefore, the automation software testing architecture in [25, 135, 110] is unsuitable for the physical testing environment. [27, 28, 102] proposed automation testing for IoT devices like the TeREES® system used currently in SGS. The central cloud-based platform receives data from sensors and gives simple commands automatically. However, the automation platform is only used for monitoring in SGS, and it remains to be tested whether it can be applied in experiments that require more human support.

Bochicchio & Longo [3] mentioned a distributed remote-control laboratory, a good example of a remote laboratory for physical use. This report refers to their mode of transmitting the data collected by the experimental equipment back to the user interface through middleware using an access control unit. But the distributed mode of its architecture means that different users use different devices of the same type. The environment discussed in this article is that different users use different types of devices. Secondly, Bochicchio & Longo's [3, 55] architecture faces a tutor with several students. Therefore, they apply for video access in its model for a better educational effect. This will only allow the platform to get complicated in our case. In my experience, most clients want a brief progress report of their testing, and most engineers would turn to a detailed data dashboard. Thus, video surveillance is not needed here. Other distributed remote laboratory models for educational purposes also share these characteristics [8, 27, 28, 56, 74, 83, 85, 130].

However, to answer the research question: "What is a suitable cloud test architecture for an SGS test lab, and how should it be implemented?" three questions need to be answered. First, it is important to clarify which test equipment is suitable for SOA architecture and which is not. SGS Suzhou branch has applied three groups of testing equipment: The safety test group, the Electromagnetic compatibility(EMS) group, and the Wireless test group. It's important to see which types of testing equipment are suitable for SOA suitable or non-suitable testing units in the architecture. Secondly, a bus alone couldn't help translate and transfer the command and status in the cloud layer. Finding a suitable structure to connect the user interface with the testing equipment is necessary. To do that, I need to investigate the compatibility of the test device's operating system. Finally, the corresponding laboratory management system should also be changed due to the change in laboratory structure. A renewed management method would be proposed based on the current SGS testing lab management criteria.

3. Requirement Analysis

This chapter analyzes the requirements of the cloud-based platform and is divided into three parts. 3.1 outlines the expected advantages of cloud-based platforms using the results of literature research. 3.2 A needs analysis has been carried out according to different inspection and certification company stakeholders. 3.3 The function analysis of the cloud-based platform is carried out. This chapter is related to Sub-research Object 2 and research questions 2 and 3.

3.1 Expected advantages of a TaaS platform in previous studies

A TaaS platform has three aspects to be measured. They are effectiveness, security, and reliability [26, 27, 28].

Validity. The testing results obtained by the TaaS platform must be valid. This requirement requires the TaaS platform to replicate the complete state of the data provided by the device during the test.

Safety. A TaaS platform must be secure, especially for the users who use the platform and the information transmitted in the platform. That means preventing platforms from being a conduit for malicious files, sharing information with people who should not see it, and security holes in users' devices.

Reliability. A TaaS platform needs to be available when it is needed. This means that the TaaS platform must be able to detect the failure of the controlled equipment, self-check the failure, and back up important information. The TaaS platform should promptly call the staff for maintenance and keep maintenance logs if necessary.

3.2 Stakeholder Analysis

Through my work experience in SGS Suzhou, I found that the stakeholders in contact with the cloud-based platform can be mainly divided into the following four categories:

1. Laboratory operators: responsibilities include managing detected samples, managing test devices, executing tests, forming test reports, etc.;
2. Administrators: who control the whole process of the test;
3. Certification team: responsibilities include producing certificates based on test reports;
4. Client: Requirements include understanding test data and obtaining test reports and certificates.

To understand more about the stakeholders' requirements on a cloud-based platform, I conducted an unstructured interview with an expert from SGS. The expert (Expert A) is introduced in 5.1.

In summary, stakeholders are divided into four categories: clients (outside the organization), certificate teams, laboratory operators, and managers. Clients want to get test data, monitoring data, and customized test reports about their samples. The certificate team needs the test standard and the matching test report. What the laboratory operator needs the most is to match the test results according to the test standards and automatically from the test report. At the same time, laboratory operators are also looking to remote monitoring and automation to reduce human resource waste. Managers require all the access that lab operators have. In addition, managers need a dashboard to show all the projects they manage, as well as access to share information with users outside the organization.

According to [98], lab operators are required to be responsible for the test equipment and process. This means that laboratory operators need to remotely control the test equipment to ensure the normal operation of the test equipment and test process. Fully automated testing is not required in the testing and certification industry. And based on [68], it is required a cloud-based platform to reduce the consumption of energy/human resources. Thus, automation, remote control, and remote monitoring seem to be necessary for the cloud-based platform to reduce work from the lab operators. At the same time, this also requires the architecture design of the cloud-based platform to be simplified as much as possible.

According to the responsibilities of each stakeholder, my Interview with an expert from SGS (Appendix F), the observation of the work of relevant personnel (refer to the motivation in 1.2), and the literature review (refer to the review results in 2.3), I organize the requirements of each type of stakeholder in the following table. The following table includes people who impact the transformation from a local control architecture to SOA-based architecture.

Stakeholder's name	Impact	What's important
Laboratory operator	High	Remote control, Remote monitoring, Equipment control automation, Test data processing
Administrator	Medium	Remote monitoring, Remote control, Information display dashboard, Information sharing with external user
Certificate team	Low	Testing results/standards sharing within the organization
Client	Medium	Information sharing with external user, Real-time monitoring (in the future)

Table 1 Stakeholder analysis result based on SGS's Suzhou's local organization

Regarding the expected benefit of the reference model, the SOA-oriented remote laboratory model helps to resolve the IoT-specific testing issues regarding coordination and scalability semi-automatically. However, considering the complexity of the actual experimental environment, the traditional cloud-based platform suits well in an actual testing environment.

The cloud allows systems to dynamically provide the computing resources their users need, thus reducing expenses and energy consumption as well as improving their scalability [22, 23].

3.3 Functional Analysis

According to SGS's vision document for a cloud-based platform (refer to Appendix E) and literature review (refer to the review results in 2.3), I organize the functions analysis of the cloud-based platform.

The functional analysis for designing the cloud-based testing platform reference model is mainly three aspects: information acquisition, data transmission, data processing, and equipment control.

Information acquisition: Platform-aware information includes the working state and properties of the device. The perceived information type is mainly information data, which may include image and video data in the future. This report takes information data as an example at this stage. The information data includes the working temperature, working state, working time of the temperature control box, the number of voltage shocks of the voltage detection equipment, the voltage value, and the test duration.

Data transmission: Based on basic data acquisition, the system designer selects one or more combinations of data transmission modes such as 4G/5G, Wi-Fi, wired network, local area network, LORA, NB-IoT, and other data transmission modes to realize data information according to the basic conditions of the site. In the SGS's laboratory, they apply Wi-Fi for data transmission.

Data processing and equipment control: First, administrators can log in with a username and password. Through the docking with MySQL database, the efficient management of basic data information can be realized. Through the interaction between employees and the cloud-based platform and database, the appointment and start of inspection tasks, such as viewing and managing equipment data and status, are convenient for laboratory operators to manage equipment. The cloud-based platform communicates instantly with multiple equipment management systems (STARS-PLUS) through middleware and feeds the results to the interactive interface in real time. The equipment management system (STARS-PLUS) completes the tasks in the inspection plan under the reservation of the cloud-based platform and controls the temperature and time independently. In addition, laboratory operators can also realize on-site control by operating experimental equipment on-site.

4. Artifact Design

This chapter describes the design of the artifact to fulfill the sub – RO 3: To design/adopt a cloud-based testing reference model for a testing and certification company and give advice on its implementation process. While designing the reference model, the functional requirement and stakeholders' needs discussed in the previous chapter (chapter 3) will be considered.

Step	Description	Related Sections	Related Sub-RO and RQs
1	Understand the current state of an inspection and certification company: ● What are the business processes of an inspection and certification company? ● How do the software applications and technology components organize?	4.1	Sub-RO3 RQ4 & RQ 5
2	Analyze the current state of the baseline architecture ● Identify the gaps between baseline architecture and stakeholders' needs. ● Identify the flaws existing in current business processes.	4.2	
3	Propose a target architecture. ● How is the architecture organized (Cloud-based testing platform)? ● How will the architecture affect the business processes?	4.3(Proposed architecture) 4.4(Control method) 4.5(Access control)	

Table 2 Artifact design method proposal

In the following chapter, three critical elements of the newly-proposed cloud laboratory architecture are analyzed and discussed: baseline architecture (4.1), flaws in the current process (4.2), and target architecture (4.3).

"A reference model is an abstract framework for understanding significant relationships among the entities of some environment and for developing consistent standards or specifications supporting that environment. A reference model is not directly tied to standards, technologies, or concrete implementation details. However, it does seek to provide a common semantics that can be used unambiguously across and between different implementations." [29]

According to this definition, this report will introduce the ArchiMate language environment to describe the existing SGS laboratory business process, data access, and service composition in 4.1. In 4.2, this report will point out the relationship between the existing structure of SGS described in 4.1 and the needs of stakeholders. In 4.3, this report will indicate the target architecture that meets the stakeholder needs of Chapter 3 in the context of the ArchiMate language. In 4.4, this report will propose a control model for controlling the target architecture based on the target architecture proposed in 4.3 and the business process in 4.1. In 4.5, it will be defined based on the target framework proposed in 4.3 and SGS's existing experimental testing equipment and common sample items. In 4.6, based on the Basic Role-based access control (RBAC) model and the stakeholder requirements and functional requirements proposed in Chapter 3, two reference checklists of data permissions will be proposed to better meet the requirements.

4.1 Baseline Architecture

To introduce the newly-proposed cloud laboratory architecture, we must introduce the current situation of a general laboratory. Hence, modeling the baseline architecture is the first step.

In order to present the proposed architecture, the ArchiMate notations will be introduced. The ArichiMate framework decomposes an enterprise along two dimensions: layers, which represent successive abstraction levels at which an enterprise is modeled, and aspects, which represent different concerns of the enterprise that need to be modeled [30]. As shown in Figure 7, the ArchiMate framework consists of six layers and three aspects.

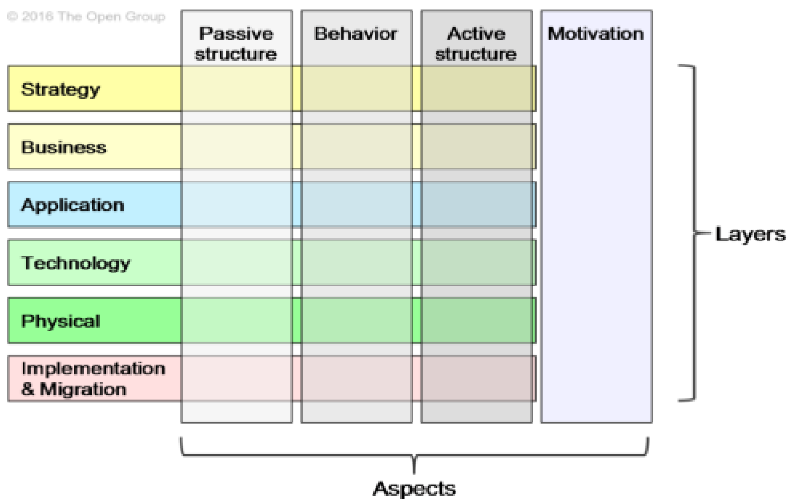


Figure 7 The ArchiMate framework [30]

Current state information is obtained through consultation with SGS Kunshan laboratory staff and information from the company's website and technical materials. The deliverable of the baseline architecture consists of two viewpoints. The first viewpoint introduces the core components of the inspection and testing company, the business process, and the required application and technical components. The second viewpoint is to show the construction of technical components and their connection with the application components and stuff.

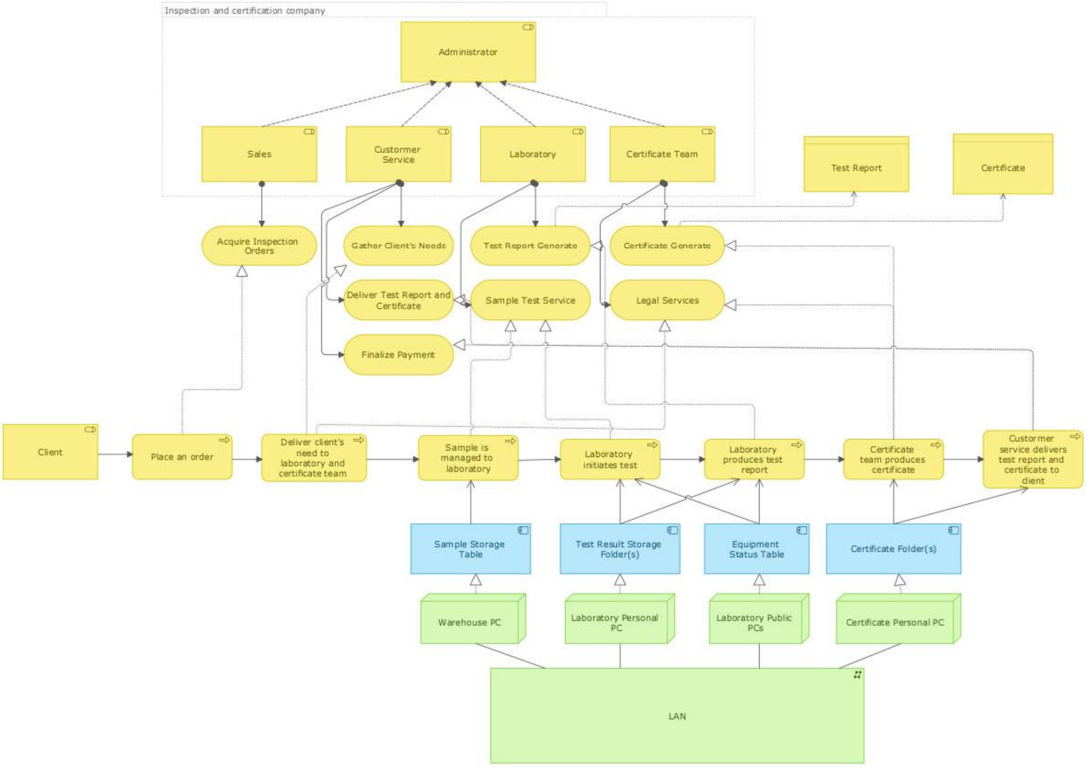


Figure 8 Total view of the baseline architecture of an inspection and certification company

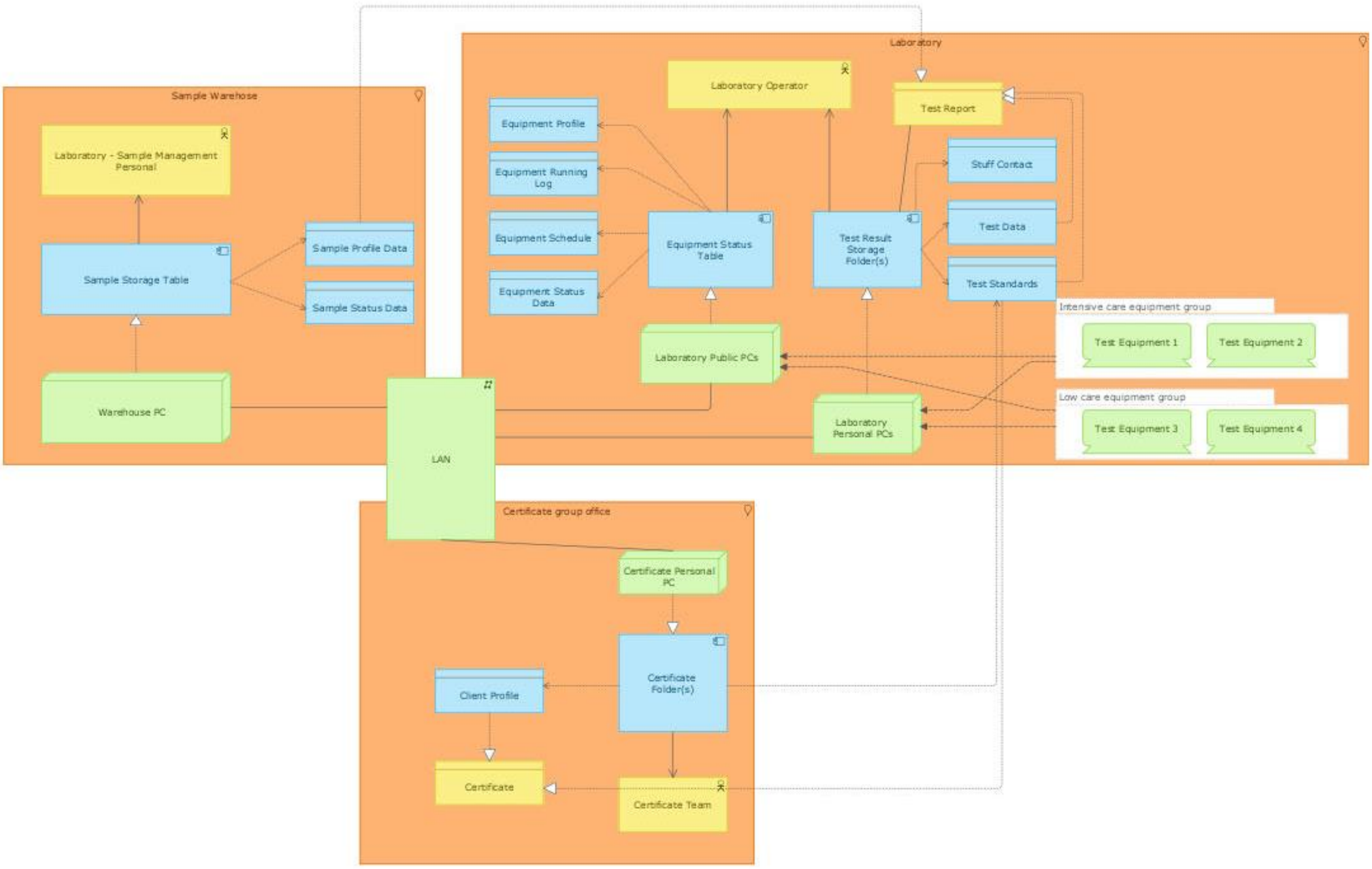


Figure 9 Baseline Data access view

We will take SGS's Kunshan laboratory as an example. This independent laboratory was just recruited to the SGS group. It is mainly used for electromagnetic compatibility (EMC) and Safety testing for electronic equipment. The equipment is divided into two groups according to the purpose. Type I is the equipment for the EMC test. These devices include but are not limited to a 10-meter anechoic chamber, two 3-meter anechoic chambers, a radiated immunity test system, a set of automation Bluetooth/Wi-Fi regulation test systems, a set of millimeter wave test facility, and a set of Specific Absorption Rate (SAR) test system. This type of equipment is characterized by the intensive need for human control and monitoring during a test. Therefore, type I equipment is presented as the" Intensive care equipment group" in Figure 9. Type II is the equipment for the Safety test. The safety test group includes:

- several programmable AC/DC variable frequency power supplies,
- several constant temperature/humidity chambers,
- a group of temperature shock chambers,
- a group of rapid temperature change chambers,
- ten ovens.

These devices are characterized by simple structure and less manual intervention. Hence, type II equipment is presented as the "Low care equipment group."

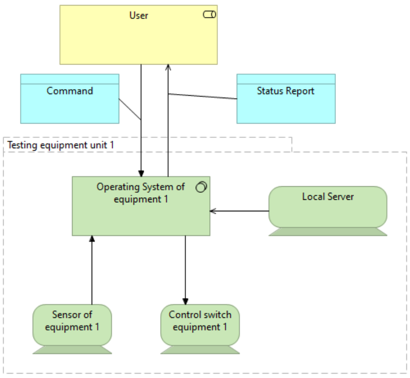


Figure 10 Local service composition

At present, laboratory equipment mainly consists of experimental equipment and operating systems installed on local servers. This local server is usually a standard desktop or laptop computer. It is equipped with many monitors or other output devices for monitoring the device's real-time status and output data. A user (usually a laboratory operator) enters commands to start, control and shut down experimental equipment through this operating system. At the same time, this part of the operation is usually accompanied by physical contact with the experimental equipment, such as placing the experimental sample in a 3-meter anechoic chamber and adjusting the distance between the instrument and the sample to complete different experimental objects. Until the end of the experiment, the experimental equipment will continuously transmit the running status and data to the monitor. At the end of the experiment, the operator will save the data as a file (usually an Excel file) and send it to colleagues via company email.

In addition to the laboratory environment, as shown in Figure 9, SGS Kunshan laboratory has a sample warehouse and a certificate team to cooperate with the laboratory operators. In the sample warehouse, a computer saves the profile and current status of the sample. The profile includes the product name, supplier, function description, detection items, etc. The current status includes samples to be sent, sent, received, sent for testing, testing completed, destroyed, sample failure, etc. The sample profile and sample status data are stored in the warehouse PC under the sample storage table. In the certificate team, a few employees use client profiles and test standards to acquire certificates. The certificate and test report will be provided to clients when the testing needs are fulfilled.

4.2 Gaps between baseline architecture and stakeholders' needs

The second step in Table 2 of the proposed method is to analyze the current state of the baseline architecture. This step is divided into two parts. The first part is to point out the gap between the baseline architecture and the needs of stakeholders, and the second part is to point out the flaws in the current business process.

Stakeholders' needs are analyzed in Table 1. In the baseline architecture, the equipment group control servers are connected to LAN. Remote monitoring and remote control are not supported under the current architecture. In the case of the baseline architecture, the monitoring and control of the equipment are performed locally by the laboratory operator. For this reason, some experiments require the laboratory operator to work in shifts to keep up with the progress of the experiment. This creates great work pressure for the laboratory operator. Moreover, experiments involving low-care equipment groups tend to last long but require little human intervention. This situation makes the need for remote monitoring, remote control, and automatic control of experimental equipment more urgent. (Gap 1)

As for the administrators for a test case, in addition to remote monitoring and remote control functions, they urgently need a one-stop information display platform to display the progress of experiments, experimental data, and the status of samples. In the current state, they need to ask relevant laboratory operators and sample management personnel and go to the laboratory to check the equipment to know the above information. This is not only not conducive to managing the progress of experimental projects but also not conducive to sharing known information with customers and thus affecting corporate reputation. (Gap 2)

As for the certificate team, they hope to obtain instant information sharing from laboratory operators on test standards and test results to facilitate the application for certificates as soon as possible. At present, the certificate team contacts the laboratory operators by email to understand the test standards and test results. This method is inefficient, and there are threats that affect the progress of the certificate application. (Gap 3)

On the client's side, they look forward to a way of sharing test results with them. Limited news regarding their test orders is transferred through the certificate team and customer service. Due to the participation of unprofessional personnel and the restrictions of the company's information security policy, the information delivered by this channel is inaccurate and not timely. Furthermore, there are clients who look forward to hiring an inspection and certification company to do real-time monitoring for their immovable large equipment field, wind turbines, for example. The real-time monitoring task would require 24h monitoring of the working status of the equipment and data synchronization with the maintenance team, which human monitoring cannot fulfill. (Gap 4)

Identify the flaws existing in current business processes.

The second part is to identify the flaws existing in current business processes (figure 8). As listed in the baseline architecture, when customer service gathers need from clients and delivers the needs to laboratory operators and certificate teams, some of the needs do not comply with relevant policies, or the requirements are not clear enough. It would take time to get the requirements correctly; otherwise, it would cause invalid spending. Secondly, as shown in Figure 9, sample status data are only stored in the warehouse PC, and the sample status data table is shared with the laboratory operator in a static form. Hence, sample location data cannot be shared with laboratory operators on time. This poses another threat to the progress of the experiment. In actual work, it often happens that samples are not processed in time. The same problem also occurs when the certificate team asks the laboratory operators for test standards and test results. The third defect occurs in file archiving. Since the test report and the certificate are respectively archived in the computers of the laboratory operators and the certificate team, and in actual work, multiple versions of the test report and the experiment certificate are often produced. It often takes a lot of time to match the test report and certificate before delivering them to clients.

4.3 Proposed Architecture

The proposed architecture is mainly displayed in figures and tables in this section. The following table will show all the figures and the relationship between these figures.

Section	Name	Title	Description
4.3.1	Figure 11	4-layered target architecture of cloud-based testing platform	This figure is the general overview of the whole architecture. This figure is to introduce the composition of the cloud-based platform.
	Figure 12	Cloud-based platform system functions	This figure is to show the functions of the cloud-based platform and the relations between those functions.
	Table 4	Cloud-based platform system functions description	This table is to describe the behaviors of the platform introduced in Figure 12.
	Figure 13	Implementation of the cloud-based testing reference model	This figure shows how the applications in Figure 11 and functions in Figure 12 are realized.
	Figure 14	The business process after implementing a cloud-based testing platform	This figure describes a new business process of an inspection and certification company after implementing the cloud-based platform compared with Figure 8.
	Figure 15	Information structure of the cloud-based testing platform	This figure shows the structure of information after implementing the cloud-based platform. The data type shown in this figure is basically the same as that shown in Figure 9.
	Figure 16	Data access view after implementing	This figure describes

		cloud-based platform	how the information in Figure 15 is organized in the cloud. This figure can also be compared with Figure 9 to show the data access view after implementing the cloud-based platform
4.3.2	Figure 17	Information transaction using message queuing	This figure shows the principle of pub/sub-broker. This broker is used for transferring information from devices to a cloud.
	Figure 18	AWS IoT Device Management Secure Tunnel	This figure shows one way to realize the information transfer from a cloud to a device.
4.3.3	Figure 19	Description of the device resource	This figure describes the description method of testing device resources on the cloud-based platform.
	Figure 20	Description of the detected sample	This figure describes the description method of the detected sample on the cloud-based platform.

Table 3 Brief introduction of the figures & table in 4.3

4.3.1 Platform system design

The third step of the method is to propose a target architecture that could fit the stakeholders' requirements and benefit the business process of an inspection and certification company. This step is divided into three parts. The first part is to propose the target architecture of a cloud-based testing platform. The second part is to propose the control method of the cloud-based testing platform. The third part is to explain how this model benefits the business of an inspection and certification company.

To propose the target architecture of a cloud-based testing platform

This report uses the middleware-based and service-oriented architecture introduced by Aguru et al. [20]and the traditional four-layer IoT architecture consisting of an application layer, platform layer, transport layer, and device layer. In the target architecture (Figure 11), there are UI level, platform level, transport level, and device level. This figure is to introduce the composition of the cloud-based platform. Each level is introduced in the following sections.

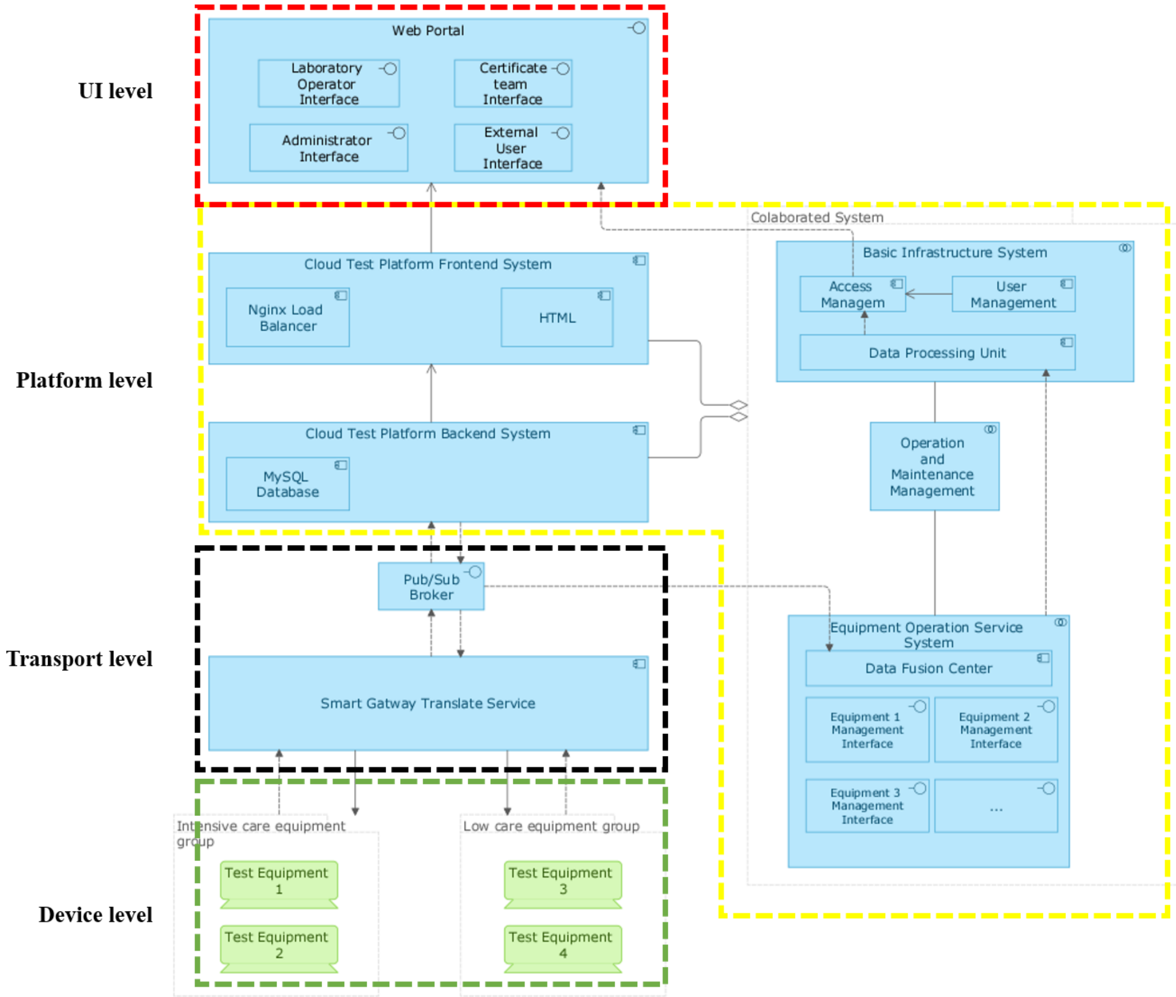


Figure 11 4-layered target architecture of cloud-based testing platform

1) UI level

The application layer is the presentation of the cloud-based platform, mainly including data visualization and user interaction. This layer will be oriented to cloud-based platform users, mainly experimental operators, certificate teams, administrators, and users from external organizations. Administrators can manage authorization through the platform so that users can obtain different information. The preset permission assignment table is shown in 4.5.

2) Platform level

The platform level is the main part of the cloud-based testing platform and related UI level on the cloud server. It is a collection of interactive operations between users and services at the Device level. Data interaction at different layers is realized through middleware and service interfaces. The platform level converts experimental data into services users require through data and algorithm analysis from the middleware. Data storage, retrieval, and use, as well as business planning and maintenance, are addressed in this layer. There are two components at the platform level: the frontend and backend systems. The two systems are aggregated to form the basic Infrastructure system (BIS), equipment operation service system (EQS), and operation maintenance management system (OMMS). EQS will aggregate and import the data in the device into its different interfaces and wait for the data processing requirements of BIS. According to the authority, BIS will process the data stored in EQS and output them to the UI level. OMMS will monitor the operation status of the cloud-based platform and record running and error logs.

3) Transport level

The Transport level is a collection of entities interacting with cloud-based platform information and services. It mainly implements the exchange of information and instructions between the cloud-based platform system and test equipment. It mainly comprises a pub/sub-broker and a set of smart gateways.

4) Device level

The Device level in the cloud-based platform system is an entity collection of sensors, actuators, and other testing devices. It is an integral part of the cloud-based platform system to perform test tasks. The testing task is fulfilled by embedding cloud-based platform control models (Figure 21).

