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**Developing, Designing, and Improving Features  
for  
CybExer's Next-Generation Cyber Range  
Platform**

Bachelor's thesis

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M Sc

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**CybExeri järgmise põlvkonna  
küberharjutusväljaku  
funktsioonide arendus, disain ja täiustamine**

Bakalaureusetöö

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Tallinn 2022

## **Author's declaration of originality**

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

Author: Robert Kaibald

11.05.2022

## **Abstract**

The aim of the current thesis is to give an overview of the projects that make the CybExer's Cyber Range, introduce some of the goals set for the release of the next cyber range platform iteration, explore options to ensure good user interface and user experience design, give an overview of the features added to the cyber range by the author, and analyse what state of usability the cyber range platform currently is.

The thesis is mainly split into three parts which are the overview of the current state of CybExer's cyber range, plans for the next iteration of the cyber range, and the development process of the cyber range. The first part will contain information about various projects that work together to provide the end-users with a working cyber range. The second part will contain information about some of the plans for the next iteration of the cyber range whilst providing some information about user interface and user experience design and why they are important. The third part will provide information about some of the technologies used developing the cyber range, explain some of the features added to the range by the author and give an overview of the state of the range usability wise.

The thesis will not include all information about the development of the next iteration of the cyber range mainly because the process will take more than a year as of writing the thesis. In addition, the thesis will not include sensitive information about the cyber range.

This thesis is written in English and is 28 pages long, including 5 chapters, 1 figure, 1 table, and 5 code examples.

## **Annotatsioon**

### **CybExeri järgmise põlvkonna küberharjutusväljaku funktsioonide arendus, disain ja parendus**

Käesoleva bakalaureusetöö eesmärgiks on anda lugejale ülevaade projektidest, mis moodustavad CybExeri küberharjutusväljaku, tutvustada mõned seatud eesmärgid küberharjutusväljaku järgmiseks versiooniks, uurida kuidas tagada hea kasutajaliidese ja kasutajakogemuse disain, anda ülevaade funktsionaalsustest, mis autor küberharjutusväljakule lisas ja analüüsida, millises kasutatavuse seisus praegune küberharjutusväljaku versioon on.

Käesolev bakalaureusetöö on põhiliselt jagatud kolmeks osaks. Need peatükid on ülevaade praegusest küberharjutusväljakust, plaanid järgmise küberharjutusväljaku versiooni jaoks ja küberharjutusväljaku arendusprotsess. Esimeses osas on kirjutatud erinevatest projektidest, mis koostöös omavahel pakuvad lõppkasutajatele töötava küberharjutusväljaku. Teises osas on kirjutatud, mis CybExeril on plaanis uude versiooni lisada, kasutajaliidese ja kasutajamugavuse disainist ning miks need olulised on. Kolmandas osas annab ülevaate osadest tehnoloogiatest, mis on CybExeri küberharjutusväljaku arenduskäigus kasutusel, selgitab autori poolt lisatud funktsionaalsusi ning annab ülevaate küberharjutusväljaku praeguse versiooni kasutatavusest.

Bakalaureusetöö ei sisalda kogu informatsiooni küberharjutusväljaku järgmise versiooni arenduskäigust, kuna tegemist on protsessiga, mis töö kirjutamise ajal võtab rohkem kui aasta. Töö ei sisalda ka informatsiooni, mis võib olla CybExeri jaoks sensitiivne.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 28 leheküljel, 5 peatükki, 1 joonist, 1 tabelit, 5 koodinäidet.

## **List of abbreviations and terms**

API	Application Programming Interface
BOSN	Binary Encoded Javascript Object Notation
DELRAP	Direct Endorsement Lender Review and Approval Process
DSN	Data Source Name
CSTR	Cyber Skills Testing Range
CTF	Capture The Flag
GMA	GameNet Monitoring Agent
HTTP	Hypertext Transfer Protocol
ICMP	Internet Control Message Protocol
ISA	Integrated Scoring and Analysis
JSON	JavaScript Object Notation
JVM	Java Virtual Machine
NICE	National Initiative for Cybersecurity Education
NIST	National Institute of Standards and Technology
REST	Representational State Transfer
SQL	Structured Query Language
UI	User Interface
UX	User Experience
VM	Virtual Machine
VLM	Virtual Lab Manager
VLM-UP	Virtual Lab Manager User Portal

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# 1 Introduction

As the world gets more digitalized the potential for cybercrime rises. The number of cyber-attacks is increasing each year. This means that to keep digital infrastructure safe we need qualified specialists.

The National Institute of Standards and Technology provides a Workforce Framework for Cybersecurity - NICE Framework. The National Initiative for Cybersecurity Education framework is a fundamental reference for describing and sharing information about cybersecurity work. Using conceptual building blocks, it presents a common language for organizations to use. The main building blocks of the NICE Framework are Tasks, Knowledge, and Skills (TKS) statements. This framework attempts to describe these statements in generic terms so that they can be applied to all organizations [1].

To develop and assess skills in cybersecurity a platform is required. A cyber range is suitable for this. It is a set of hardware and software that is configured to provide environments for cyber trainings and exercises. It includes a set of automation and access tools, that provide fast deployment and customizability for its environments. In short it offers a safe environment where personnel, technical, and organisational capabilities can be assessed, analysed, and developed.

The author of this thesis is part of a development team that is working on a cyber range platform in a company called CybExer Technologies. This thesis will be focused on the named cyber range, giving insight to the platform, and describing parts of the process of developing, improving, and designing the platforms features. Some details are left undisclosed as they are trade secrets or might otherwise be harmful to the company. Since the development process is a team effort the author cannot make every decision independently. Due to limited time, only the first steps of the new iteration of the cyber range will be discussed.

In this thesis the author will analyse CybExer's existing cyber range, explore some of the new requirements for the next iteration of the project and try to find the best solution for

said requirements. Some focus will also be put on the UI and UX design of the project as the author will analyse the platform and see how some features can be improved to provide the end-user with the best experience. The author also provides information about the development process and technologies used by the CybExer development team and the author.

## **2 Background**

CybExer Technologies is a cybersecurity company that has developed a cyber range that supports both cloud and on-premises demands while delivering NIST and NICE-compliant testing and evaluation. It consists of a complex set of underlying infrastructure and cyber range management software upon which various virtual or physically integrated machines can be installed and supports the development, delivery, and use of interactive simulation environments [2].

