Singhealth Data Breach

(directly based on COI report)

Overview Diagram slide 5

Crisis in a Nutshell

- Between 23/8/17 -20/7/18, a cyberattack of unprecedented scale & sophistication was carried out on Singhealth patient database.
- DB was illegally accessed & personal particulars of 1.5 million patients, including names, NRIC numbers, addresses & dates of birth, were exfiltrated over the period of 27/6/18 to 4/7/18.
- Around 159,000 of these 1.5 million patients also had their outpatient dispensed medication records exfiltrated.
- The Prime Minister's personal and outpatient medication data was specifically targeted and repeatedly accessed.

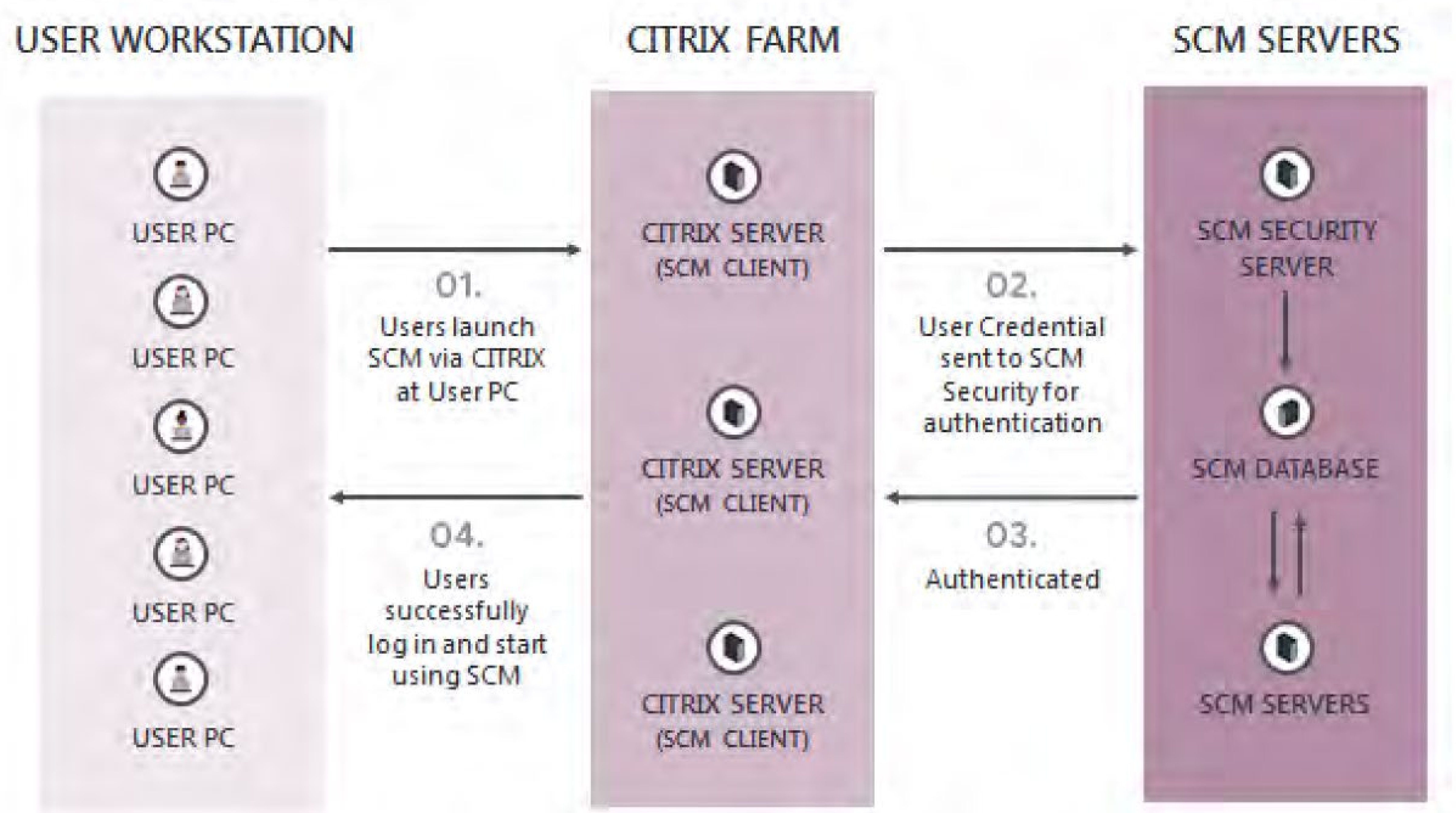
Crisis in a Nutshell

- The crown jewels of the SingHealth network are the patient electronic medical records contained in the SingHealth "SCM" database.
- The SCM is an electronic medical records software solution, which allows healthcare staff to access real-time patient data.
- It can be seen as comprising front-end workstations, Citrix servers, and the SCM database.
- Users would access the SCM database via Citrix servers, which operate as an intermediary between front-end workstations & the SCM database.
- The Citrix servers played a critical role in the Cyber Attack.

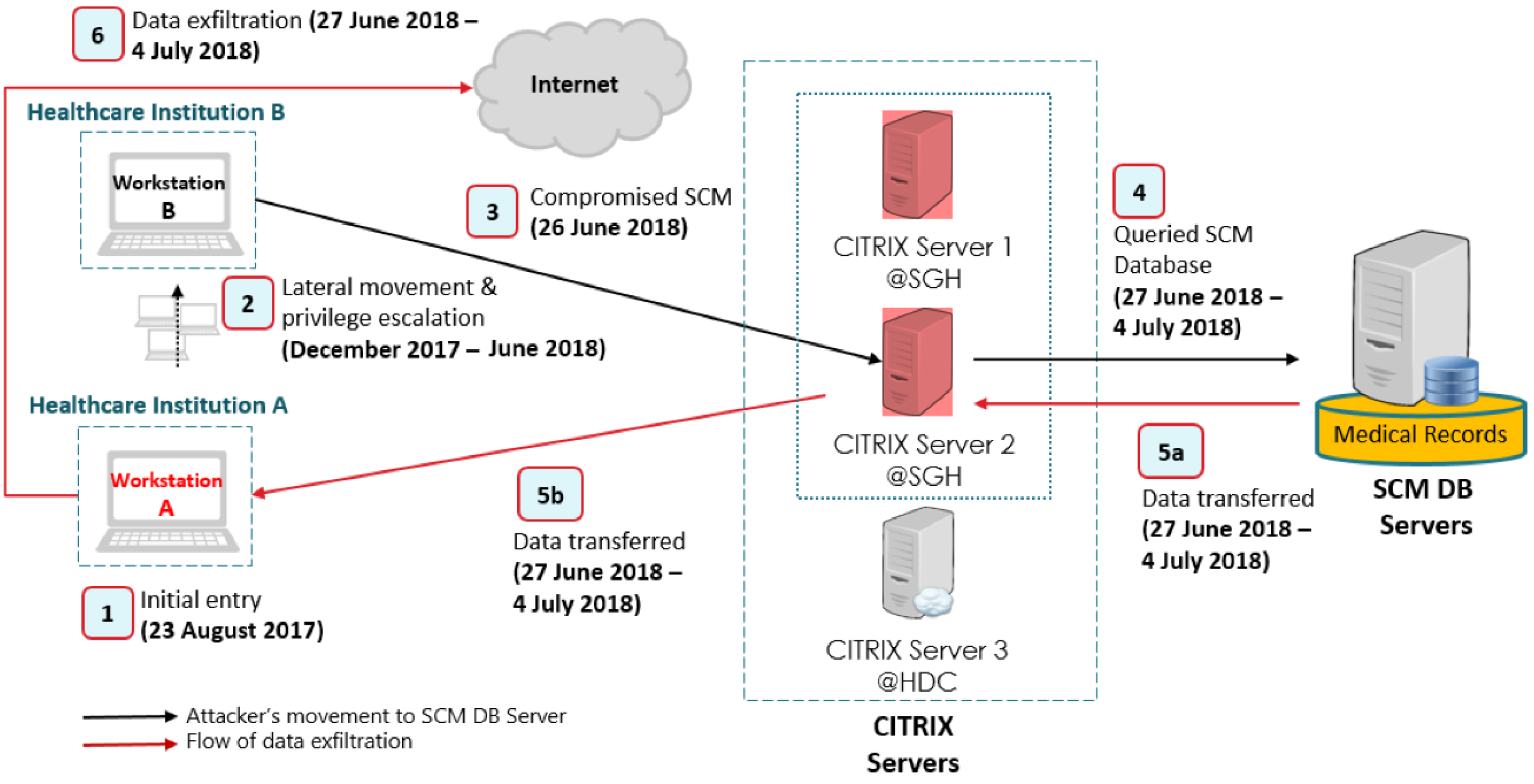
Crisis in a Nutshell

- At time of the Cyber Attack, SingHealth owns the SCM system.
- Integrated Health Information Systems Private Limited (“IHiS”) was responsible for administering and operating the system, including implementing cybersecurity measures.
- IHiS was also responsible for security incident response and reporting.

Figure 3:SingHealth user authentication process to access the SCM Database


USER WORKSTATION
CITRIX FARM
SCM SERVERS
USER PC
USER PC
USER PC
USER PC
USER PC
CITRIX SERVER (SCM CLIENT)
CITRIX SERVER (SCM CLIENT)
CITRIX SERVER (SCM CLIENT)
SCM SECURITY SERVER
SCM DATABASE
SCM SERVERS
01.
Users launch SCM via CITRIX at User PC
02.
User Credential sent to SCM Security for authentication
03.
Authenticated
04.
Users successfully log in and start using SCM

Key Events of the Cyberattack



6 Data exfiltration **(27 June 2018 – 4 July 2018)**

3 Compromised SCM **(26 June 2018)**

2 Lateral movement & privilege escalation **(December 2017 – June 2018)**

4 Queried SCM Database **(27 June 2018 – 4 July 2018)**

5a Data transferred **(27 June 2018 – 4 July 2018)**

5b Data transferred **(27 June 2018 – 4 July 2018)**

1 Initial entry **(23 August 2017)**

→ Attacker's movement to SCM DB Server
→ Flow of data exfiltration

Summary of Key Events: 1

- The attacker gained initial access to SingHealth's IT network around 23/8/17, infecting front-end workstations, most likely through phishing attacks.
- Attacker then lay dormant for 4 months, before commencing lateral movement (6 months) in the network between Dec2017 and Jun2018, compromising many endpoints and servers, including the Citrix servers located in SGH, which were connected to the SCM database.
- Along the way, the attacker also compromised a large number of user and administrator accounts, including domain administrator accounts.