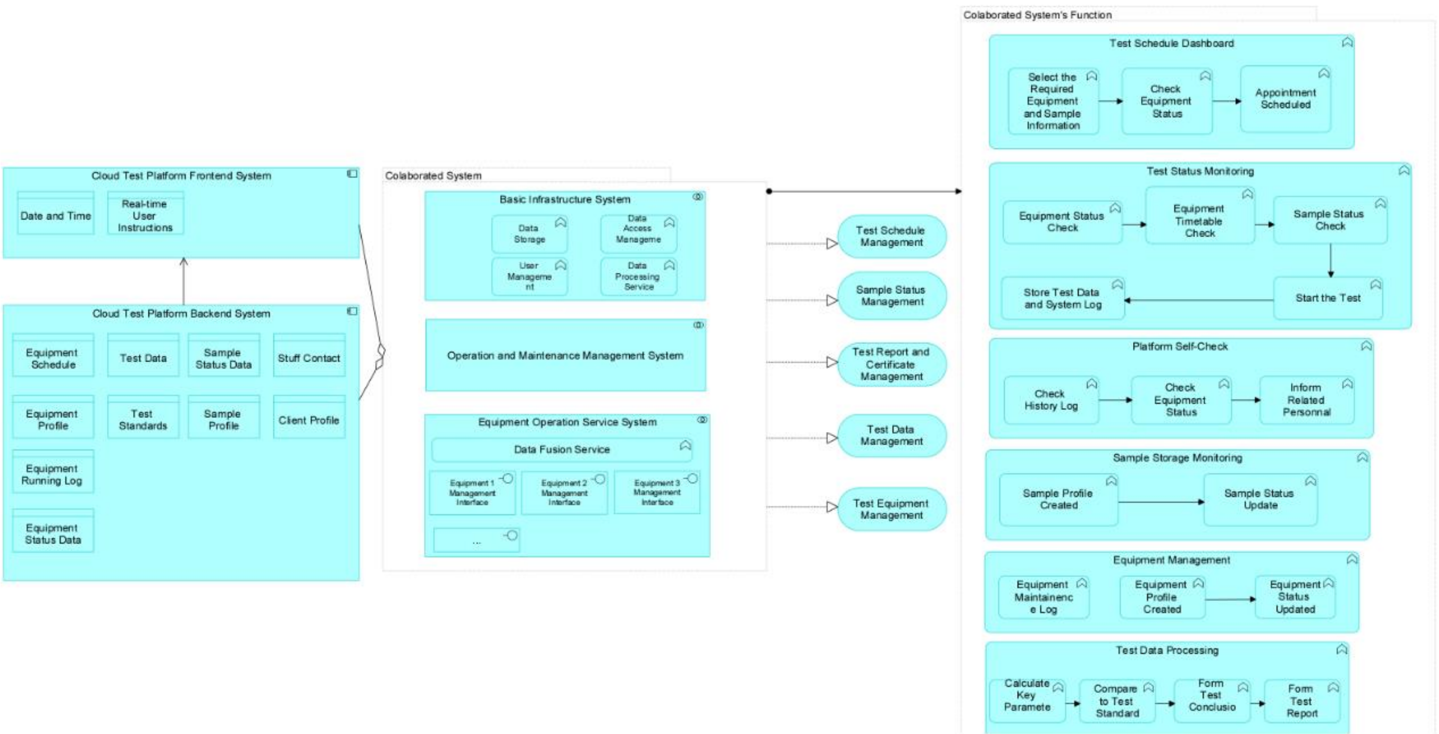


Figure 12 Cloud-based platform system functions

Figure 12 describes the main functions of the cloud-based testing platform described in Figure 11. The main functions of the platform are divided into the functions realized by the collaborated systems and the functions realized by one of the collaborated systems. The design of this figure refers to the Application behavior viewpoint in ArchiMate core viewpoints.

The first purpose of designing Figure 12 is to specify the functions responsible for carrying the cloud-based platform in Figure 11. For a description of these functions, see Table 4. And the second purpose is to fill Gap 1 and Gap 2, described in 4.2. Because of the implementation of Test Status Monitoring and Equipment Management, the monitoring of the experiment and the control of the equipment is performed by the laboratory operator through the cloud-based platform. Experiments involving low-care equipment groups can alert relevant experiment operators through the cloud-based platform when human intervention is required, thereby reducing the pressure on these operators. As for filling Gap 2, the realization of Test Schedule Dashboard, Test Status monitoring, and Test Data Processing could help test administrators manage the process of the test by browsing a few simple web pages. This will help speed up the test and make it easier for the test administrator to solve problems that arise during the test.

Name of the function	Collaborated system	Description
Test Schedule Dashboard	BIS, EQS	The dashboard can be used to check, add, and modify experimental equipment test plans. This function could fulfill Gap 2.
Test Status Monitoring	BIS, EQS	Real-time monitoring of the experimental status and progress by checking the three elements of the experiment (test equipment, required sample, equipment-related operator). This function also needs to save the experiment data and system log at the end of the experiment. This function could fulfill Gap 2.
Platform Self-Check	OMMS, EQS	Through the inspection of the system log, and the inspection of the status of the experimental equipment saved by ESQ, a self-inspection of the running status of the cloud test platform is carried out by the OMMS system. Conditions will be sent to related personnel saved in the system for reference.
Sample Storage Monitoring	BIS	This function provides the creation and status update of the tested sample profile.
Equipment Management	EQS, OMMS	This function provides the creation and status update of experimental equipment data through the connection with the equipment side. This function realizes the synchronization of equipment detection logs through the connection with the OMMS system.
Test Data Processing	BIS	This function calculates key parameters by reading the experimental data uploaded from the device. By comparing the test standards in the database, this function can automatically form experimental conclusions and standardized experimental reports.

Table 4 Cloud-based platform system functions description

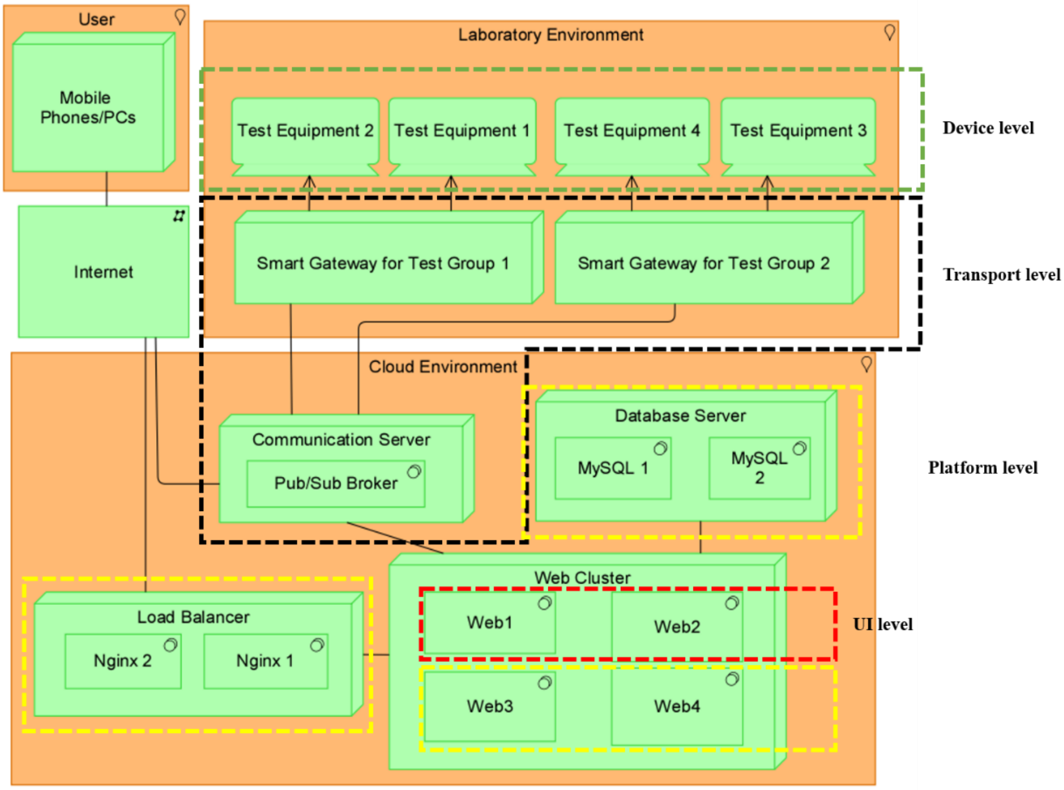


Figure 13 Implementation of the cloud-based testing reference model

Figure 13 depicts the implementation of the cloud-based platform. This reference execution architecture is divided into three environments: user environment, cloud environment, and laboratory environment. The user environment accesses the Web cluster through the Internet through the load balancer (Nginx 1&2). The web cluster will interact with the database server (MySQL 1&2) and access data. The cloud environment interacts with the lab environment through the Communication server. This interaction is likely completed through the Broker introduced in 4.2.2. The Broker will interact with Smart Gateway for Test Groups 1&2 to collect device-side data and give device-side instructions.

The purpose of designing this figure is to show how the applications in Figure 11 are realized in a cloud environment and laboratory environment. The design of this figure refers to the technical infrastructure viewpoint and the implementation and deployment viewpoints in ArchiMate core viewpoints.

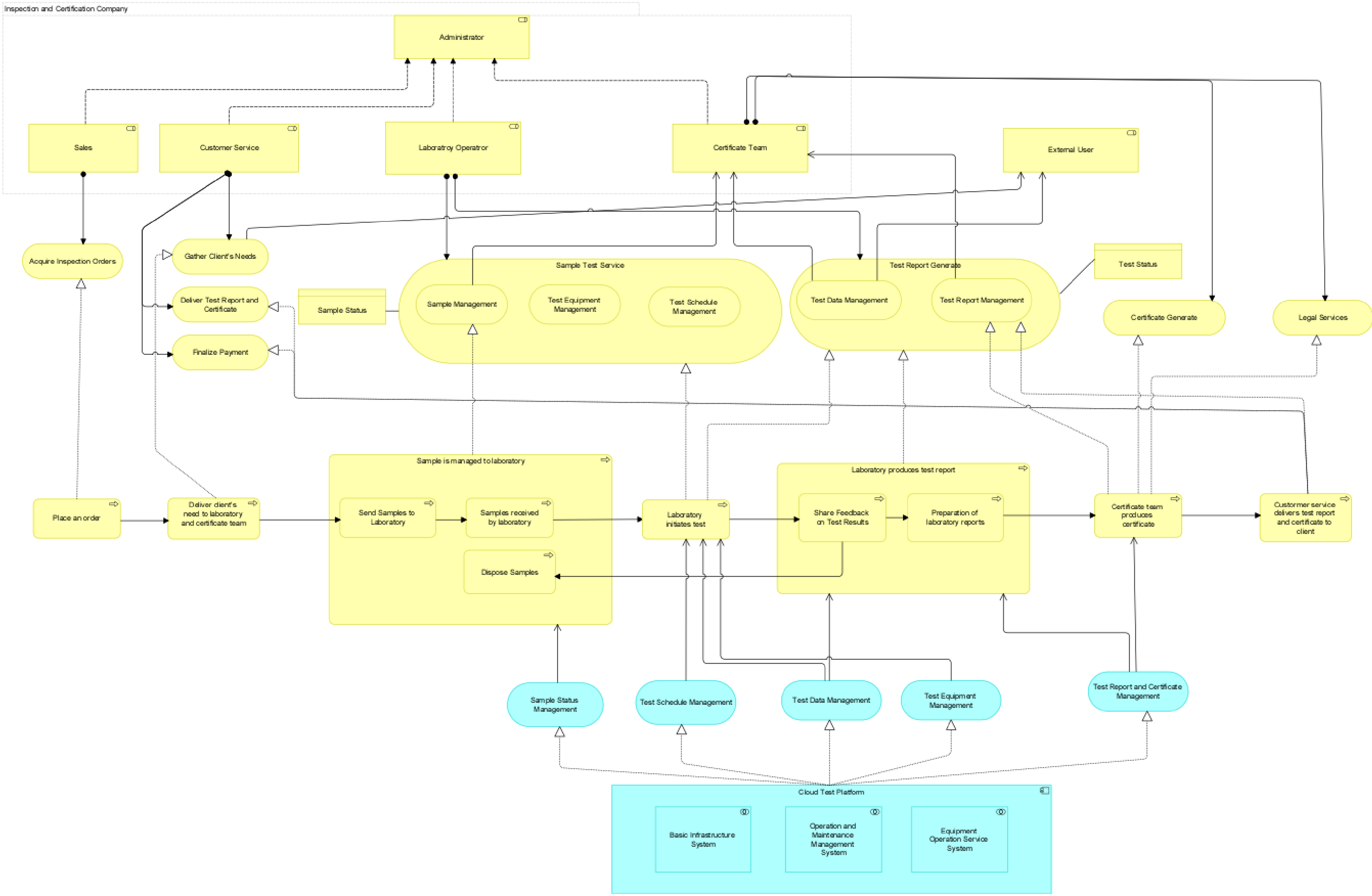

Inspection and Certification Company
Administrator
Sales
Customer Service
Laboratroy Operatror
Certificate Team
External User
Acquire Inspection Orders
Gather Client's Needs
Deliver Test Report and Certificate
Finalize Payment
Sample Status
Sample Test Service
Sample Management
Test Equipment Management
Test Schedule Management
Test Report Generate
Test Data Management
Test Report Management
Test Status
Certificate Generate
Legal Services
Sample is managed to laboratory
Laboratory produces test report
Place an order
Deliver client's need to laboratory and certificate team
Send Samples to Laboratory
Samples received by laboratory
Dispose Samples
Laboratory initiates test
Share Feedback on Test Results
Preparation of laboratory reports
Certificate team produces certificate
Custormer service delivers test report and certificate to client
Sample Status Management
Test Schedule Management
Test Data Management
Test Equipment Management
Test Report and Certificate Management
Cloud Test Platform
Basic Infrastructure System
Operation and Maintenance Management System
Equipment Operation Service System

Figure 14 The business process after implementing a cloud-based testing platform

Figure 14 depicts the business process after the inspection and certification company has implemented the cloud-based platform. This diagram connects the main roles and service functions of the business process, the service functions of the main roles, the business process that uses the role function, and the services provided by the cloud-based platform for a specific process. The purpose of designing Figure 14 is to describe the changes in business processes after implementing a cloud-based platform. Compared with the baseline business process (figure 8), the sample experiment process can be synchronized to all project-related experimenters through the cloud-based platform, which improves the efficiency of the entire business process.

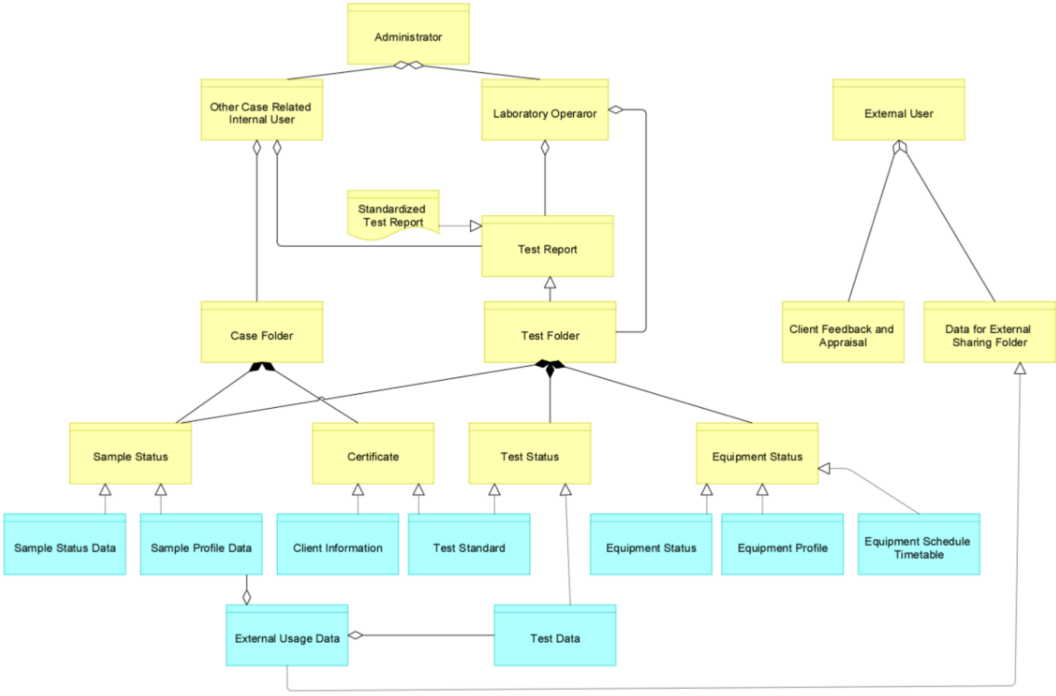


Figure 15 Information structure of the cloud-based testing platform

Figure 15 depicts the information architecture after the inspection and certification company implemented the cloud-based platform. This picture describes the composition of the critical business objects in Figures 7 and 8: Test report and Certificate and the composition of different role permissions. The design of this figure refers to the information structure viewpoint in ArchiMate core viewpoints.

The first purpose of designing Figure 15 is to solve the information-sharing difficulties explained by Gap 3 and Gap 4. Figure 15 combines 4.4 to solve the file archiving problem of matching test reports and certificates mentioned in the baseline architecture. The solution to this problem is to record the Instrument ID of the experimental equipment, the experimental process number Experiment ID, and the sample number into Equipment status, Test status, and Sample status, respectively. Realize correct file filing for certificate team sharing through the Test report and Case folder. The second purpose of designing Figure 15 is to show the structure of the information used in the cloud-based platform.

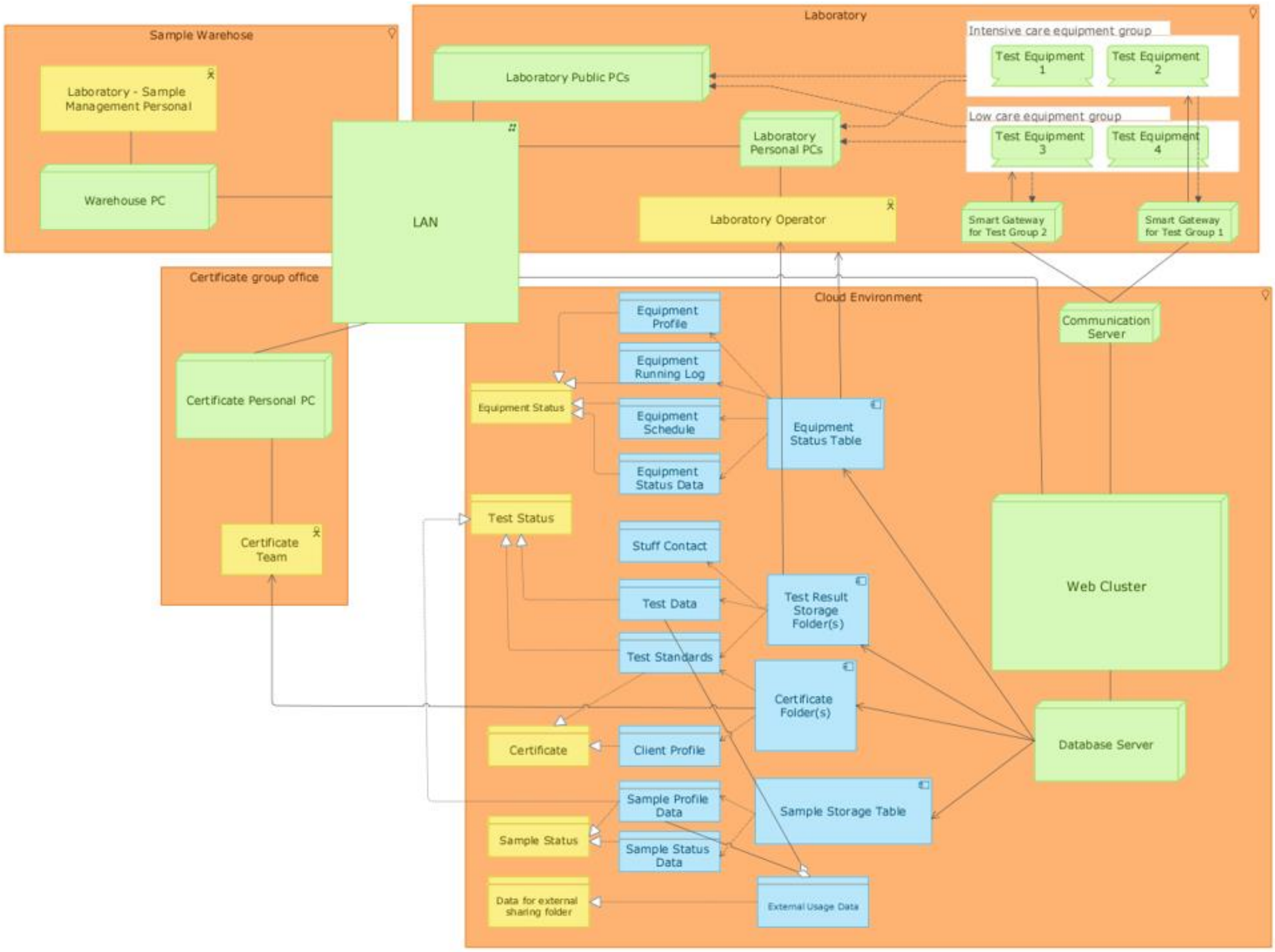


Figure 16 Data access view after implementing cloud platform

Figure 16 depicts the data access interface after implementing the cloud-based platform. The first purpose of designing Figure 16 is to show the change in data access perspective within an inspection and certification company after implementing a cloud-based platform. Due to the addition of the cloud environment, a lot of data access and data downloads are passed through the cloud environment, which is the major change compared with the baseline data access view in Figure 9.

Because Equipment status table, Test result Folder, Certificate folder, and Sample storage folder are stored in the cloud database, internal and external users could receive updates when related information is uploaded onto the cloud environment. In this way, users working on the same project can receive the latest project files and experimental data simultaneously. This design complements Gap4, which is the second purpose of designing Figure 16.

4.3.2 Broker Architecture Design

This section describes the structure of the information transfer broker. The information transfer broker will include two structures. The device reports the operational status to the cloud-based platform (upward transfer), and the cloud-based platform transfers instructions to the device (downward transfer).

Upward transfer
This function will be realized by pub/sub message queuing. The Equipment operation system publishes its status as a message to the broker. The equipment operation service system would subscribe to each topic of the equipment's operation system and receive the notification.

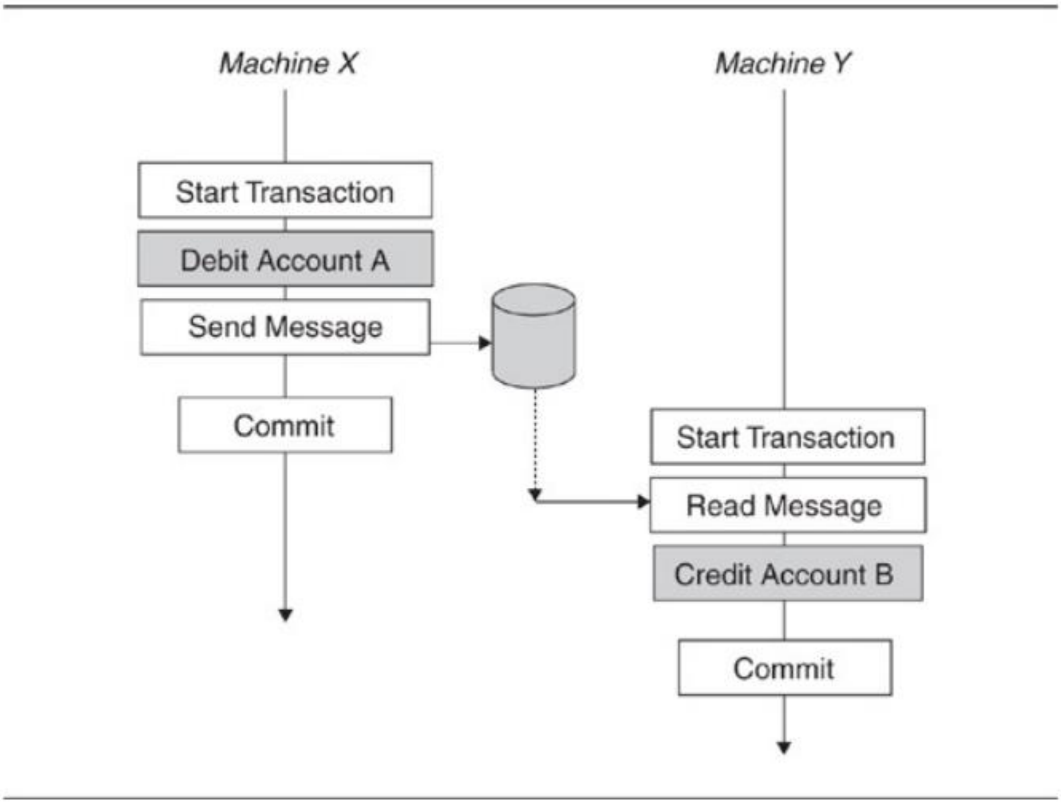


Figure 17 Information transaction using message queuing; Excepted from Britton & Bye [31]

Downward transfer

There are two ways to implement this function. One is to use PaaS, such as a cloud-based platform called AWS IoT Device Management. After the device is configured on AWS IoT Device Management, the cloud-based platform calls AWS IoT Device Management through the API to realize remote control of the device, including functions such as logging, device startup, shutdown and restart, and monitoring job queues. IoT Device Management will generate a tunnel for each device to ensure a secure device connection. The advantages of this method are that the price is low and the structure is simple, but it requires AWS to support the operating system of the experimental equipment.

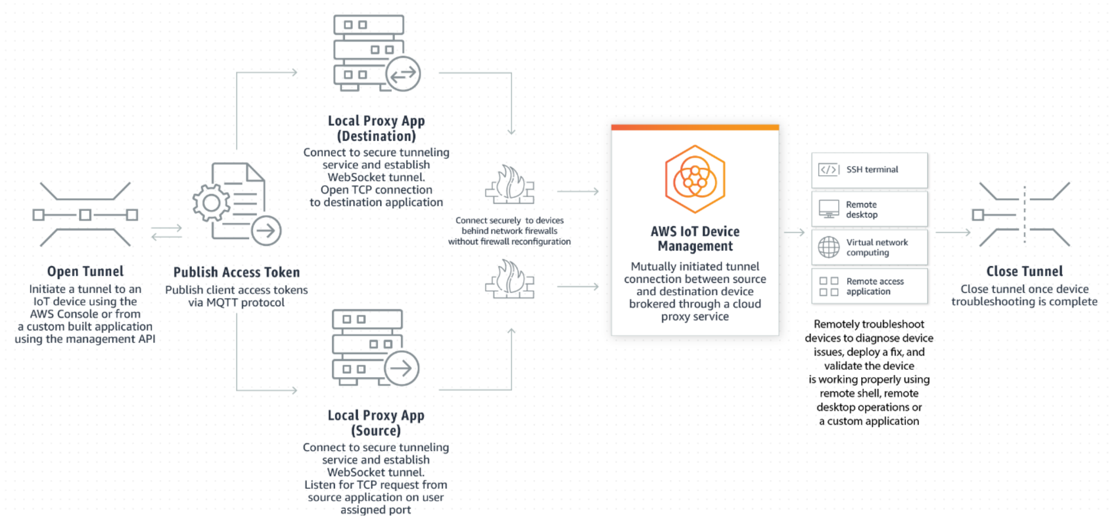


Figure 18 AWS IoT Device Management Secure Tunnel [32];

Another way is to use hardware access, such as applying a Programmable logic controller (PLC) and smart gateway. Arrange the PLC equipment on the experimental equipment, connect the intelligent gateway to each PLC equipment, and use the cloud-based platform to call the intelligent gateway's operation application to realize each PLC equipment's wireless communication and control. Intelligent gateways usually support 4G, 5G, Wi-Fi, and Ethernet communications. The advantage of this method is that it has good scalability and supports more operating systems, but it is relatively more complex and expensive.

4.3.3 Description of instrument resources

At the platform level, the description and management of equipment are mainly concentrated in the Equipment operation service system. Among them, the device's resources are diverse, and a unified method needs to be used to simplify the representation of the device on the cloud-based platform. This section s describing the expression of experimental device resources and detected samples on the cloud-based platform.

Extensible Markup Language (XML) has the characteristics of platform independence, extensibility, and easy processing and has become the primary standard for network data representation and exchange. Therefore, XML is used to extract the commonality of the detection resources, the heterogeneity of different entities of the same resources is discarded, and the cloud-based platform description template of the resource is formed.

The device resource description model established in this report is shown in Figure 19. The primary attribute is static information, which needs to be determined when registering to the cloud test platform. Functional properties, status, and maintenance information are dynamic information that is constantly updated as the device is used. In the function attribute, the ID of each experiment, the experiment's title, the experiment's start and end time, and the remarks-related information are saved under the experiment attribute. The experimental plan reflects the working schedule of the equipment, and each scheduled experiment is marked in the bid. The state information is a Boolean value, including three states running, idle, and fault. The maintenance attribute holds a record of the equipment being maintained.

The essential property of the detected samples is static data found in Figure 20 which should be determined when it is entered into the system. The detection target includes the total number of tests and the information of each test, where the device ID should correspond to the ID of the experimental device. Status data includes current status and performance status. Current status means in transit, in stock, still being tested, or scrapped. Each state should have a timestamp and a location label. Performance data includes performance ratings, exception records, and maintenance records, which vary with the detection status of the detected samples. Inspection properties save the data and results of all inspection points, in which a general inspection report can be generated directly.