It includes a simulated internet for emulating real-world use-cases, can operate as either online or air-gapped and can provide multiple isolated training environments for simultaneous training sessions on the same range [3].

### **2.1 Projects used in the cyber range platform**

The Cyber Range consists of multiple software solutions. Some of the most noteworthy are DELRAP, ISA, Omnibus, VLM, VLM-UP, and VCenter. Figure 1 shows a simplified flow diagram of how these solutions work together and describe how users access them. The end-users represent users who experience the various functionalities that the cyber range solutions have to offer. The technical users represent the users who ensure that the platforms run smoothly, provide technical support, and that cyber exercises run properly.

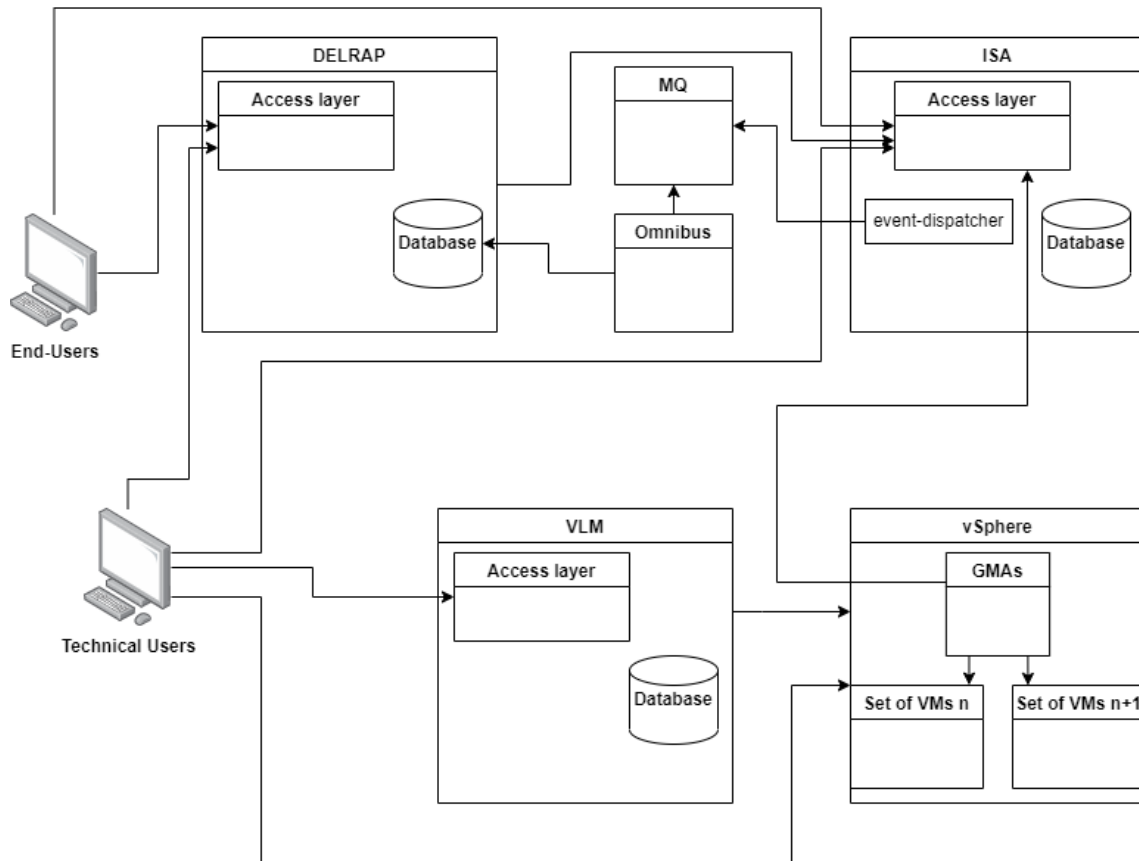


Figure 1. Simplified flow diagram of the platform

### 2.1.1 DELRAP

DELRAP is a e-testing module for technical trainings. It enables learning and testing processes that provide auditing and risk assessment across all levels of the organization. This platform allows for the adaptation of courses to the specifics of the organization, as well as the creation of detailed risk analysis for both the entire organization and its subdivisions. ISA can be integrated with this as well allowing the use of virtual machines and more [3].

Visually speaking, DELRAP has a login page where users can either register or log in. The main page consists of different training modules. A navigation bar is located at the top of the page, consisting of sections such as:

- Dashboard
- Profile
- Risk Profile

- Support
- Leaderboard
- Theme selection
- Language selection
- User dropdown menu

If the user is an admin, analyst or both then additional options will appear:

- Admin dropdown menu
- Analyst dropdown menu

Dashboard navigates the user to the main page where they can select a module. The module can be either informative consisting of informational videos, text, or slides or practical, giving the user theoretical tests or navigate the user to the ISA platform where more practical exercises can be completed. The user also has access to their chats and can see how many tasks they have completed, their points and news. When navigating to Profile the user can once again see their points and completed tasks. Here users can also see their activity timeline, depending on the module different data will be shown. On the support page users get information about contacting support, admins and analysts can also run an external systems health check. The leaderboard can be categorized by modules. It shows user scores and if they have passed the tests in the selected module. By default, the themes include a light theme and dark theme, however custom themes can be added by admin users. When opening the user dropdown menu, the user can easily access their feedback, logout option and password change.

Admin users have access to the admin dropdown menu. There they can access module management, group management, product key management, administer users, import modules, change settings, manage integrations, add news, and manage translations. They also have multiple options in the settings menu where they can configure the DELRAP application to their organization's specific needs.



### 2.1.2 ISA

Integrated Scoring and Awareness (ISA) is a software solution which provides a near real-time scoring and situational awareness visualization and reporting functions during cyber exercises. It is the main user interface for exercise tasks and feedback. It consists of multiple purpose-built virtual appliances and integrations to external software components [3].

ISA CR external data sources are components which are not a part of the ISA product, but act as the important but optional counterparts. These external data sources are usually separate products providing additional data input for exercise configuration, scoring or situational awareness visualization. They are VLM-UP and GMA. In short, the GameNet Monitoring Agent is a standalone service in Blue Team's network and is responsible for polling Blue Team's services and sends availability information to the ISA. VLM User Portal allows team users to manipulate their virtual machines.