Summary of Key Events: 2

- Starting from May 2018, the attacker made use of compromised user workstations in the SingHealth IT network and suspected virtual machines to remotely connect to the SGH Citrix servers.

- Attacker initially tried unsuccessfully to access the SCM database from the SGH Citrix servers.

Summary of Key Events: 3

- IHiS’ IT administrators first noticed unauthorised logins to Citrix servers & failed attempts at accessing the SCM DB on 11 June 2018.

- On 27 June 2018, the attacker began querying the SCM database, stealing and exfiltrating patient records, and doing so undetected by IHiS.

Summary of Key Events: 4

- 1 Week later, on 4 July 2018, an IHiS administrator for the SCM system noticed suspicious queries being made on the SCM database.

- Working with other IT administrators, ongoing suspicious queries were terminated, and measures were put in place to prevent further queries to the SCM database.

- These measures proved to be successful, and the attacker could not make any further successful queries to the database after 4 July 2018.

Summary of Key Events: 5

- Between 11/6 & 9/7/18, the persons who knew of & responded to the incident were limited to IHiS' line-staff & middle management from various IT administration teams, & the security team.
- After 1 month, on 9/7/18, IHiS senior management were finally informed of the Cyberattack…
- 3 days later, 10/7/18, matter was escalated to Cyber Security Agency ("CSA"), SingHealth's senior management, the Ministry of Health ("MOH"), and the Ministry of Health Holdings ("MOHH")

Summary of Key Events: 6

- Starting from 10 July 2018, IHiS and CSA carried out joint investigations and remediation.
- Several measures aimed at containing the (a) existing threat, (b) eliminating the attacker’s footholds, and ©preventing recurrence of the attack were implemented.
- In view of further malicious activities on 19 July 2018, internet surfing separation was implemented for SingHealth on 20 July 2018.
- No further suspicious activity was detected after 20 July 2018.

Summary of Key Events: 7

- The public announcement was made on 20 July 2018, and patient outreach and communications commenced immediately thereafter.
- SMS messages were used as the primary mode of communication, in view of the need for quick dissemination of information on a large scale.
- COI Committee has identified 5 key Findings!

KEY FINDING 1

IHiS staff did not have adequate levels of cybersecurity awareness, training, and resources to appreciate the security implications of their findings and to respond effectively to the attack.

KEY FINDING 2

Certain IHiS staff holding key roles in IT security incident response and reporting failed to take appropriate, effective, or timely action, resulting in missed opportunities to prevent the stealing and exfiltrating of data in the attack

KEY FINDING 3

There were a number of vulnerabilities, weaknesses, and misconfigurations in the SingHealth network and SCM system that contributed to the attacker’s success in obtaining and exfiltrating the data, many of which could have been remedied before the attack

KEY FINDING 4

The attacker was a skilled and sophisticated actor bearing the characteristics of an Advanced Persistent Threat group

KEY FINDING 5

While our cyber defences will never be impregnable, and it may be difficult to prevent an Advanced Persistent Threat from breaching the perimeter of the network, the success of the attacker in obtaining and exfiltrating the data was not inevitable

Key Finding #3 Details

- **There were a number of vulnerabilities, weaknesses, and misconfigurations in the SingHealth network and SCM system that contributed to the attacker's success in obtaining and exfiltrating the data, many of which could have been remedied before the attack**

Key Finding #3-1

1. A significant vulnerability was the network connectivity (referred to in these proceedings as an "open network connection") between the SGH Citrix servers and the SCM database, which the attacker exploited to make queries to the database.

- The network connectivity was maintained for the use of administrative tools and custom applications, but there was no necessity to do so.

Key Finding #3-2

2. The SGH Citrix servers were not adequately secured against unauthorised access. Notably, the process requiring 2-factor authentication (“**2FA**”) for administrator access was not enforced as the exclusive means of logging in as an administrator. This allowed attacker to access the server through other routes that did not require 2FA.

3. There was a **coding vulnerability** in the SCM application which was likely exploited by the attacker to obtain credentials for accessing the SCM database.

Key Finding #3-3

4. There were a number of other vulnerabilities in the network which were identified in a penetration test in early 2017, and which may have been exploited by the attacker (remained unfixed!)

- These included weak administrator account passwords and the need to improve network segregation for administrative access to critical servers such as the domain controller and the Citrix servers.
- Unfortunately, the remediation process undertaken by IHiS was mismanaged and inadequate, and a number of vulnerabilities remained at the time of the Cyber Attack.

Key Finding #4 Details

- **The attacker was a skilled and sophisticated actor bearing the characteristics of an Advanced Persistent Threat group**

Key Finding #4-1

1. The attacker had a clear goal in mind, namely the personal and outpatient medication data of PM in the main, and other patients.

2. The attacker employed advanced TTPs (tools/tactics, techniques, procedures), as seen from the suite of advanced, customised, and stealthy malware used, generally stealthy movements, and its ability to find and exploit various vulnerabilities in SingHealth's IT network and the SCM application.

Key Finding #4-2

3. The attacker was persistent, having established multiple footholds and backdoors, carried out its attack over a period of over 10 months, and made multiple attempts at accessing the SCM database using various methods.

4. The attacker was a well-resourced group, having an extensive command and control network, the capability to develop numerous customised tools, and a wide range of technical expertise.

Key Finding #5 Details

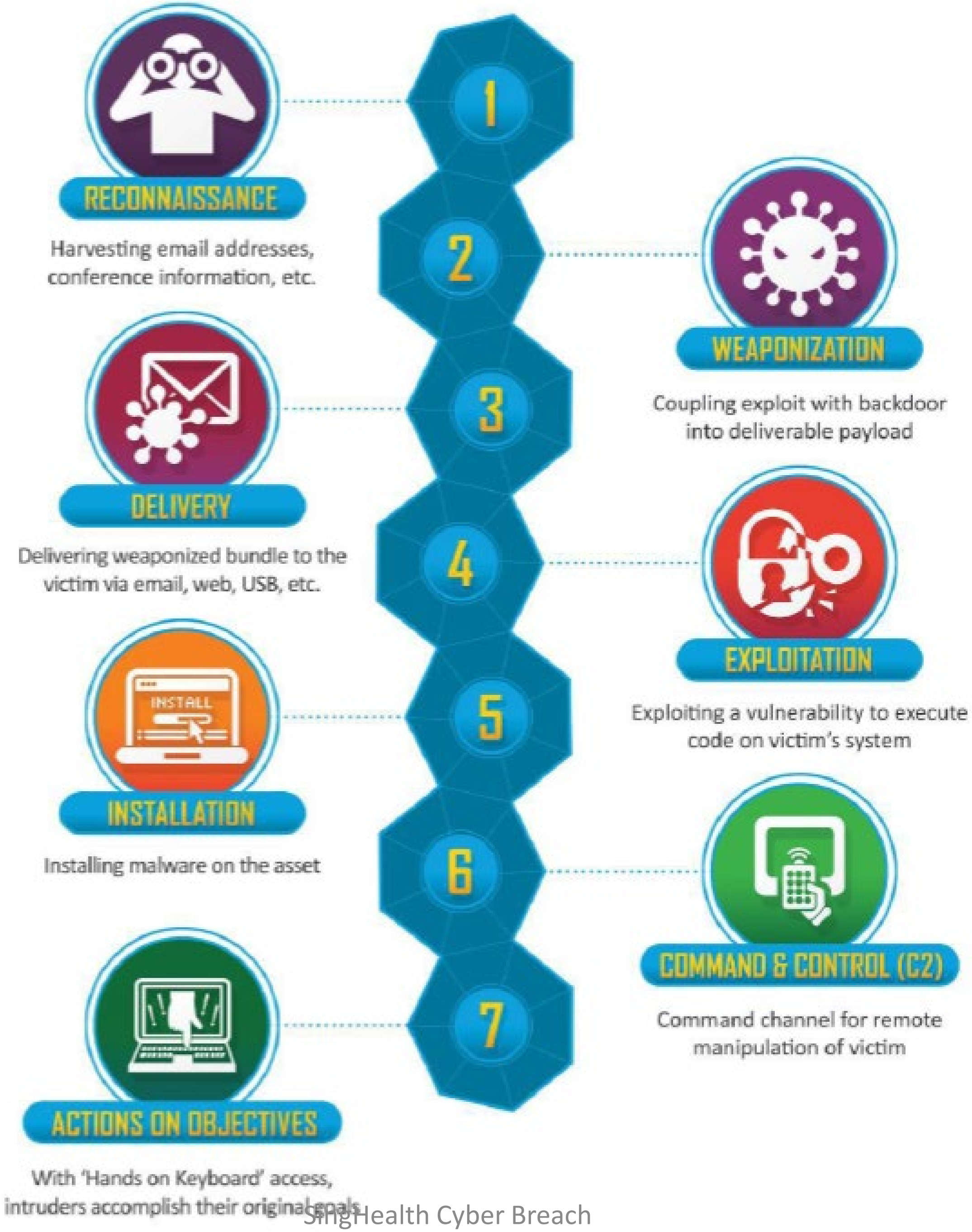
- **While our cyber defences will never be impregnable, and it may be difficult to prevent an Advanced Persistent Threat from breaching the perimeter of the network, the success of the attacker in obtaining and exfiltrating the data was not inevitable**

Key Finding #5-1,2

1. A number of vulnerabilities, weaknesses, and misconfigurations could have been remedied before the attack. Doing so would have made it more difficult for the attacker to achieve its objectives.
2. The attacker was stealthy but not silent, and signs of the attack were observed by IHiS' staff. Had IHiS' staff been able to recognise that an attack was ongoing and take appropriate action, the attacker could have been stopped before it achieved its objectives.

Cyber Kill Chain Framework

- In considering the events of the Cyber Attack, it is useful to bear in mind the **7 Steps Cyber Kill Chain framework** developed by Lockheed Martin, which identifies what adversaries must complete in order to achieve their objectives, going through 7 stages starting from early reconnaissance to the final goal of data exfiltration.
- Having this framework in mind will facilitate understanding of the actions and the tactics, techniques and procedures ("**TTPs**") of the attacker in this case.



RECONNAISSANCE

Harvesting email addresses, conference information, etc.