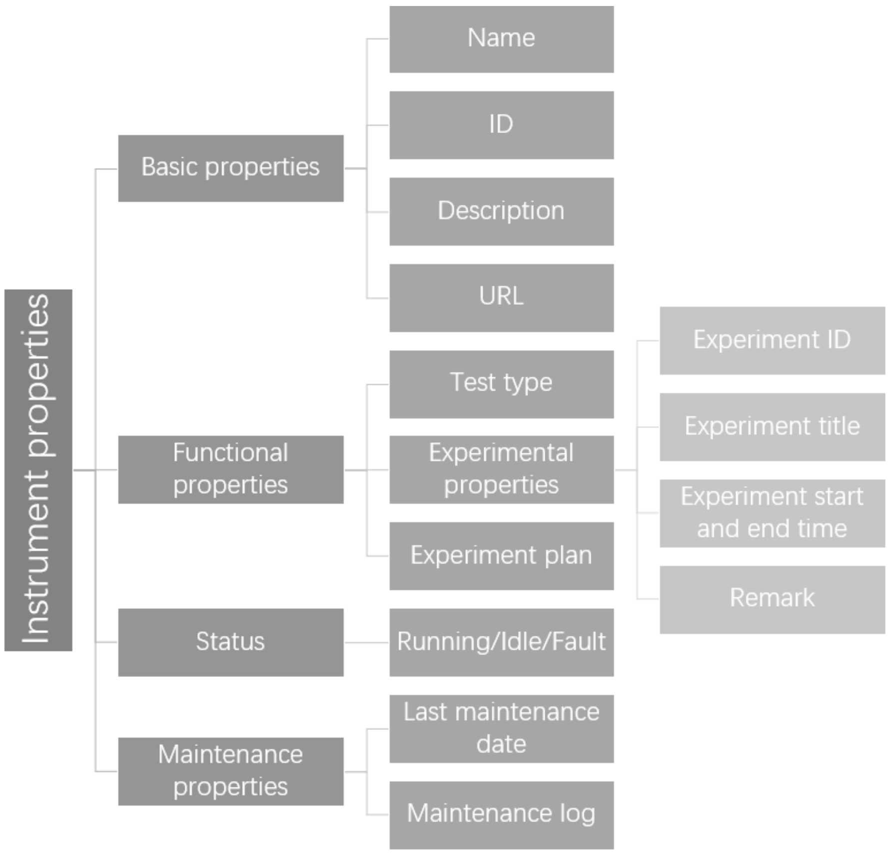


Figure 19 Description of the device resource

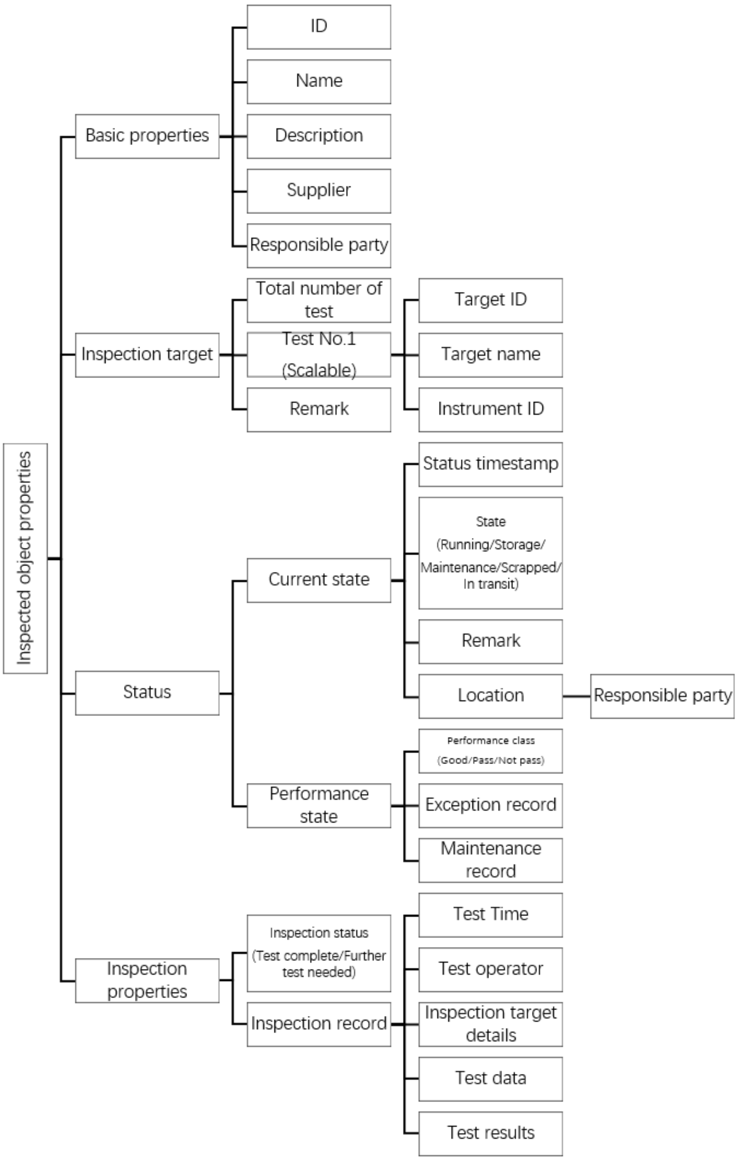


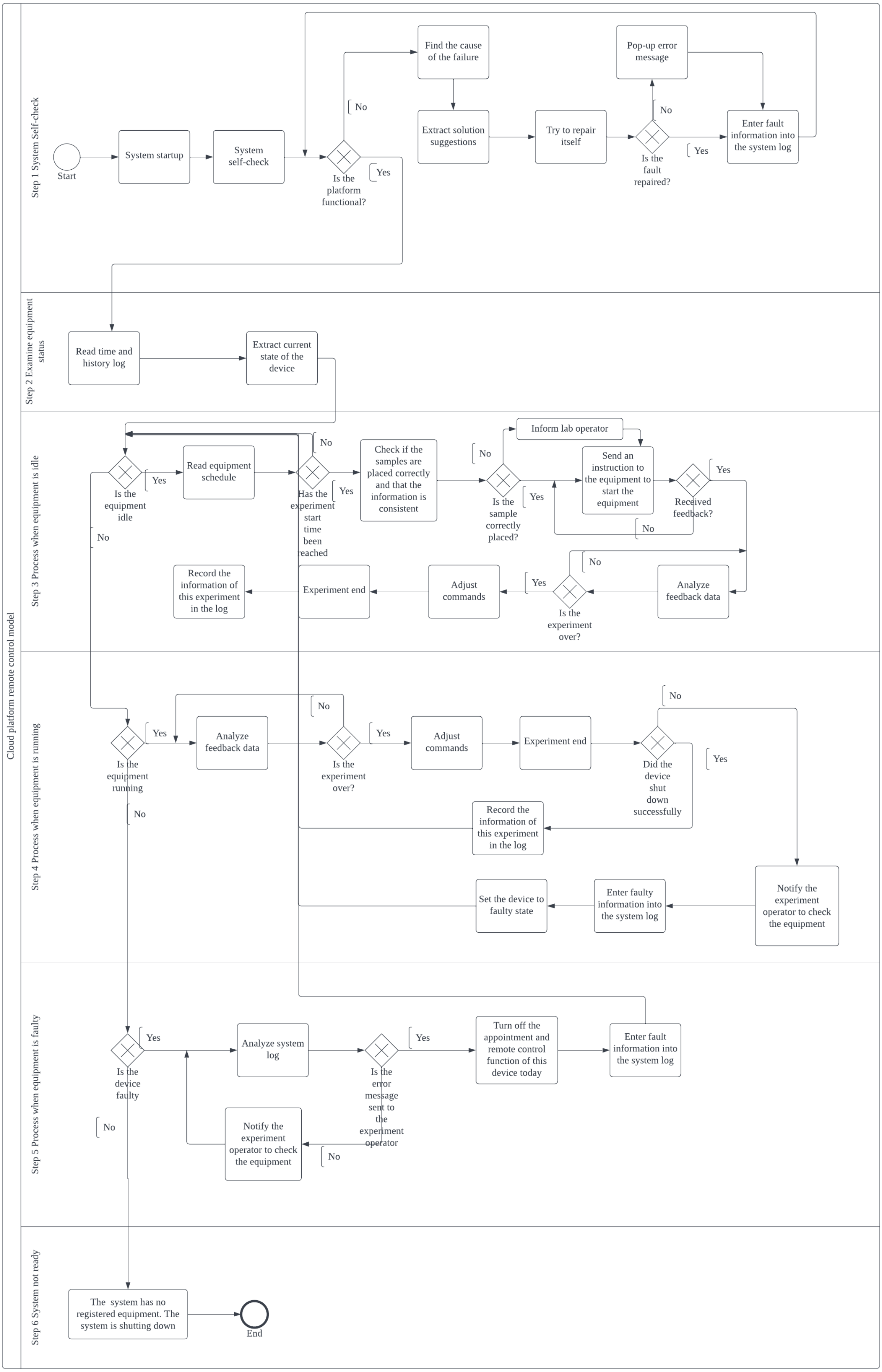
Figure 20 Description of the detected sample

4.4 Cloud-based platform remote control model

Combined with the device resource description, this section builds a cloud-based platform control model. The model covers the various states of the equipment and performs experiments autonomously by judging the equipment's state and the equipment's appointment schedule. The model covers the various states of the equipment and performs experiments autonomously by judging the equipment's state and the equipment's appointment schedule. This control model describes the control process of the cloud-based platform remote control model designed in Chapter 4.3. The facility remote control model is shown in Figure 21.

As shown in the figure, the model is divided into three control modes after doing a self-check (step 1): idle (step 3), running (step 4), and fault (step 5). When the device is idle, the cloud-based platform will check the appointment schedule and whether the state of the tested sample meets the experimental requirements. When the device runs, the cloud-based platform will check whether the experiment is over. If the experiment has ended, the cloud-based platform will issue a shutdown command and check whether the device is usually shut down. If the device does not shut down properly, the experiment operator is notified to check the device status. When the equipment is in a fault state, the system will check whether the error message is sent to the experimental operator. If the information has been sent, the platform will turn off the device's appointment and remote-control functions on the same day.

When the cloud-based platform cannot detect the device status (step 6), the system will automatically shut down to wait for the device to be registered.



Cloud platform remote control model
Step 1 System Self-check
Start
System startup
System self-check
Is the platform functional?
No
Yes
Find the cause of the failure
Extract solution suggestions
Try to repair itself
Is the fault repaired?
No
Yes
Pop-up error message
Enter fault information into the system log
Step 2 Examine equipment status
Read time and history log
Extract current state of the device
Step 3 Process when equipment is idle
Is the equipment idle
Yes
No
Read equipment schedule
Has the experiment start time been reached
No
Yes
Check if the samples are placed correctly and that the information is consistent
Is the sample correctly placed?
No
Yes
Inform lab operator
Send an instruction to the equipment to start the equipment
Received feedback?
Yes
No
Analyze feedback data
Is the experiment over?
No
Yes
Adjust commands
Experiment end
Record the information of this experiment in the log
Step 4 Process when equipment is running
Is the equipment running
Yes
No
Analyze feedback data
Is the experiment over?
No
Yes
Adjust commands
Experiment end
Did the device shut down successfully
No
Yes
Record the information of this experiment in the log
Notify the experiment operator to check the equipment
Enter faulty information into the system log
Set the device to faulty state
Step 5 Process when equipment is faulty
Is the device faulty
Yes
No
Analyze system log
Is the error message sent to the experiment operator
Yes
No
Turn off the appointment and remote control function of this device today
Enter fault information into the system log
Notify the experiment operator to check the equipment
Step 6 System not ready
The system has no registered equipment. The system is shutting down
End

Figure 21 Cloud-based platform remote control model

4.5 Management Policy

Currently, SGS's laboratory management procedures mainly focus on Sample management, personnel management, training operation, and environment control. There should be information security guidelines and procedures to protect experimental data and related information. However, the current procedures issued within SGS do not explicitly list access control regarding experiment data. This section recommends adding laboratory access control procedures to current laboratory management policies. Since this cloud-based platform involves sharing information with external users and for the purpose of protecting experimental information security, this report believes that it is necessary to design a basic access control model for the cloud-based platform.

Role-Based Access Control (RBAC) model

This report refers to the rights management model designed based on the Role-Based Access Control (RBAC) model, which divides the existing functions into Users and roles, Permissions, and Sessions. The definition of the RBAC model in this report is taken from the 1996 paper by Sandhu and his colleagues [33, 34].

User and Role: the user is a human being. A role is a named job function within the organization describing the authority and responsibility conferred on a member.

Permissions: Permission is an approval of a particular mode of access to one or more objects in the system. Permissions are always positive and confer on their holder the ability to act as the system.

Sessions: Users establish sessions during which they may activate a subset of their roles. Each session maps one user to possibly many roles.

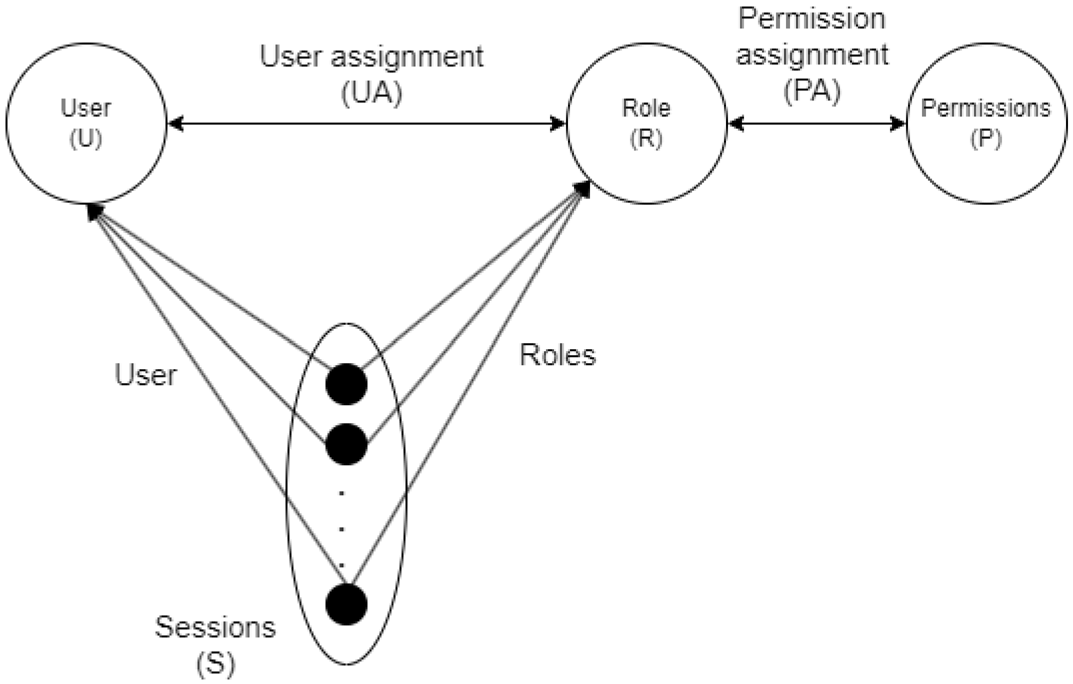


Figure 22 Basic Role-based access control (RBAC) model; Excerpted from Sandhu et al in 1996[33].

According to the RBAC model, this report designed and defined user and permission assignment checklists.

Permission: System management; Module management; Data entry; Data read; Data output; Data Sharing (within the platform);
Role: System Administrator; Module administrator; Laboratory operator; Related Internal users; Invited users; External visitor.

Type		Definition
Permission	System management	All management rights to all systems, including all system rights granting, data entry, data reading, data export, and data sharing.
	Module management	All management rights to a module, including the rights granted to this module, data entry, data reading, data export, and data sharing.
	Data entry	Import data into a module
	Data read	Read the data of a certain module
	Data output	Export the data of a module to an external file
	Data Sharing	A module's data can be shared with other users through a link.
Role	System Administrator	Maintenance and management of the entire system
	Module administrator	Maintenance and management of a module
	Laboratory operator	Data entry, data reading, and data sharing
	Related Internal users	Data reading, data output, and data sharing
	Invited users	Data reading, and data sharing
	External visitor	Data reading

Table 5 Permission assignment checklist

User	Role
IT department group; Chief laboratory leader	System Administrator
Program manager; Program experiment manager	Module administrator
Experiment operator	Laboratory operator
Other project related staff	Related Internal users
Client company's project leader	Invited users
Client company's related party	External visitor

Table 6 User assignment checklist

5. Evaluation

In order to verify the reference model proposed in this report, this report selected the TeREES project of SGS that conforms to the structure of this model as a verification case. Afterward, I cooperated with some staff members of the TeREES project team of SGS, using the TeREES project as the background, to implement the cloud-based platform described in 4.3 as a test instance for evaluation. The result is explained in 5.2.

In this chapter, this report describes the evaluation method, proposes evaluation criteria, and analyzes this case against the evaluation criteria. 5.1 introduces the evaluation method, the Technical Action Research (TAR) method. 5.2 introduces the background of the TeREES project and the test instance after implementing the cloud-based platform introduced in 4.3. Figure 13 is used as the orientation for the implementation process, and the results are displayed in figure 24 and figure 25. Three out of six functions introduced in Table 4 are realized in the test instance. The implemented functions in the test instance are Test schedule dashboard, Test status monitoring and Equipment management. Since the devices in the test instance are all virtual devices, not actual devices, the virtual devices in the instance cannot generate data, so the Test Data Processing function cannot be realized. Since the test instance has not been connected to the device and sample data, the Platform Self-Check function and Sample Storage Monitoring function of the platform cannot be realized. 5.3 introduces the results of the evaluation. This chapter is related to Sub-research Object 3 and research question 6.

5.1 Evaluation Method

Evaluation research aims to investigate how implemented artifacts interact with their real-world context (Wieringa, 2014). The Test Resource & Equipment Eco-System (TeREES®) provides a practical case for the reference model to investigate. Technical Action Research (TAR) methodology (Wieringa, 2014) is introduced for this case.

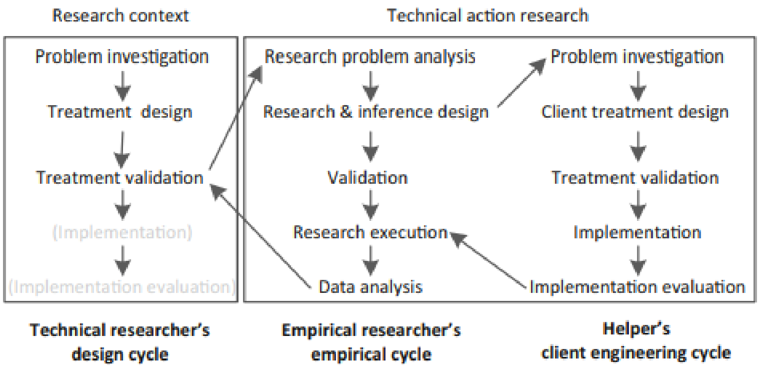


Figure 23 The three-level structure of TAR

The evaluation process consists of the following step:

- Design the questions for evaluation;
- Evaluate the reference model using the TeREES® case;
- Reflection on the reference model and management policy.

Questions for evaluation outcome:

Subject	Definition	Evaluation question
Performance Expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.	How the reference model performs in the build process of a cloud-based testing platform? (EQ1)
		Did the model match the intended guiding purpose for designing and implementing a cloud-based testing platform in an inspection and certification company? (EQ2)
Effort Expectancy	The degree of ease associated with the use of the system	Is the model easy to use? (EQ3)
		What were specific parts of the environment in the reference and built models impacted? (EQ4)
Social Influence	The degree to which an individual perceives that important other believes he or she should use the new system.	What social influence do you think will result from using the reference model? (EQ5)
Facilitating Conditions	The degree to which an individual believes that an organizations and technical infrastructure exist to support the use of the system.	Is this reference model compatible with other tools when building a cloud test platform? (EQ6)
		Will you use this reference model when building a cloud test platform? (EQ7)

Table 7 Evaluation question

The respondent will face the main assessment questions designed according to the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT model is a unified theory that aims at predicting usage behavior and user acceptance, and it consists of four determinants: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions [35]. EQ1 and EQ2 are designed according to performance expectancy. EQ3 and EQ4 are designed according to effort expectancy. EQ5 is designed according to social influence. EQ6 and EQ7 are designed according to facilitating conditions. These questions are designed to obtain stakeholder feedback to improve and critically revise the model presented in the previous chapters.

Evaluation Interviews:

Assessment interviews are conducted as online video calls. The author of this report introduced the ArchiMate modeling language and the reference model (appendix D), Artifact (figure 8 to figure 20 & Table 5 & Table 6), the control model (figure 21), and the business process (figure 8 & figure 14) to the interviewees. Slides (Appendix D) regarding the reference model are offered for each respondent. Each respondent is asked to have an unstructured discussion of the project with each other. Afterward, the author of this report successively conducted a separate interview with expert A and interviews with experts B and C to collect their feedback.

Respondent panel:
The experts that agreed to join the experiment are:

- Two laboratory cloud-based platform design team members from SGS Guangzhou Laboratory. （Expert A and B）
- One laboratory operator works in the SGS Kunshan laboratory. She is from the EMC experiment group. (Expert C)

Expert A

As a senior engineer of the TeREES cloud-based platform project, Expert A understands the entire business process and all aspects affected by it: internal and external personnel, laboratory environment, and technology impact. Expert A was selected as a member of the expert panel because of his rich experience in business processes and understanding of the motivation for implementing cloud-based platform projects. His feedback is important for whether the test instance meets the basic requirements of the TeREES project.

Expert B

Like expert A, he is also an engineer of the TeREES cloud-based platform project, and expert B has a better understanding of the company's existing IT system and the differences between different laboratory environments. His feedback is, therefore, valuable for the suitability of the reference models and the test instance for the verification and certification of the company's laboratory environment.

Expert C

The operator who belongs to the laboratory is familiar with the practice and standards, and business processes of safety experiments such as temperature and humidity. Her feedback is invaluable for the practicality and user-friendliness of the reference models and test cases in practical applications.

These experts are familiar with the company's existing business process (figure 8). Only one member of the laboratory cloud-based platform design team is familiar with the introduction materials of the cloud-based platform, and the other members are new to the cloud-based platform. Therefore, this experiment will show the control model (figure 21) and architecture model (Figures 8 to 20) to the expert panel. In addition, experts from inspection and certification companies have also verified the context of the cloud-based platform. Each expert agreed to interview afterward to give feedback on their areas of expertise.

5.2 Test Instance under TeREES Context

SGS named the expected cloud-based platform TeREES system. TeREES system is hoped to be an industrial IoT system based on IoT architecture + web-side platform. It has a few design plans currently within the company, and the reference model provides one of the plans. According to the deployment part of the reference model (figure 13), a scheme of the TeREES system is also designed for the cloud system environment and laboratory environment.

Laboratory environment: Through STAS-Plus as an interactive hub, various equipment of the SGS laboratory is connected, such as a constant temperature and humidity chamber, temperature shock chamber, rapid temperature change chamber, and oven. STAS-Plus can control and collect data from these devices and report relevant data to the cloud for data analysis and statistics. STAS-Plus also plays the role of an intelligent gateway, which can convert the cloud commands conveyed by the MQTT protocol into device-readable commands and control the device accordingly.

The connection method of receiving cloud-based platform information and instructions on the device side is to use the MQTT protocol to connect with the MQTT Broker.

Cloud system environment: This system can be divided into two parts: the TeREES Web system and the device message processing application. The TeREES Web system is implemented using the front-end and back-end separation architecture. The front-end static page is deployed in the static directory under Nginx and then interacts with the back-end TeREES interface service through interface calls.

The device message processing application, also called data fusion, is an application instance that is only responsible for processing the messages reported by the device. It connects to the MQTT Broker and processes the messages reported by the Broker. There is also a similar application called command fusion, which handles delivering commands for a cloud to the MQTT broker.

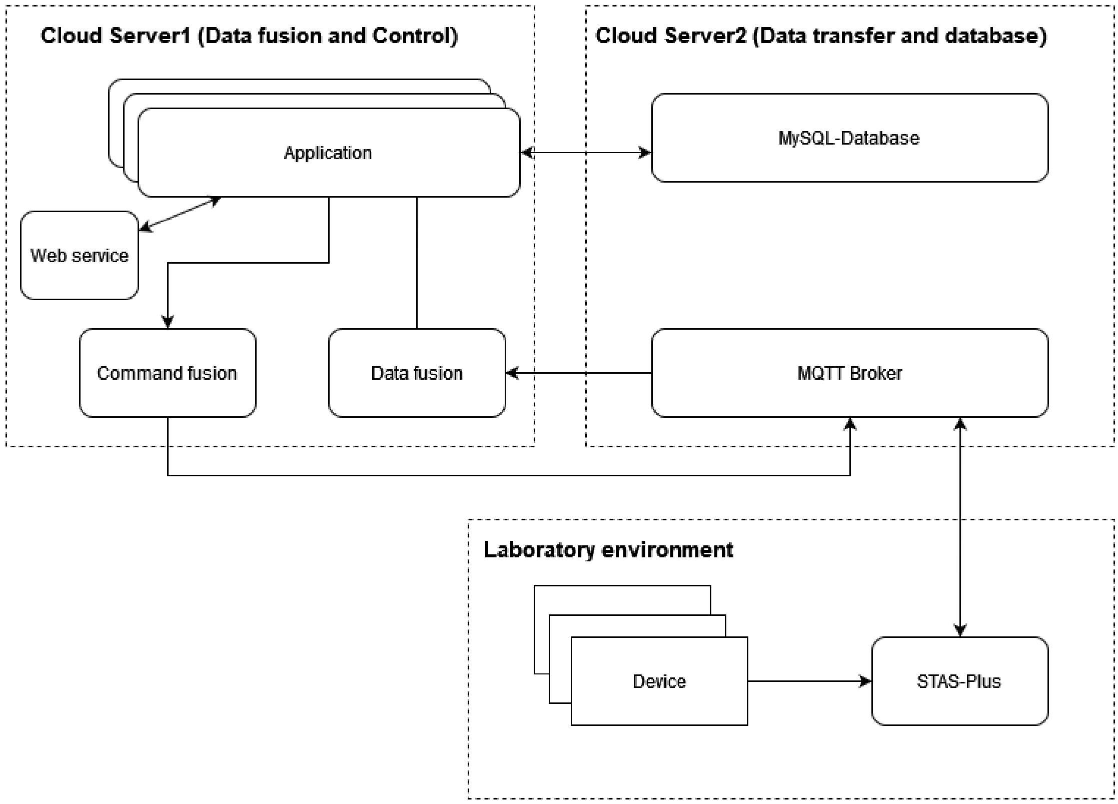


Figure 24 TeREES case test instance architecture diagram after adopting the reference model

As shown in Figure 24, application, web service, command fusion, and data fusion are arranged in one server, while MySQL database and MQTT broker are arranged in another server.

According to Figure 11, Figure 12, and Figure 24, the role of the "Cloud Test Platform Backend System" of the reference model is taken by the "MySQL-Database" of the test instance. This database saves ten types of data, including "Equipment Schedule."

The "Equipment Operation Service System" and "Operation and Maintenance Management System" roles of the reference model are taken care of by the "Data fusion" and "Application" of the test instance. These two parts complete the fusion and display of the data uploaded by the device and, at the same time, complete the monitoring of the working status of the device.

The "Basic Infrastructure System" of the reference model is mainly responsible for data rights management and data processing. This part is implemented by the cloud-based platform called another "Web Service." The outgoing data and instructions are passed to the MQTT broker through a "Command fusion." After translation, they are handed over to STAS-Plus for control and the device for execution.

Next, this section will link the content of Figure 24 with the reference model mentioned in 4.3.

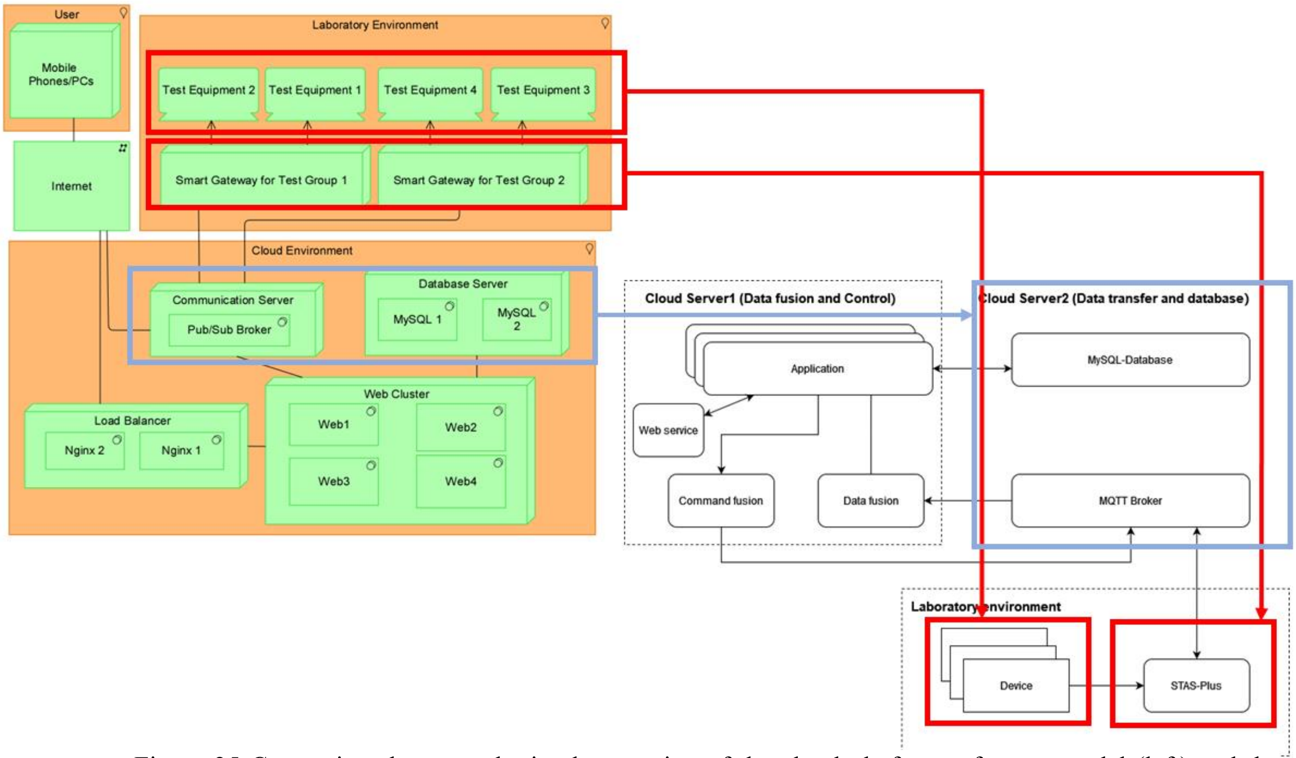


Figure 25 Comparison between the implementation of the cloud platform reference model (left) and the actual implementation of the test instance (right)

Figure 25 above compares Figure 24 with Figure 13. The part in the red box compares the laboratory environment layout in the reference model(left) and the laboratory environment layout of the test instance(right). Among them, "test equipment 1-4" in the reference model is expressed as "Device" in the test instance. "Smart Gateway for Test Group 1" and "Smart Gateway for Test Group 2" in the reference, model is represented as "STAS-Plus" in the test instance. "STAS-Plus," as mentioned earlier in this chapter, can convert messages transmitted by Broker into machine-readable instructions. But for now, the "Device" of the test case is currently just a virtual device on STAT-Plus. At present, no specific experimental equipment is connected. Since the connection between STAS-Plus and experimental equipment has been tested by SGS (as described in Chap.1.12), the connection here is verified to be feasible.

The "Communication server" in the blue box is deployed as "MQTT Broker" in the test case(right). MQTT broker is a middleware that handles device-side message reporting and cloud message delivery. We use the open-source Apollo service to deploy on a cloud host. The Broker transmits the instructions of the cloud-based platform to subscriber "STAS-Plus" in the form of a Pub/Sub pattern. In the test instance, because the current pressure of transmitting instructions is not high, a MySQL database is also deployed in the same cloud server to store cloud-based platform information.

The functions mentioned in Figure 12 are "Test schedule dashboard," "Test status monitoring," "Platform self-check," "Sample storage monitoring," "Equipment management," and "Test data processing." Since the test instance has not yet been connected to the Internet and the sample warehouse data, and the front-end entry of the self-test program has not been set, the following will only demonstrate the realization of the "Test schedule dashboard," "Test status monitoring," and

"Equipment management."

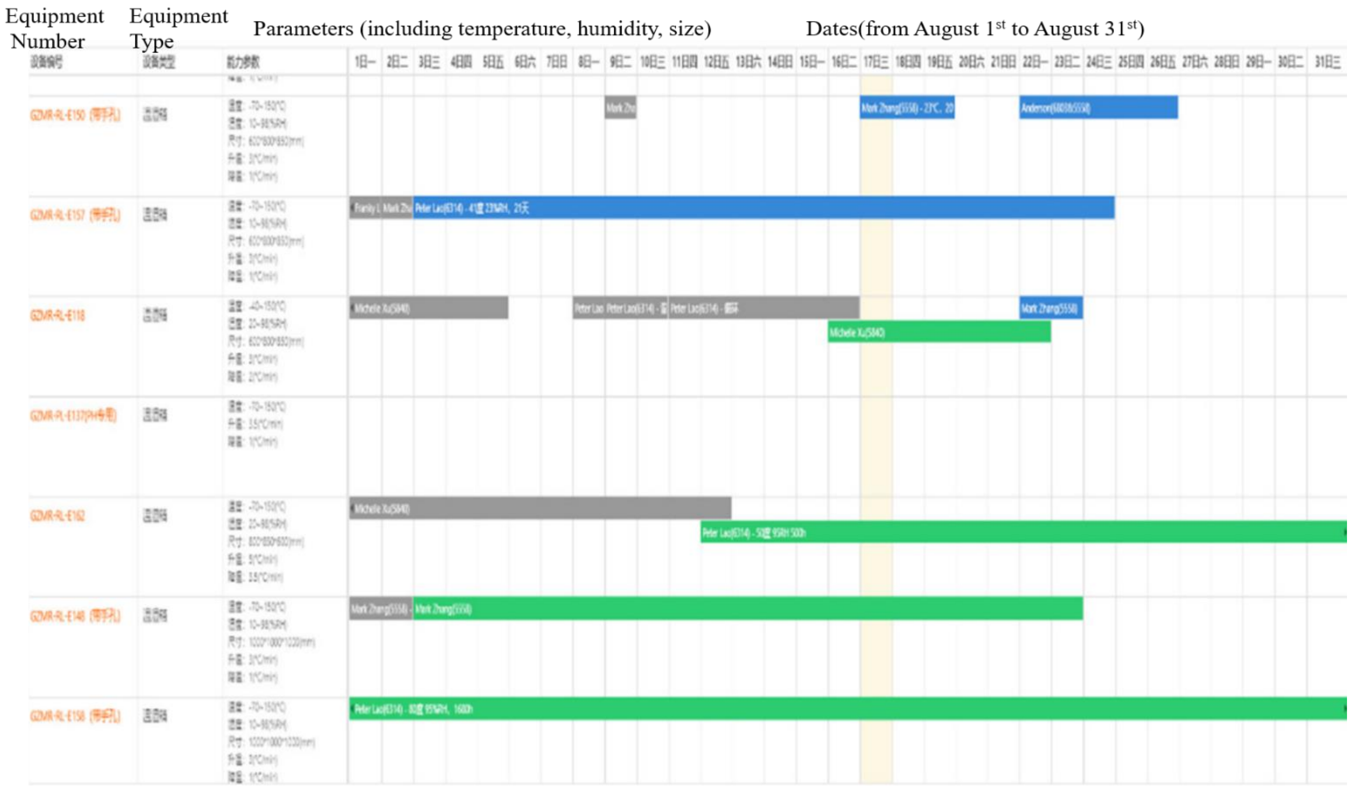


Figure 26 Test schedule dashboard on test instance. The equipment types in every row are constant temperature/humidity chambers. The parameters in every row are listed successively as temperature, humidity, size, heating, and cooling.

Figure 26 shows the Test schedule dashboard functionality described in Figure 12. The contents displayed from left to right in the table above are equipment number, equipment type, and parameters (including temperature, humidity, and size). Since the devices entered in the current test instance are all virtual devices, the contents of the "Equipment number," "Equipment type," "Parameters," and "Dates" columns are all from the previous test record from SGS, Suzhou branch. This figure is presented only to show the visual effect of this function.