ISA can be integrated with DELRAP or function separately from it. When integrated, a user may select an ISA module and be rerouted to the ISA environment with their DELRAP login credentials. If the ISA platform is operating separately from DELRAP for instance in a special cyber security event, then the user will be asked to register or log in first.

There are four different types of modules, that represent the type of the exercise:

- Live-Fire
- CTF
- Hybrid (Live-Fire and CTF combined)
- CSTR

A Live-Fire exercise consists of Red Team (attackers), Blue Team (defenders) and White Team (judges). Blue teams defend virtual machines, that have targets such as web service, ICMP, etc. specified. With these targets there are different objectives defined for the Red Team to attack. The objectives are divided between campaign phases. Not all exercise objectives are available all the time. The exercise can also contain CTF missions.

Scoring for the Blue Teams is based on Blue Team VMs availability, Blue Team awareness, successful Red Team attacks, Blue Teams' reports and results of CTF missions. The availability score is calculated automatically based on VMs availability. Both Red Team successful attacks as well as Blue Teams awareness and situation reports are analysed and confirmed by the judges. Judges may also give additional points for any valid reason they see fit. CTF scores are also calculated automatically.

Capture the Flag tasks are special missions for Blue Teams to solve where answers (Flags) must be taken from live targets. The CTF Mission Board allows Blue Team users to start the missions where they can see the mission description, points, and submit answers. In some cases, missions have hints that can be taken by the users. Tasks, hints, and answers are defined in the exercise JSON. The scores from these missions are shown in the Team Scoring view.

Cyber Skills Testing Range tasks are special missions for individuals to solve. Users need to modify or create something on a live system and ISA checks that if the correct modification has been made. The exercise definitions and mission board are like those of the CTFs where definitions are defined in the exercise JSON. Scores from the missions are shown in the Team Scoring view. The user status is trackable for all applicable tasks under a specific role with progress information that includes a NICE summary.

The navigation bar for ISA is located on the left of the page. Users can select a module which they wish to solve, dependent on this, the navigation bar varies accordingly to the user's needs.

Technical users have an overview of the status of the exercises and the tools to configure them. Furthermore, they can monitor the progress of the participants.

### **2.1.3 Omnibus**

Omnibus is a middle service that is exchanging data between the ISA and DELRAP platforms with the help of Apache ActiveMQ.

Apache ActiveMQ (Apache Active Message Queuing) is an open-source protocol developed by Apache which functions as an implementation of message-oriented middleware. Its basic function is to send messages between different applications [4].

#### **2.1.4 VLM**

VLM is a standalone Linux-based virtual appliance running within a VMware vSphere environment. It integrates to vCenter providing a rich set of vSphere-specific deployment features. VLM provides web-based UI for GameNet administrators and developers allowing them to modify existing or add new VLM VM definitions. Thanks to VLM it is possible to rapidly deploy and customize GameNet and do post-exercise clean-ups [3].

#### **2.1.5 VLM-UP**

VLM User Portal (VLM-UP) is a web-based application for end-user training class access. It integrates to the existing VLM application and provides users access to VM consoles and their basic operations such as power off, reset, shutdown guest, restart guest, and revert to current snapshot. VLM-UP eliminates the need to give class users direct access to the vSphere environment [3].

#### **2.1.6 VCenter**

VCenter Server is a service created by VMware that acts as a central administration point for ESXi hosts and their virtual machines, connected on a network. It can support up to a thousand hosts and up to ten thousand powered-on virtual machines per VCenter Server instance [5].

### **3 Plans for Improvement**

To keep the digital world safe, we need experienced specialists, and they need a platform where they can execute different exercises and trainings to keep their skills up to date. The development of cyber ranges is costly and complicated thus not many exist. Thanks to funding from investors, CybExer Technologies has the flexibility to develop the next iteration of their cyber range.

The main goal is to develop CybExer's cyber range to a state that appeals to a wider userbase. This means that it is necessary to release a cyber range with the highest possible quality with functionalities that benefit both the business and the end users. To appeal to a wider userbase it is important to ensure great user experience [3].

Current users tend to have some previous knowledge about cybersecurity and thus can use the cyber range with ease, however this might not be the case with users that are new to this. Ideally our platform will increase the amount of people who are interested in cybersecurity. Furthermore, the user interface needs to be comfortable and easy to use.

#### **3.1 New Functionalities**

From the cyber range platform development perspective, the CybExer team develops three distinct components: DELRAP, ISA, and VLM. The grand vision is to enable these distinct components to work as one [3].

In addition, there are other functionalities in development that will improve the overall usage of the cyber range, such as:

- Data Strategy and Automated Benchmarking
- Cyber Range Operator Console
- Range Content Development Portal

- Breach Simulation Agents [3]

Data Strategy and Automated Benchmarking would use the data that is currently captured and recorded during an exercise, create a model and benchmarking engine to provide more numerical value to organizations on the performance of an individual compared against others within the company, industry, or the world [3].

The Cyber Range Operator Console would be a central view where an operator of an exercise can effectively manage different aspects of the exercise like closing or opening VPN access, Start or Stop technical exercises, revert GameNet partially or as a whole unit and run contextual maintenance scripts based on the actual content provisioned on the Cyber Range [3].

The Range Content Development Portal would be a platform that would have all the necessary resources available for the developers to create, test, package and publish new playable content [3].

Breach Simulation Agents are a fleet of technical agents that can be fully automated, scheduled, or called on-demand to run simulated attacks against the Cyber Range GameNet content [3].

## **3.2 User Interface**

In software design, UI design is an essential part. This part needs to meet the expected skills and expectations of users to realize the full potential of the entire software. Therefore, a good UI can be defined as a good UI that can meet the user's expectations of the software and maximize its role [6].

The UI is a vital part of almost all computer systems. Numerous accidents and disasters have been blamed on the design of the UI. Every day, poor UIs result in increased error rates, higher training costs, and reduced throughput [7].

UI Design focuses on anticipating what users might need to do and ensuring that the interface has elements that are easy to access, understanding, and use to facilitate those actions. UI brings together concepts from interaction design, visual design, and information architecture [8].

Users have become familiar with interface elements acting in a certain way, so it is important to be consistent and predictable with their layout. Doing so will help with task completion, efficiency, and satisfaction [8].