WEAPONIZATION

Coupling exploit with backdoor into deliverable payload

DELIVERY

Delivering weaponized bundle to the victim via email, web, USB, etc.

EXPLOITATION

Exploiting a vulnerability to execute code on victim's system

INSTALLATION

Installing malware on the asset

COMMAND & CONTROL (C2)

Command channel for remote manipulation of victim

ACTIONS ON OBJECTIVES

With 'Hands on Keyboard' access, intruders accomplish their original goals

First evidence of breach and establishing control over Workstation A – August to December 2017

- Forensic investigations uncovered signs of callbacks to an overseas command & control server ("C2 server") from 23 August 2017.

- Callbacks refer to communications between malware and C2 servers, to either fetch updates and instructions, or send back stolen information.

First evidence of breach and establishing control over Workstation A – August to December 2017

- CSA discovered many malicious artefacts in Workstation A, including (i) a log file which was a remnant of a malware set;
- (ii) a publicly available hacking tool,
- (iii) a customised Remote Access Trojan referred to as "**RAT 1**".
    - (i) The log file was a remnant file from a known malware which has password dumping capability;
    - (iii) **RAT 1** provided the attacker with the capability to access and control the workstation, enabling the attacker to perform functions such as executing shell scripts remotely, and uploading and downloading files.

First evidence of breach and establishing control over Workstation A – August to December 2017

- (ii) The publicly available hacking tool enables an attacker to maintain a persistent presence once an email account has been breached, even if the password to the account is subsequently changed.

- Hacking tool also allows an attacker to
  - interact remotely with mail exchange servers,
  - perform simple brute force attacks on the user's email account password,
  - and serve as a hidden backdoor for the attacker to regain entry into the system in the event that the initial implants are removed;

First evidence of breach and establishing control over Workstation A – August to December 2017

- The log file was created on Workstation A on 29 August 2017. The file contained password credentials in plaintext, which appeared to belong to the user of Workstation A.

- The malware was likely to have been used by the attacker to obtain passwords for privilege escalation and lateral movement.

First evidence of breach and establishing control over Workstation A – August to December 2017

- Public hacking tool was installed on Workstation A on 1 Dec 2017 by exploiting a vulnerability in the version "**Outlook**" that was installed on the workstation.
- Although a patch was available at that time, but the patch was not installed on Workstation A then.
- The tool was thus successfully installed and was used to download malicious files onto Workstation A.
- Some of these files were masqueraded as .jpg image files, but in fact contained malicious PowerShell scripts, one of which is thought to be a modified PowerShell script taken from an open source post-exploitation tool.

First evidence of breach and establishing control over Workstation A – August to December 2017

- With the introduction of the hacking tool and RAT 1 in Dec 2017, the attacker gained the capability to execute shell scripts remotely, as well as to upload and download files to Workstation A.
- Referring to the Cyber Kill Chain framework referred to earlier, it can be seen that the attacker was able to go through the ‘Delivery’, ‘Exploitation’, ‘Installation’ and ‘Command and Control’ phases by 1 Dec 2017.

Privilege escalation and lateral movement – December 2017 to June 2018

- After the attacker established an initial foothold in Workstation A, it moved laterally in the network between December 2017 and June 2018,
  - compromising a number of endpoints and servers,
  - including the Citrix servers located in SGH, which were connected to the SCM database.

Privilege escalation and lateral movement – December 2017 to June 2018

- Evidence of the attacker's lateral movements was found in the proliferation of malware across a number of endpoints and servers.
  - Malware samples found and analysed by CSA were either tools that were stealthy by design, or unique variants that were not seen in-the-wild and not detected by standard anti-malware solutions.
- Such malware included RAT 1, another Remote Access Trojan referred to in this report as "**RAT 2**", and the malware associated with the earlier-mentioned log file.

Privilege escalation and lateral movement – December 2017 to June 2018

- Evidence of PowerShell commands used by the attacker to distribute malware to infect other machines, and of malicious files being copied between machines over mapped network drives..
- CSA has also assessed that the attacker is likely to have compromised the Windows authentication system and obtained administrator and user credentials from the domain controllers.
- This meant that the attacker would have gained full control over all Windows based servers and hosted applications, all employee workstations, and underlying data, within the domain.

Notable events between December 2017 and June 2018

- *Establishing control over the NCC server*
- *Callbacks to a foreign IP address in Jan 2018 from Workstation A and the PHI 1 Workstation*
- *Obtaining credentials of the L.A. local administrator account*
  - A local administrator account ("**L.A. account**") was found on all the Citrix servers at the SGH data centre.
  - L.A. account has FULL admin privileges to login to the Citrix server, including logging in interactively[18], and logging in remotely *via* RDP. **Remote Desktop** Protocol (**RDP**) is a Microsoft protocol designed to facilitate application data transfer security and encryption between client users, devices and a virtual network server.
  - Attacker obtained and used the credentials of the L.A. account to log in to at least 2 SGH Citrix servers on multiple occasions in May and June 2018.

Privilege escalation and lateral movement – December 2017 to June 2018

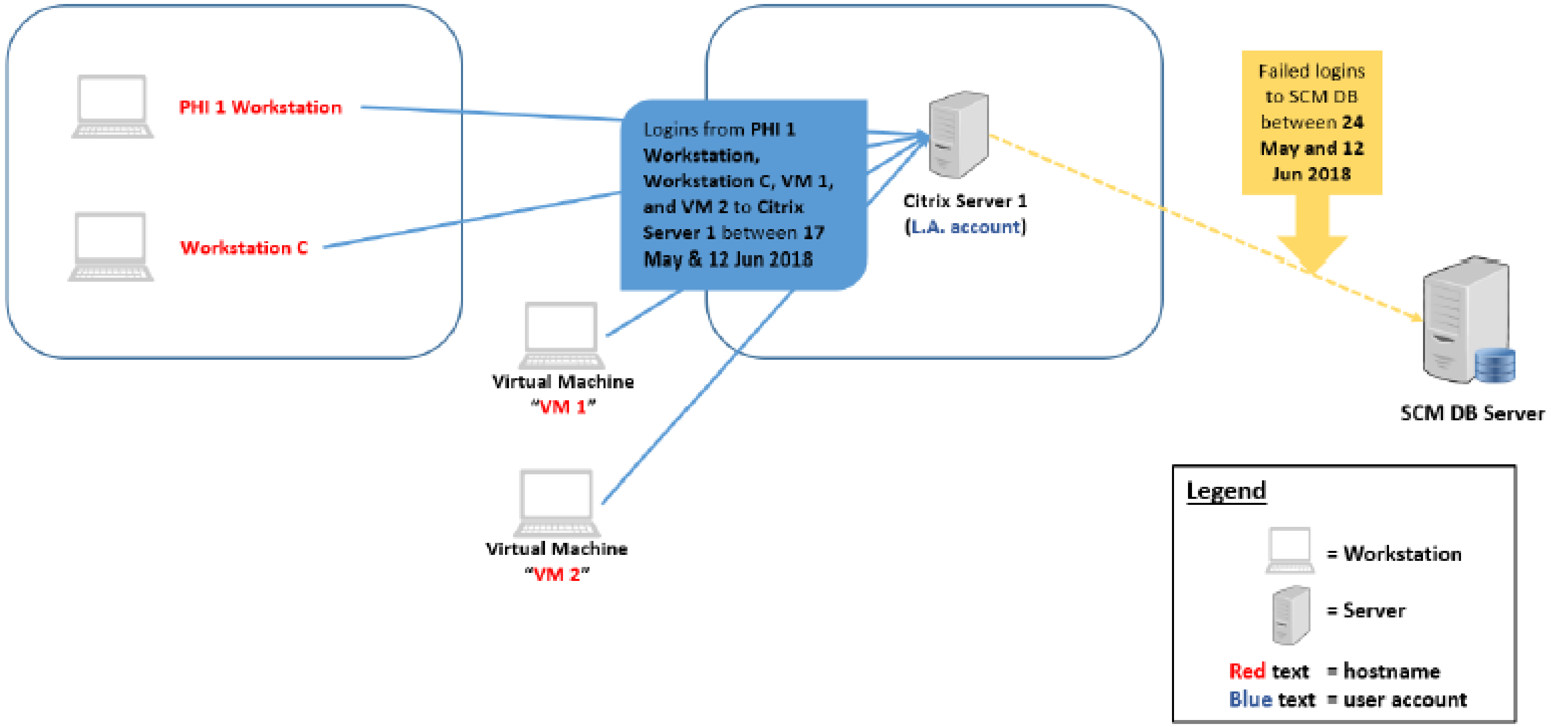
- *Obtaining credentials of the S.A. service account*
- *Obtaining credentials for the D.A. domain administrator account*
  - Attacker also compromised a domain administrator acct (“**D.A. acct**”).
  - D.A acct is a member of administrators group on all domain controllers, all domain workstations, and all servers that are members of the domain.
  - D.A acct gives user full control of files, directories, services & other resources that are under the control of the servers in the domain.
  - Compromising D.A. acct allowed attacker to access & control the SGH Citrix servers.
  - The D.A. acct was subsequently used in attempts to log in to the SCM database, and in connecting from Citrix Server 2 in SGH to Citrix Server 3 in the H-Cloud.