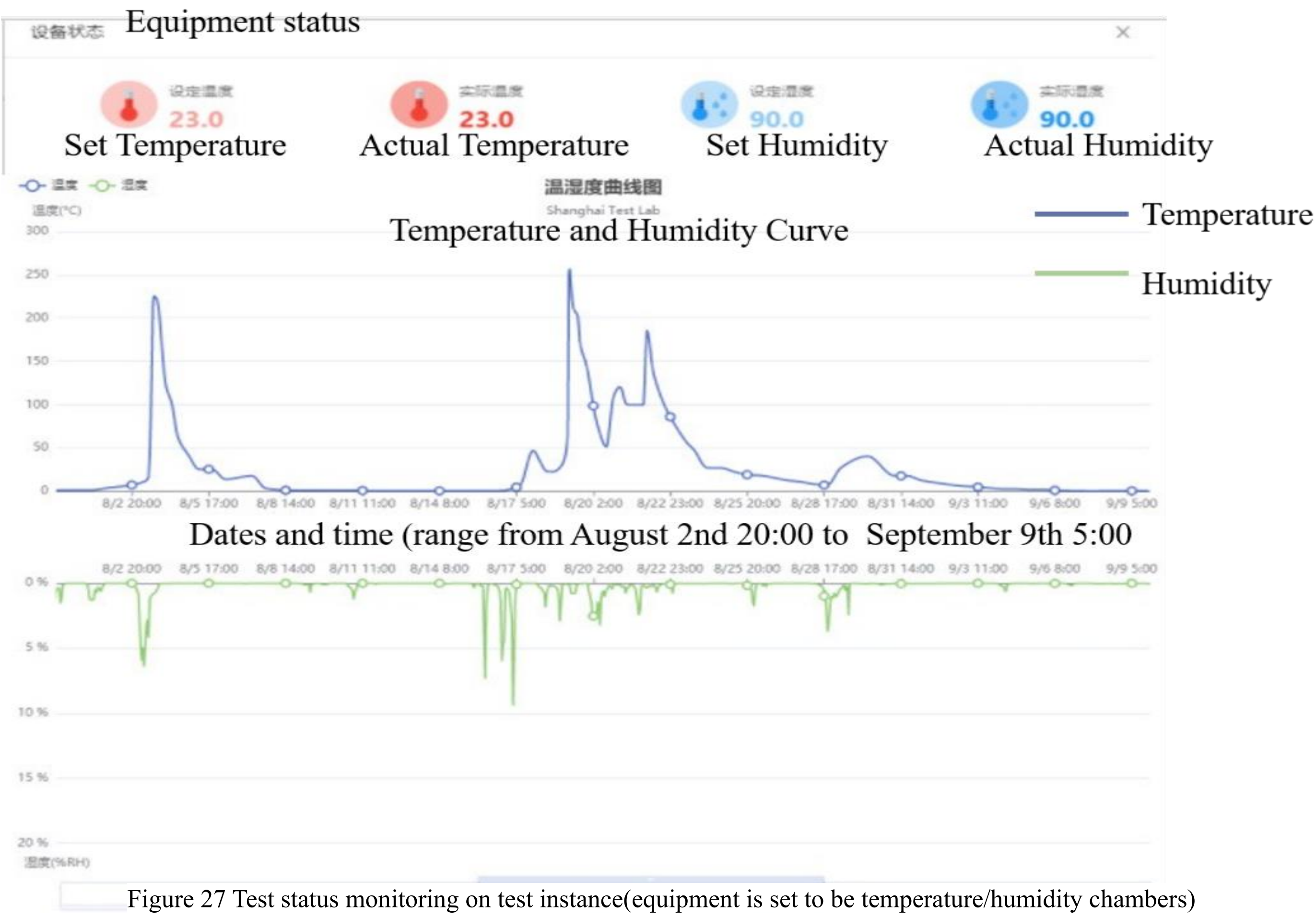
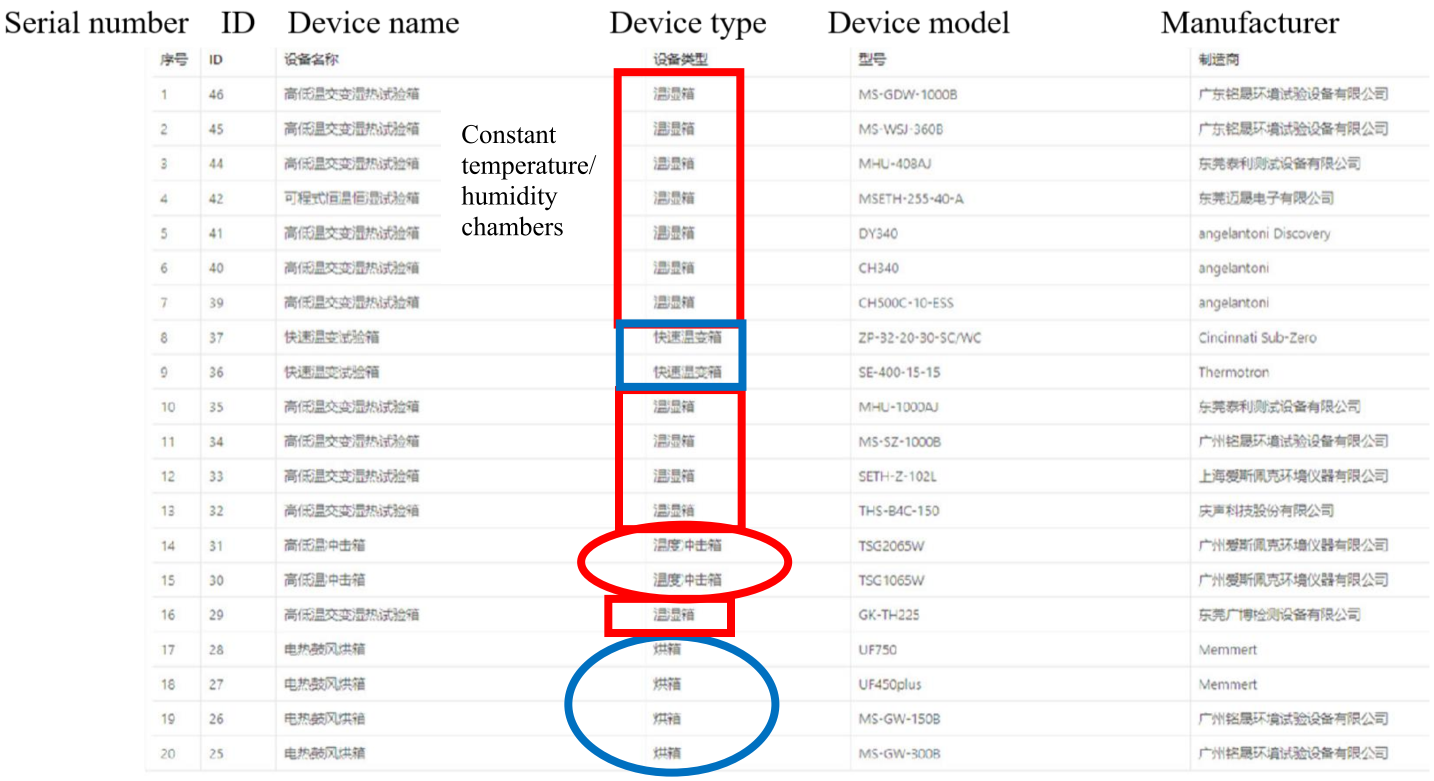


Figure 27 Test status monitoring on test instance(equipment is set to be temperature/humidity chambers)

Figure 27 shows the Test status monitoring function described in Figure 12. Since the simulated device is temperature and humidity chambers, the upper parameters from left to right are temperature set, actual temperature, humidity setting, and actual humidity. In the line chart below, the upper blue line shows temperature versus time, with time on the horizontal axis and degrees Celsius on the vertical axis. The lower green line shows the humidity versus time curve, where the horizontal axis is time, and the vertical axis is the percentage of humidity.



Serial number 序号	ID	Device name 设备名称	Device type 设备类型	Device model 型号	Manufacturer 制造商
1	46	高低温交变湿热试验箱	温湿箱	MS-GDW-1000B	广东铭晟环境试验设备有限公司
2	45	高低温交变湿热试验箱	温湿箱	MS-WSJ-360B	广东铭晟环境试验设备有限公司
3	44	高低温交变湿热试验箱	温湿箱	MHU-408AJ	东莞泰利测试设备有限公司
4	42	可程式恒温恒湿试验箱	温湿箱	MSETH-255-40-A	东莞迈晟电子有限公司
5	41	高低温交变湿热试验箱	温湿箱	DY340	angelantoni Discovery
6	40	高低温交变湿热试验箱	温湿箱	CH340	angelantoni
7	39	高低温交变湿热试验箱	温湿箱	CH500C-10-ESS	angelantoni
8	37	快速温变试验箱	快速温变箱	ZP-32-20-30-SC/WC	Cincinnati Sub-Zero
9	36	快速温变试验箱	快速温变箱	SE-400-15-15	Thermotron
10	35	高低温交变湿热试验箱	温湿箱	MHU-1000AJ	东莞泰利测试设备有限公司
11	34	高低温交变湿热试验箱	温湿箱	MS-SZ-1000B	广州铭晟环境试验设备有限公司
12	33	高低温交变湿热试验箱	温湿箱	SETH-Z-102L	上海爱斯佩克环境仪器有限公司
13	32	高低温交变湿热试验箱	温湿箱	THS-B4C-150	庆声科技股份有限公司
14	31	高低温冲击箱	温度冲击箱	TSG2065W	广州爱斯佩克环境仪器有限公司
15	30	高低温冲击箱	温度冲击箱	TSG1065W	广州爱斯佩克环境仪器有限公司
16	29	高低温交变湿热试验箱	温湿箱	GK-TH225	东莞广博检测设备有限公司
17	28	电热鼓风烘箱	烘箱	UF750	Memmert
18	27	电热鼓风烘箱	烘箱	UF450plus	Memmert
19	26	电热鼓风烘箱	烘箱	MS-GW-150B	广州铭晟环境试验设备有限公司
20	25	电热鼓风烘箱	烘箱	MS-GW-300B	广州铭晟环境试验设备有限公司

Figure 28 Equipment management dashborad
The devices in red boxes are constant temperature/humidity chambers.
The devices in the blue box are rapid temperature change chambers.
The devices in the red circle are temperature shock chambers.
The devices in the blue circle are ovens.

Figure 28 shows the Equipment management functionality described in Figure 12. This table shows all the information about the (virtual) devices currently connected to the cloud-based platform. The table is from left to right: serial number, ID, device name, device type, device model, and manufacturer. Since the devices entered in the current test instance are all virtual devices, the contents of the "Device name," "Device type," and "Manufacturer" columns are all from the device suppliers that SGS has cooperated with, and the dashboard function will not be affected by these data.

5.3 Evaluation Outcome

According to the experts' feedback on the performance of the test instance and their answers to the evaluation questions in Table 6(Appendix B &C), this section will describe the evaluation outcomes. The structure of this section is arranged in the order of the evaluation questions in Table 6.

EQ1: How the reference model performs in the build process of a cloud-based testing platform?

Due to the background of fully understanding the SGS laboratory environment and equipment, this cloud test reference model can thoroughly guide the development of the SGS cloud test platform. The cloud test platform established concerning the reference model has achieved small-scale applications. However, due to cost control reasons and time problems, SGS has not yet promoted implementing the cloud test platform in a large area.

EQ2: Did the model match the intended guiding purpose for designing and implementing a cloud-based testing platform in an inspection and certification company?

Due to the high degree of standardization and the similar purpose of automation in the internal laboratories of testing and certification companies, the reference model of the cloud-based testing platform has theoretically feasible. At the same time, this model can be combined with various IoT technologies, such as programmable intelligent gateways used in many test laboratories, making this model a good guide. But simultaneously, the reference model gives each role fixed permissions. Experts report that it will cause inconvenience in actual use. And laboratory operators need more detailed access distribution in real work instead of all laboratory operators getting the same access.

EQ3: Is the model easy to use?

In terms of ease of use, experts said that after understanding the ArchiMate language, the reference model is clear and easy to use. However, this conclusion is based on the reason that the inspection and certification company is already sufficiently familiar with the Enterprise Architecture and ArchiMate languages. Experts believe that inspection and certification companies that have not referenced Enterprise Architecture may find it difficult to utilize the reference model. Experts specifically mentioned that under the context of TeREES, since the cloud-based platform requires displaying its functions to customers outside the organization, the reference model built with the ArchiMate language increases the cost of communication.

EQ4: What were specific parts of the environment in the reference and built models impacted?

a. Due to the limited number of devices connected to the current instance, there is no independent application of the "operation and maintenance management system" to independently collect and monitor the fault information of each device. The error information in the current instance is saved in the system log, which can be found on the device's property page.

b. Since this instance is still in development, the current data isolation and permission control are based only on different information sources. For example, the experimenter responsible for the oven equipment cannot access the data from the rapid temperature change chamber through the platform instance.

c. Considering the economics, use the reference model example and add equipment that requires high human involvement. Therefore, the current cloud-based platform test sample is only connected to virtual temperature monitoring devices.

d. Experts suggest that the reference model sets different implementation suggestions according to different periods of cloud-based platform implementation to cooperate with the implementation of the cloud-based platform. For example, it is necessary to pay attention to the stability of the operation of the cloud-based platform during the initial implementation period and to pay attention to the scalability of the cloud-based platform during the expansion of connected devices on the cloud-based platform, etc.

EQ5: What social influence do you think will result from using the reference model?

Experts have different opinions on this issue. A member of the laboratory's cloud test platform design team said that systematically using this reference model for cloud-based platform design work allows him to complete his work more confidently. But another opinion was different. Since his leadership wanted a creative cloud-based platform design, the expert worried that using a reference model to guide the design effort would make his leadership think he was being lazy.

EQ6: Is this reference model compatible with other tools when building a cloud test platform?

Experts agree that the adoption of the reference model can be compatible with the required technologies, such as Web tools, intelligent gateways, and so on. Therefore, the compatibility of the reference model meets the requirements. However, experts suggest that the reference model should be used as a guidance document to point out compatible technologies, such as the two downward transfer methods proposed in 4.3.2, and point out the advantages and disadvantages of different ways. As for the compatible equipment, because the matching intelligent gateway STAS-PLUS has been used in the laboratory environment of SGS for compatibility equipment, the compatibility is good.

EQ7: Will you use this reference model when building a cloud test platform?

Experts say they will consider applying the reference model to build a cloud test platform. However, an expert is concerned about whether the cloud test platform reference model will affect the competitiveness of the case company when it is adopted by other inspection and certification companies. Similarly, experts are concerned about whether the verification and validation company managers will agree that all stakeholders learn the ArchiMate language to apply the reference model. Experts worry managers will see learning costs as too high.

6. Conclusions and Recommendations

This report takes the proposed cloud test platform reference model in the past literature as the starting point, takes the laboratory in the inspection and certification company as the target environment, and builds a cloud test platform architecture reference model suitable for inspection and certification laboratories. The cloud-based platform control model of the laboratory and the related permission control table. This report uses the TeREES cloud-based platform of SGS, which refers to this model, to verify the feasibility of the reference model. The main research contents are as follows.

6.1 Research Questions

The goal of the research is to propose a cloud-based testing reference model for inspection and certification companies to improve their business performance and complete complicated tasks. As described in Chapter 1.3, the main research question is:

What is an appropriate cloud-based testing reference model for the SGS testing lab, and how should it be implemented?

In order to answer the main research question, some sub-research objectives and sub-research questions are proposed, and each of them will be discussed in the following paragraphs:

RQ1: What is the existing reference model for the cloud-based testing?

There are mainly three types of architecture: three-layer architecture, middleware-based architecture, and service-oriented architecture (figure 5). The three-layer architecture composed of the perception layer, network layer, and application layer is too simple and not instructive. In the middleware-based architecture, the role of middleware has been replaced by an intelligent gateway, so there is no need to build a complex middleware in the reference model. Finally, a service-oriented architecture is better for tests that require less human intervention, while tests that require more human intervention are harder to implement. A different finding is the Physical Mashups reference model (figure 4). The “physical mashups – event club” connection mode is introduced to the reference model. Due to the research in this report, we decided to draw on the advantages of these architectures and design a cloud test platform reference model suitable for inspection and certification company laboratories.

RQ2: Which are the benefits of adopting cloud-based testing platform for the stakeholders?

This report summarizes the demand analysis of the cloud test platform's inspection and certification company laboratory through a literature search and field observation.

There are three main functional requirements: first, the platform is required to be able to use the working status, attributes, and generated data of various equipment in the laboratory; second, as a medium for the laboratory to share data within the company and externally; third, for equipment generated The data, is used for preliminary data processing and equipment status control, including the addition, deletion, and modification of data, reservation of equipment experiments, remote opening and closing, etc.

RQ3: What requirements are needed to be fulfilled for testing and certification company and their stakeholders when adopting cloud-based testing?

The functional requirements of the cloud test platform reference model mainly include three aspects: information collection, data transmission, data processing, and device control. The stakeholders' needs are mainly remote monitoring, remote control, information display, and information sharing.

RQ4: How should the cloud-based testing reference model be designed?

Concerning the above three points, this report designs the following content: this report designs a cloud test platform reference model (4.3) and a cloud-based platform control model (figure 21).

1. Cloud-based platform reference model for Inspection and certification Laboratories

First, this report uses ArchiMate to describe the existing environment of SGS company's laboratory (4.1) and conducts stakeholder analysis for inspection and certification companies based on literature and field research. Second, this report designs a four-layer architecture cloud test platform reference model (4.3) based on middleware-based architecture and service-oriented architecture. Table 4 describes the functions of the reference model. Figure 13 describes the implementation diagram of the cloud test platform. The research refers to the reference models of Three-Layer Architecture, middle-ware-based architecture, and service-oriented architecture and designs a four-layer cloud test platform reference model suitable for inspection and certification laboratories. The model introduces the entities arranged at each layer and the interfaces connected. It is proved that the model can be applied in practice after a small-scale adoption in a laboratory of SGS.

2. Cloud-based platform control model for inspection and certification laboratories

This report designs a control model (4.4) based on different states of equipment based on the reference model of the cloud test platform. In order to adapt to the implementation of the cloud-based platform reference model, this report designs a cloud-based platform control model based on monitoring the device status and appointment schedule from the Device level. This control model lays the foundation for the system to realize the intelligent control of the test process.

RQ5: How to change the laboratory management policy to fit the cloud-based testing system?

In order to fit the implementation of the cloud-based testing platform, a new business process (figure 14), a device resource description (figure 19), a detected sample description (figure 20), a permission assignment table (Table 5), and a user assignment checklist (Table 6) based on stakeholder analysis are designed.

Figure 14 depicts the business process after the inspection and certification company has implemented the cloud-based platform. The difference between the new business process and the baseline process is that documents and information can be shared through the cloud-based platform.

This report also describes the representation in the cloud-based platform for equipment and experimental samples and the required parameters as a sample for companies to reference (4.3.3). For the permission assignment table, this article takes the Basic Role-Based access control model as a reference. It defines an access control table suitable for testing and certification companies adapted to the cloud test platform reference model.

RQ6: How effective is the cloud-based testing reference model?

This report applies the research method of TAR, uses TeREES of SGS Company as the background and introduces this reference model to the cloud-based platform designers of SGS Company. These designers designed a test case (figure 24) referring to this reference model (Chapter 4) and the company's business process. Finally, this article discusses the test case and reference model with three experts from SGS according to the impact question list mentioned in Table 7 of 5.1 and evaluates the reference model.

6.2 Reflection and Contribution

As mentioned in Chapter 5, the reference model has generally been positively evaluated by experts. These evaluations mean that the cloud-based platform technology has good applicability to the inspection and certification industry under the background that the inspection and certification industry has not yet widely adopted the cloud-based platform. At the same time, the requirements of inspection and certification industry stakeholders described in Chapter 3 also indicate that companies in this industry have incentives to introduce cloud-based platform technologies. The above two points prove that this reference model has high practical value for the inspection and certification industry.

This report takes the business process of the inspection and certification company and the local laboratory composition as the starting point; through literature research and stakeholder analysis, builds a cloud-based platform suitable for the inspection and certification company, a remote-control model for the cloud-based platform and a role-based access control method. The main research content is as follows.

(1) The cloud-based testing platform and a new business process suitable for inspection and certification companies

This report compares Physical Mashups architecture, Three-Layer Architecture(a), middle-ware-based architecture(b), and service-oriented architecture [19, 36], combines the advantages of these models with the needs of stakeholders, and designs a cloud-based test platform with a 4-layer architecture through the ArchiMate modeling language, the platform's functions, implementation methods and new business processes applicable to the platform. Finally, the feasibility of the model is proved through the implemented test instance and expert review. This lays the foundation for the realization of cloud-based remote control and partially automated testing in laboratories of inspection and certification companies.

(2) The remote-control model applicable for the cloud-based test platform

This report, based on BPMN language and device resource description, builds a cloud-based platform control model. The model presents three states of the device: idle, running, and faulty, and it conducts experiments by judging the state of the device and the appointment time of the device. It should be noted that since the current test samples of the cloud-based test platform only control temperature-controlled box-type equipment, the preset equipment status of this control model is relatively simple. This provides the basis for fully automated testing for future inspection and certification companies.

(3) Role-based access control method

This report, based on Role-Based Access Control (RBAC) model, builds an access control method. This method consists of a permission assignment checklist and a user assignment checklist, designed to meet the requirements of inspection and certification company information confidentiality and information sharing. It should be noted that this method has not yet been verified by the test instance.

The results of this study will contribute to the research fields of LaaS, cloud-based platforms, and cloud-based testing. In the field of LaaS, reference models such as Three-Layer Architecture(a), middle-ware-based architecture(b), and service-oriented architecture have been proposed [36]. However, we applied the research results earlier than others to the inspection and certification industry (previous studies mostly focus on cloud-based testing in the education field). A reference model is proposed to assist in the automation of the inspection and certification industry. The model delivered by this study is a model designed by the ArchiMate language and a control model designed by the BPMN language, and the technology and structure adopted by the middle-ware, the expression method of the equipment and samples, and the authority distribution table are added. In addition, the model designs a new business process after adopting the cloud-based platform for the past business process of the inspection and certification company to focus on the implementation of the reference model.

6.3 Limitation and Future Research

There are several limitations points identified in this research.

Currently, the model has only been partially implemented, and the feasibility of the LAN remote control has only been verified on equipment with a constant temperature and humidity chamber, temperature shock chamber, rapid temperature change chamber, and oven. The reference model needs to be verified in a wider range of laboratory environments with equipment that receives more complex instructions. In addition, if it can be implemented in the Internet environment, the reference model will also be of great significance for the intelligent management and control of testing and certification companies.

Second, the access control list fails the test in the validation instance. This is due to the current TeREEs project is still in the experimental stage. At this stage, no multi-user interface and control system was added. It is suggested that an access control method can be added in future research to fulfill stakeholders' requirements.

Third, the current reference model does not set different implementation suggestions according to different periods of cloud-based platform implementation to match the actual implementation of the cloud-based platform. The time constraints of this study affected this step. Since the duration of this study was completed within half a year, this step could not be fully completed. Therefore, it is suggested that in future research, based on the different stages of the cloud-based platform implementation and the size of the company, different implementation suggestions can be added to make the cloud platform more applicable.

Regarding the mentioned limitations, for future research, it is recommended to verify the feasibility of remote control in different devices that may be applied by inspection and certification companies. It is recommended to set up access control under Internet conditions and test the impact of multi-user interfaces on cloud-based platforms to keep information from leakage. And it is also recommended to give implementation suggestions step by step for the implementation process of reference models for inspection and certification companies under different circumstances.

7. Reference

[1] V. Janani and D. K. Krishnamoorty, “Cloud Testing as a Service (CTaaS) – Analysis, Design and Implementation,” p. 15.

[2] A. A. Kist et al., “Overlay network architectures for peer-to-peer Remote Access Laboratories,” in 2014 11th International Conference on Remote Engineering and Virtual Instrumentation (REV), Porto, Portugal: IEEE, Feb. 2014, pp. 274–280. doi: 10.1109/REV.2014.6784274.

[3] M. A. Bochicchio and A. Longo, “Delivering Collaborative Web Labs as a Service for Engineering Education,” Int. J. Onl. Eng., vol. 8, no. 2, p. 4, May 2012, doi: 10.3991/ijoe.v8i2.1897.

[4] J. Broisin, R. Venant, and P. Vidal, “Lab4CE: a Remote Laboratory for Computer Education,” Int J Artif Intell Educ, vol. 27, no. 1, pp. 154–180, Mar. 2017, doi: 10.1007/s40593-015-0079-3.

[5] A. H. Celdran, F. J. G. Clemente, J. Saenz, L. De La Torre, C. Salzmann, and D. Gillet, “Self-Organized Laboratories for Smart Campus,” IEEE Trans. Learning Technol., vol. 13, no. 2, pp. 404–416, Apr. 2020, doi: 10.1109/TLT.2019.2940571.

[6] M. Tawfik et al., “Laboratory as a Service (LaaS): a Novel Paradigm for Developing and Implementing Modular Remote Laboratories,” Int. J. Onl. Eng., vol. 10, no. 4, p. 13, Jun. 2014, doi: 10.3991/ijoe.v10i4.3654.

[7] A. C. Caminero et al., “On the Creation of Customizable Laboratory Experiments: Deconstruction of Remote Laboratories to Create Laboratories as a Service (LaaS),” Int. J. Onl. Eng., vol. 10, no. 6, p. 35, Oct. 2014, doi: 10.3991/ijoe.v10i6.3989.

[8] V. Komarov and A. Sarafanov, “IoT systems in the process of multidisciplinary training of personnel for the digital economy and their design,” Bus. Inform., vol. 15, no. 2, pp. 47–59, Jun. 2021, doi: 10.17323/2587-814X.2021.2.47.59.

[9] R. Pastor et al., “Laboratories as a Service (LaaS): Using Cloud Technologies in the Field of Education,” p. 15.

[10] C. Tao and J. Gao, “On building a cloud-based mobile testing infrastructure service system,” Journal of Systems and Software, vol. 124, pp. 39–55, Feb. 2017, doi: 10.1016/j.jss.2016.11.016.

[11] L. Tobarra et al., “Creation of Customized Remote Laboratories Using Deconstruction,” IEEE R. Iberoamericana Tecnologias Aprendizaje, vol. 10, no. 2, pp. 69–76, May 2015, doi: 10.1109/RITA.2015.2418011.

[12] L. Tobarra et al., “An Integrated Example of Laboratories as a Service into Learning Management Systems,” Int. J. Onl. Eng., vol. 12, no. 09, p. 32, Sep. 2016, doi: 10.3991/ijoe.v12i09.6149.

[13] “About SGS,”. (2002). SGS homepage. https://www.sgs.com/en/our-company/about-sgs(accessed Sep. 2022)
[14] Peffers, K et al., "A design science research methodology for information systems research," Journal of Management Information Systems. 24. 45-77, 2007
[15] A. Touhafi, A. Braeken, A. Tahiri, and M. Zbakh, “CoderLabs: A cloud-based platform for real-time online labs with user collaboration,” Concurrency Computat Pract Exper, vol. 30, no. 12, p. e4377, Jun. 2018, doi: 10.1002/cpe.4377.
[16] B. Kitchenham, “Procedures for Performing Systematic Reviews,” p. 33, Jul. 2004.
[17] Y. Yin and H. Niu, “Quantitative Evaluation Approach of Cloud Capability Service for Knowledge in Cloud Manufacturing,” Nongye Jixie Xuebao/Transactions of the Chinese Society for Agricultural Machinery, vol. 47, no. 8, pp. 325–332, Aug. 2016, doi: 10.6041/j.issn.1000-1298.2016.08.043.
[18] J. Gao, Xiaoying Bai, Wei-Tek Tsai, and T. Uehara, “Testing as a Service (TaaS) on Clouds,” in 2013 IEEE Seventh International Symposium on Service-Oriented System Engineering, Redwood City: IEEE, Mar. 2013, pp. 212–223. doi: 10.1109/SOSE.2013.66.
[19] D. Guinard, V. Trifa, and E. Wilde, “A resource oriented architecture for the Web of Things,” in 2010 Internet of Things (IOT), Tokyo, Japan: IEEE, Nov. 2010, pp. 1–8. doi: 10.1109/IOT.2010.5678452.
[20] A. D. Aguru, E. S. Babu, S. R. Nayak, A. Sethy, and A. Verma, “Integrated Industrial Reference Architecture for Smart Healthcare in Internet of Things: A Systematic Investigation,” Algorithms, vol. 15, no. 9, p. 309, Aug. 2022, doi: 10.3390/a15090309.
[21] A. De Francesco, C. Di Napoli, M. Giordano, G. Ottaviano, R. Perego, and N. Tonellotto, “A SOA Testing Platform on the Cloud: The MIDAS Experience,” in 2014 International Conference on Intelligent Networking and Collaborative Systems, Salerno: IEEE, Sep. 2014, pp. 659–664. doi: 10.1109/INCoS.2014.62.
[22] Janani, V., & Krishnamoorty, D. K, “Cloud-based testing as a Service (CTaaS) – Analysis, Design and Implementation”. 15.
[23] Buyya, R., Ranjan, R., Calheiros, R.N, “ InterCloud: Utility-Oriented Federation of Cloud Computing Environments for Scaling of Application Services”. In: Hsu, CH., Yang, L.T., Park, J.H., Yeo, SS. (eds) Algorithms and Architectures for Parallel Processing. ICA3PP 2010. Lecture Notes in Computer Science, vol 6081. Springer, Berlin, Heidelberg. https://doi-org.ezproxy2.utwente.nl/10.1007/978-3-642-13119-6_2.
[24] W. Tang, Z. Niu, B. Zhao, T. Ji, M. Liu, and Q. Wu, “Research and Application of Data-driven Artificial Intelligence Technology for Condition Analysis of Power Equipment,” Gaodianya Jishu/High Voltage Engineering, vol. 46, no. 9, pp. 2985–

2999, Sep. 2020, doi: 10.13336/j.1003-6520.hve.20191902.
[25] D. Chhillar and K. Sharma, “ACT Testbot and 4S Quality Metrics in XAAS Framework,” in 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon), Faridabad, India: IEEE, Feb. 2019, pp. 503–509. doi: 10.1109/COMITCon.2019.8862212.
[26] R. Li et al., “POTASSIUM: Penetration Testing as a Service,” in Proceedings of the Sixth ACM Symposium on Cloud Computing, Kohala Coast Hawaii: ACM, Aug. 2015, pp. 30–42. doi: 10.1145/2806777.2806935.
[27] A. Maiti, A. A. Kist, and A. D. Maxwell, “Components relationship analysis in distributed remote laboratory apparatus with data clustering,” in 2015 IEEE 24th International Symposium on Industrial Electronics (ISIE), Buzios, Rio de Janeiro, Brazil: IEEE, Jun. 2015, pp. 797–802. doi: 10.1109/ISIE.2015.7281571.
[28] A. Maiti, A. A. Kist, and A. D. Maxwell, “Building Markov Decision Process Based Models of Remote Experimental Setups for State Evaluation,” in 2015 IEEE Symposium Series on Computational Intelligence, Cape Town, South Africa: IEEE, Dec. 2015, pp. 389–397. doi: 10.1109/SSCI.2015.65.
[29] “OASIS SOA Reference Model (SOA-RM) TC, “, from https://www.oasis-open.org/committees/soa-rm/faq.php, (accessed October 24, 2022)
[30] Iacob, M. E., Jonkers, H., Quartel, D., Franken, H., & van den Berg, H., “Delivering Enterprise Architecture with TOGAF® and ARCHIMATE®”, 2012
[31] C. Britton and P. Bye, IT architectures and middleware: strategies for building large, integrated systems, 2nd ed. Boston: Addison-Wesley, 2004.
[32] "AWS IoT Device Management Secure Tunnel,"AWS, https://aws.amazon.com/cn/iot-device-management/features/,(accessed Sep. 2022)
[33] R. S. Sandhu, E. J. Coyne, H. L. Feinstein, and C. E. Youman, “Role-based access control models,” Computer, vol. 29, no. 2, pp. 38–47, Feb. 1996, doi: 10.1109/2.485845.
[34] Lin, L., Luo, J., Deng, X., Song, Z., “Role Based Access Control in MIS,” Application Research of Computers, pp. 82-84, 2022.
[35] Venkatesh Babu, R., Ramakrishnan, K.R, “Compressed domain human motion recognition using motion history information,” in 2003 IEEE International Conference on Image Processing, 3, pp. 321-324.
[36] Yan, M., Sun, H., Wang, X., & Liu, X., “Building a TaaS Platform for Web Service Load Testing”. 2012 IEEE International Conference on Cluster Computing, 576–579. https://doi.org/10.1109/CLUSTER.2012.20
[37] M. A. Bochicchio, A. Longo, and A. Secco, “An online laboratory for SLA management,” in 2013 IEEE Global Engineering Education Conference (EDUCON), Berlin: IEEE, Mar. 2013, pp. 1130–1136. doi: 10.1109/EduCon.2013.6530250.
[38] D. Adhipta and M. F. B. Hassan, “Single and replicated simulations for colored

Petri Nets nondeterministic network,” in 2010 International Symposium on Information Technology, Kuala Lumpur, Malaysia: IEEE, Jun. 2010, pp. 1–5. doi: 10.1109/ITSIM.2010.5561378.
[39] A. Agrawal and S. Srivastava, “WebLab: A Generic Architecture for Remote Laboratories,” in 15th International Conference on Advanced Computing and Communications (ADCOM 2007), Guwahati, Assam, India: IEEE, Dec. 2007, pp. 301–306. doi: 10.1109/ADCOM.2007.71.
[41] A.-R. Al-Ghuwairi, H. Eid, M. Aloran, Z. Salah, A. H. Baarah, and A. A. Al-oqaily, “A mutation-based model to rank testing as a service (TaaS) Providers in cloud computing,” in Proceedings of the International Conference on Internet of things and Cloud Computing, Cambridge United Kingdom: ACM, Mar. 2016, pp. 1–5. doi: 10.1145/2896387.2896403.
[42] E. Al-Masri, “Lab-as-a-Service (LaaS): A Middleware Approach for Internet-Accessible Laboratories,” in 2018 IEEE Frontiers in Education Conference (FIE), San Jose, CA, USA: IEEE, Oct. 2018, pp. 1–5. doi: 10.1109/FIE.2018.8658702.
[43] A. Ali and N. Badr, “Performance testing as a service for web applications,” in 2015 IEEE Seventh International Conference on Intelligent Computing and Information Systems (ICICIS), Cairo, Abbassia, Egypt: IEEE, Dec. 2015, pp. 356–361. doi: 10.1109/IntelCIS.2015.7397245.
[44] A. Ali, H. A. Maghawry, and N. Badr, “Automated parallel GUI testing as a service for mobile applications,” J Softw Evol Proc, vol. 30, no. 10, p. e1963, Oct. 2018, doi: 10.1002/smr.1963.
[45] S. Ali and H. Li, “Moving Software Testing to the Cloud: An Adoption Assessment Model Based on Fuzzy Multi-Attribute Decision Making Algorithm,” in 2019 IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA), Tokyo, Japan: IEEE, Apr. 2019, pp. 382–386. doi: 10.1109/IEA.2019.8714986.
[46] I. Angulo, J. Garcia-Zubia, P. Orduna, and O. Dziabenko, “Addressing low cost remote laboratories through federation protocols: Fish tank remote laboratory,” in 2013 IEEE Global Engineering Education Conference (EDUCON), Berlin: IEEE, Mar. 2013, pp. 757–762. doi: 10.1109/EduCon.2013.6530192.
[47] J. A. Asumadu et al., “A Web-Based Electrical and Electronics Remote Wiring and Measurement Laboratory (RwmLAB) Instrument,” IEEE Trans. Instrum. Meas., vol. 54, no. 1, pp. 38–44, Feb. 2005, doi: 10.1109/TIM.2004.834597.
[48] M. E. Auer and R. Langmann, Eds., Smart Industry & Smart Education: Proceedings of the 15th International Conference on Remote Engineering and Virtual Instrumentation_pp395_402_, vol. 47. in Lecture Notes in Networks and Systems, vol. 47. Cham: Springer International Publishing, 2019. doi: 10.1007/978-3-319-95678-7.