Interface elements include but are not limited to:

- Input Controls: buttons, text fields, checkboxes, radio buttons, dropdown lists, list boxes, toggles, date fields
- Navigational Components: search field, slider, tags, icons, pagination
- Informational Components: tooltips, icons, progress bar, notifications, message boxes, modal windows
- Containers

There are times when multiple elements might be appropriate for displaying content. When this happens, it's important to consider trade-offs. For example, sometimes elements that can help save space, put more of a burden on the user mentally by forcing them to guess what is within the dropdown or what the element might be [8].

Numerous things should be considered when designing UI:

- Keeping the interface simple
- Staying consistent with the use of UI elements
- Considering readability and spatial relationships between elements
- Strategic use of colours and textures
- Giving users feedbacks for their actions
- Thinking about the defaults of users

### **3.3 User Experience**

UX design involves taking a human-centred approach to product development and crafting an experience around the needs, and desires of the target audience [9].

Some of the principles of good UX design are as follows:

- Visibility of system status
- User control and freedom
- Consistency and standards
- Error prevention
- Memorability
- Flexibility and efficiency of use
- Feedback
- Help and documentation
- Usefulness
- Usability
- Accessibility
- Credibility

Since information about UX varies depending on different sources there is no certain ruleset for an ideal UX design. However, gathering information from different sources and trying to apply the standards given by the named sources to a software solution would nevertheless greatly improve the UX of the software.

## **4 Development process**

This chapter contains information about the technologies used throughout the authors development process and information about the features implemented or improved by the author. The author is part of the CybExer's development team where each member is working on their own tasks.

### **4.1 Methodology**

The CybExer development team takes an agile approach to software development. Agile is an iterative approach to project management and software development that helps teams deliver value to their customers faster and with fewer headaches. An agile team delivers work in small, but consumable, increments. Requirements, plans and results are evaluated continuously so teams have a natural mechanism for responding to change quickly. Agile isn't defined by a set of ceremonies or specific development techniques. Rather, agile is a group of methodologies that demonstrate a commitment to tight feedback cycles and continuous improvement. Teams choose agile so they can respond to changes in the marketplace or feedback from customers quickly without derailing a year's worth of plans. An agile team unites under a shared vision, then brings it to life the way they know best. Each team sets their own standards for quality, usability, and completeness. Their "definition of done" then informs how fast they will churn out the work out [10].

Each week the CybExer development team participates in a meeting where the current goals, issues, and plans are discussed. Scrum is a framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible value. Scrum is a lightweight framework that helps people, teams and organizations generate value through adaptive solutions for complex problems. The fundamental unit of Scrum is a small team of people, a Scrum Team. The Scrum Team consists of one Scrum Master, one Product Owner, and Developers. It is a cohesive unit of professionals focused on one objective at a time, the Product Goal [11].



KISS (Keep it simple, stupid) approach is used in this thesis. This means that the project at hand is managed as simply as possible, whilst different options will be explored in the choice of tools and the best is chosen [12].

## **4.2 Choice of Technologies**

### **4.2.1 Kotlin**

Most of the back-end code has been written in Kotlin. Kotlin is a programming language that is designed to interoperate fully with Java. The JVM version of Kotlin's standard library depends on the Java Class Library. The Kotlin language, including the compiler, libraries, and all related tooling, is entirely open source and free to use for any purpose. It's available under the Apache2 license [13].

Kotlin fixes a series of issues that Java suffers from:

- Null references are controlled by the type system
- No raw types
- Arrays in Kotlin are invariant
- Kotlin has proper function types, as opposed to Java's SAM-conversions
- Use-site variance without wildcards
- Kotlin does not have checked exceptions [14]

Since all the CybExer's development team members feel comfortable writing code in Java they also have no trouble doing the same in Kotlin whilst also taking advantage of its features that are not present in Java.

### **4.2.2 Angular and Riot.js**

Most of the front-end code is written with the Angular framework that is built in typescript. Outdated views that are still using Riot.js components are being converted to Angular. Some of the Angular advantages are as follows:

- Due to less bandwidth being used and as entire page is not refreshed as the user navigates, application works faster
- Angular replicates changes made to the model instantly into views because of two-way data binding, in a simple, effective, and intuitive manner
- MVVM (Model-View-ViewModel) which enables developers to operate with the same collection of data separately on the same application
- Structure and architecture built especially for better scalability of projects
- Dependency injection to the components contributes to the modularity of the application [15]

### **4.2.3 REST**

REST is a set of architectural constraints, not a protocol or a standard. API developers can implement REST in a variety of ways. When a client request is made via a RESTful API, it transfers a representation of the state of the resource to the requester or endpoint. This information, or representation, is delivered in one of several formats via HTTP. JSON is the most generally popular file format to use because, despite its name, it's language-agnostic, as well as readable by both humans and machines [16].

### **4.2.4 MongoDB**

MongoDB is an open-source document database. Instead of storing data in tables of rows or columns like SQL databases, each record in a MongoDB database is a document described in BSON, a binary representation of the data. Applications can then retrieve this information in a JSON format. As a document database, MongoDB makes it easy for developers to store structured or unstructured data. It uses a JSON-like format to store documents. This format directly maps to native objects in most modern programming languages, making it a natural choice for developers, as they don't need to think about normalizing data [17].

Typical use cases for MongoDB include:

- Integrating large amounts of diverse data
- Describing complex data structures that evolve

- Delivering data in high-performance applications
- Supporting agile development and collaboration [17]

Due to these reasons, it is a perfect solution for the development team to use.

#### **4.2.5 Docker**

Docker is an open-source project for building, shipping, and running programs. It is a command-line program, a background process, and a set of remote services that take a logistical approach to solving common software problems and simplifying your experience installing, running, publishing, and removing software. It accomplishes this by using an operating system technology called containers [18].

Teams that use continuous integration and continuous deployment techniques can build more expressive pipelines and create more robust functional testing environments if they use Docker. The containers being tested hold the same software that will go to production. The results are higher production change confidence, tighter production change control, and faster iteration [18].

Docker is good for multiple things such as prototyping software, packaging software, enabling a microservices architecture, modelling networks, enabling full-stack productivity when offline, reducing debugging overhead, documenting software dependencies and touchpoints, and enabling continuous delivery [19].

#### **4.2.6 Maven**

Apache Maven is a software project management and comprehension tool. Based on the concept of a project object model (POM), Maven can manage a project's build, reporting and documentation from a central piece of information [20].