Privilege escalation and lateral movement – December 2017 to June 2018

- *Establishing control over Workstation B on 17 April 2018*
  - Attacker gained access to Workstation B (SGH) & planted RAT 2, thus gaining control of the workstation-which had access to the SCM application.
  - Workstation B was used to log in remotely to the SGH Citrix Servers 1 and 2. It is also suspected that Workstation B was used to host virtual machines[20]

- *Attempts to log in to the SCM database from Citrix Server 1 from 24 May to 12 June 2018*

Figure 8: Attempts to log in to the SCM database from Citrix Server 1



Logins from PHI 1 Workstation, Workstation C, VM 1, and VM 2 to Citrix Server 1 between 17 May & 12 Jun 2018

Failed logins to SCM DB between 24 May and 12 Jun 2018

Privilege escalation and lateral movement – December 2017 to June 2018

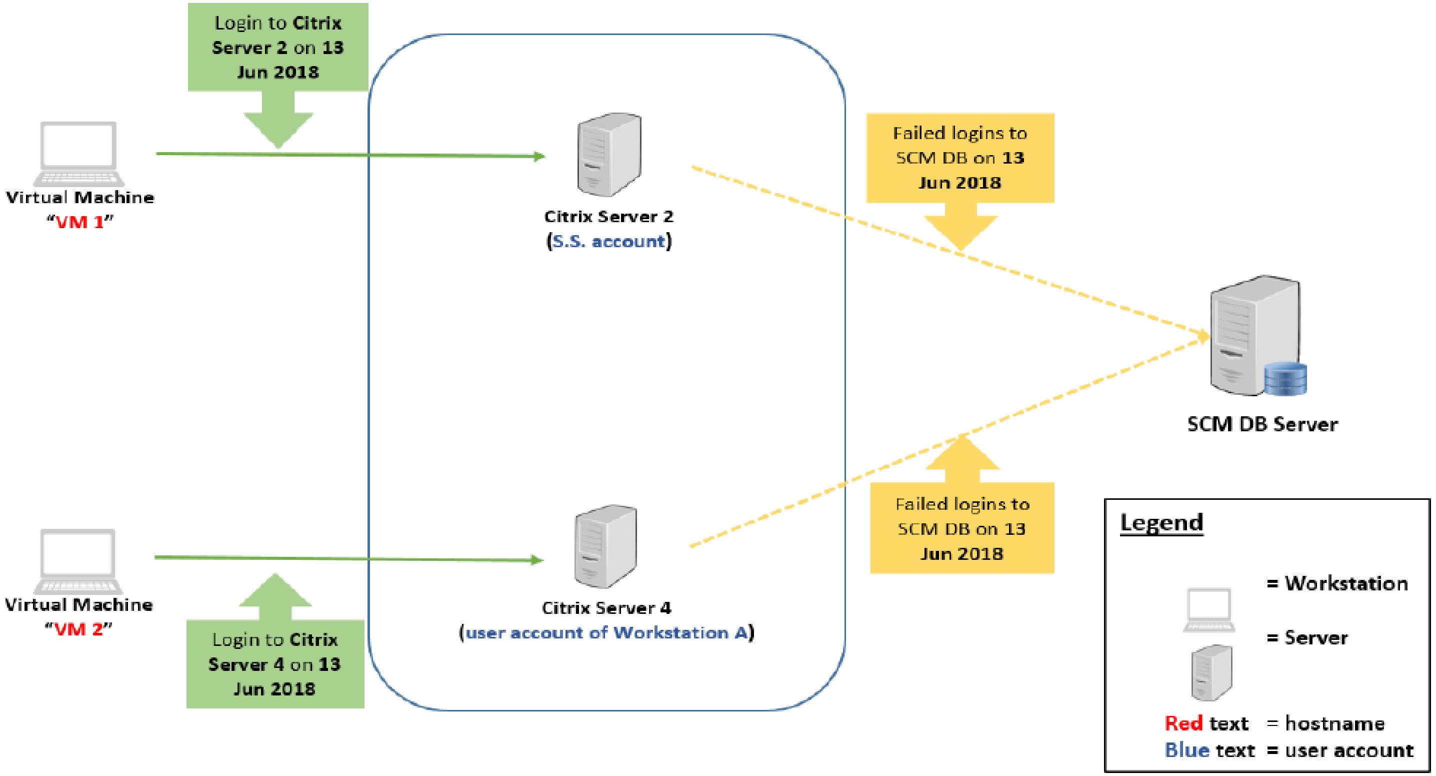
Unauthorised access to Citrix Server 1 from 17 May to 12 June 2018

- From 17 May 2018 to 11 June 2018, the attacker used the L.A. account to remotely log in to SGH Citrix Server 1 on numerous occasions.
  - The L.A. account is a local domain administrator account not ordinarily used for day to day operations.

- The unauthorised logins to Citrix Server 1 were also made *via* Remote Desktop Protocol (“**RDP**”) from workstations which would not ordinarily use the L.A. account, including (i) the PHI 1 Workstation; (ii) a SGH workstation referred to in this report as “**Workstation C**”; (iii) VM 1; and (iv) VM 2.

Privilege escalation and lateral movement – December 2017 to June 2018

Figure 9: Attempts to log in to the SCM database from Citrix Servers 2 and 4



Login to Citrix Server 2 on 13 Jun 2018
Virtual Machine "VM 1"
Citrix Server 2 (S.S. account)
Failed logins to SCM DB on 13 Jun 2018
SCM DB Server
Virtual Machine "VM 2"
Login to Citrix Server 4 on 13 Jun 2018
Citrix Server 4 (user account of Workstation A)
Failed logins to SCM DB on 13 Jun 2018
Legend
= Workstation
= Server
Red text = hostname
Blue text = user account

Privilege escalation and lateral movement – December 2017 to June 2018

Citrix Server 2:

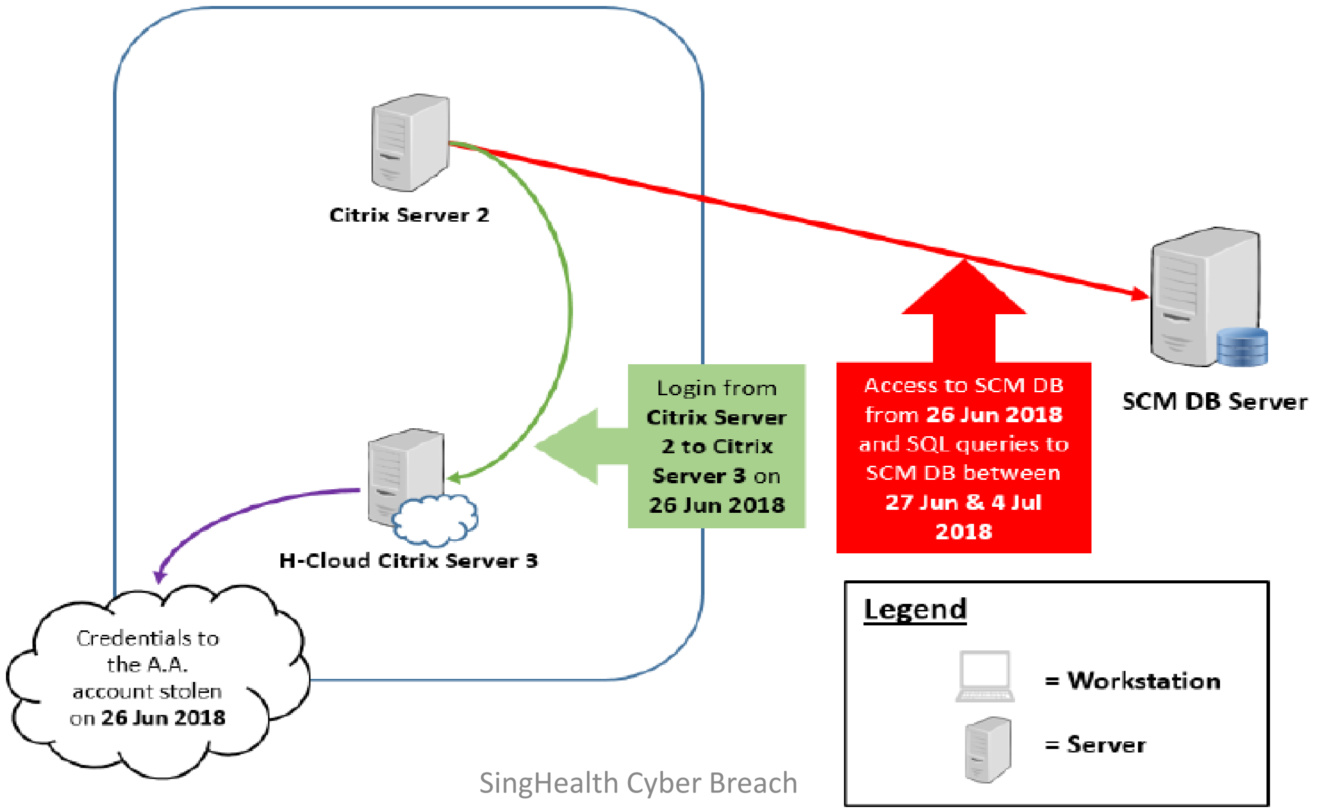
- On 13 June 2018, the attacker used a compromised local service account, the S.A. account, to remotely log in to Citrix Server 2, which was an SGH Citrix server.
- VM 1 was used to log in to Citrix Server 2, and these were not legitimate logins.

Privilege escalation and lateral movement – December 2017 to June 2018

- On 26 June 2018, attacker remotely logged-in to Citrix Server 2 from Workstation B using the S.A. account.
- From Citrix Server 2, attacker used the D.A. account to access a H-Cloud Citrix server, Citrix Server 3.
- CSA assesses that it is probable that whilst logged into Citrix Server 3, the attacker stole credentials to an account referred to in this report as the "**A.A. account**".
    - Obtaining the credentials to the A.A. account allowed the attacker to cross the last-mile to the SCM server, as it could be used to make SQL queries to the database.

Privilege escalation and lateral movement – December 2017 to June 2018

Figure 10: Obtaining credentials to the A.A. account and querying the SCM database



Credentials to the A.A. account stolen on **26 Jun 2018**

Login from **Citrix Server 2 to Citrix Server 3** on **26 Jun 2018**

Access to SCM DB from **26 Jun 2018** and SQL queries to SCM DB between **27 Jun & 4 Jul 2018**

Privilege escalation and lateral movement – December 2017 to June 2018

- CSA's assessment
  - there was a coding vulnerability in the SCM application, and it is highly probable that this vulnerability allowed the attacker to easily retrieve the credentials of the A.A. account. Details-section 15.6 of COI report pg 86.

- Lateral movement to Citrix Server 3 was significant because credentials of the A.A. account could not be obtained from the SGH Citrix Servers 1 & 2.

- With the credentials to the A.A. account, the attacker began the 'Actions on Objectives' phase as described in the Cyber Kill Chain, retrieving and exfiltrating patient data from the SCM database.

Queries to the SCM database from 26 June to 4 July 2018

From 26 June 2018, the attacker began querying the database from Citrix Server 2 using the A.A. account.

3 types of “**SQL**” queries which the attacker ran:

- (i) reconnaissance on the schema of the SCM database,
- (ii) direct queries relating to particular individuals, and
- (iii) bulk queries on patients in general.