[49] A. K. M. Azad, M. E. Auer, and V. J. Harward, Eds., Internet Accessible Remote Laboratories: Scalable E-Learning Tools for Engineering and Science Disciplines. IGI Global, 2012. doi: 10.4018/978-1-61350-186-3.
[50] E.-S. Aziz, Z. Wang, S. Esche, and C. Chassapis, “Development of a Modularized Architecture for Remote-Access Laboratories,” in 2011 ASEE Annual Conference & Exposition Proceedings, Vancouver, BC: ASEE Conferences, Jun. 2011, p. 22.475.1-22.475.16. doi: 10.18260/1-2--17756.
[51] X. Bai, M. Li, X. Huang, W.-T. Tsai, and J. Gao, “Vee@Cloud: The virtual test lab on the cloud,” in 2013 8th International Workshop on Automation of Software Test (AST), San Francisco, CA, USA: IEEE, May 2013, pp. 15–18. doi: 10.1109/IWAST.2013.6595785.
[52] P. Beňo, F. Schauer, S. Šprinková, M. Šimko, and T. Komenda, “Road to Strengthen of Virtual Infrastructure and Security of Remote Laboratories on Trnava University in Trnava,” Int. J. Onl. Eng., vol. 16, no. 12, p. 33, Oct. 2020, doi: 10.3991/ijoe.v16i12.16701.
[53] L. Berruti, F. Davoli, and S. Zappatore, “Performance evaluation of measurement data acquisition mechanisms in a distributed computing environment integrating remote laboratory instrumentation,” Future Generation Computer Systems, vol. 29, no. 2, pp. 460–471, Feb. 2013, doi: 10.1016/j.future.2012.07.007.
[55] M. A. Bochicchio and A. Longo, “Hands-On Remote Labs: Collaborative Web Laboratories as a Case Study for IT Engineering Classes,” IEEE Trans. Learning Technol., vol. 2, no. 4, pp. 320–330, Oct. 2009, doi: 10.1109/TLT.2009.30.
[56] J. Broisin, R. Venant, and P. Vidal, “A remote laboratory to leverage motivation of learners to practice: An exploratory study about system administration,” in Proceedings of 2015 12th International Conference on Remote Engineering and Virtual Instrumentation (REV), Bangkok, Thailand: IEEE, Feb. 2015, pp. 140–142. doi: 10.1109/REV.2015.7087280.
[58] J. Cano, R. Hernandez, S. Ros, and L. Tobarra, “A distributed laboratory architecture for game based learning in cybersecurity and critical infrastructures,” in 2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), Madrid: IEEE, Feb. 2016, pp. 183–185. doi: 10.1109/REV.2016.7444461.
[61] M. Corrado, L. De Vito, H. Ramos, and J. Saliga, “Hardware and software platform for ADCWAN remote laboratory,” Measurement, vol. 45, no. 4, pp. 795–807, May 2012, doi: 10.1016/j.measurement.2011.12.003.
[62] D. Sa´nchez, “On the use of cloud technologies to provide remote laboratories as a service,” Computer Physics Communications, vol. 156, no. 2, pp. 199–204, Jan. 2004, doi: 10.1016/S0010-4655(03)00440-5.
[64] K. Efstathiou, D. Karadimas, and K. Zafeiropoulos, “A Remote Electrical

Engineering Laboratory based on Re-Configurable Hardware,” in 2007 IEEE Instrumentation & Measurement Technology Conference IMTC 2007, Warsaw, Poland: IEEE, May 2007, pp. 1–6. doi: 10.1109/IMTC.2007.379198.
[65] L. Favario, A. R. Meo, and E. Masala, “Seamless cross-platform integration of educational resources for improved learning experiences,” in 2015 IEEE Frontiers in Education Conference (FIE), Camino Real El Paso, El Paso, TX, USA: IEEE, Oct. 2015, pp. 1–4. doi: 10.1109/FIE.2015.7344387.
[67] J. Gao et al., “A cloud-based TaaS infrastructure with tools for SaaS validation, performance and scalability evaluation,” in 4th IEEE International Conference on Cloud Computing Technology and Science Proceedings, Taipei, Taiwan: IEEE, Dec. 2012, pp. 464–471. doi: 10.1109/CloudCom.2012.6427555.
[68] F. J. García-Peñalvo, M. Johnson, G. R. Alves, M. Minović, and M. Á. Conde-González, “Informal learning recognition through a cloud ecosystem,” Future Generation Computer Systems, vol. 32, pp. 282–294, Mar. 2014, doi: 10.1016/j.future.2013.08.004.
[69] G. Goos et al., “Lecture Notes in Computer Science”.
[70] C. Gravier, J. Fayolle, B. Bayard, M. Ates, and J. Lardon, “Remote laboratories: Proposed guidelines,” in 2007 2nd International Conference on Digital Information Management, Lyon, France: IEEE, 2007, pp. 786–792. doi: 10.1109/ICDIM.2007.4444320.
[71] E. Grosclaude, F. López Luro, and M. L. Bertogna, “Grid Virtual Laboratory Architecture,” in Euro-Par 2007 Workshops: Parallel Processing, L. Bougé, M. Forsell, J. L. Träff, A. Streit, W. Ziegler, M. Alexander, and S. Childs, Eds., in Lecture Notes in Computer Science, vol. 4854. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, pp. 164–173. doi: 10.1007/978-3-540-78474-6_21.
[72] S. Hammoudi, L. F. Pires, B. Selic, and P. Desfray, Eds., Model-Driven Engineering and Software Development_p114_Automated Web Service Composition Testing as a Service, vol. 692. in Communications in Computer and Information Science, vol. 692. Cham: Springer International Publishing, 2017. doi: 10.1007/978-3-319-66302-9.
[73] J. L. Hardison, K. DeLong, V. J. Harward, J. A. del Alamo, R. Shroff, and O. Oyabode, “Enabling Remote Design and Troubleshooting Experiments Using the iLab Shared Architecture,” in Earth and Space 2010, Honolulu, Hawaii, United States: American Society of Civil Engineers, Mar. 2010, pp. 3721–3733. doi: 10.1061/41096(366)357.
[74] J. L. Hardison, K. DeLong, P. H. Bailey, and V. J. Harward, “Deploying interactive remote labs using the iLab Shared Architecture,” in 2008 38th Annual Frontiers in Education Conference, Saratoga Springs, NY, USA: IEEE, Oct. 2008, pp. S2A-1-S2A-6. doi: 10.1109/FIE.2008.4720536.

[75] S. Herbold et al., “The MIDAS Cloud-based platform for Testing SOA Applications,” in 2015 IEEE 8th International Conference on Software Testing, Verification and Validation (ICST), Graz, Austria: IEEE, Apr. 2015, pp. 1–8. doi: 10.1109/ICST.2015.7102636.
[76] S. Herbold and A. Hoffmann, “Model-based testing as a service,” Int J Softw Tools Technol Transfer, vol. 19, no. 3, pp. 271–279, Jun. 2017, doi: 10.1007/s10009-017-0449-2.
[77] Á. Herrero, B. Baruque, J. Sedano, H. Quintián, and E. Corchado, Eds., International Joint Conference: CISIS’15 and ICEUTE’15_pp559_569_2015, vol. 369. in Advances in Intelligent Systems and Computing, vol. 369. Cham: Springer International Publishing, 2015. doi: 10.1007/978-3-319-19713-5.
[78] S. Jameela, K. T. Rao, V. K. Reddy, P. Saikiran, and B. T. Rao, “Efficient Framework for Testing Cross-Cloud Application,” p. 9.
[79] G. C. Jana, S. Barman, A. Swetapadma, and S. Banerjee, “Notice of Violation of IEEE Publication Principles: Enactment of remote laboratory management model based on mobile cloud computing,” in 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), Bangalore: IEEE, May 2017, pp. 1396–1401. doi: 10.1109/RTEICT.2017.8256827.
[81] D. Karadimas and K. Efstathiou, “An Integrated Educational Platform Implementing Real, Remote Lab-Experiments for Electrical Engineering Courses,” JCP, vol. 2, no. 2, pp. 37–44, Apr. 2007, doi: 10.4304/jcp.2.2.37-44.
[82] M. Kaur, “Testing in the cloud: New challenges,” in 2016 International Conference on Computing, Communication and Automation (ICCCA), Greater Noida, India: IEEE, Apr. 2016, pp. 742–746. doi: 10.1109/CCAA.2016.7813826.
[83] A. M. Khamis, F. J. Rodriguez, and M. A. Salichs, “Remote Interaction with Mobile Robots,” p. 15.
[85] A. A. Kist, A. Maiti, and A. D. Maxwell, “Introducing RALfie — Remote access laboratories for fun, innovation and education,” in 2015 3rd Experiment International Conference (exp.at’15), Ponta Delgada, Portugal: IEEE, Jun. 2015, pp. 124–125. doi: 10.1109/EXPAT.2015.7463236.
[86] A. A. Kist, A. Maiti, A. D. Maxwell, L. Orwin, P. Albion, and W. Ting, “The game and activity environment of RALfie: Remote access laboratories for fun, innovation and education,” in 2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), Madrid, Spain: IEEE, Feb. 2016, pp. 324–325. doi: 10.1109/REV.2016.7444492.
[87] A. Kist et al., “Hosting and Sharing Your Own Remote Experiments with RALfie – an Open Ended Experiment Design Experience,” Int. J. Onl. Eng., vol. 12, no. 04, p. 40, Apr. 2016, doi: 10.3991/ijoe.v12i04.5101.
[89] A. Kutlu and T. Aydogan, “Performance Analysis of MicroNet: A Higher Layer

Protocol for Multiuser Remote Laboratory," IEEE Trans. Ind. Electron., vol. 56, no. 12, pp. 4784–4790, Dec. 2009, doi: 10.1109/TIE.2008.2006228.
[90] D. Lakatos, J. Poruban, and M. Nosal', "Performing experiments in 3rd party premises using cloud-based virtual machine as remote laboratory: Case study of controlled experiment with high school students in their school," in 2016 International Conference on Emerging eLearning Technologies and Applications (ICETA), Vysoke Tatry: IEEE, Nov. 2016, pp. 189–194. doi: 10.1109/ICETA.2016.7802041.
[91] M. Latorre Garcia, G. Carro Fernandez, E. Sancristobal Ruiz, A. Pesquera Martin, and M. Castro Gil, "Rethinking remote laboratories: Widgets and smart devices," in 2013 IEEE Frontiers in Education Conference (FIE), Oklahoma City, OK, USA: IEEE, Oct. 2013, pp. 782–788. doi: 10.1109/FIE.2013.6684933.
[92] J. H. Lee, "Grid-based recording and replay architecture in hybrid remote experiment using distributed streaming network," J Supercomput, vol. 67, no. 3, pp. 757–777, Mar. 2014, doi: 10.1007/s11227-013-0996-6.
[93] Lei Ning, Zhenyong Wang, Qing Guo, Kaiyuan Jiang, and Ming Li, "Design of cooperation-based remote laboratory for distributed experimentation and simulation," in 2013 IEEE Wireless Communications and Networking Conference (WCNC), Shanghai, Shanghai, China: IEEE, Apr. 2013, pp. 4499–4503. doi: 10.1109/WCNC.2013.6555303.
[94] Z. Lei et al., "Modular Web-Based Interactive Hybrid Laboratory Framework for Research and Education," IEEE Access, vol. 6, pp. 20152–20163, 2018, doi: 10.1109/ACCESS.2018.2821713.
[96] A. Maiti and C. K. Maiti, "Development of remote laboratories using cloud architecture with web instrumentation," in 2013 10th International Conference on Remote Engineering and Virtual Instrumentation (REV), Sydney, NSW: IEEE, Feb. 2013, pp. 1–4. doi: 10.1109/REV.2013.6502902.
[97] A. Maiti, A. A. Kist, and A. D. Maxwell, "Real-Time Remote Access Laboratory with Distributed and Modular Design," IEEE Trans. Ind. Electron., pp. 1–1, 2014, doi: 10.1109/TIE.2014.2374572.
[98] A. Maiti, A. A. Kist, and A. D. Maxwell, "Design and operational reliability of a Peer-to-Peer distributed remote access laboratory," in Proceedings of 2015 12th International Conference on Remote Engineering and Virtual Instrumentation (REV), Bangkok, Thailand: IEEE, Feb. 2015, pp. 94–99. doi: 10.1109/REV.2015.7087270.
[101] A. Maiti, D. G. Zutin, H.-D. Wuttke, K. Henke, A. D. Maxwell, and A. A. Kist, "A Framework for Analyzing and Evaluating Architectures and Control Strategies in Distributed Remote Laboratories," IEEE Trans. Learning Technol., vol. 11, no. 4, pp. 441–455, Oct. 2018, doi: 10.1109/TLT.2017.2787758.
[102] B. H. Malik et al., "IoT Testing-as-a-Service: A New Dimension of Automation," IJACSA, vol. 10, no. 5, 2019, doi: 10.14569/IJACSA.2019.0100545.

[103] C. Markan, S. Gupta, S. Mittal, and G. Kumar, “Remote Laboratories - A Cloud Based Model for Teleoperation of Real Laboratories,” Int. J. Onl. Eng., vol. 9, no. 2, p. 36, Apr. 2013, doi: 10.3991/ijoe.v9i2.2491.
[104] M. A. Martínez-Carreras and A. F. Gómez-Skarmeta, “Towards interoperability: a wrapper model for integrating remote laboratories in a collaborative discovery learning environment,” Softw: Pract. Exper., vol. 38, no. 15, pp. 1601–1620, Dec. 2008, doi: 10.1002/spe.881.
[105] N. Mohammadi, I. Murray, and G. Hsiung, “Remote renewable energy laboratory: Green Electric Energy Park (GEEP),” in 2017 4th Experiment@International Conference (exp.at’17), Faro, Portugal: IEEE, Jun. 2017, pp. 196–201. doi: 10.1109/EXPAT.2017.7984365.
[106] G. Molto and M. Caballer, “On using the cloud to support online courses,” in 2014 IEEE Frontiers in Education Conference (FIE) Proceedings, Madrid, Spain: IEEE, Oct. 2014, pp. 1–9. doi: 10.1109/FIE.2014.7044041.
[107] S. Mungekar and D. Toradmalle, “W TaaS: An architecture of website analysis in a cloud environment,” in 2015 1st International Conference on Next Generation Computing Technologies (NGCT), Dehradun, India: IEEE, Sep. 2015, pp. 21–24. doi: 10.1109/NGCT.2015.7375075.
[108] P. Orduña, J. Irurzun, L. Rodriguez-Gil, J. Garcia-Zubia, F. Gazzola, and D. López-de-Ipiña, “Adding New Features to New and Existing Remote Experiments through their Integration in WebLab-Deusto,” Int. J. Onl. Eng., vol. 7, no. S2, p. 33, Oct. 2011, doi: 10.3991/ijoe.v7iS2.1774.
[109] W. Osten, M. Wilke, and G. Pedrini, “Remote laboratories for optical metrology: from the lab to the cloud,” Opt. Eng, vol. 52, no. 10, p. 101914, Jul. 2013, doi: 10.1117/1.OE.52.10.101914.
[110] R. Pastor et al., “Online laboratories as a cloud service developed by students,” in 2013 IEEE Frontiers in Education Conference (FIE), Oklahoma City, OK, USA: IEEE, Oct. 2013, pp. 1081–1086. doi: 10.1109/FIE.2013.6684994.
[112] D. Petrova-Antonova, S. Ilieva, and D. Manova, “TASSA: Testing Framework for Web Service Orchestrations,” in 2015 IEEE/ACM 10th International Workshop on Automation of Software Test, Florence, Italy: IEEE, May 2015, pp. 8–12. doi: 10.1109/AST.2015.9.
[113] D. Petrova-Antonova, S. Ilieva, I. Manova, and D. Manova, “Towards Automation Design Time Testing of Web Service Compositions,” p. 10.
[114] R. Ramos De Oliveira, R. M. Martins, and A. Da Silva Simao, “Impact of the Vendor Lock-in Problem on Testing as a Service (TaaS),” in 2017 IEEE International Conference on Cloud Engineering (IC2E), Vancouver, BC: IEEE, Apr. 2017, pp. 190–196. doi: 10.1109/IC2E.2017.30.
[115] B. Ramprasad, J. Mukherjee, and M. Litoiu, “A Smart Testing Framework for

IoT Applications," in 2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion (UCC Companion), Zurich: IEEE, Dec. 2018, pp. 252–257. doi: 10.1109/UCC-Companion.2018.00064.
[116] N. Ranaldo, S. Rapuano, M. Riccio, and F. Zoino, "On the use of Video-Streaming Technologies for Remote Monitoring of Instrumentation," in 2006 IEEE Instrumentation and Measurement Technology Conference Proceedings, Sorrento, Italy: IEEE, Apr. 2006, pp. 861–866. doi: 10.1109/IMTC.2006.328234.
[117] N. Ranaldo, S. Rapuano, M. Riccio, and F. Zoino, "Remote Control and Video Capturing of Electronic Instrumentation for Distance Learning," IEEE Trans. Instrum. Meas., vol. 56, no. 4, pp. 1419–1428, Aug. 2007, doi: 10.1109/TIM.2007.900152.
[118] A. Rasche, F. Feinbube, P. Tröger, B. Rabe, and A. Polze, "Predictable interactive control of experiments in a service-based remote laboratory," in Proceedings of the 1st ACM international conference on PErvasive Technologies Related to Assistive Environments - PETRA '08, Athens, Greece: ACM Press, 2008, p. 1. doi: 10.1145/1389586.1389664.
[119] W. Rekik, M. Mhiri, and M. Khemakhem, "A smart cloud repository for online instrument," in International Conference on Education and e-Learning Innovations, Sousse: IEEE, Jul. 2012, pp. 1–4. doi: 10.1109/ICEELI.2012.6360628.
[120] A. Robles-Gómez, L. Tobarra, R. Pastor-Vargas, R. Hernández, and J. Cano, "Emulating and Evaluating Virtual Remote Laboratories for Cybersecurity," Sensors, vol. 20, no. 11, p. 3011, May 2020, doi: 10.3390/s20113011.
[121] J. Saenz, F. Esquembre, F. J. Garcia, L. de la Torre, and S. Dormido, "A new model for a remote connection with hardware devices using Javascript," in 2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), Madrid: IEEE, Feb. 2016, pp. 143–144. doi: 10.1109/REV.2016.7444454.
[122] H. Saliah-Hassane, A. Kourri, and I. La Teja, "Building a Repository for Online Laboratory Learning Scenarios," in Proceedings. Frontiers in Education. 36th Annual Conference, San Diego, CA, USA: IEEE, 2006, pp. 19–22. doi: 10.1109/FIE.2006.322603.
[123] H. Saliah-Hassane, M. Saad, W. Ofosu, K. Djibo, H. Mayaki, and M. M. Dodo Amadou, "Lab@Home: Remote Laboratory Evolution in the Cloud Computing Era," in 2011 ASEE Annual Conference & Exposition Proceedings, Vancouver, BC: ASEE Conferences, Jun. 2011, p. 22.995.1-22.995.13. doi: 10.18260/1-2--18691.
[124] J. A. Sanchez-Viloria, L. F. Zapata-Rivera, C. Aranzazu-Suescun, A. E. Molina-Pena, and M. M. Larrondo-Petrie, "Online Laboratory Communication Using MQTT IoT Standard," in 2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC), Madrid, Spain: IEEE, Nov. 2021, pp. 550–555. doi: 10.1109/WEEF/GEDC53299.2021.9657292.
[125] I. Sanogo, S. Ouya, A. D. Gueye, and C. Lishou, "Proposal of cloud-based

online laboratory model for practical training in the telecoms and networking fields," in 2016 IEEE Global Engineering Education Conference (EDUCON), Abu Dhabi: IEEE, Apr. 2016, pp. 1101–1105. doi: 10.1109/EDUCON.2016.7474691.
[126] A. Schoen et al., "Testing Automated Operation and Control Algorithms for Distribution Grids Using a Co-simulation Environment," p. 6.
[127] Shaodong Ying and Shanan Zhu, "Remote laboratory based on client-server-controller architecture," in ICARCV 2004 8th Control, Automation, Robotics and Vision Conference, 2004., Kunming, China: IEEE, 2004, pp. 2194–2198. doi: 10.1109/ICARCV.2004.1469506.
[128] Siqin Chen, Junfei Huang, and Yunzhan Gong, "Static Testing as a Service on Cloud," in 2013 27th International Conference on Advanced Information Networking and Applications Workshops, Barcelona: IEEE, Mar. 2013, pp. 638–642. doi: 10.1109/WAINA.2013.257.
[129] O. Starov and S. Vilkomir, "Integrated TaaS platform for mobile development: Architecture solutions," in 2013 8th International Workshop on Automation of Software Test (AST), San Francisco, CA, USA: IEEE, May 2013, pp. 1–7. doi: 10.1109/IWAST.2013.6595783.
[130] V. Terokhin, M. Stervoyedov, and O. Ridozub, "Design and implementation of the distributed dosimetric system based on the principles of IoT," EEJET, vol. 5, no. 9 (113), pp. 91–100, Oct. 2021, doi: 10.15587/1729-4061.2021.243153.
[131] I. Titov, "Labicom.net - The on-line laboratories platform," in 2013 IEEE Global Engineering Education Conference (EDUCON), Berlin: IEEE, Mar. 2013, pp. 1137–1140. doi: 10.1109/EduCon.2013.6530251.
[133] P. Troger and A. Rasche, "SOA Meets Robots - A Service-Based Software Infrastructure For Remote Laboratories," p. 7.
[134] Y.-H. Tung, C.-C. Lin, and H.-L. Shan, "Test as a Service: A Framework for Web Security TaaS Service in Cloud Environment," in 2014 IEEE 8th International Symposium on Service Oriented System Engineering, Oxford, United Kingdom: IEEE, Apr. 2014, pp. 212–217. doi: 10.1109/SOSE.2014.36.
[135] I. K. Villanes, E. A. Bezerra Costa, and A. C. Dias-Neto, "Automated Mobile Testing as a Service (AM-TaaS)," in 2015 IEEE World Congress on Services, New York, NY: IEEE, Jun. 2015, pp. 79–86. doi: 10.1109/SERVICES.2015.20.
[136] N. Wang, X. Chen, G. Song, Q. Lan, and H. R. Parsaei, "Design of a New Mobile-Optimized Remote Laboratory Application Architecture for M-Learning," IEEE Trans. Ind. Electron., vol. 64, no. 3, pp. 2382–2391, Mar. 2017, doi: 10.1109/TIE.2016.2620102.
[137] Y. Wei-feng, S. Rong-gao, and W. Zhong, "Realization of Distributed Remote Laboratory and Remote Debug Software for Embedded System," vol. 7, no. 12, p. 10, 2008.

[138] S. Werner, A. Lauber, J. Becker, and E. Sax, “Cloud-based remote virtual prototyping platform for embedded control applications: Cloud-based infrastructure for large-scale embedded hardware-related programming laboratories,” in 2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), Madrid: IEEE, Feb. 2016, pp. 168–175. doi: 10.1109/REV.2016.7444459.
[139] P. Wieder, O. Waldrich, and W. Ziegler, “Advanced Techniques for Scheduling, Reservation, and Access Management for Remote Laboratories,” in 2006 Second IEEE International Conference on e-Science and Grid Computing (e-Science’06), Amsterdam, Netherlands: IEEE, Dec. 2006, pp. 128–128. doi: 10.1109/E-SCIENCE.2006.261061.
[140] C. Xie, C. Li, S. Sung, and R. Jiang, “Engaging Students in Distance Learning of Science With Remote Labs 2.0,” IEEE Trans. Learning Technol., vol. 15, no. 1, pp. 15–31, Feb. 2022, doi: 10.1109/TLT.2022.3153005.
[141] M. Yan, H. Sun, X. Liu, T. Deng, and X. Wang, “Delivering Web service load testing as a service with a global cloud: DELIVERING WEB SERVICE LOAD TESTING AS A SERVICE WITH A GLOBAL CLOUD,” Concurrency Computat.: Pract. Exper., vol. 27, no. 3, pp. 526–545, Mar. 2015, doi: 10.1002/cpe.3246.
[142] M. Yan, H. Sun, X. Wang, and X. Liu, “Building a TaaS Platform for Web Service Load Testing,” in 2012 IEEE International Conference on Cluster Computing, Beijing, China: IEEE, Sep. 2012, pp. 576–579. doi: 10.1109/CLUSTER.2012.20.
[143] M. Yan, H. Sun, X. Wang, and X. Liu, “WS-TaaS: A Testing as a Service Platform for Web Service Load Testing,” in 2012 IEEE 18th International Conference on Parallel and Distributed Systems, Singapore, Singapore: IEEE, Dec. 2012, pp. 456–463. doi: 10.1109/ICPADS.2012.69.
[144] L. Yu et al., “Testing as a Service over Cloud,” in 2010 Fifth IEEE International Symposium on Service Oriented System Engineering, Nanjing, China: IEEE, Jun. 2010, pp. 181–188. doi: 10.1109/SOSE.2010.36.
[145] W. Zamojski, J. Mazurkiewicz, J. Sugier, T. Walkowiak, and J. Kacprzyk, Eds., Contemporary Complex Systems and Their Dependability: Proceedings of the Thirteenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX, July 2-6, 2018, Brunów, Poland_p326_p337_Models and Scheduling Algorithms for a Software Testing System Over Cloud, vol. 761. in Advances in Intelligent Systems and Computing, vol. 761. Cham: Springer International Publishing, 2019. doi: 10.1007/978-3-319-91446-6.
[146] L. F. Zapata Rivera and M. M. Larrondo-Petrie, “Design of a Latin American and Caribbean remote laboratories network,” in 2016 IEEE Frontiers in Education Conference (FIE), Erie, PA, USA: IEEE, Oct. 2016, pp. 1–5. doi: 10.1109/FIE.2016.7757581.
[147] L. F. Zapata Rivera, M. M. Larrondo-Petrie, and L. Ribeiro Da Silva,

"Implementation of cloud-based smart adaptive remote laboratories for education," in 2017 IEEE Frontiers in Education Conference (FIE), Indianapolis, IN: IEEE, Oct. 2017, pp. 1–5. doi: 10.1109/FIE.2017.8190473.
[148] L. F. Zapata-Rivera et al., "Scalable. Ad Hoc, Low Cost, Mobile, Online Laboratories," in 2018 Learning With MOOCS (LWMOOCS), Madrid: IEEE, Sep. 2018, pp. 155–158. doi: 10.1109/LWMOOCS.2018.8534612.
[149] "Towards Software Testing as a Service for Software as a Service Using Cloud".