Maven's primary goal is to allow a developer to comprehend the complete state of a development effort in the shortest period of time. Maven deals with several areas of concern:

- Making the build process easy
- Providing a uniform build system

- Providing quality project information
- Encouraging better development practices [20]

Since CybExer’s development team is working with Kotlin based applications and Kotlin is designed to run on a JVM, Maven is a suitable software solution.

#### **4.2.7 Git**

Git is a free and open-source distributed version control system designed to handle everything from small to large projects with speed and efficiency. Git is well documented, easy to learn, and has great performance [21].

### **4.3 New Features**

In this section the author will give an overview of some of the features they added to the cyber range during the making of this thesis.

#### **4.3.1 GMA Overview and Health Check**

The ISA platform consists of multiple microservices. To ensure that the platform is running smoothly and that users don’t experience any errors it is important that all necessary services are in a working state. Most of ISA services had existing health checks except for GameNet Monitoring Agents where technical users only had an overview of them. The main purpose of these health-checks is to monitor whether GMA services are connected and if their exercises are running properly.

When ISA manages to poll GMA data then it gets added to the list of GMA overviews. Afterwards with the help of a scheduler ISA starts polling this data continuously, updating the “lastGmaPollTimestamp” attribute accordingly. When an exercise has started, it will begin to continuously send out events in a similar manner. Each event will update the “lastActivityTimestamp” in “GmaOverviews”.

With this timestamp data a function can determine each GMAs status. The mentioned function will determine the status by calculating the timestamps difference with the current time and comparing the two with one another. If a proper status cannot be determined it will be set to unknown which in any normal case should not happen. Parameter combinations that don’t result the status to be unknown are shown in Table 1.

GMA Poll Timestamp	GMA Activity Timestamp	Status
Null	Null	No GMA connection
Ok	Null	Connected to GMA
Ok	Ok	Exercise running
Ok	Timeout	Exercise stopped

Table 1. ISA GMA Health Check Parameters

To keep technical users comfortably up to date with the status of a GMA without having to refresh the list every time they need data that is up to date, the author took use of an interval service and applied it to the view component. The named interval service is an injectable class written by the development team that contains functions that make the use of TypeScript's interval functions more comfortable to use. An example of the initialization of the view of GMA overviews is found in Code example 1.

```

ngOnInit(): void {
    this.setData();

    this.intervalService
        .getInterval(GmaOverviewComponent.REFRESH_INTERVAL)
        .subscribe(() => this.setData());
}

private setData(): void {
    this.gmaService
        .getGmaOverviews()
        .pipe(finally(() => (this.loading = false)))
        .subscribe(it => (this.gmaOverviews = it));
}

```

Code example 1. A snippet of the initialization of GMA overviews view with Angular

With this feature authorized users can confirm that the exercises that are using a GMA are running properly thus providing a better user experience.

### 4.3.2 Public Group Mappings

One of the requested features by current users has been the ability to create public groups in DELRAP where users could enrol themselves. Allowing users to select their own group

in cases where it is necessary will remove confusion, improve user experience, and save the admins from unnecessary manual labour.

Since this is an optional feature, it can be enabled by the admins in the settings menu. This was implemented by modifying the setting data class by adding a Boolean attribute which I named “isPublicGroupsEnabled”. If an admin user navigates to the Manage Groups menu, they can add custom group mappings. With Public Groups enabled a new toggle option appears where a group can be switched to either public or private. The mentioned option toggles a Boolean attribute called “isPublicGroup” in the “UserGroup” data class. An example of the user group data class is located in Code example 2. If public groups are enabled and public groups exist, users will be requested to select a group they wish to be enrolled in upon registration.

```
data class UserGroup(  
    val userGroupType: UserGroupType,  
    val mappedGroupId: String,  
    val created: Date = Date(),  
    var _id: ObjectId? = null,  
    val name: String,  
    val origin: UserGroupOrigin,  
    val analysts: List<UserGroupAnalyst>? = null,  
    val groupUsers: Set<String>? = null,  
    val isDefaultGroup: Boolean = false,  
    val isPublicGroup: Boolean = false  
) : JsonBased
```

Code example 2. User group data class in Kotlin

Since users that are not validated or in other words logged in can't request data from user groups the author added functions and validators to enable the communication between the registration form and user group data. The validators ensure that no faulty data gets inserted to the database.

### 4.3.3 Error Tracking and Performance Monitoring

For the CybExer team it is important that the end users don't experience slow load time and are not bothered by unexpected errors. The team might not be aware of all the issues that users might run in to. Monitoring the application load time is also important however such functionality has yet to exist.

Therefore, a great way for improving the application and UX is to find and fix errors and performance issues as soon as they occur. For this our team decided to use Sentry. Sentry is an Application Monitoring and Error Tracking software [22].

The first plant is to try and add Sentry to the ISA platform. Sentry provides a DSN key that needs to be added to the source code of ISA so Sentry would know which accounts it should send the occurred errors to. When catching errors Sentry also provides information on how many times it has occurred before, how many users have been affected by it, when it happened, what sort of request caused the error, etc.

Sentry can be configured to catch different types of errors some of which being exceptions thrown in specific functions in the applications source code and errors or notifications that have been captured by a logger in the application. It is also possible to group errors by their types. For example, exceptions can be grouped by the exception types. An example of Sentry initialization in the ISA software is located in Code example 3.

```
Sentry.init({
  dsn: environment.sentryUrl,
  integrations: [new TracingIntegrations.BrowserTracing()],
  ignoreErrors: ['Non-Error exception captured'],
  tracesSampleRate: 0.2,
  environment: environment.production ? 'production' : 'development',
  beforeBreadcrumb(breadcrumb, hint) {
    if (
      breadcrumb.category === 'xhr' ||
      breadcrumb.category === 'console' ||
      breadcrumb.category === 'fetch'
    ) {
      return null;
    }
    return breadcrumb;
  },
  beforeSend(event) {
    if (environment.production) {
      return event;
    } else {
      return null;
    }
  },
  enabled: environment.sentryEnabled,
});
```

Code example 3. Sentry initialization on the ISA platform

The implementation of Sentry is still in progress.

## **4.4 Usability and Visuals**

As talked about in chapters 3.2 and 3.3 there are multiple principals to take into consideration when ensuring that a software has good software usability and design.