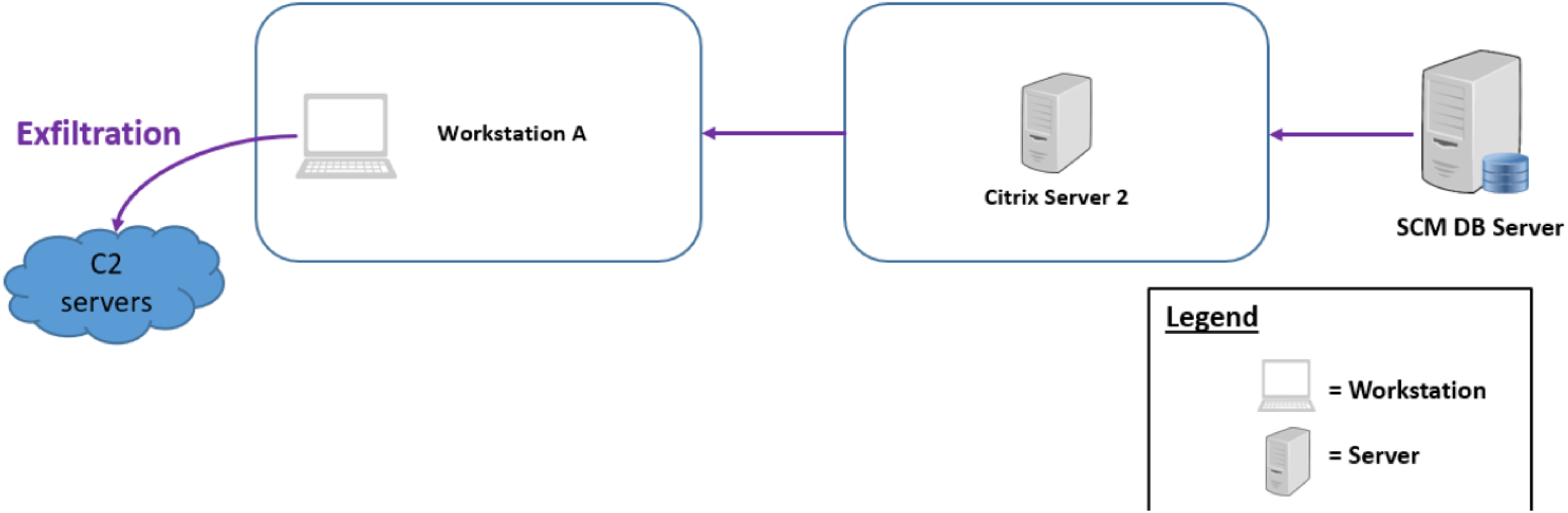
Queries to the SCM database from 26 June to 4 July 2018

The attacker was able to retrieve the following information from the SQL queries:

1. The Prime Minister's personal and outpatient medication data;
2. The demographic records of 1,495,364 patients, including their names, NRIC numbers, addresses, gender, race, and dates of birth;
3. The outpatient dispensed medication records of about 159,000 of the 1,495,364 patients mentioned in sub-paragraph (b) above.

Queries to the SCM database from 26 June to 4 July 2018

Figure 11: Data exfiltration route



Queries to the SCM database from 26 June to 4 July 2018

- The copying and exfiltration of data from the SCM database was stopped on 4 July 2018, after staff from IHiS discovered the unusual queries and took steps to prevent any similar queries from being run against the SCM database.

Attempts to re-enter the SingHealth Network on 18 and 19 July 2018

Although no data queries to the SCM database or exfiltration of patient records were detected after 4 July 2018, there was malicious activity in the SingHealth network on 18 and 19 July 2018, which suggested that:

- the attacker was trying to establish a fresh pathway into the network; and
- the attacker had established multiple footholds in the network and had re-entered the network through one of these hitherto unknown footholds

Attempts to re-enter the SingHealth Network on 18 and 19 July 2018

On 18 July 2018, phishing emails were sent to a number of recipients in various SingHealth institutions.

- One of the recipients of the email was the user of a previously infected workstation – the PHI 1 Workstation.
- The email contained content similar to the earlier mentioned publicly available hacking tool, and would run automatically when the mail was previewed or read.
- It was also configured to lead to callbacks to a C2 (command&control) server.

Attempts to re-enter the SingHealth Network on 18 and 19 July 2018

- After detection of malware on and communications from the S.P. server, CSA recommended that internet surfing separation should be implemented, to prevent the attacker from exercising command and control over any remaining footholds it may have in the network.
- Internet surfing separation was implemented on 20 July 2018.
- No further signs of malicious activity were detected thereafter.

CONTRIBUTING FACTORS LEADING TO THE CYBER ATTACK

Network connections between the SGH Citrix servers & SCM database were allowed

- The network connection was a critical pathway to the SCM database, over which the attacker was able to make SQL queries to and retrieve data from the SCM database.
- but for this open network connection, the SCM database was adequately protected within the H-Cloud perimeter defences, and the attacker would not have been able to access the SCM database as easily.
- This open connection not necessary, more for convenience to administer database

Network connections between the SGH Citrix servers & SCM database were allowed

- A basic security review of the network architecture and connectivity between the SGH Citrix servers and the SCM database could have shown that the open network connection created a security vulnerability.
- However, no such review was carried out.

Lack of monitoring at the SCM database for unusual queries and access

From 26 June to 4 July 2018, attacker ran queries on the SCM database, including bulk queries. Attacker was able to do so unchallenged because of a lack of monitoring at the SCM database

- there were no existing controls to detect bulk queries being made to the SCM database.
- there were no controls in place at the time of the attack to detect or block any queries to the SCM database made using illegitimate applications.
- database activity monitoring ("**DAM**") solutions available on the market which could address these gaps highlighted above. DAM was not implemented by IHiS at the time of the attack

Lack of monitoring at the SCM database for unusual queries and access

- database activity monitoring (“**DAM**”) solutions available on the market which could address some or all of the three gaps highlighted above.
  - DAM was not implemented by IHiS at the time of the attack

SGH Citrix servers were not adequately secured against unauthorised access

The compromise of the SGH Citrix servers was critical in giving the attacker access to the SCM database.

- *Privileged Access Management was not the exclusive means for accessing the SGH Citrix servers, and logins to the servers by other means without 2-factor authentication were possible*
- *IHiS Citrix administrators not only were aware of this alternative route, but made use of it form convenience!*

SGH Citrix servers were not adequately secured against unauthorised access

Lack of firewalls to prevent unauthorised remote access using RDP to the SGH Citrix servers

- the attacker had moved laterally using RDP to remotely access multiple SGH Citrix servers.
- This was done from compromised workstations and suspected VM, and by using compromised user credentials.
- After compromising the SGH Citrix servers, the attacker was able to connect to Citrix Server 3 in the H-Cloud.
- The attacker also queried the SCM database from Citrix Server 2, a SGH server.

SGH Citrix servers were not adequately secured against unauthorised access

- If RDP access from end-user workstations to the SGH Citrix servers had been disabled or restricted, it would have made it harder for the attacker to move laterally and to compromise the SGH Citrix servers.
- However, at the time of the attack, there were no firewalls in place to prevent unauthorised remote access to the SGH Citrix servers using RDP.

Weak controls over and inadequate monitoring of local administrator accounts

the password to the (dormant) L.A. account was ‘P@ssw0rd’, which is easily cracked, and it is possible that the attacker gained control over the account by cracking the password.

- The weak password and the fact that the attacker was able to use the dormant account to access Citrix Server 1 were in spite of three relevant IHiS policies:

1. user passwords are to be changed periodically. However, the password to the L.A. account was unchanged from 2012 till 11 June 2018.
2. 2017, IHiS instituted a policy under which administrators were required to have more complex passwords.
3. Dormant or unused accounts should be identified and disabled, in order to prevent usage in unauthorised activities

Lack of sight over and mismanagement of the S.A. service account

the S.A. account was used by the attacker to access Citrix Server 2, including when querying the SCM database. The existence of and privileges attached to the account facilitated this use.

1. there was no real need for the S.A. account to exist, as there was no actual use in IHiS of the relevant service for which it was created. Yet it existed on all Citrix servers in which the service had been installed, and the account had full administrative privileges to login to the server, including logging in interactively.
2. The Citrix Team did not know of this account!
3. S.A. account was an unused account that should have been disabled

Observations on the overall management of SGH Citrix servers

They were treated as not mission critical, unlike SCM database

- The SGH Citrix servers were not monitored for real-time analysis and alerts of vulnerabilities and issues arising from these servers.
- Vulnerability scanning, which was carried out for mission-critical systems, was not carried out for the SGH Citrix servers.
  - Vulnerability scanning is an inspection of the potential points of exploit on a computer to identify gaps in security.

Internet connectivity in the SingHealth IT network increased the attack surface

- The SingHealth network's connection to the Internet, while serving their operational needs, created an avenue of entry and exit for the attacker. This allowed the attacker to make use of an internet-connected workstation (Workstation A) to gain entry to the network, before making his way to the SCM database to steal the medical data.

Internet connectivity in the SingHealth IT network increased the attack surface

- The security risks arising from internet-connectivity in the SingHealth network were raised by CSA to MOH from as early as August 2015;
- By June 2017, the healthcare sector had determined, that
  - internet access would be removed for staff that did not require the internet for work,
  - for staff that required the internet for work, access would be through a secure internet access platform which, at that time, was to take the form of a 'remote browser'.
- When the Cyber Attack occurred, the remote browser solution was not yet rolled out. IHiS was on the cusp of awarding the tender for the remote browser solution in July 2018 when the Cyber Attack occurred

Internet connectivity in the SingHealth IT network increased the attack surface

1. SGH Citrix servers: At the time of the attack, a user who accessed pre-configured internet websites through the SGH Citrix servers would be able to access websites other than the pre-configured sites simply by keying in the internet URL in the address bar of the web browser. If such other websites were malicious, it would be possible that malware would be downloaded onto the SGH Citrix server.
2. The S.P. server: The S.P. server was detected trying to connect to a C2 server on 19 July 2018.

Versions of Outlook used by IHiS were not patched against a publicly available hacking tool

- The attacker was able to install the hacking tool (publicly available) on Workstation A on 1 December 2017 by exploiting a vulnerability in the version of the Outlook application installed on the workstation!

- A patch that was effective in preventing the vulnerability from being exploited (and thus to prevent the installation of the tool) was available since late-2017!

- Clear need to improve software upgrade policies!