8. Appendices

8.1 Appendix A – Table - Review results of studies about remote laboratory SLRs

No.	Study Ref.	Year	Topic	Purpose	Quality Score	Q1	Q2	Q3	Field
1	Yan et al.	2015	A web service load testing platform	Design a new method	3	Y	Y	Y	CS, Taas
2	Ning et al.	2017	A mobile application architecture to integrate remote laboratory	Design a new method	3	Y	Y	Y	Edu, RL, Mobile
3	Xie et al.	2022	A distributed online laboratory framework	Design a new method	3	Y	Y	Y	Edu, RL
4	Broisin et al.	2017	A remote laboratory model for computer education which adopts a distributed, modular and flexible architecture	Design a new method	3	Y	Y	Y	Edu, RL
5	Lei et al.	2018	A web-based hybrid laboratory framework for education and research	Design a new method	3	Y	Y	Y	Edu, RL
6	Troger et al	2014	The performance, reliability and security of virtual remote laboratory	Introduce a method	3	Y	Y	Y	RL
7	Yan et al.	2012	A web service-based cloud Paas platform for performance testing on web services	Design a new method	3	Y	Y	Y	Cloud, RL, Paas
8	Gao et al.	2012	A Taas infrastructure and a cloud-based environment	Design a new method	2.5	Y	Y	P	Engr, RL, Taas
9	Chhillar & Sharma	2019	An automation continuous testing as a service dashboard	Design a new method	2.5	P	Y	Y	Engr, Taas
10	Villanes et al	2015	An automation mobile Taas model	Design a new method	2.5	Y	Y	P	Engr, Taas,Cloud
11	Janani & Krishnamoorty	2015	An introduction for cloud Taas	Literature review	2.5	P	Y	Y	Taas,

12	Touhafi et al.	2018	An architecture for remote experiments	Design a new method	2.5	Y	Y	P	Engr, RL
13	Maiti et al.	2015	A timed automation based model of experimental rigs	Design a new method	2.5	P	Y	Y	Engr, Automation
14	Jang Ho Lee	2014	A grid-based system designed for Real Time Hybrid Testing Facility in construction engineering	Design a new method	2.5	Y	Y	P	Engr, distributed
15	Bochicchio & Longo	2009	A framework for remote laboratory in engineering school	Design a new method	2.5	Y	Y	P	Edu, RL
16	Li et al.	2015	A penetration testing as a service (PTaaS) system	Design a new method	2.5	P	Y	Y	Taas
17	Maiti et al.	2015	A remote access laboratory system that enables peer-to-peer (P2P) experimental design and sharing	Introduce a method	2.5	P	Y	Y	Edu, RL
18	Ying & Zhu	2004	An engineering education laboratory architecture	Design a new method	2.5	P	Y	Y	Edu, RL
19	Latorre Garcia et al.	2013	The process to transfer remote web lab into smart devices which are able to work with IoTs	Introduce a method	2.5	Y	Y	P	Edu, RL, IoT
20	Tung et al	2014	A cloud-based safety testing Taas architecture	Design a new method	2.5	P	Y	Y	Taas, Cloud
21	Gao et al.	2013	A comprehensive tutorial on testing as a	Literature review	2.5	P	Y	Y	Taas, Cloud

			service in a cloud environment						
22	Martínez-Carreras et al.	2008	A wrapper model based on SOA for interoperability	Design a new method	2.5	P	Y	Y	Edu, RL
23	Rekik et al.	2012	A model based on semantic web Tech. designed for remote laboratory	Design a new method	2	Y	Y	N	Semantic Web, RL
24	De Francesco et al.	2014	The cloud-based software architecture based on AWS	Design a new method	2	P	Y	P	Engr, RL
25	Orduña et al.	2011	How the development of experiments is handed in remote laboratory model	Introduce a method	2	P	Y	P	Edu, RL
26	Karadimas & Efstathiou	2007	An Internet-based laboratory model for remote monitored and controlled	Design a new method	2	P	Y	P	Edu, RL
27	Bochicchio et al.	2013	A design for online interactive laboratory	Design a new method	2	Y	N	Y	Edu, RL
28	Yan et al.	2012	A web service load testing platform	Design a new method	2	Y	N	Y	CS, Taas
29	Werner et al.	2016	A cloud-based environment allowing the design of virtual platforms and prototyping of the system	Design a new method	2	Y	N	Y	Edu,
30	Maiti et al.	2015	An introduction on the characteristics and components in distributed remote laboratories	Introduce a method	2	Y	Y	N	Engr, RL
31	El-Sayed et al	2011	An introduction	Literature	2	P	Y	P	Edu, RL

			on several remote laboratory architecture	review					
32	Kist et al.	2016	A remote access laboratory design for STEM education	Design a new method	2	P	Y	P	Edu, RL
33	Rivera et al	2017	An approach that integrates remote laboratory with virtual learning environment	Design a new method	2	P	Y	P	Edu, RL
34	Oleksii & Sergiy	2013	A mobile universal Taas platform	Design a new method	2	Y	Y	N	Mobile Taas
35	Thames et al.	2012	Using technology such as command and control communications, Web 2.0, and cloud computing to develop large scale remote laboratory	Introduce a method	2	Y	Y	N	RL, Edu
36	Kist et al.	2015	A remote access laboratory design for STEM education	Design a new method	2	P	Y	P	Edu, RL
37	Komarov & Sarafanov	2021	An IoT-based distributed architecture for solving multidisciplinary research problems	Design a new method	2	Y	Y	N	Edu, RL
38	Al-Masri	2018	A remote-controlled middleware infrastructure called Laas	Introduce a method	2	P	Y	P	Edu, RL
39	Pastor et al.	2013	Using cloud-technology to enhance remote laboratory model	Introduce a method	2	P	Y	P	Edu, RL
40	Petrova-Antonova et al.	2017	Proposed a TaaS-enabled framework	Design a new method	2	N	Y	Y	Taas, Cloud

			offering cloud-based testing services.						
41	Chandra Jana et al.	2017	An architecture to deploy remote laboratory based on mobile cloud computing	Design a new method	2	Y	Y	N	Mobile cloud, RL
42	Pastor et al.	2013	An automation system based on cloud providers	Design a new method	2	Y	Y	N	Edu, RL
43	Kist et al.	2014	A prototype network architecture based on remote laboratory	Design a new method	2	Y	N	Y	Edu, RL
44	Rasche et al.	2008	an architecture for predictable and interactive control of remote laboratory experiments accessed over Web service protocols	Design a new method	2	P	Y	P	Edu, RL
45	Wei-feng	2008	A remote laboratory for embedded system	Design a new method	2	Y	Y	N	Edu, RL
46	Markan et al	2013	A cloud-based architecture for remote laboratories	Design a new method	2	Y	Y	N	Cloud, RL
47	Osten te al	2013	An architecture that provides the opportunity to communicate with and eventually control the physical setup of a remote metrology system.	Design a new method	2	P	Y	P	Cloud. Engr, RL
48	Celdran et al	2020	A SDN based architecture for remote laboratory design	Design a new method	2	Y	N	Y	Edu, RL

49	Petrova-Antonova et al.	2015	A testing as a Service Software Architecture (TASSA) for testing web service	Design a new method	2	Y	N	Y	Taas, CS
50	Yu et al.	2010	A prototype of TaaS over cloud to evaluate the test task load	Design a new method	2	Y	Y	N	Taas, Cloud
51	Manveen Kaur	2016	An introduction on cloud based Taas architecture	Introduce a method	2	Y	Y	N	Taas, Cloud
52	Herbold et al	2015	A cloud-based platform for the testing of SOAs MIDAS Testing as a Service (TaaS),	Design a new method	2	Y	Y	N	Taas, Cloud
53	Maiti et al.	2018	An evaluation method for Remote access laboratories	Design a new method	1.5	Y	N	P	Engr, RL
54	Efstathiou et al.	2007	An Internet-based laboratory model	Design a new method	1.5	Y	N	P	Engr ,Edu,RL
55	Ramprasad et al.	2018	The implementation of a testing framework to evaluate and maintain IoT network	Design a new method	1.5	Y	N	P	Engr, IoT
56	Asumadu et al.	2005	A remote wired and measurement Laboratory architecture	Introduce a new method	1.5	P	Y	N	Engr, RL
57	Ali et al.	2018	A Taas infrastructure for mobile application testing	Design a new method	1.5	Y	N	P	Taas, CS
58	Maiti et al.	2015	A method to create Markov's Decision Process between user and experimental equipment	Design a new method	1.5	P	N	Y	Engr, RL

59	Hardison et al.	2008	A distributed service infrastructure to support online laboratory experiment	Design a new method	1.5	P	N	Y	Edu, RL
60	Terokhin et al.	2021	A description of distributed information and management system	Introduce a method	1.5	Y	N	P	Edu, RL
61	Rivera & Felipe	2016	A design for online laboratory network in LAC	Design a new method	1.5	P	Y	N	Edu, RL
62	Maiti & Maiti	2013	An approach to design remote experiments by representing instruments in the internet as objects or resources	Design a new method	1.5	Y	N	P	Engr, RL
63	Jameela et al.	2014	A review on cross cloud application testing	Literature review	1.5	P	Y	N	CS, Cloud
64	Hardison et al.	2010	A distributed service infrastructure to support online laboratory experiments	Introduce a method	1.5	P	N	Y	Edu, RL
65	Malik et al.	2019	An automated IoT testing service-based framework	Design a new method	1.5	P	Y	N	IoT, Automation
66	Herbold & Hoffmann	2017	Introducing cloud computing for scaling up model- based testing	Design a new method	1.5	Y	N	P	RL,cloud
67	Ranaldo et al.	2007	Real-time visualization of the instrumentation involved in distance learning of electric and electronic measurement	Design a new method	1.5	Y	N	P	Edu, RL

68	Favario et al	2015	An open-source architecture for open access educational resources	Design a new method	1.5	P	Y	N	Edu, RL
69	Chen et al	2013	A cloud-based platform architecture offering static testing service	Design a new method	1.5	Y	N	P	Cloud, RL
70	Schoen et al	2021	A co-simulation framework that enables joint simulation experiments by multiple remote laboratories for analyses	Design a new method	1.5	P	N	Y	Engr, RL
71	Kist et al.	2016	Remote access laboratory platform for RALife experiment	Design a new method	1.5	P	Y	N	RL, Edu
72	Naseer & Saeed		An evaluation on Taas infrastructure with five layers	Introduce a method	1.5	P	Y	N	Taas, Cloud
73	Mungekar & Toradmalle	2015	An architecture of TaaS in which we have integrated numerous testing types	Design a new method	1.5	Y	N	P	Taas, CS
74	Cano et al.	2016	A remote laboratory to learn cybersecurity and infrastructure protection systems.	Design a new method	1	P	Y	P	Edu, RL
75	Al-Ghuwairi et al.	2016	A measurement approach to evaluate the effectiveness of TaaS, over cloud computing environment	Design a new method	1	P	N	P	Engr, RL
76	Broisin et al.	2015	A distributed remote	Design a new method	1	P	N	P	Edu, RL

			laboratory framework for online practical activities						
77	Angulo & García-Zubia	2013	An inexpensive remote laboratory model used for a real fish tank	Introduce a new method	1	P	N	P	Edu, RL
78	Wieder et al.	2006	An approach that integrates remote laboratories as another resource into the Grid	Design a new method	1	N	N	Y	CS, RL
79	Hamadou Saliah-Hassane	2006	A model for online laboratory repositories of online learning	Design a new method	1	P	N	P	Edu, RL
80	Ning et al.	2013	A web-based remote laboratory architecture	Design a new method	1	Y	N	N	Distributed, RL
81	Robles-Gómez et al.	2020	An evaluation on virtual and remote laboratory	Experiment	1	N	Y	N	Edu, RL
82	Grosclaude et al.	2008	An approach to managing networked virtual and physical resources which could be viewed as components of remote laboratories	Introduce a method	1	P	N	P	Engr, RL
83	Corrado et al.	2010	An innovative hardware and software platform designed for Analog to Digital Converter (ADC) testing	Design a new method	1	Y	N	N	Engr.
84	De Oliveira et al.	2017	a novel approach for solving the lock-in problem in TaaS with the	Design a new method	1	P	N	P	CS, Taas

			use of design patterns						
85	Epelde et al.	2015	A remote laboratory design of public use	Introduce a method	1	Y	N	N	RL, Edu
86	Saliah-Hassane et al.	2011	An introduction on the components of the environment of a remote laboratory in Electrical Engineering	Introduce a method	1	P	N	P	Engr, RL
87	Igor Titov	2013	A web-based software online laboratory system	Design a new method	1	P	N	P	Edu, CS, RL
88	Sa´nchez et al.	2012	A paradigm proposes the use of cloud technologies to enhance RELATED	Design a new method	1	Y	N	N	Cloud, RL
89	Ranaldo et al.	2006	A real-time visualization of instrumentation in distance learning	Introduce a method	1	P	N	P	Edu, Engr
90	Molto & Caballer	2014	An architecture based on Cloud services designed for online course management	Design a new method	1	Y	N	N	Edu, RL
91	Sanchez-Viloria et al.	2021	A general context of the technology used in terms of protocols of communication that support the operation of online laboratory systems	Introduce a method	1	Y	N	N	Engr, RL
92	Kutlu & Aydogan	2009	A remote laboratory modeling and validation	Design a new method	1	Y	N	N	Edu, RL
93	Lakatos	2016	A flexible	Design a	1	P	N	P	Edu, RL

			laboratory architectural solution to controlled experiment environments.	new method					
94	Sanogo et al	2016	A cloud-based laboratory model	Design a new method	1	Y	N	N	Edu, CS, RL
95	Khamis et al	2003	An architecture used to be built remote laboratories to interact remotely via Internet with mobile robots	Design a new method	1	Y	N	N	Distributed, RL
96	Gravier et al	2007	A literature review of modern remote laboratories and the next generation of remote laboratories	Literature review	1	N	Y	N	RL
97	Mohammadi et al	2017	The background, methods, evaluation, and analysis of remote laboratory model for Curtin University's Green Electric Energy Park (GEEP) facility	Design a new method	1	Y	N	N	Edu,RL
98	Beňo et al	2020	A virtualized cloud for remote laboratory	Design a new method	1	Y	N	N	Cloud, RL
99	Zapata-Rivera et al	2018	Three scalable, ad hoc, low-cost, mobile, online laboratories that utilize the proposed distributed and centralized architectures are described	Introduce a method	1	P	N	P	Mobile, RL
100	Parkhomenko et al	2019	Remote Lab Smart House & IoT cyber	Design a new method	1	P	N	P	RL, IoT

			security architecture was proposed						
101	Bai et al	2013	the research and implementation of a TaaS system called Vee@Cloud	Design a new method	1	Y	N	N	RL, Laas
102	Agrawal & Srivastava	2007	A Web based 3-tier architecture (WebLab) that provides shared batch mode access to experiments	Design a new method	1	P	N	P	Web, RL
103	Saenz et al.	2016	A Java-based structure for virtual and remote laboratory	Introduce a new method	0.5	P	N	N	Edu, CS, RL
104	Lampe & Rudy	2019	A distributed algorithms for software testing	Design a new method	0.5	N	N	P	CS, Taas
105	García-Peñalvo et al.	2014	A cloud-based architecture for e-learning	Design a new method	0.5	P	N	N	Edu, RL
106	Ali & Li.	2019	A cloud-based testing adoption assessment model	Design a new method	0.5	P	N	N	Cloud, RL
107	Berruti et al.	2013	A validation measurement on distributed computing environment	Introduce a method	0.5	P	N	N	Distributed, RL
108	Ali & Badr	2015	An evaluation on the performance of mechanisms for the collection of data generated by instruments	Introduce a method	0.5	P	N	N	Distributed, RL
109	Adhipta & Hassan	2010	Distributed random variate values in Colored Petri Nets nondeterministic network	Introduce a method	0.5	P	N	N	Distributed, simulation

			behavior						
110	Petrova-Antonova et al.	2012	A framework, named Testing as a Service Software Architecture, aims to provide design testing of both functional and nonfunctional behavior of web service	Design a new method	0.5	P	N	N	CS, Taas

Table 8 Review results of studies about remote laboratory SLRs

8.2 Appendix B – Evaluation interview – Expert A

Siyuan: Now we will evaluate the applicable value of the cloud-based platform reference model for inspection and certification companies such as SGS. I have a list of questions and I will score the entire model based on your answers. The main method I take is to analyze different cloud-based platform reference models to understand the key components of the cloud-based platform, and to build a cloud-based platform reference model suitable for the inspection and certification company according to the different needs of the stakeholders of the inspection and certification company. This model is constructed using ArchiMate and BPMN languages. This model includes figure 8 to figure 16, Figure 19 device resource description, Figure 20 sample resource description, and Table 5 & 6 authorization management forms. We designed 7 performance standards, the performance of the reference architecture in the process of building the cloud test platform (1), whether the reference model meets the expected guidance purpose (2), whether the model is easy to use (3), the impact of the reference model and the environment (4), the social impact of the reference model on users (5), the compatibility of the reference model with other tools (6), and the practitioners' willingness to use the reference model (7). My first question to you is, how do you think the reference architecture performs in the process of building a cloud testbed?

Expert A: When I first saw this model, my first thought was whether we need to build a cloud test platform at the inspection and verification company. For SGS, we are in the stage of expanding scale and improving inspection efficiency, so we need a cloud-based testing platform.

Siyuan: Indeed, this reference model is intended for verification and validation companies that require a cloud test platform. The requirements for stakeholders have been discussed in Chapter 3, Table 1.

Expert A: Exactly. When building a cloud-based platform, we need to constantly contact the needs of stakeholders to adjust the construction method.

Siyuan: Yes, that's true.

Expert A: In building a cloud testbed, the reference model really helps us provide the guidance we need to build a cloud-based platform. For example, the reference model proposes to use the method of intelligent gateway to integrate the same type of devices and translate the instructions of the cloud-based platform through Broker. This method solves the problem of inconsistent instruction formats between cloud-based platforms and devices.

Siyuan: Glad a reference model can help. Then the second question is "did the model match the intended guiding purpose for designing and implementing a cloud-based testing platform in an inspection and certification company?" As a member of the laboratory management design team, do you think this reference model can help the laboratory management team realize remote control and remote monitoring?

Expert A: From the perspective of the laboratory management team alone, this reference model can indeed meet the requirements of remote control of experimental equipment and remote monitoring of experimental equipment. However, meeting this requirement is only a condition for small-scale testing. Because the management also needs to consider other aspects such as cost before it can be applied on a large scale.

Siyuan: Yes, I understand.

Expert A: Similarly, even if the needs of other departments are met, we still need to study the impact of cloud-based platform deployment on actual business processes and the interaction of the impact on various departments.

Siyuan: Indeed, the impact on actual business processes may be more insidious and require longer studies to determine. So, the next question, is the model easy to use?

Expert A: For me, not all parts of this model are easy to understand. I also need to use the information you shared about the ArchiMate language to understand the architectural part of the cloud-based platform. However, after a preliminary understanding, I think the entire reference model is still well understood.

Siyuan: The next question is what were specific parts of the environment in the reference and built models impacted?

Expert A: In fact, many parts have been adjusted. For example, in Figure 13 you set up a cloud environment using four servers. But on our experimental platform, we only used two servers. At this stage, due to the small load on the cloud-based platform, two servers can complete the construction of the cloud environment. Similarly, we currently do not fully use the device description in Figure 19. The experimental cloud-based platform now only has one temperature monitoring device connected to simulate the device.

Siyuan: Yeah, I understand.

Expert A: So, what I'm thinking is that it is possible to set different states to the reference model. For example, what parts are the most important in the initial stage, and what parts can be deployed at a later stage. Or set different deployment steps for different stages. This will be more suitable for the deployment of the actual platform.

Siyuan: Yes, this is indeed a good suggestion. At present, the cloud test platform reference model only prepares a reference model of one state.

Expert A: So, the next question is?

Siyuan: What social influence do you think will result from using the reference model?

Expert A: Social influence? what are you referring to?

Siyuan: Social influence generally refers to the degree to which others believe that method users will use a new method. For example, using new methods to make people's conclusions more reliable, etc.

Expert A: Ah I see. The use of reference models does make the models we build easier to be understood by others, provided that the other party understands some construction language.

Siyuan: Good. The next question is "Is this reference model compatible with other tools when building a cloud test platform?"

Expert A: OK, I think the model is the first step. It should then be up to the reference model to provide the technology that can be applied to a certain location. For example, you choose Nginx in the load balancer position. It is up to you to provide the corresponding technology, which is naturally more compatible with the reference model itself.

Siyuan: My initial thought was to use the reference model as a reference for a company that is implementing a cloud test platform. So, we need to consider the issue of compatibility.

Expert A: You should ask for more. Because some inspection and certification companies do not have and do not know that cloud-based platforms should be used to manage experimental equipment. So, I would like to see this reference model become a tool like a guidance document to guide companies in the construction of cloud-based platforms. In order to accomplish this, it should be the job of the reference model to indicate the techniques that can be applied.

Siyuan: Fair enough. This point can be set as a future work direction.

Expert A: So, the next questions is ?

Siyuan: The next question is “Will you use this reference model when building a cloud test platform?”

Expert A: Yes, but only if the reference model meets our requirements for the role of cloud-based platform implementation guidebook. As you know, the construction of SGS's cloud-based platform is still in the early stage, and we are still testing different possibilities until the final large-scale promotion. We welcome all kinds of tools that may help us complete this process.

Siyuan: Very good, thank you for accepting today's interview. Your comments helped a lot with my reference model.

Expert A: You're welcome, and good luck with your reference model too.

8.3 Appendix C - Evaluation interview – Expert B & C

Siyuan: Hello Ted and Emma. Thanks for accepting the interview.

Expert B: Hello Derek.

Expert C: Morning Derek!

Siyuan: Good morning! Now we will evaluate the applicable value of the cloud-based platform reference model for inspection and certification companies such as SGS. I have a list of questions and I will score the entire model based on your answers. The main method I take is to analyze different cloud-based platform reference models to understand the key components of the cloud-based platform, and to build a cloud-based platform reference model suitable for the inspection and certification company according to the different needs of the stakeholders of the inspection and certification company. This model is constructed using ArchiMate and BPMN languages. This model includes Figure 11, Figure 12, Figure 13, Figure 19 device resource description, Figure 20 sample resource description, Table 5 permission assignment checklist, and Table 6 user assignment checklist. We designed 7 performance standards, the performance of the reference architecture in the process of building the cloud test platform (1), whether the reference model meets the expected guidance purpose (2), whether the model is easy to use (3), the impact of the reference model and the environment (4), the social impact of the reference model on users (5), the compatibility of the reference model with other tools (6), and the practitioners' willingness to use the reference model (7). My first question to you is, how do you think the reference architecture performs in the process of building a cloud testbed?

Expert C: I think this is your question, Emma.

Expert B: Yes, I believe so. I think this platform has a certain reference significance for the design of the cloud-based platform. Because it involves basically all aspects, and provides a certain choice. What I like the most is that it provides a variety of platform and device communication options.

Siyuan: This is because I found many solutions that can be referred to when searching the literature.

Expert B: Very good, but in actual deployment, the cheaper and simpler solution will still be chosen.

Siyuan: I understand. Did the model match the intended guiding purpose for designing and implementing a cloud-based testing platform in an inspection and certification company?

Expert C: From an experimental manipulation point of view, the model is complete. But from the perspective of laboratory operators, because not everyone has the same job, and not everyone can assume the role of experimental operation, so the reference model lacks the division of labor for laboratory operators. Different laboratory operators should have different divisions of labor in order to complete the experiment normally. If you need, I can share with you the division of labor reference in your experimental case.

Siyuan: Thank you. That would be perfect.

Expert C: You're welcome. But going further, our laboratory operators will face different experimental requirements, so I hope that the cloud-based platform cannot define the permissions of each role too rigidly. Defining the role of the laboratory operator too clearly will make the experiment require too much help from the administrator, which will affect the progress of the experiment.

Siyuan: Ok I will consider your request. The clear definition now is to allow stakeholders to better understand the functions of the cloud-based platform.

Expert C: I understand, but lab administrators would prefer the cloud-based platform to be a tool to help with experiments, not just another bureaucratic tool.

Siyuan: I see. Ted, do you have anything to add?

Expert B: No comments from my side, I think the reference model completes the work up to the cloud-based platform design.

Siyuan: Thank you. And the third question is "is the model easy to use?"

Expert B: I believe you have heard it from my colleague. Members of our cloud-based platform design team studied the ArchiMate language. None of us had been exposed to this architectural language before. However, based on the information you provided; it is quite understandable. I personally think that this language can express each role of the company from a global perspective, so it is necessary for the design of the cloud-based platform, especially our company's cloud-based platform design involving many stakeholders. But still because I don't know much, I doubt how many people really understand the meaning of this language.

Expert C: It's not that I don't understand its meaning, but it's used too little, and other languages can also be used instead. If it is used, it is too time-consuming to explain the meaning of each concept to the leader and the customer.

Siyuan: I understand. So….What were specific parts of the environment in the reference and built models impacted?

Expert C: Do you mean…?

Siyuan: For example, in understanding the reference model or in applying the reference model, which parts will be changed.

Expert B: First, I must say that the cloud-based platform is currently in the testing stage, and only small-scale deployments have been carried out. Currently, the load balancer and Broker are deployed in one server. At the same time, only one device is currently deployed on the device side.

Siyuan: Cloud has told me about that.

Expert B: Very good. I would also like to say that the description of the equipment and samples is good, but we will leave the definition of this part of the concept to the lab operator who is responsible for the equipment. Because they will have a better understanding of what parameters and what sample information is needed.

Expert C: Yes, in actual work, it will be much more convenient for this part of the adjustment to be handed over to the actual personnel involved in the experiment.

Siyuan: Alright.

Expert C: So, the next question is?

Siyuan: What social influence do you think will result from using the reference model? Social influence generally refers to the degree to which others believe that method users will use a new method. For example, using new methods to make people's conclusions more reliable, etc.

Expert B: I think this reference model will improve the efficiency of communication in the case where everyone else understands the architectural language. I really like that this language can let more people understand the purpose of cloud-based platform design and the effect of operation, you can understand The bigger picture. However, it seems that this is a bit difficult now, because our stakeholders are very diverse and the knowledge background is also very complicated, and we cannot understand the meaning of this language.

Expert C: I agree with Ted. It takes us time to understand that a cloud-based platform design means little to us lab operators.

Siyuan: I see. So, the next question is “Is this reference model compatible with other tools when building a cloud test platform?”

Expert B: I believe this platform is still very compatible. You yourself have applied many other techniques as options.

Expert C: I'm curious if there is any impact on cloud-based platforms taking different approaches to device connectivity. You understand the advantages and disadvantages of different methods. We want to know the practical impact of taking a different approach.

Siyuan: Like pros and cons, right?

Expert C: Yes, especially for practical work implications.

Siyuan: I understand. The next question is “Will you use this reference model when building a cloud test platform?”

Expert B: Personally, I like this reference model very much. As I said before, the reference model under this language architecture can introduce the cloud-based platform and its significance to each role from a global perspective. This is something that many other languages cannot do. The second point, from the perspective of the reference model, it can give a company who knows nothing a preliminary guidance and what role the cloud-based platform will play in the business process in the future.

Siyuan: I feel like there's a “but”.

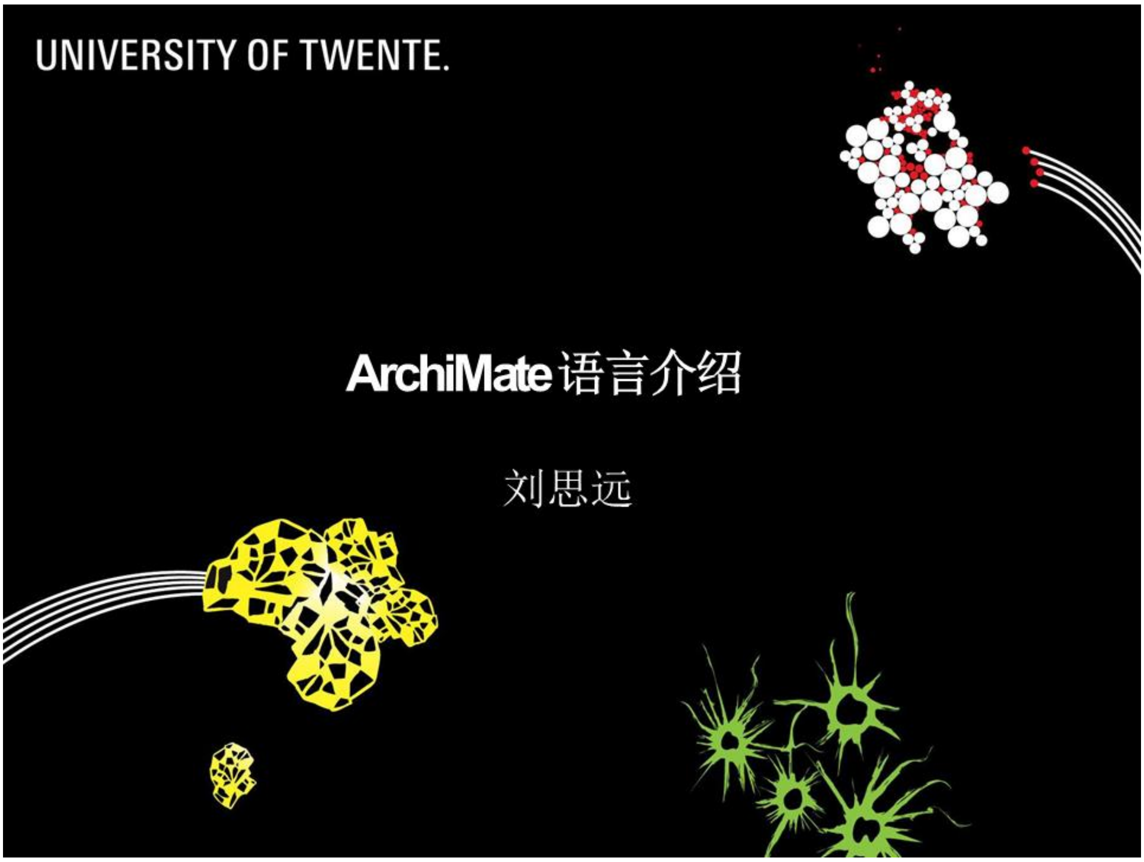
Expert B: Yes, there is. I very much doubt that companies will want all of us to learn a new language to build cloud-based platforms. The management prefers the parts that directly affect the construction of the cloud-based platform, such as the intelligent gateway. If we succeed in convincing management that this is the ideal way to communicate between devices and the cloud, they will be willing to give more resources. But a language that aids in building cloud-based platforms and aids in understanding, I doubt they'd agree to spend a few hours on us learning it.

Expert C: Yes, from the perspective of the laboratory operator, the cloud-based platform is at best an auxiliary tool. For laboratory operators, learning this new language will not help them complete their work. We believe that this language is still meaningful for the design stage, but it is not of much value to us operators in actual operation.

Expert B: Another thing is that if the reference model is widely used among all inspection and certification companies, how will SGS maintain its advantage of forwardness? Widespread use of reference models may close the gap between other companies and SGS.

Siyuan: I understand what you mean. Thanks for accepting this interview.

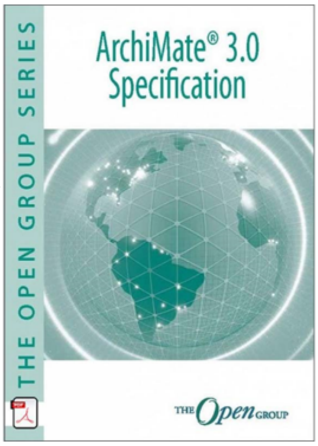
8.4 Appendix D – Evaluation - ArchiMate Introduction for experts



ArchiMate language introduction Siyuan Liu

ArchiMate 历史介绍

ArchiMate起源于本世纪初的荷兰，是由荷兰在信息技术领域的研究组织Telematica Institute（2009年重组并重命名为Novay）组建的开发团队定制而成。这一建设过程开始于2002年7月，并于2004年12月截止，这期间消耗了35人年以及将近400万欧元的资金。



2008年，ArchiMate的主导权被转移到了Open Group的手中。

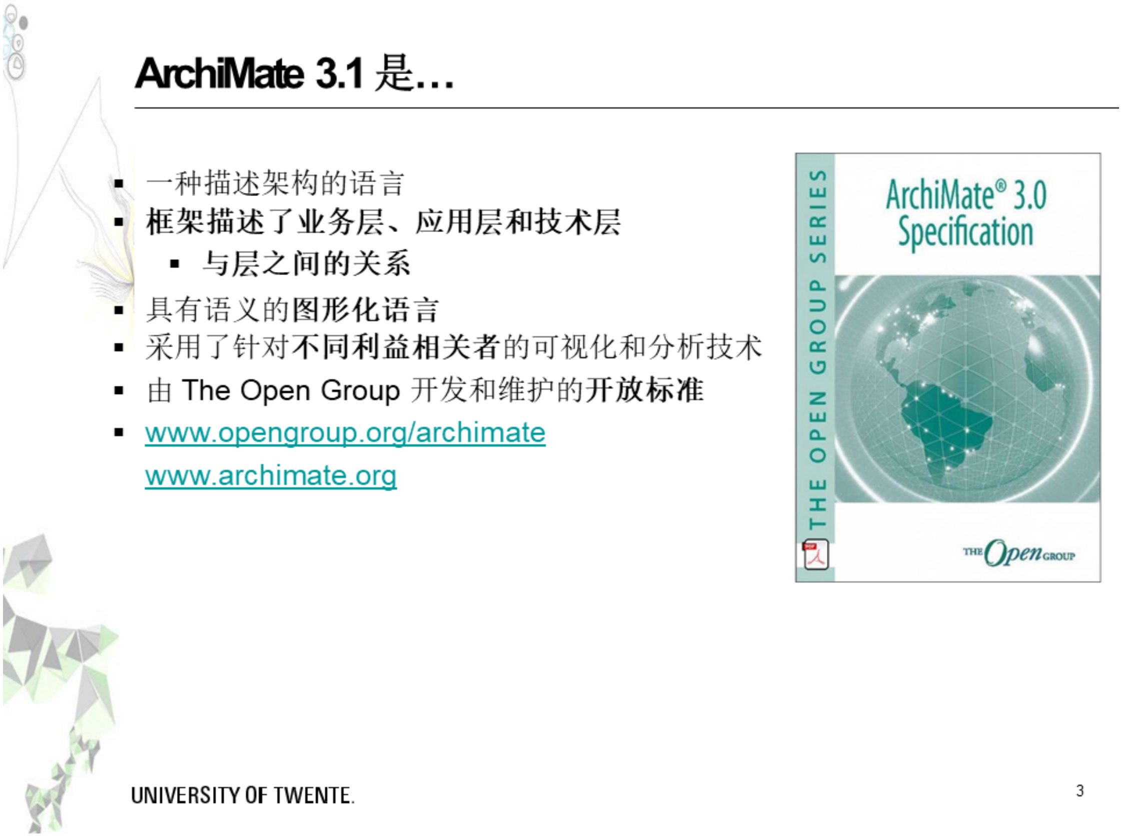
2009年2月，Open Group将ArchiMate 1.0版作为正式的技术标准进行了发布，而截止到目前最新的版本是2019年发布的ArchiMate 3.1版

UNIVERSITY OF TWENTE. 2

ArchiMate history Introduction

ArchiMate originated in the Netherlands at the beginning of this century and was customized by the development team formed by the Telematica Institute (reorganized and renamed Novay in 2009), a research organization in the field of information technology in the Netherlands. The construction process, which began in July 2002 and ended in December 2004, consumed 35 man-years and nearly 4 million euros in capital.