To ensure that these standards are applied to the cyber range the author navigated throughout the various platforms that make the cyber range and tested its various functionalities.

### **4.4.1 DELRAP Usability**

The landing page of DELRAP shows the user their score and various exercise modules available to them. It leaves a good first impression since there is no unnecessary noise and is personalized for the user. Navigating to other views or functionalities is only clicks away thus the design is effective. Different elements throughout the platform such as the header, footer and buttons are easily distinguishable thus ensuring good visibility. The navigation bar, colour pattern and design are consistent as well however since DELRAP allows organizations to add their custom design to the platform it can't always be ensured. Since the design and the pages functionalities are consistent it is also easy for the users to familiarize themselves with different views. The various functions in the platform such as the registration form, exercise modules and different admin configuration options mostly have validation functions that prevent the users from inserting a faulty input that may cause various errors. Furthermore, users receive feedback whenever their activity has been successful or unsuccessful.

The main issues that the author found in the DELRAP platform were related to the page's responsiveness. In some theoretical test modules users need to first confirm their answers before proceeding to the next section of the test. After confirming their answers, a text with feedback will appear above their confirmation button causing it to change its position. By giving the text its own area before appearing the button no longer changes position.

As mentioned, most of the DELRAP functionalities have validators in place, however the author found some that were missing. DELRAP is highly customizable. Since there are numerous variables, developers need to consider which ones work together and which don't. For example, admin users can select which login types are enabled however it is not possible for all these types to co-exist. The author added a function that validates



whether the configuration set by an admin is allowed, if not they will be notified, and the settings will remain unchanged.

#### **4.4.2 ISA Usability**

The landing page of isa depends on its configuration. For instance, if a user selects an ISA module in DELRAP they will be navigated to the ISA mission board. This is not the case if ISA is running as a standalone product. When ISA is not integrated to a DELRAP environment users can see the overview of different available missions. Either way the first impression of the platform is positive and corresponds to the end-user's needs. As it was with the DELRAP platform different elements such as the header, footer and navigation bar are easily distinguishable from one another therefore providing good visibility. All necessary navigation is clicks away thus being effective. The colours, design and navigation elements are consistent. The various functions in the platform such as the registration form, mission board and different admin configuration options mostly have validation functions that prevent the users from inserting a faulty input that may cause various errors. In addition, users receive feedback for their actions such as changing their username, changing configuration options etc. to confirm whether their actions were successful. Furthermore, users with the admin privilege have access to health checks that show whether necessary services are up and running.

Overall, the ISA platform is in a good state usability wise. One of the main issues that the author found was the copy and paste functionality with the virtual machines. Since the virtual machines are running on a different platform some functionalities are limited. To paste text to the VM the user needs to first paste this text to a textbox and send it to the VM. To copy text from a VM they need to use a functionality implemented into ISA that takes a so-called screenshot of the text sending it to the user using ISA. The algorithm that converts the text in the image is not fool proof and may interpret some letters as something they are not therefore this algorithm should be improved. On a positive note, due to the VMs running on a separate platform they don't cause any performance issues on the ISA platform.

Another issue was found with the ISA mission board. On the ISA platform, mission exercises and their points are not visible to the participants until the mission has started. In this case, exercise points are shown as a question mark. In some exercises ISA tasks can have questions that award the player with zero points. Due to the use of a double

equals (==) operator instead of a triple equals (===) operator, the questions which provided zero points displayed the points as a question mark. For clarity, this was changed.

In situations where admin users want to change some exercise attributes such as various answer scores, hints, penalties etc. there is no proper interface for doing so. The technical users need to modify the exercise JSON which is not ideal since finding different attributes can be difficult, typos may make the exercise flawed and requires users to understand how JSON works. Therefore, creating an interface that makes the exercise attributes easy to read and allows technical users to only change the values they need would be a welcome addition to the ISA platform.

As mentioned, technical users have an overview of different services and their states. One of the issues was that health checks for GMA services were previously missing. In addition, the UI for the health checks is not fully responsive. Issues occur when the browser is resized to an extremely narrow view. Smaller containers which represent the microservices that are used by a service are in larger containers which represent the services themselves. Whilst the larger containers are responsive to the browser resizing the smaller ones are not and may end up causing visual inconsistencies. This visual bug can be fixed by changing the smaller containers into flexboxes that will be resized.

#### **4.4.3 VLM Usability**

VLM is used by the technical users who are responsible for the GMA instances. Since there are not many views on this platform it is easy to provide simple and effective navigation. Different elements are distinguishable from one another. The design is consistent, and elements are visible. Since this platform is meant only for technical users many operations and configurations require prior knowledge that can be obtained from CybExer's Operator Manual. Users are provided feedback when completing an operation and, in some cases, they are asked to confirm their changes.

#### **4.4.4 VLM-UP Usability**

VLM-UP is almost identical to VLM design wise. Navigation is efficient. The colours, layout and overall design is consistent. Different elements are distinguishable from one another. Users are provided feedback after their operations. This platform is used to provide users the ability to perform basic functions with their VMs and this is provided

by giving the users an overview of the VM environments they are using, their details and access to their basic functions.

The only issue the author found was the responsiveness of the VM overview page. Before selecting a VM there is nothing to show in the details section so it is redundant at that point. Furthermore, resizing the window to a smaller state pushes the different sections together causing visual inconsistencies such as the names of the VMs and their environments to become unreadable. In conclusion, this page needs to be made responsive.

## **4.5 Testing**

It's important to ensure that the changes made to the software code work properly and don't cause existing functionalities to break. Therefore, every implemented feature added to the cyber range has its own set of automated tests.

Automated software testing is the best way to increase the effectiveness, efficiency, and coverage of software testing. Automation testing does what manual testing does not. Automation testing improves the accuracy & it saves the time of the tester & organization's money. Automation testing is best suited in the environment where the requirements are frequently changing & huge amount of regression testing is required to be performed [23].

Developers at CybExer write automated tests for each functionality they add. These include unit tests and integration tests for both back-end and front-end functionalities.

Unit tests are close to the source of the application. They consist in testing individual methods and functions of the classes, components or modules used by the software. Unit tests are in general quite simple to automate [24].

Integration tests verify that different modules or services used by the application work well together. For example, it can test the interaction with the database or making sure that microservices work together as expected. These types of tests cost more resources since they require multiple parts of the application to be up and running [24].