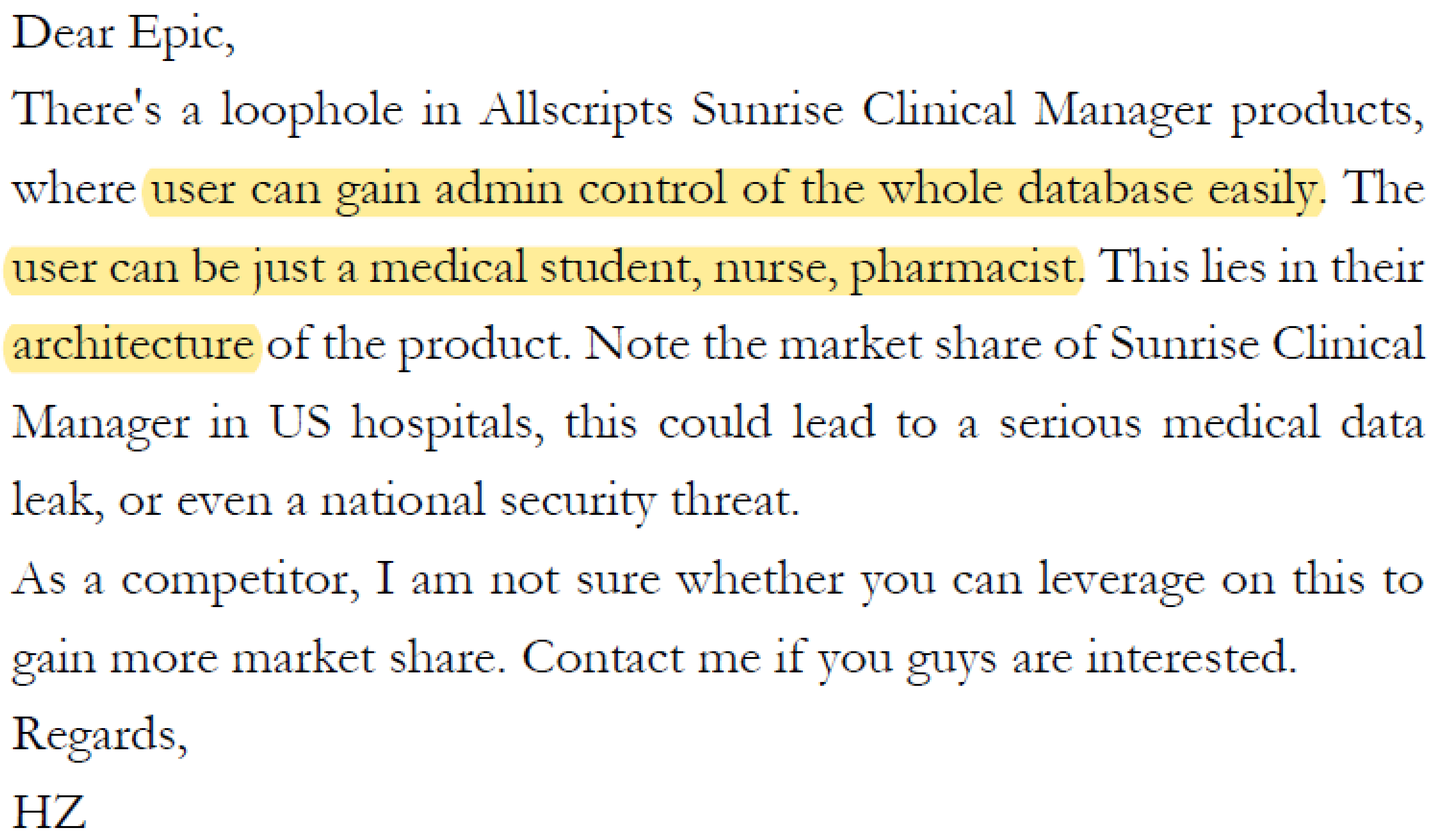
Coding vulnerability in the SCM application

CSA's analysis of the SCM application showed that there were signs of insecure coding practices, giving rise to a vulnerability that was likely exploited by the attacker to obtain the credentials to the A.A. account.

- Sep 2014, Zhao, then-employee of IHiS, discovered a method of exploiting the vulnerability. He reported to his supervisor.
- Vulnerability likely played a pivotal role in allowing the attacker to obtain the SCM database credentials and cross the last mile to gain access into the SCM database.
- IHiS has accepted that if further queries and investigations had in fact been carried out, the coding vulnerability could have been discovered

Coding vulnerability –more details

- Supervisor gave evidence that she asked Zhao to log a case with Allscripts (soln provider), but she did not follow-up with him on whether he had in fact done so.
- Zhao did not; instead Sept 17, he emailed Allscripts competitor EPIC abt this vulnerability.
- Allscripts boss David Chambers came to know abt Zhao's email & he wrote to CEO IHIS abt it!
- CEO IHIS fired Zhao immediately after verification.
- But no action was taken to investigate alleged vulnerability!



Dear Epic,

There's a loophole in Allscripts Sunrise Clinical Manager products, where user can gain admin control of the whole database easily. The user can be just a medical student, nurse, pharmacist. This lies in their architecture of the product. Note the market share of Sunrise Clinical Manager in US hospitals, this could lead to a serious medical data leak, or even a national security threat.

As a competitor, I am not sure whether you can leverage on this to gain more market share. Contact me if you guys are interested.

Regards,

HZ

Other vulnerabilities in the network that were identified in the FY16 H-Cloud Pen-Test

- Administrator credentials were found on network shares
- A Citrix administrator password was also found in a Windows batch file.
- During a scanning process done after the Cyber Attack, a script file containing credentials for an administrator account was found, which had the password ‘P@ssw0rd’.
- This was in fact the very same account flagged by the penetration testers during the FY16 H-Cloud Pen-Test!

Other vulnerabilities in the network that were identified in the FY16 H-Cloud Pen-Test

- *The Citrix virtualisation environment was not configured adequately to prevent attackers from breaking out into the underlying operating system*
- Exploiting the vulnerability allowed the penetration testers to access files and execute arbitrary commands.
- CSA’s hypothesis is that this vulnerability could have been the means by which the attacker gained initial access to the file system of any of the compromised SGH Citrix servers.

THE ATTACKER – TOOLS AND COMMAND AND CONTROL INFRASTRUCTURE

- Customised and stealthy malware –new even to cybersecurity experts
- A variety of custom web shells, tools, and unique malware were used in the attack. Early-stage tools were used to gain a foothold within the network. Intermediate-stage tools, including some custom tools, were used to perform various tasks such as reconnaissance, privilege escalation and lateral movement.
- Remote Access Trojans, such as the abovementioned RAT 1 and RAT 2, were used to provide the attacker with full control over specific infected systems and to serve as backdoors to re-enter the network.

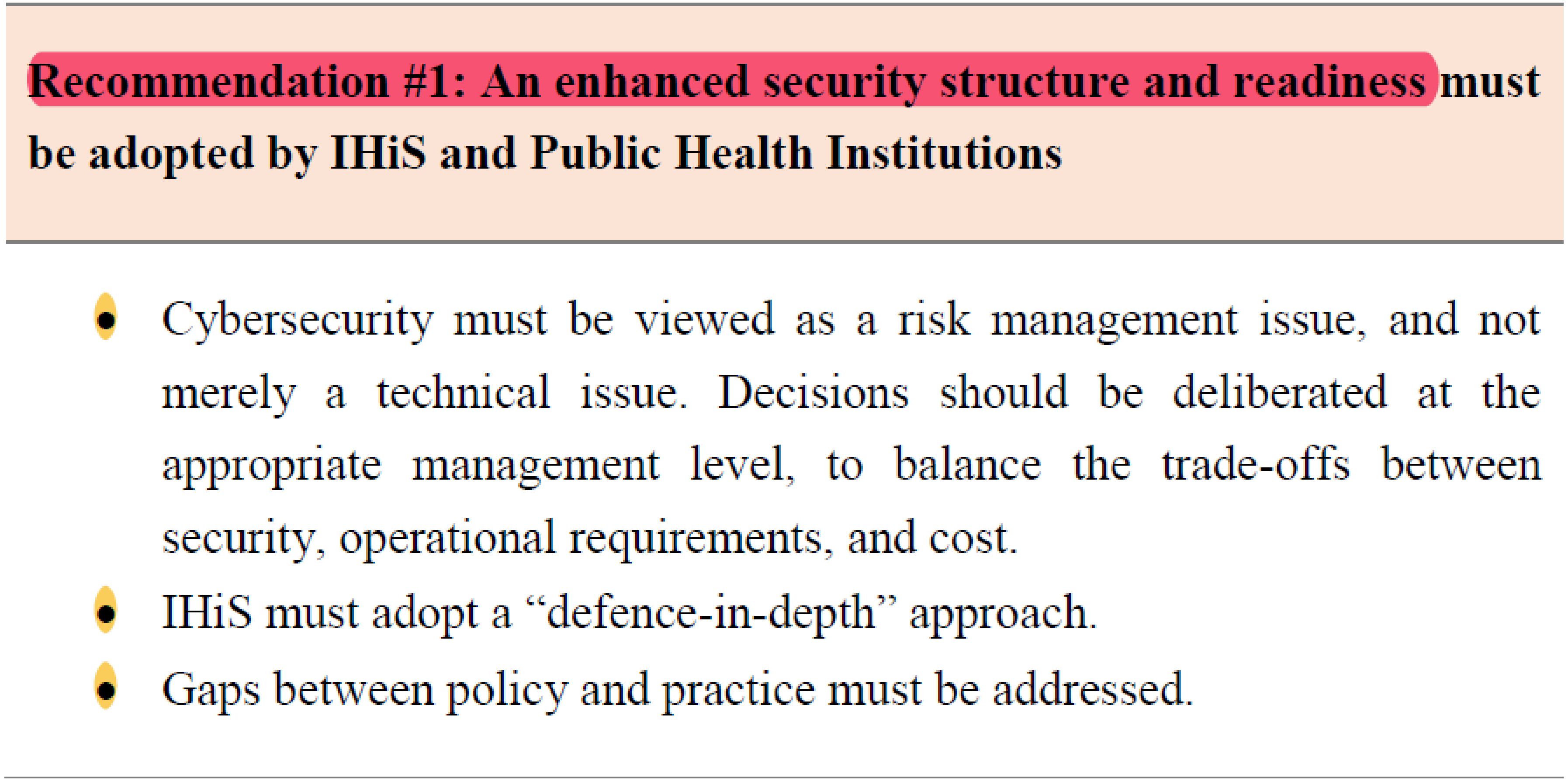
Extensive C2 Infrastructure

CSA’s forensic analysis revealed a number of network Indicators of Compromise (“**IOCs**”) which appeared to be overseas C2 servers. CSA has explained that generally, the C2 servers were used for:

- Infection: where the server is used as a means of dropping malware into the system it is trying to infect;
- Data exfiltration: there were indications of technical data being sent to the servers; and
- Beacon: infected machines may have connected to C2 servers to establish a ‘heartbeat’, which refers to a slow, rhythmic communication meant just to sustain communications.