In 2008, the dominance of ArchiMate was transferred to the Open Group.
In February 2009, the Open Group released ArchiMate version 1.0 as a formal technical standard, and the latest version so far is ArchiMate version 3.1 released in 2019.



ArchiMate is

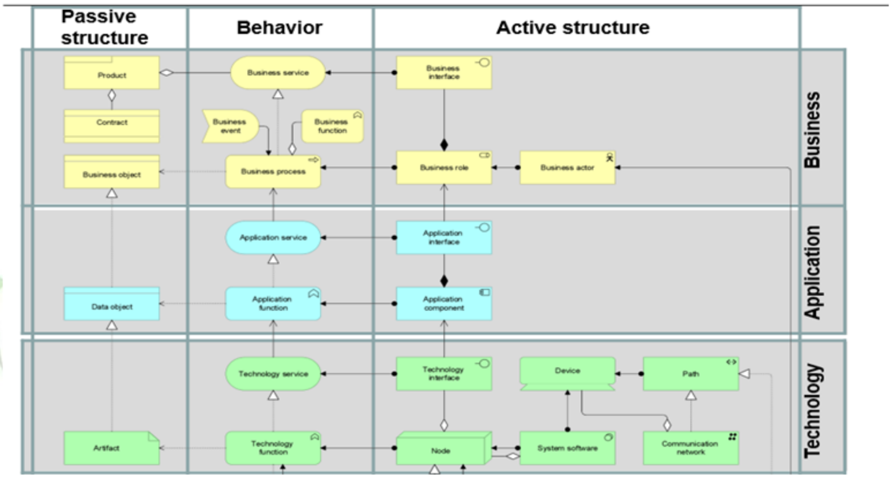
- A language for describing the architecture
- The framework describes the business layer, application layer, and technical layer
- relationship with layers
- Graphical Language with Semantics
- Adoption of visualization and analysis techniques for different stakeholders
- An open standard developed and maintained by The Open Group
- www.opengroup.org/ArchiMate www.ArchiMate.org

ArchiMate 核心层

1. 业务层(Business)：提供对外部客户（用户）的产品和服务，这些服务由组织内的业务角色通过业务流程来实现

2. 应用层(Application)：支持业务服务的应用

3. 技术层(Technology)：通过硬件和软件交互来运行应用

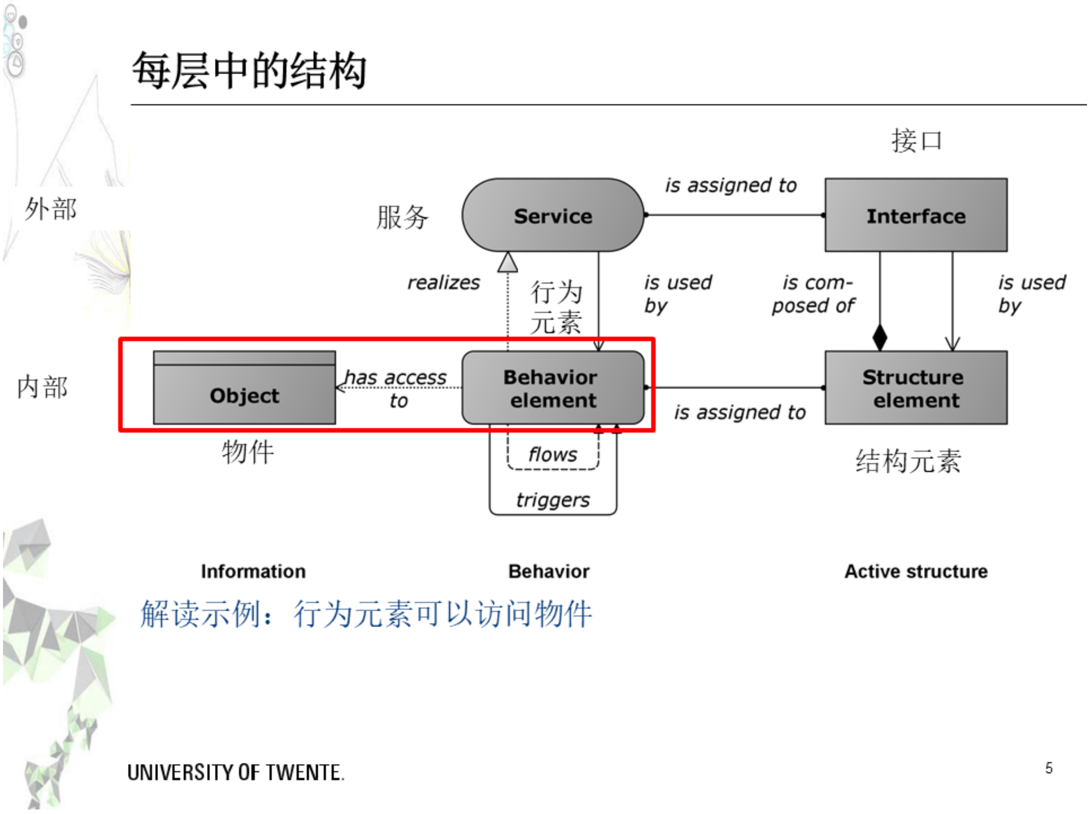


ArchiMate Core

- Business layer (Business): Provides products and services to external customers (users), and these services are implemented by business roles within the organization through business processes

- Application layer (Application): applications that support business services

- Technology layer (Technology): Run applications through hardware and software interaction

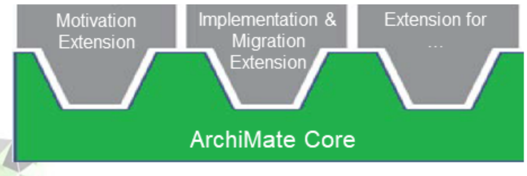


Components in each layer

Example: Behavior elements has access to objects

ArchiMate 核心和拓展

- **ArchiMate ‘核心’**
  (= ArchiMate 1.0)
  - Business（业务层）
  - Applications（应用层）
  - Technology（技术层）
  - Physical (ArchiMate 3.0)（物理层）

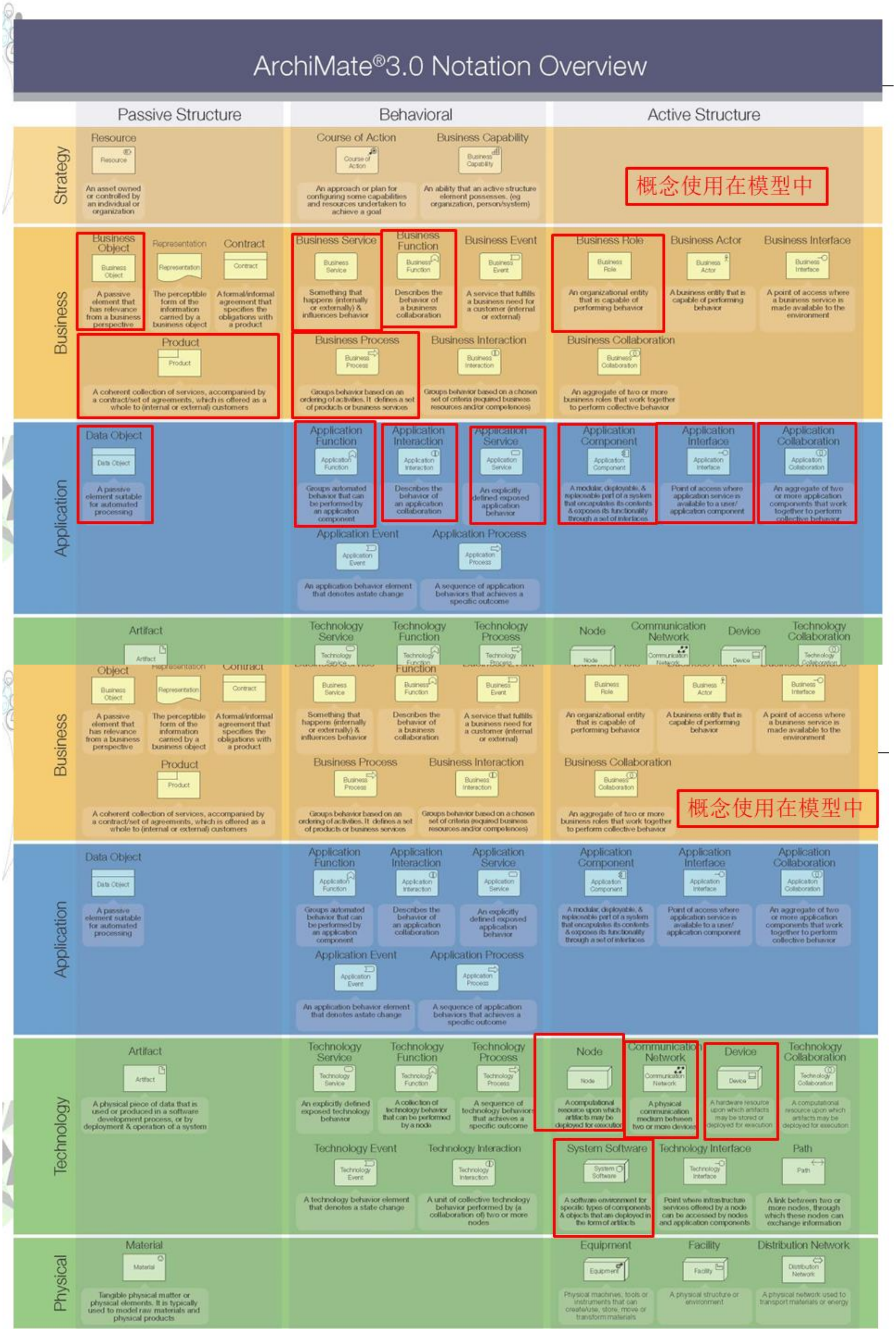


UNIVERSITY OF TWENTE.

ArchiMate 3.0 的三个拓展层:

- **Implementation & migration extension (2.0)（部署和转移层）**
  - Programs and projects
  - Plateaus
- **Motivation extension (2.0)（动机层）**
  - Stakeholders, drivers and goals（利益相关者，动机和目标）
  - Principles（准则）
  - Requirements（需求）
- **Strategy extension (3.0)（策略层）**
  - Resources and Capabilities

ArchiMate core and extensions



The concepts in red blocks mean this concept is used in the reference model.

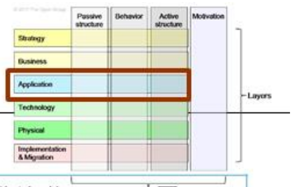
Business layer（业务层）

Business actor	业务参与者	Business Actor	能够执行行为的组织实体
Business role	业务角色	Business Role	可以分配给参与者的特定行为的责任
Business service	业务服务	Business Service	为客户（组织内部或外部）满足业务需求的服务
Business function	业务功能	Business Function	根据选定的一组标准对行为进行分组的行为元素
Business process	业务流程	Business process	一种行为元素，它根据活动的顺序对行为进行分组。 它旨在生产一组定义的产品或业务服务
Product	产品	Product	连贯的服务集合，附有合同或协议集，作为一个整体提供给客户

UNIVERSITY OF TWENTE. 9

Business actor Organizational entity capable of performing an act
Business role Responsibility for specific actions that can be assigned to participants
Business service A service that fulfills a business need for a customer (internal or external to an organization)
Business function Behavior elements that group behaviors according to a selected set of criteria
Business process A behavioral element that groups behaviors according to the sequence of activities. It is designed to produce a defined set of products or business services
Product Coherent collection of services, accompanied by a set of contracts or agreements, offered to customers as a whole

Application layer（应用层）

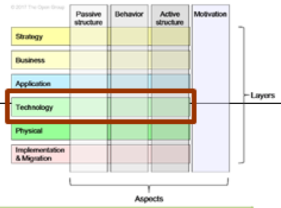


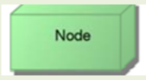
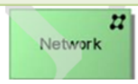
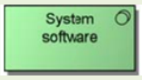
Application component	应用组件	Application component	软件系统的一个模块化、可部署和可替换的部分，它封装了它的行为和数据并通过一组接口公开它们
Application interface	应用接口	Application interface	应用程序服务可供用户或其他应用程序组件使用的访问点
Application collaboration	应用协作	Application collaboration	两个或多个应用组件的集合，它们一起工作以执行集体行为
Data object	数据	Data object	适合自动化处理的对象
Application service	应用程序服务	Application service	描述自动化行为的服务
Application interaction	应用程序协作	Application interaction	描述应用程序交互协作行为的行为元素
Application function	应用程序功能	Application function	一种行为元素，它对可由应用程序组件执行的自动化行为进行分组

UNIVERSITY OF TWENTE. 10

Application component A modular, deployable, and replaceable part of a software system that encapsulates its behavior and data and exposes them through a set of interfaces
Application interface An access point where application services can be used by users or other application components
Application collaboration A collection of two or more application components that work together to perform a collective behavior
Data object Objects suitable for automation
Application service Services that describe automated behavior
Application interaction Behavioral elements that describe the interaction and collaboration behavior of an application
Application function A behavioral element that groups automated behaviors that can be performed by application components

Technology layer（技术层）



Device	设备		一种物理计算资源，可以在其上部署元件以供执行
Node	节点		一种计算资源，可以在其上部署元件以执行
Network	网络		两个或多个设备之间的物理通信介质
System software	系统软件		部署在物理设备上的特定类型组件和对象的软件环境

Device	A physical computing resource on which elements can be deployed for execution
Node	A computing resource on which elements can be deployed to perform
Network	The physical communication medium between two or more devices
System software	A software environment for specific types of components and objects deployed on physical devices

Relationships（关系）

结构性关系		
Association	is associated with	关联模型对象之间的关系不具有另一个更具体的关系
Access	has access to	访问关系模拟行为对业务或数据对象的访问
Used by	is used by	被使用关系用于流程/功能/交互对服务的使用或者是角色/组件/协作对接口的使用
Realization	realizes	实现关系将逻辑实体与物理实体联系起来
Assignment	is assigned to	分配关系将行为与执行它们的元素（例如角色、组件）联系起来，或者将角色与参与者联系起来
Aggregation	aggregates	聚合关系是指一个对象集合了多个其他对象
Composition	is composed of	组合关系表示一个对象由多个其他对象组成

UNIVERSITY OF TWENTE. 12

Association A relationship between associated model objects does not have another more specific relationship
Access Access relationships simulate behavioral access to business or data objects
Used by Used by relationships for process/function/interaction use of services or roles/components/collaboration use of interfaces
Realization Implementing relationships to link logical entities with physical entities
Assignment Assignment relationships link behaviors to the elements that perform them (e.g., roles, components) or roles to actors
Aggregation An aggregation relationship is an object that aggregates multiple other objects
Composition A composition relationship means that an object is composed of multiple other objects

Relationships（关系）

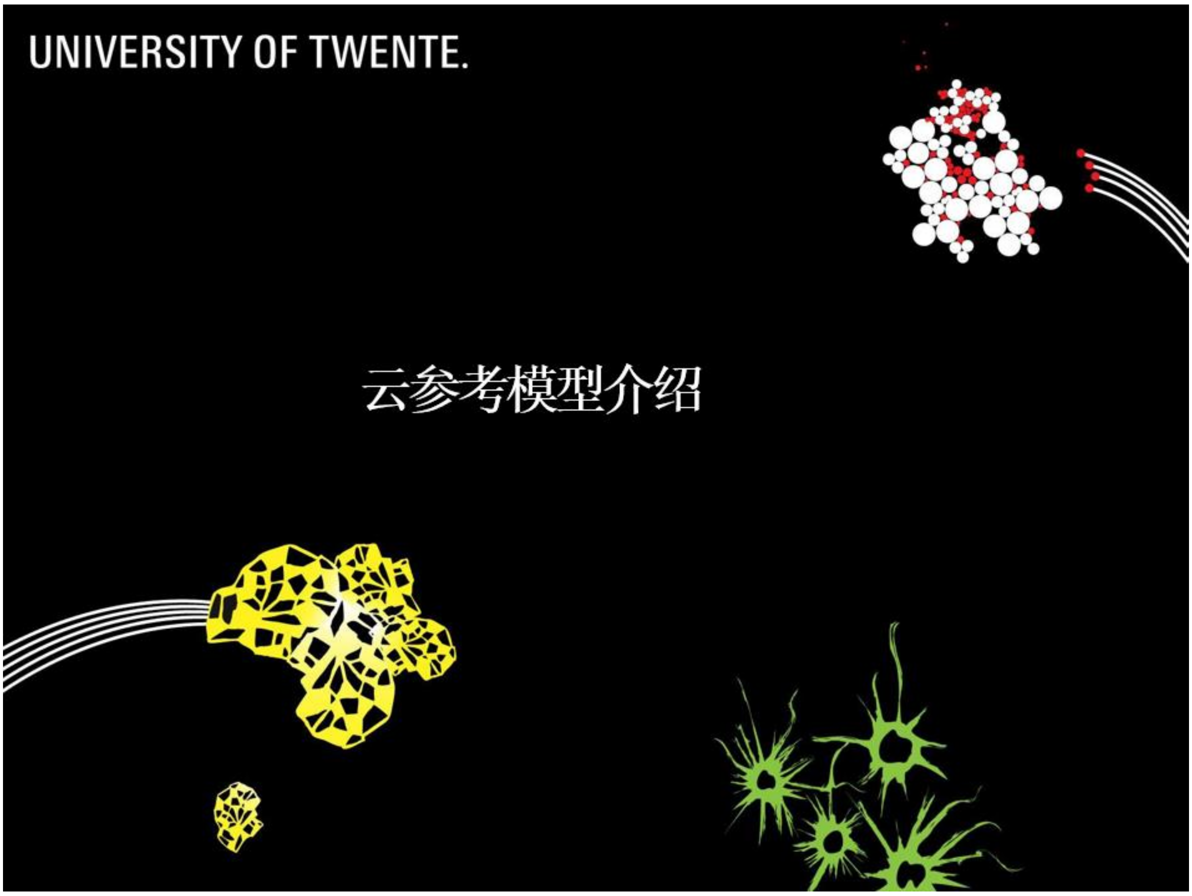
动态关系		
Flow	fows to	流向关系描述了过程、功能、交互和事件之间的信息或价值的交换或传递
Triggering	triggers	触发关系描述了过程、功能、交互和事件之间的时间或因果关系
其他		
Specialization	is specialization of	特化关系表示一个对象是另一个对象的特化

UNIVERSITY OF TWENTE. 13

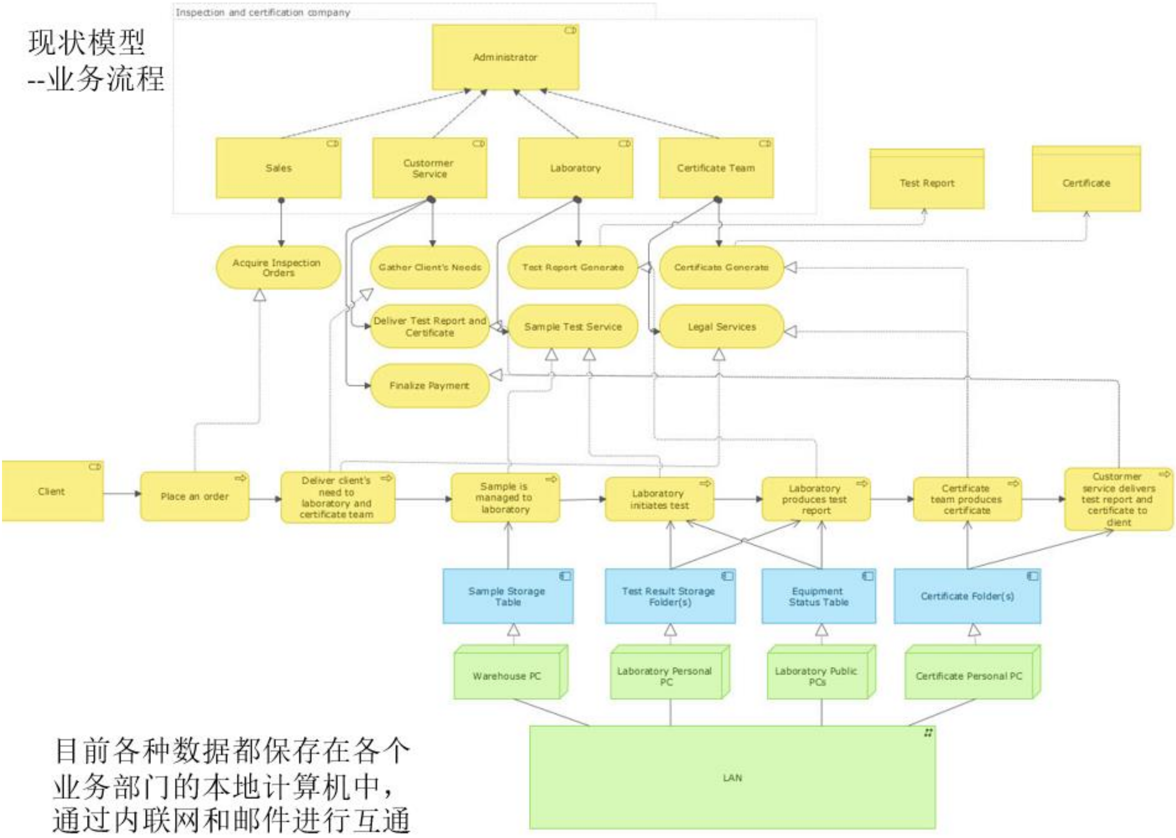
Flow Flow relationships describe the exchange or transfer of information or value between processes, functions, interactions, and events

Triggering Trigger relationships describe temporal or causal relationships between processes, functions, interactions, and events

Specialization A specialization relationship means that one object is a specialization of another

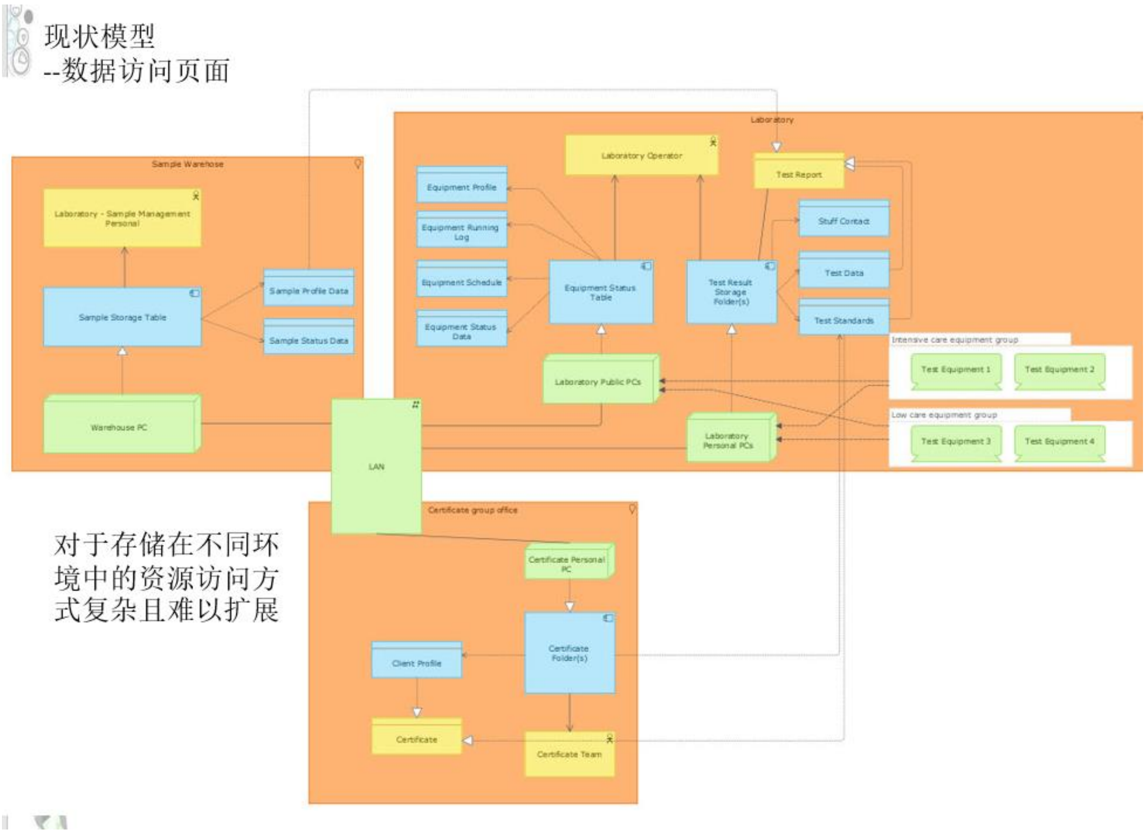


Cloud-based reference model introduction



Baseline model--Business Process

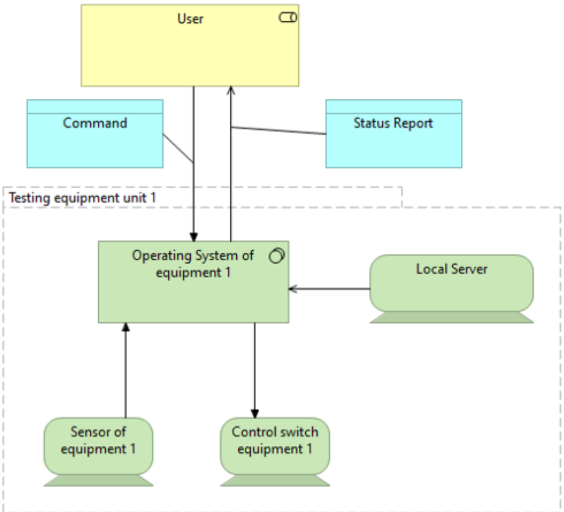
At present, all kinds of data are stored in the local computers of various business departments, and communicated through intranet and mail.



Baseline model-Data access view

Access to resources stored in different environments is complex and difficult to expand.

现状模型
--本地实验设备的组成



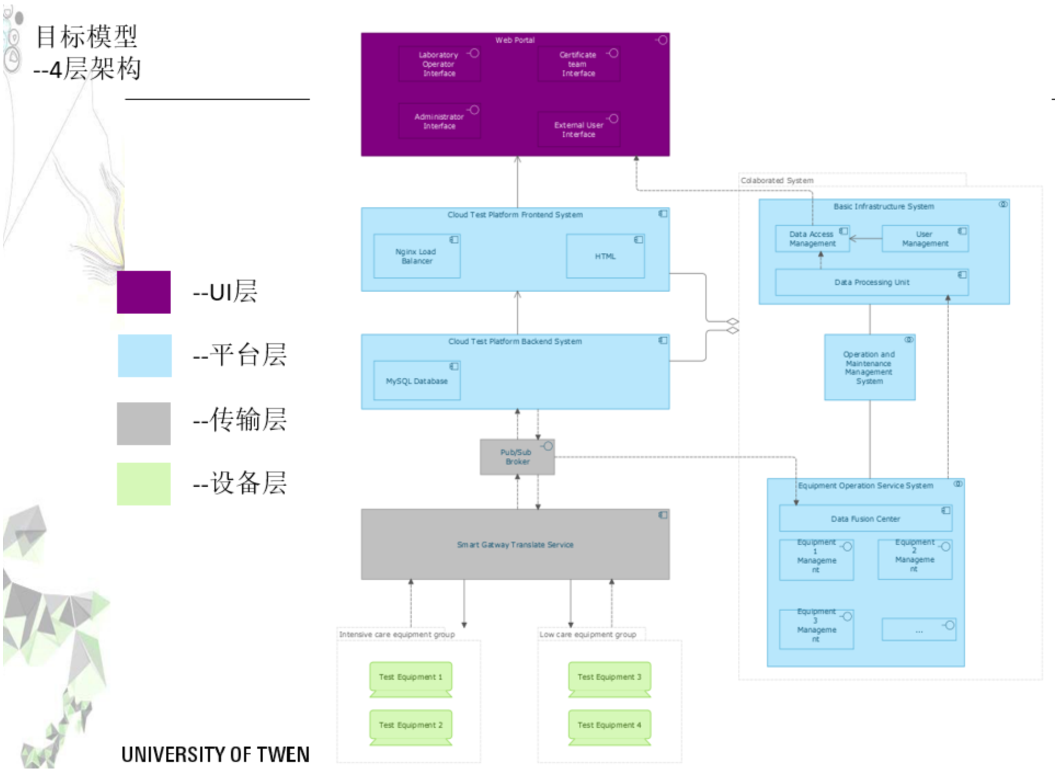
实验设备直接通过在实验室的本地计算机控制，目前暂未联网

UNIVERSITY OF TWENTE.

17

Baseline model-Local test equipment composition

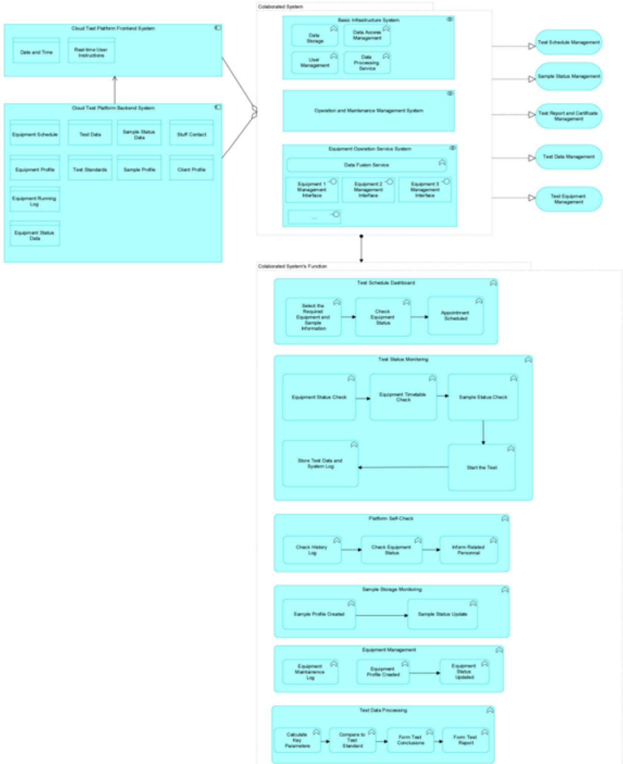
The experimental equipment is directly controlled by the local computer in the laboratory, which is currently not connected to the Internet.



Target model--4-layer architecture

目标模型
--平台层功能

名称	参与的系统	描述
测试状态展示板	BIS, EQS	仪表板可用于查看、添加和修改实验设备测试计划。
测试状态监测	BIS, EQS	通过查看实验三要素（测试设备、所需样品、设备相关操作人员），实时监控实验状态和进度。该功能还需要在实验结束时保存实验数据和系统日志。
平台自检	OMMS, EQS	通过系统日志的查看和ESQ保存的实验设备状态的查看，通过OMMS系统对云测试平台的运行状态进行自检。条件将发送给相关人员保存在系统中以供参考。
样品位置监测	BIS	此功能提供测试样本配置文件的创建和状态更新。
设备管理	EQS, OMMS	该功能通过与设备端的连接，提供实验设备数据的创建和状态更新。该功能通过与OMMS系统的连接实现设备检测日志的同步。
测试数据传输	BIS	该函数通过读取设备上传的实验数据来计算关键参数。该功能通过比对数据库中的测试标准，自动形成实验结论和规范化的实验报告。

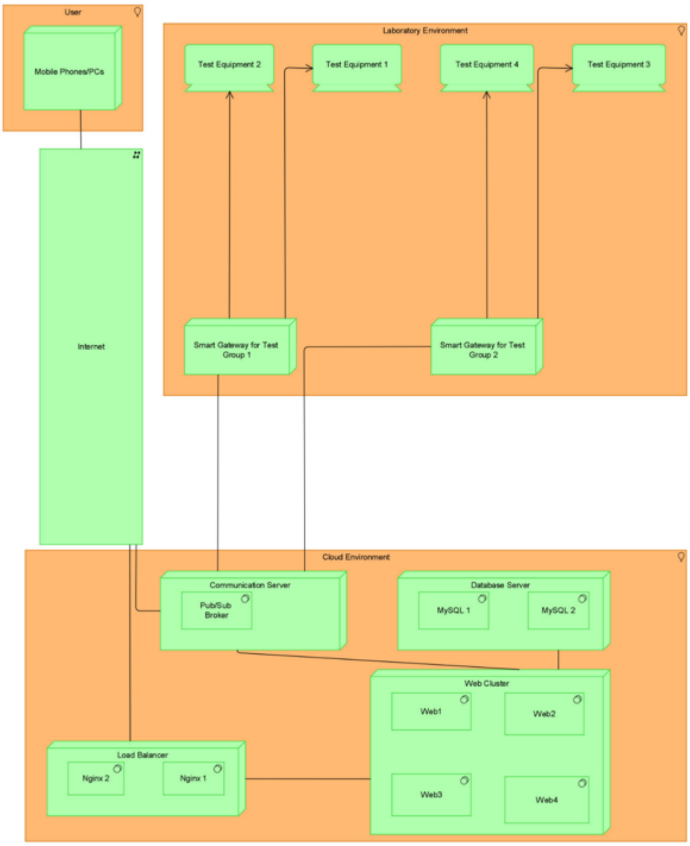


UNIVERSITY OF TWENTE.