Therefore, since automated tests can increase effectiveness, efficiency, and coverage of the software it would be safe to say that they are almost mandatory to some extent. Being part of the development team, the author also wrote tests that verified that the added

features don't break the existing software and function properly. This means that tests were written and sometimes modified for both the front-end and back-end of the software. An example of a front-end test is located in Code example 4 where the test validates that the text located in a GMA tooltip is correct. An example of a back-end test is located in Code example 5 where the test validates that updating a public group with its id attribute functions correctly.

```
describe('when getting matTooltip text', () => {
  it('should return correct text if GmaStatus.HEARTBEAT', () => {
    // given
    const gmaOverview = new GmaOverview({
      latestGmaPollTimestamp: '2017-06-19T11:40:51',
      latestActivityTimestamp: '2017-06-19T11:40:51',
    });

    gmaOverview.status = GmaStatus.HEARTBEAT;

    // when
    const result = component.getMatTooltipText(gmaOverview);

    // then
    expect(result).toBe(
      TooltipStatus.HEARTBEAT +
      '\n' +
      'Last activity message: 19.06.2017 11:40:51' +
      '\n' +
      'Last successful poll: 19.06.2017 11:40:51'
    );
  });
});
```

Code example 4. Snippet of a front-end test that validates the text contained in a GMA tooltip

```

@Test
open fun updateById - true - if updated to public group() {
    // given
    val idData = ObjectId("59d4d804ad373d6f07abe2aa")
    val analystLdapGroup = "analyst-ldap"
    val analystsData = listOf(UserGroupAnalyst(analystLdapGroup))
    val customGroup = UserGroup(
        CUSTOM,
        "NEW-ldapgroup",
        name = "NEW-customName",
        _id = idData,
        origin = AD,
        analysts = analystsData,
        isDefaultGroup = true,
        isPublicGroup = true
    )

    // when
    val result = userGroupRepository.updateById(customGroup)

    // then
    assertTrue(result)
    val dateFormat = SimpleDateFormat("yyyy-MM-dd'T'HH:mm:ssXXX")
    val updatedEntity = getMongoCollection().findOne(eq("_id", idData))
    assertTrue(updatedEntity)
        .usingRecursiveComparison()
        .ignoringFields("created")
        .isEqualTo(customGroup)

    assertTrue(updatedEntity)
        .hasFieldOrPropertyWithValue(
            "created",
            dateFormat.parse("2016-09-19T11:40:51+00:00"))
    assertTrue(updatedEntity?.analysts)
        .isNotNull
        .usingRecursiveComparison()
        .ignoringFields("created")
        .isEqualTo(analystsData)
}

```

Code example 5. Snippet of a test that validates that user groups are updated correctly

## 4.6 Result

Overall, the cyber range has notably improved. The author added numerous functionalities and improvements which improve the user experience of the platform. The author added a feature to ISA that gives an overview of registered GMA services and provides information about their status. Furthermore, they added a feature that enables the creation of public groups and the user enrolment to them. In addition, they implemented the initialization of Sentry and tested some of its various functionalities.

Lastly, the author analysed the state of the platforms that make the cyber range and talked about some of the aspects that could be or were improved.

Many more features have been added to the cyber range by other development team members which have not been disclosed in this thesis because they are not in the scope of this work. The goals set for the author have been completed on time. The development of the next iteration of the cyber range is still ongoing.

## 5 Summary

The main objective of this thesis was to give an overview of the projects that make the CybExer's Cyber Range platform, talk about some of the goals set for the release of the next cyber range platform iteration, explore options to ensure good UI and UX design, give an overview of some of the features added to the cyber range by the author, and analyse what state of usability the cyber range platform currently is.

The analysis of this thesis gave an overview of the different software solutions that are used by the cyber range. In addition, it shines a light on some of the goals set for the next iteration of the cyber range whilst providing some information about practices that ensure the cyber range provides a good experience for the end-users. The chapter that talks about the development process gives an overview of some of the technologies used by CybExer's development team, features added by the author, and gives a brief analysis of the overall usability of the different platforms used by the cyber range.

As of this point, the development cycle is still ongoing, and many changes will be made to the software solutions talked about in this thesis. Overall, the development of CybExer's cyber range is going according to plan and the range is steadily improving.

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## Appendix 2 – DELRAP views

The dashboard features a navigation bar with 'Dashboard', 'Profile', and 'Support Chat' on the left, and 'English' and 'Robert Kalbald' on the right. The main content area includes a user profile for 'robert.kalbald@gmail.com' with a '0%' progress indicator for '0/6 tasks completed' and '0pts of available 300pts'. A 'News' section lists recent updates. Below are two course cards: 'INTRO' (CTF TECH) and 'BEGINNER' (Beginner's level), both with '1 Study' progress and 'Start' buttons.

The 'Linux Basics' course content shows a progress indicator for '1 Study' and a sequence of steps. The current section is 'Steganography', with a sub-section 'What is Steganography?'. It defines steganography as embedding secret messages in cover messages. The next section is 'Verify steghide installation', which instructs the user to run 'steghide --help' and then 'apt-get -y install steghide'. A terminal screenshot shows the output of 'apt-get -y install steghide', including package lists and dependency resolution.

Dashboard Admin - Support English - Built-in Admin -

## Settings

System **Login** E-mail Appearance Content

### Login

Login type: Local

User role onboarding:  NO

Show EULA:  NO [RESET ALL](#)

Show GDPR-agreement:  NO [RESET ALL](#)