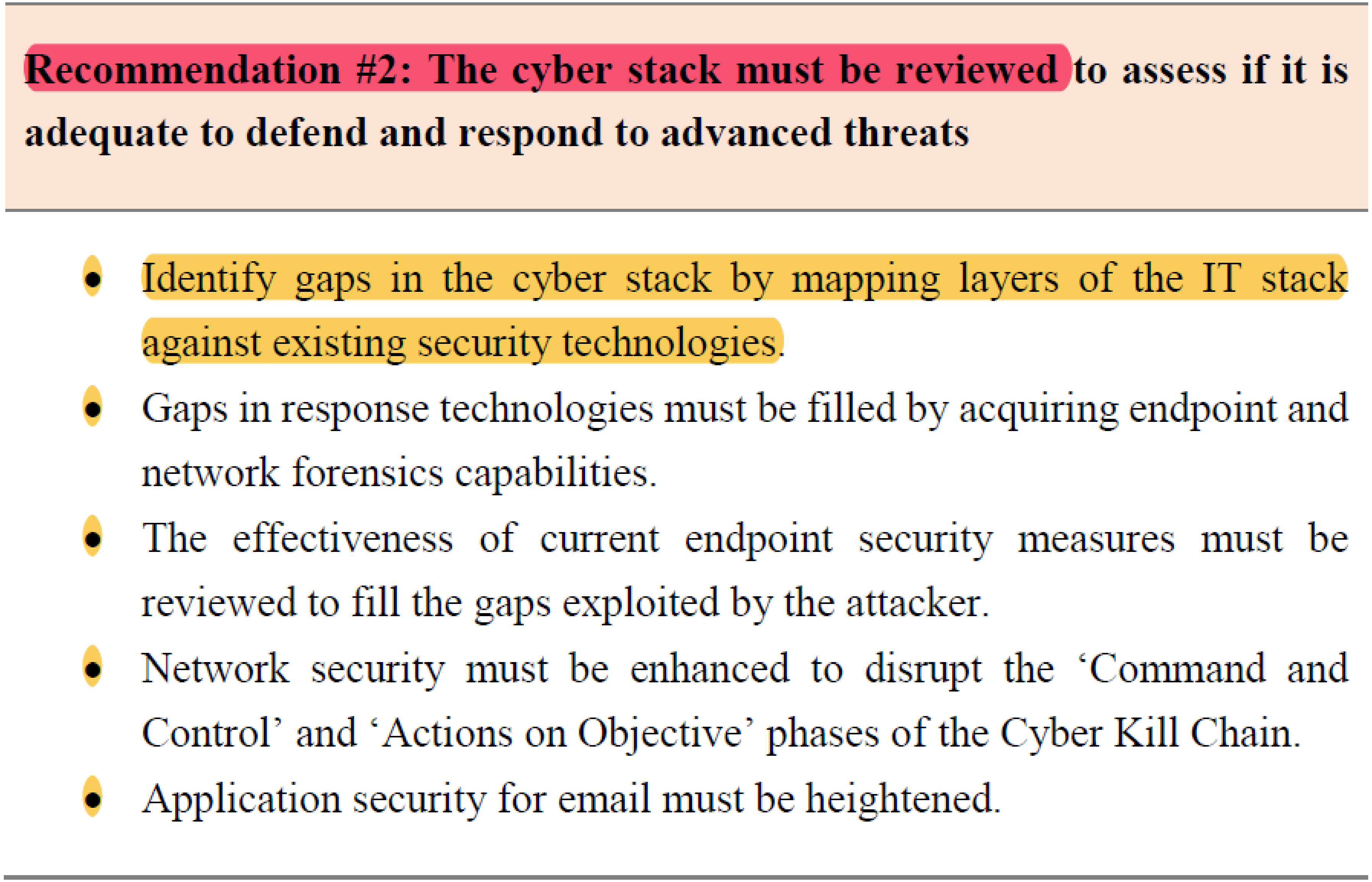
Actions of COI Committee

The Committee made 16 recommendations, 7 of which are priority ones, to be implemented immediately! They are



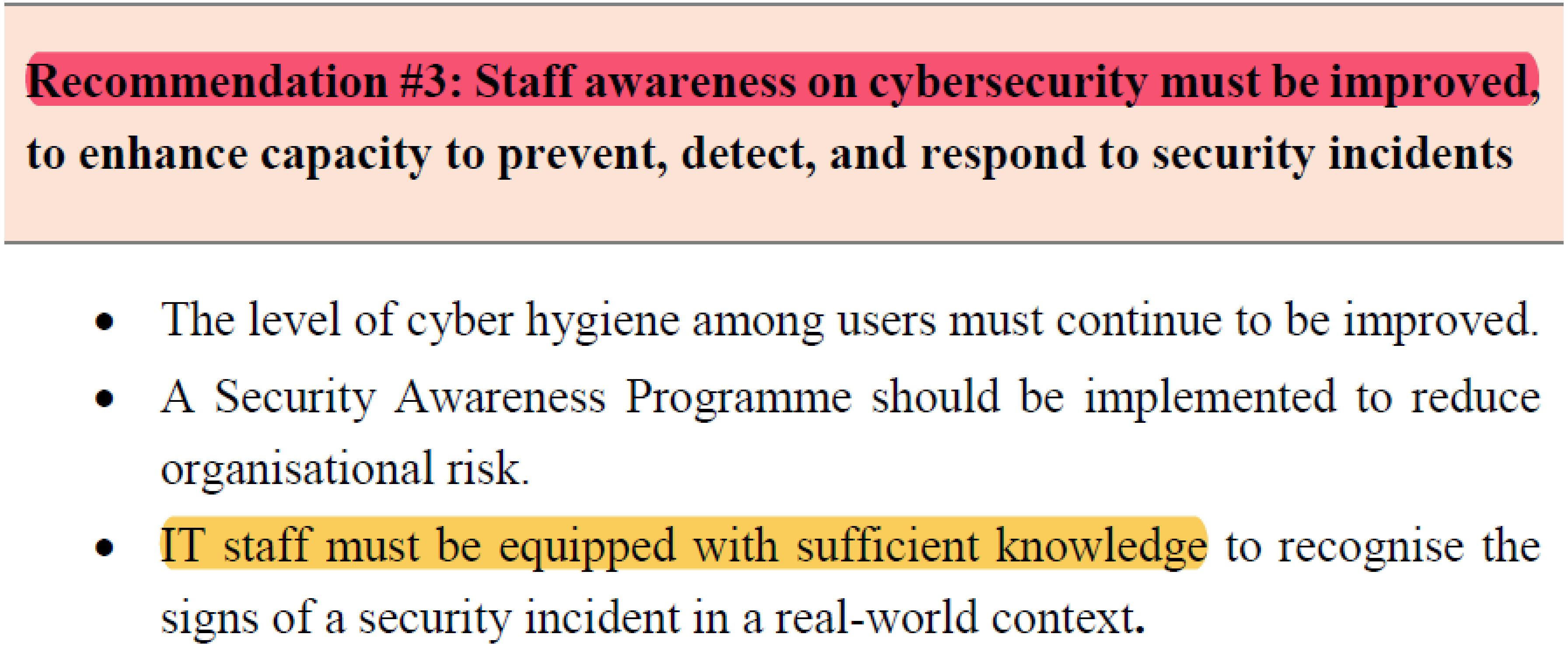
Recommendation #1: An enhanced security structure and readiness must be adopted by IHiS and Public Health Institutions

- Cybersecurity must be viewed as a risk management issue, and not merely a technical issue. Decisions should be deliberated at the appropriate management level, to balance the trade-offs between security, operational requirements, and cost.
- IHiS must adopt a "defence-in-depth" approach.
- Gaps between policy and practice must be addressed.



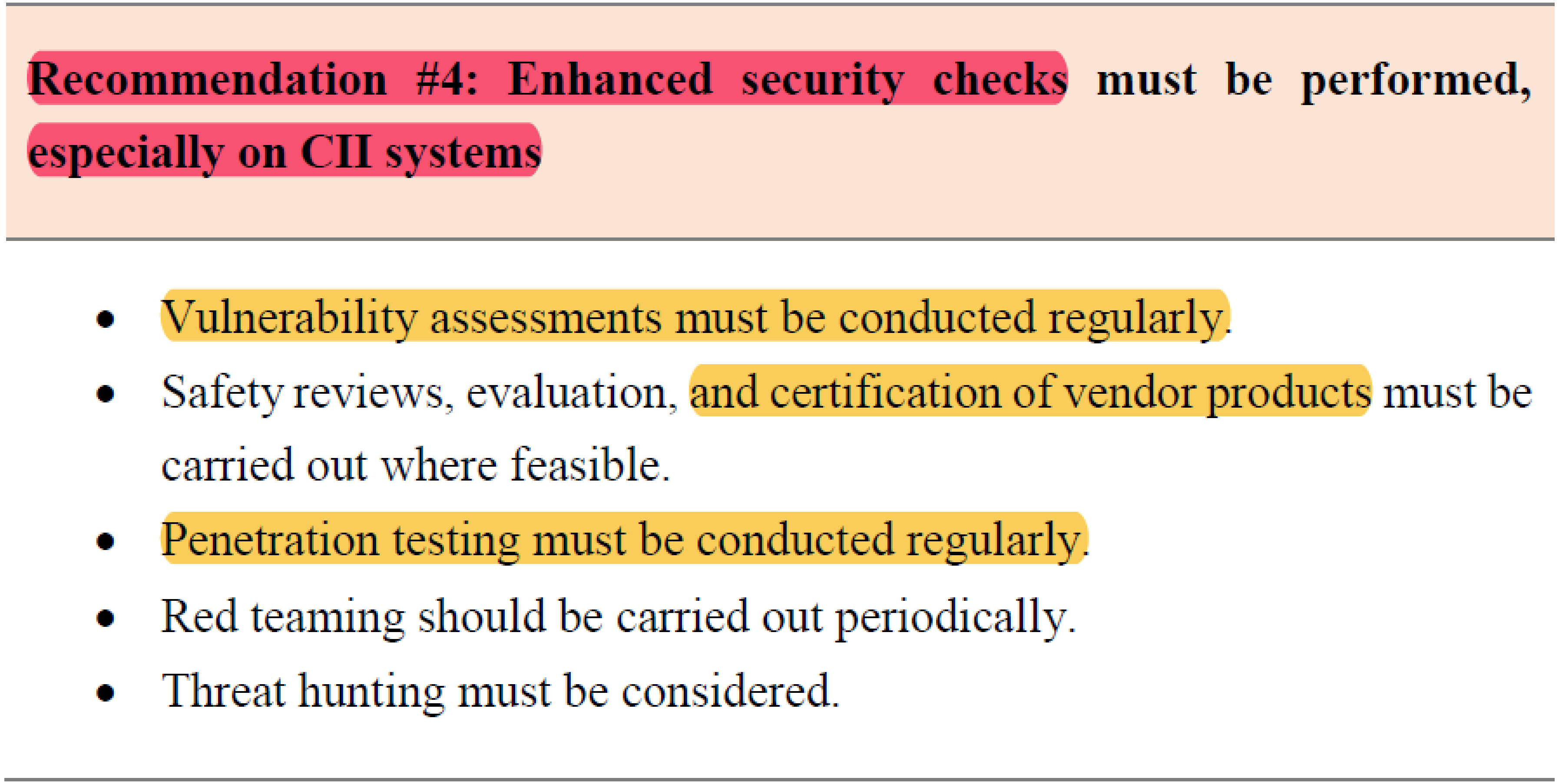
Recommendation #2: The cyber stack must be reviewed to assess if it is adequate to defend and respond to advanced threats