19

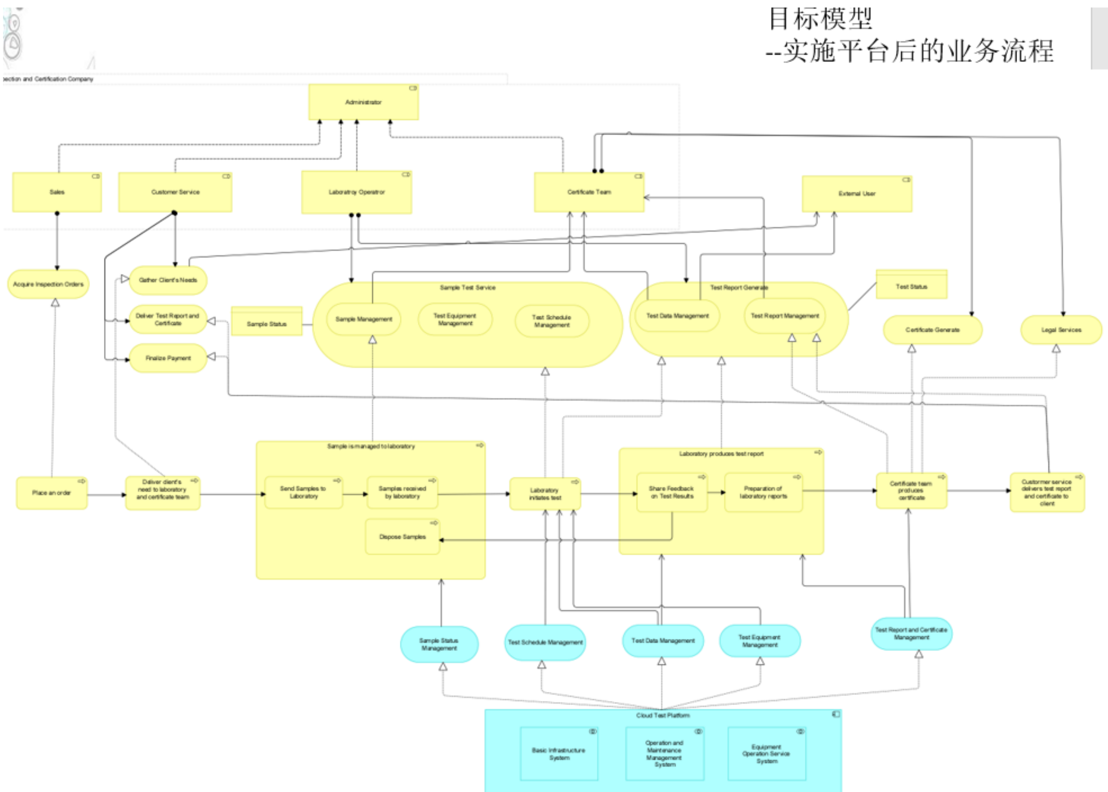
Target model—Platform layer functions

目标模型
--平台实施方案



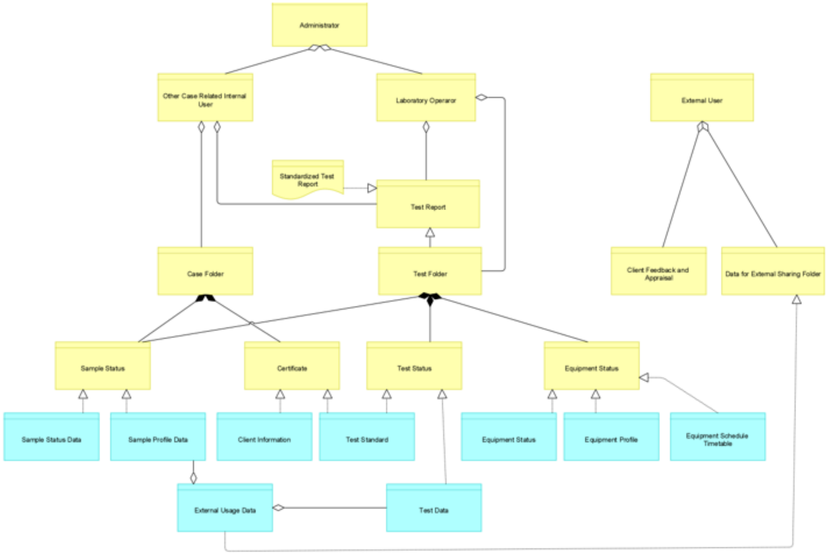
UNIVERSITY OF TWENTE.

Target model—Implementation plan



Target model – Business process after implementing the platform

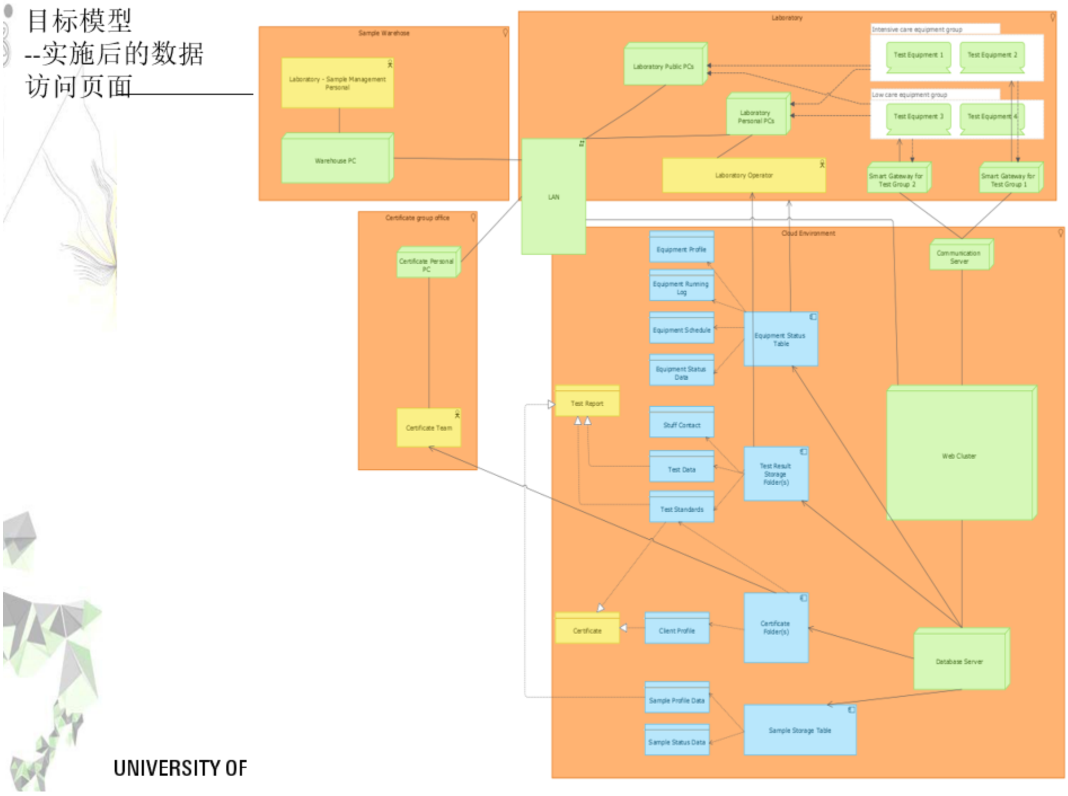
目标模型
--信息结构



UNIVERSITY OF TWENTE.

22

Target model – Information structure



Target model – Data access view after implementing the platform

8.5 Appendix E – Figure - SGS's vision document for a cloud-based platform

STAS®-PLUS

STAS®-PLUS

SGS在实验室自动化、数字化及智能化持续投入研发资源，在原有安规检测自动化系统Safety Testing Automation System (STAS)基础上，开发出具备更高可靠性、可用性、可维护性及可扩展性的智能测试增强系统Smart Testing Augmenting System (STAS®-PLUS)。

STAS®-PLUS

SGS has been inputting its R & D resources in lab automation, digitalization and intelligence continuously, and has developed its Smart Test Augmenting System (STAS®-PLUS) with higher reliability, usability, maintainability and expansibility on the basis of the original Safety Test Automation System (STAS).

STAS®-PLUS的功能特点

- 实现实验室通用检测设备的连接、交互与控制
- 实现检测流程与检测数据的数字化与自动化
- 实现实验室资源使用及调配效率的提升
- 高可扩展性 — 根据业务场景及作业流程的需要：
  - 连接、交互与控制更多检测设备
  - 开发更多自动化/智能化的检测流程

FEATURES OF STAS®-PLUS

- Achieved connecting, interaction and control of universal lab test equipment
- Automated and digitalized testing processes and test data
- Enhanced utilization and allocation efficiency of lab resources
- Highly expansive – according to the needs of business scenarios and work-flows to:
  - Connect, interact with and control more test equipment
  - Develop more automatic and intelligent test processes

A connected SGS materials & reliability lab

TeREES®

以 STAS®-PLUS 作为交互枢纽的，基于物联网的实验室设备资源管理系统

TEST RESOURCE & EQUIPMENT ECO-SYSTEM (TEREES®) WITH STAS®-PLUS AS THE INTERACTING HUB AND BASED ON IOT ARCHITECTURE

数字化的实验室运维管理：

- 看板式的实时设备运行状态监控
- 在线预定与排期
- 线上à线下 — 下达测试任务及远程控制
- 任务管理、数据采集、表单/报告的自动生成
- 设备管理

DIGITALIZED LAB OPERATION, MAINTENANCE AND MANAGEMENT:

- Real-time dashboard monitoring of equipment's operation status
- Online booking and scheduling
- Online-to-offline test task assignment and remote controlling
- Task management, data acquisition and automatic generation of datasheets and reports
- Equipment management

日程看板
SCHEDULE DASHBOARD

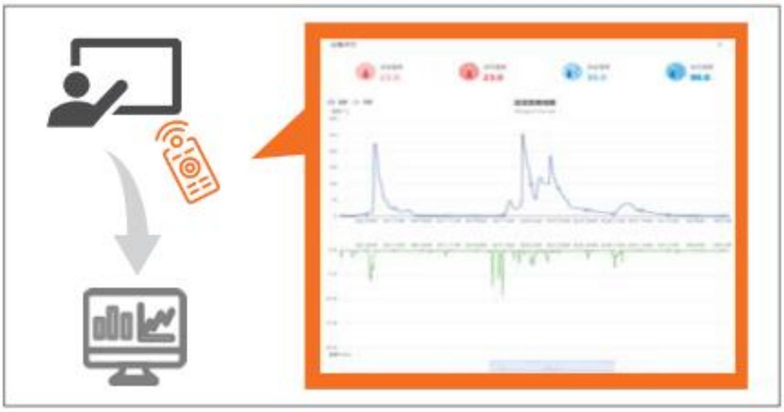
- 查看任务信息进程 Test Schedule
- 预定设备 Equipment Booking

实验室地图
LAB DASHBOARD

- 虚拟实验室地图 Virtual Lab Map
- 查看设备实时状态 Real-time Status

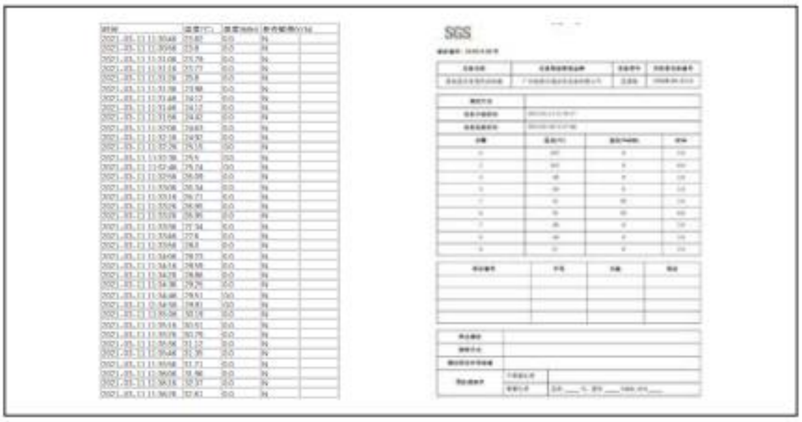
远程控制 & 实时状态
REMOTE CONTROL & REAL-TIME STATUS

- 线上下达测试任务 Test Program
- 远程控制设备/管理任务 Remote Control
- 查看设备实时运行数据曲线 Real-time curve



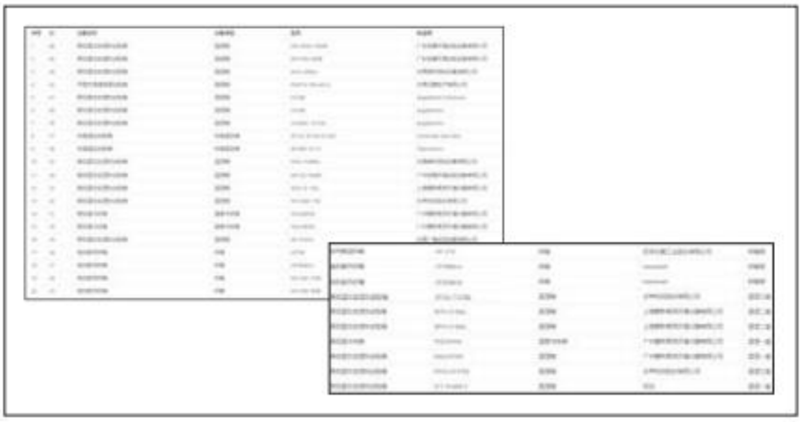
数据采集及报告
DATA & REPORT

- 实时测试数据采集 Data Capture
- 生成测试记录 Datasheet & Reporting



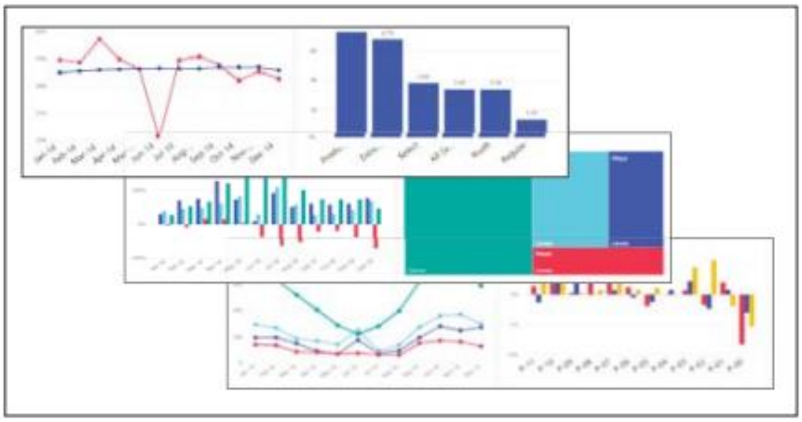
设备档案
EQUIPMENT PROFILE

- 设备能力参数档案 Equipment Profile
- 设备管理 Equipment Management



资源使用效率
UTILIZATION EFFICIENCY

- 有效使用率 Utilization Rate
- 故障率 Mal-function Rate
- 待机率 Standby Rate



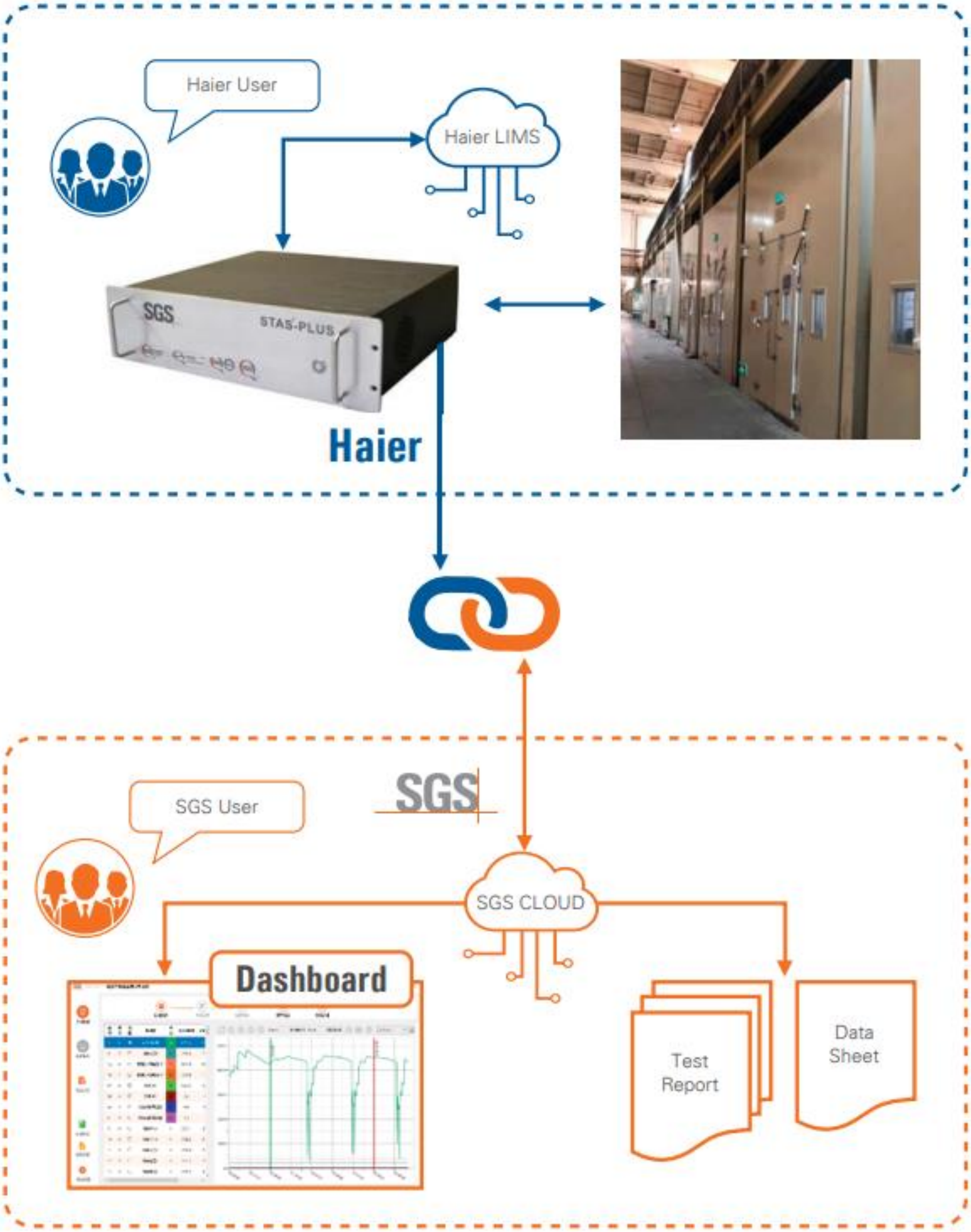
SGS与海尔商用空调测试中心

Connected labs: SGS & HAIER commercial air-conditioner test center

AIR-CONDITIONER BALANCE TESTING PLATFORM

以STAS®-PLUS作为交互枢纽，与空调低温平衡室集成空调热平衡测试平台，实现：

- 智能化分析
  Intelligent Analysis
- 数据以及检测流程监控
  Real-time data & process monitoring
- 数据计算验证
  Data computing & verifying
- 出具定制报告
  Customized reporting


Haier User
Haier LIMS
SGS
STAS-PLUS
Haier
SGS User
SGS
SGS CLOUD
Dashboard
Test
Report
Data
Sheet

Connected HIKVISION & SGS JOINT lab

STAS®-PLUS TO HIKVISION V2

基于STAS®-PLUS为海康威视(HIKVISION)开发第二代智能产品测试系统：

- 多种输入电压不断电自动切换
- 自动采集/计算/报告
- 24小时不间断作业

- Automation Switching
- Automation Computing & Report
- 24 hours un-manned operation


Hikvision User
Hikvision LIMS
SGS
STAS-PLUS
HIKVISION
SGS User
SGS
SGS CLOUD
Dashboard
Test Report
Data Sheet

Connected labs: OCM Online™

- 传感器通过STAS®-PLUS连接安装于设备(如风电机组齿轮箱)，对油液指标(如污染、磨损、粘度等)进行实时监测
- 实时数据通过4G/5G传输至SGS云端
- 在云端对数据进行监测与分析

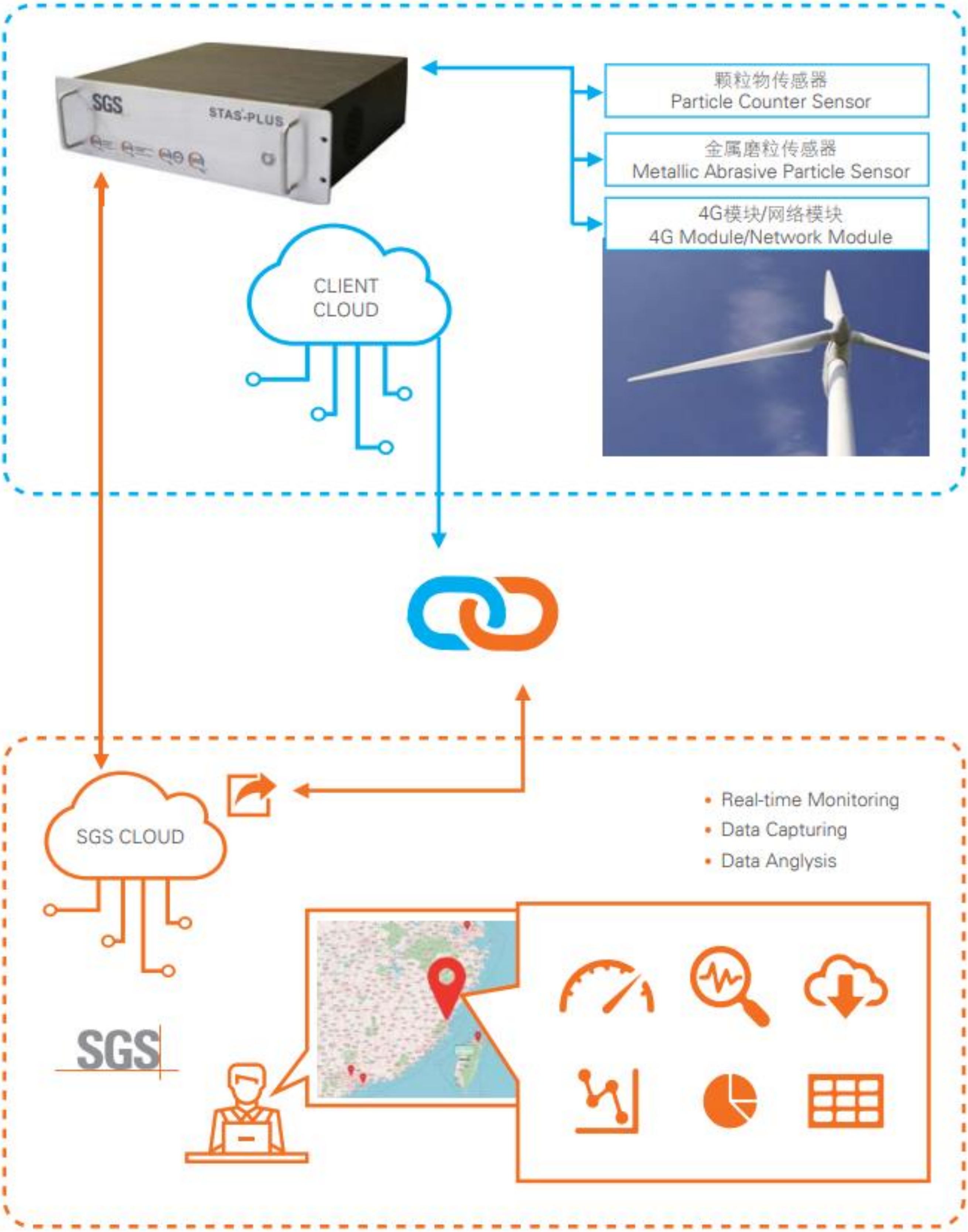
- Sensors are connected by STAS®-PLUS and installed in equipment (e.g. turbines) for oil condition (e.g. contamination, wear, viscosity) monitoring
- Real-time data to SGS Cloud via 4G/5G
- Cloud platform for data monitoring/analysis

SGS与某风电集团基于物联网与云计算的合作模式

通过OCM Online™系统与某大型风电集团的数据平台对接，SGS为客户完善其"智能风电诊断平台"，为风场运维提供数据保障。

COOPERATION MODEL BETWEEN SGS AND WIND POWER CORPORATE BASED ON CLOUD COMPUTING & IOT

By merging OCM Online™ with client's cloud platform, SGS further improves client's 'Smart Turbine Diagnosis Platform', which ensures the operation & maintenance of wind field.


SGS
STAS-PLUS
颗粒物传感器
Particle Counter Sensor
金属磨粒传感器
Metallic Abrasive Particle Sensor
4G模块/网络模块
4G Module/Network Module
CLIENT CLOUD
SGS CLOUD
• Real-time Monitoring
• Data Capturing
• Data Anglysis
SGS

组织内部
– 基于物联的实验室集群运营与管理

■ 实验室及检测设备高度物联

- 指针/看板式可视化实时监控
- 高效的跨区域资源调配及资产的智能化管理
- 检测的高度自动化与数字化

■ 基于物联及大数据的智能化运营

- 跨区域的远程技术支持，提高知识管理效率
- 测试、数据、报告、认证流程的数字化，提高业务流程的时效性及准确性
- 构建实验室检测数据与运营数据的大数据平台

SGS与客户
– 基于物联的跨组织检测平台

■ 对SGS客户实验室(CTF)及认可合作实验室(QTL)建立互联

- 跨组织、直播式检测状态监控 — 客户端测试，SGS实时获得数据，线上完成检测报告及认证流程，提高业务流程的时效性及准确性
- 实现跨组织、跨区域的远程技术支持，提升服务质量
- 基于实验室大数据平台，提升客户端实验室运维效率

超越传统检测认证
– 基于物联的全生命周期管理

■ 对生产端产线检测设备建立互联

■ 对产品运行周期建立物联

- 实现产线检测数据与SGS型式试验数据相融合
- 建立生产过程检测数据+SGS型式试验数据+产品生命周期数据的大数据模型
- 实现针对每一个产品的智能化数字档案，实现基于大数据的覆盖产品全生命周期的智能化运维、诊断与管理

INSIDE THE ORGANIZATION
– LAB'S CLUSTERED OPERATION AND MANAGEMENT BASED ON IOT

■ HIGHLY CONNECTION OF LAB AND TEST EQUIPMENT

- Pointer/signboard visual real-time monitoring
- Highly efficient cross-regional resource allocation and smart management of assets
- Highly automation and digitalization

■ SMART OPERATION BASED ON IOT AND BIG DATA

- Cross-regional remote technical support and improve management efficiency of knowledge
- Digitalization of test, data, reporting and certification process and improve timeliness and accuracy of business process
- Build a big data platform of lab test data and operation data

SGS AND CLIENTS
– CROSS-ORGANIZATIONAL TEST PLATFORM BASED ON IOT

■ BUILD UP CONNECTION FOR SGS'S CLIENT LAB(CTF) AND ITS RECOGNIZED COOPERATIVE LABS (QTL):

- Cross-organizational, live broadcasting test status monitoring-test conducted at client's end, SGS's acquiring data at real time, completing test report and certification process on line and improve timeliness and accuracy of business process
- Achieve cross-organizational and cross-regional remote technical support and improve service quality
- Improve operation and maintenance efficiency at client's end based on the laboratory big data platform

SURPASS TRADITIONAL TEST CERTIFICATION
– WHOLE-LIFE CYCLE MANAGEMENT BASED ON IOT

■ BUILD UP CONNECTION FOR PRODUCTION LINE TEST EQUIPMENT AT MANUFACTURER'S END

■ BUILD AN IOT FOR OPERATION CYCLE OF PRODUCTS

- Integrate production line test data and SGS's type test data
- Build a big data model for production process test data+ SGS's type test data + product life cycle data
- Achieve intelligent digital file for each product and achieve big data based intelligent operation, maintenance, diagnosis and management covering the whole life cycle of products

8.6 Appendix F - Interview about stakeholders' requirements

Siyuan: Hello Cloud. Thanks for accepting the interview.

Expert A: Hello Derek.

Siyuan: Good afternoon! I always have a question about how does SGS draws a conclusion that stakeholders need a cloud-based platform. Therefore, this brief interview is about introducing how does SGS find stakeholders need a cloud-based platform.

Expert A: Well, by stakeholder, do you mean company-related or experiment-related participants?

Siyuan: Generally speaking, it is related to experiments, but it is not limited to inside and outside SGS company. I learned that SGS's TeREES project is willing to share some data with people outside the company.

Expert A: Indeed, SGS's TeREES project is willing to share some experimental and monitoring data with some clients. For example, the air-conditioning test center we cooperated with Haier before shared the real-time data of the experiment, monitoring status, inspection process and customized experiment report with Haier.

Siyuan: Then I can understand that the data or permissions shared with customers mainly refer to real-time monitoring and sharing of experimental data and test reports. Is it right?

Expert A: In general, it is true.

Siyuan: What about the needs of stakeholders within the company? According to my understanding of the company's test process, there are three main characters that really need to participate in the company's experimental process: laboratory operators, certificate team, and the program manager. Do these three have any requirements for the cloud-based platform?

Expert A: Let's start with the simplest: certificate team. What the certifier needs is to produce a certificate that complies with relevant standards based on the experimental report of the test. So, they need to match test reports, applicable test standards and sample information. Since the sample information is currently stored in the computer of the sample bank and shared with the company's employees, what the certifier needs more is the report of the matching test and the applicable test standard. This is also what I think they need most for the cloud-based platform.

Siyuan: Ok, so what about laboratory operators, what do you think their needs are for cloud-based platforms.

Expert A: As you can see, laboratory operators need to do a lot of testing work, as well as produce test reports based on the test results and related standards. What they need most is to match the test results according to the test standards and automatically form the experimental report. This can reduce the workload of laboratory operators.

Siyuan: Yes, I understand that. What about automation? As I mentioned to you before, I found that the tests on temperature and humidity lasted a long time, but the laboratory operators interfered few with the test equipment. In these experiments, laboratory operators usually spend a lot of time, even overnight in the laboratory monitoring the progress of the experiment. This seems unnecessary to me. Could these wastes of human resources be avoided through remote monitoring or automation?

Expert A: We have already considered this situation. But there is currently no solution to this problem, you can design your ideas into your model.

Siyuan: May I ask why SGS has not yet had a solution for this problem?

Expert A: The first point is that considering that there is no mature solution in the testing and certification industry to realize remote monitoring of test equipment. The second point is that out of respect for laboratory safety regulations, it is still required to have at least two laboratory operators stay on-site during the test. However, I believe that remote control of equipment and remote monitoring are the development directions of cloud-based platform, and it is also the future demand of laboratory operators.

Siyuan: I see. And what about the requirements from the project managers? Do they have specific requirements on cloud-based platform?

Expert A: Managers usually need all the permissions that laboratory operators have. In addition, managers also need a dashboard to show all the projects they manage and their progress. At the same time, due to the need to contact and share information with clients, they also need permission to share information with users outside the organization.

Siyuan: I see. Thanks for accepting this interview and your honest replies. That's all I need.

Expert A: Don't mention it. Good luck with your project.