Default user role: Disabled

User sign up:  NO

Show password recovery link:  NO

Enable public groups:  NO

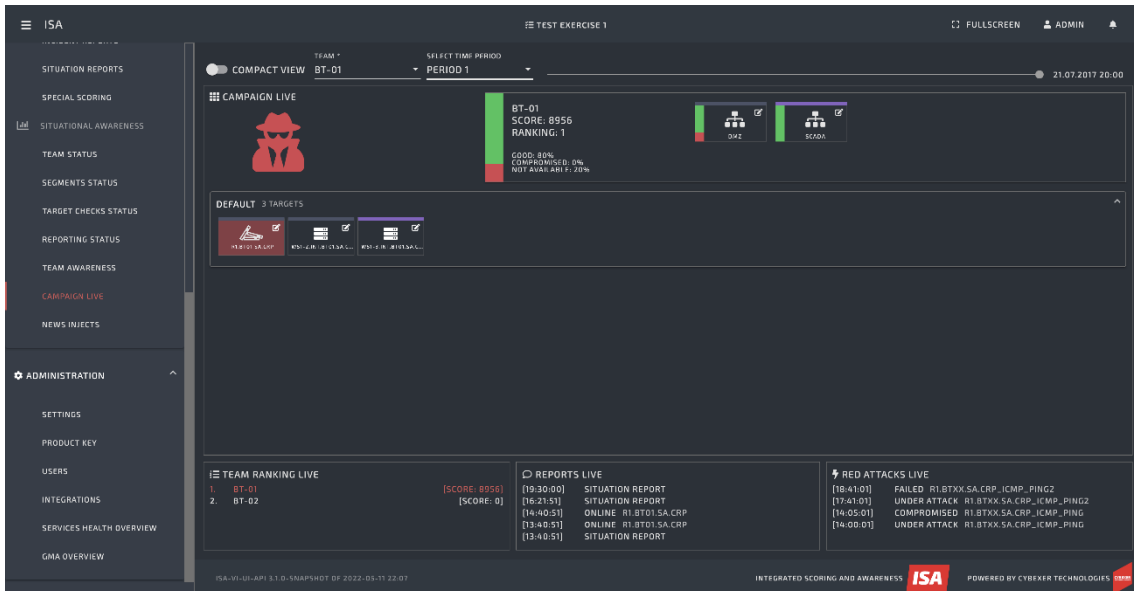
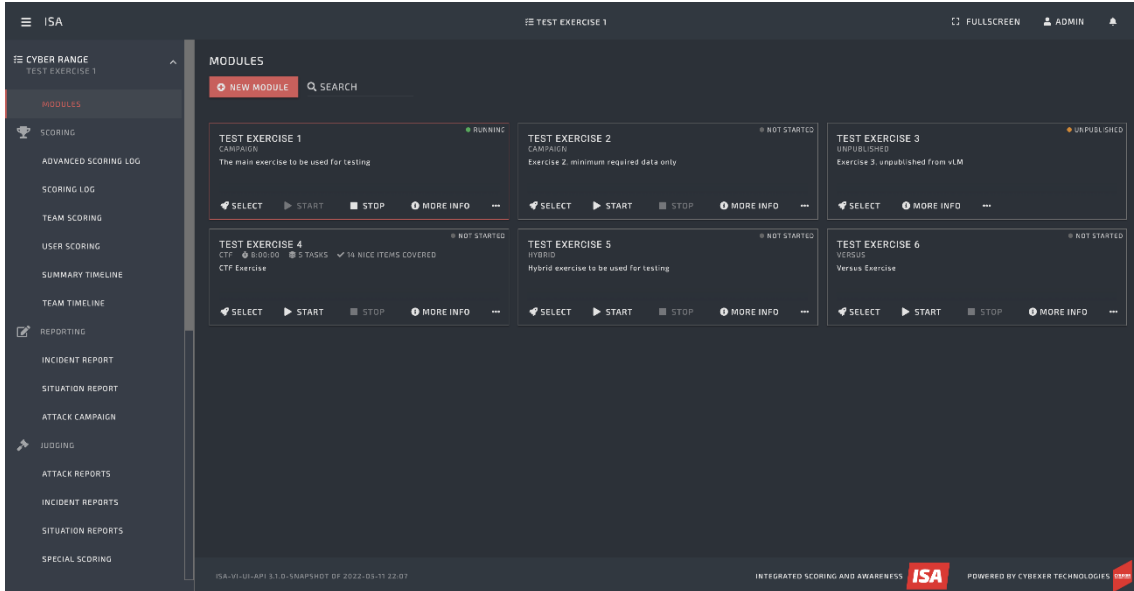
### Multi-factor Authentication

Enable multi-factor authentication:  NO

ipinfo.io token:

[SAVE SETTINGS](#)

# Appendix 3 – ISA views



ISA FULLSCREEN ADMIN

SERVICE HEALTH OVERVIEW LAST UPDATED: 12.05.2022 01:41:00

COMMON (14 SERVICES)

■ LIVE & READY ■ LIVE & NOT READY ■ NOT LIVE & NOT READY

<b>CDR</b> Central Data Repository 	<b>CTF</b> Visualization Interface - Capture The Flag 	<b>ED</b> Event Dispatcher 
<b>EMI</b> Visualization Interface - Exercise Media Interface 	<b>EPI</b> Visualization Interface - Exercises Preparation Interface 	<b>ERI</b> Visualization Interface - Exercises Reporting Interface 
<b>GDR</b> Gamernet Data Repository 	<b>MF</b> Mitre Framework 	<b>PAPI</b> Public API 
<b>SAD</b> Visualization Interface - Situational Awareness Dashboards 	<b>SD</b> Visualization Interface - Scoring Dashboard 	<b>SE</b> 

ISA-VIUI-API 3.1.0-SNAPSHOT OF 2022-05-11 22:07 INTEGRATED SCORING AND AWARENESS **ISA** POWERED BY CYBEREXER TECHNOLOGIES

ISA TEST EXERCISE 4 FULLSCREEN BTI USER

CYBER RANGE MISSION IS NOT RUNNING

TEST EXERCISE 4

PROGRESS				PROGRESS			
LEADER SCORE	LEADER PROGRESS	SCORE	POSITION	PROGRESS	HINTS USED	TASKS IN PROGRESS	
0	0/5	0	1/12	0/5	0/8	0/3	

PHASE 1 0% SOLVED				PHASE 2 0% SOLVED				PHASE 3 0% SOLVED			
? pts	Task 1	TEAMS SOLVED 0/12	NOT STARTED	? pts	Task 1	TEAMS SOLVED 0/12	LOCKED	? pts	Task 1	TEAMS SOLVED 0/12	LOCKED
? pts	Task 2	TEAMS SOLVED 0/12	NOT STARTED	? pts	Task 2	TEAMS SOLVED 0/12	NOT STARTED				

ISA-VIUI-API 3.1.0-SNAPSHOT OF 2022-05-11 22:07 INTEGRATED SCORING AND AWARENESS **ISA** POWERED BY CYBEREXER TECHNOLOGIES

## Appendix 4 – VLM and VLM-UP views