- Identify gaps in the cyber stack by mapping layers of the IT stack against existing security technologies.
- Gaps in response technologies must be filled by acquiring endpoint and network forensics capabilities.
- The effectiveness of current endpoint security measures must be reviewed to fill the gaps exploited by the attacker.
- Network security must be enhanced to disrupt the ‘Command and Control’ and ‘Actions on Objective’ phases of the Cyber Kill Chain.
- Application security for email must be heightened.



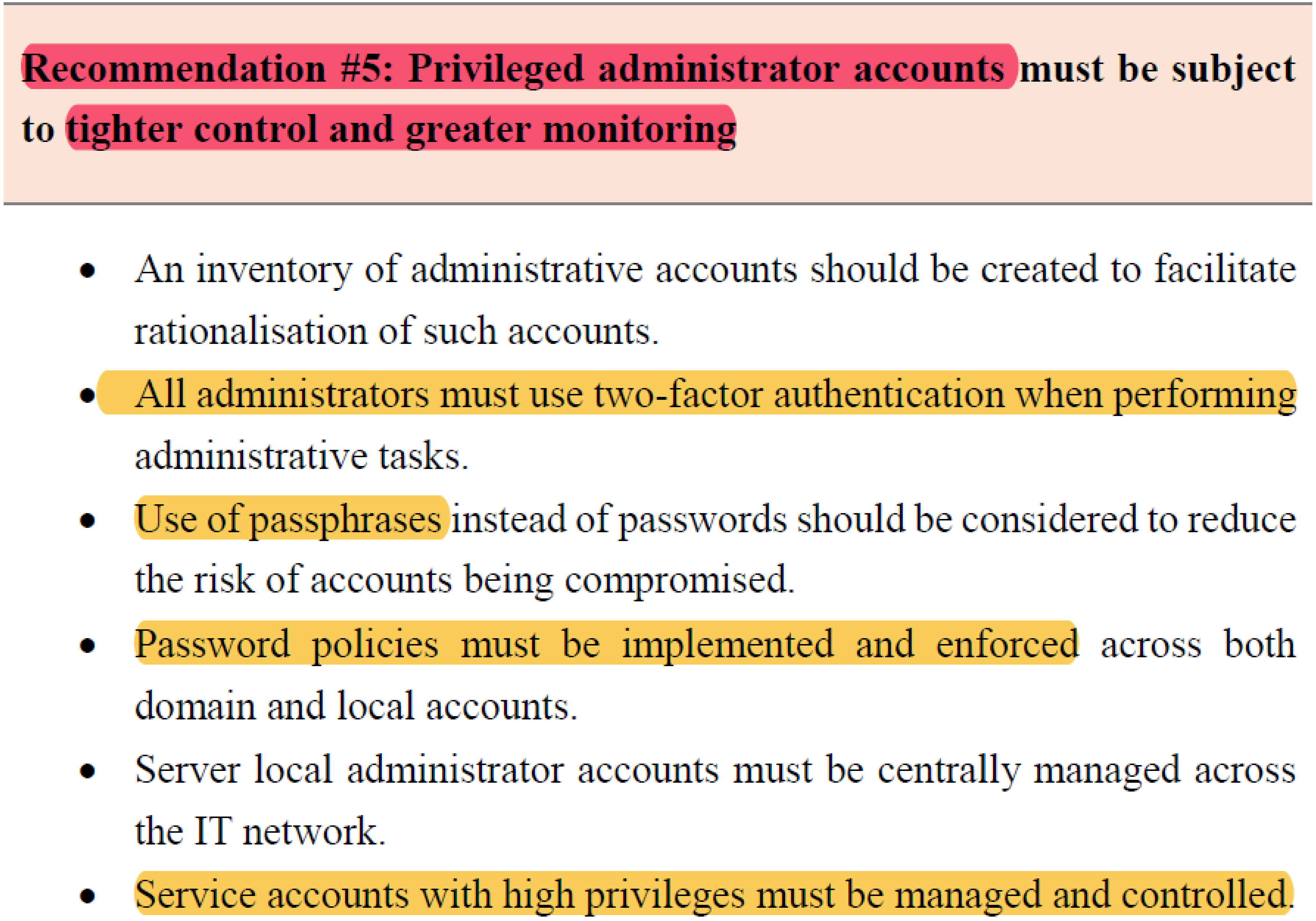
Recommendation #3: Staff awareness on cybersecurity must be improved, to enhance capacity to prevent, detect, and respond to security incidents

- The level of cyber hygiene among users must continue to be improved.
- A Security Awareness Programme should be implemented to reduce organisational risk.
- IT staff must be equipped with sufficient knowledge to recognise the signs of a security incident in a real-world context.



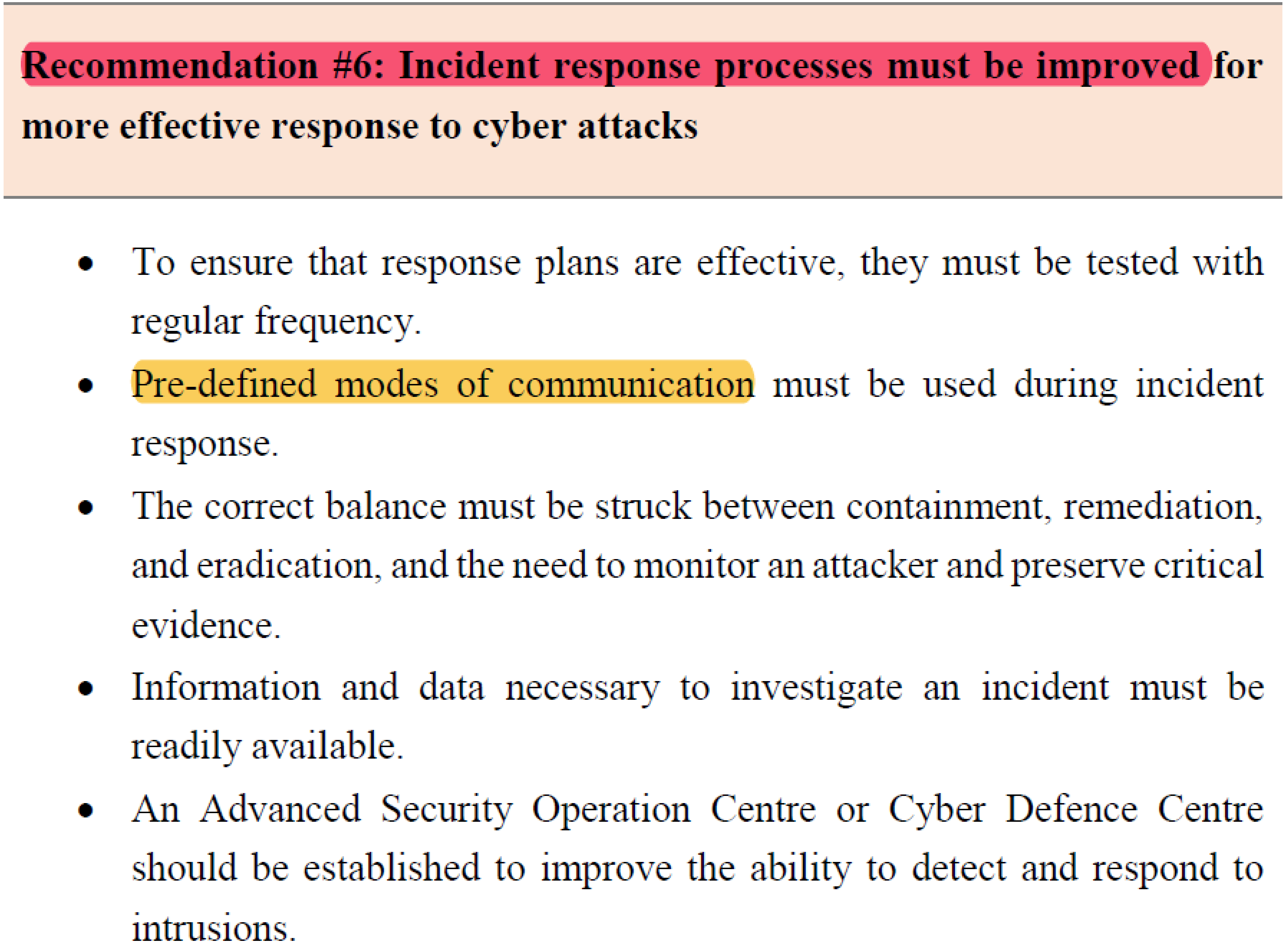
Recommendation #4: Enhanced security checks must be performed, especially on CII systems

- Vulnerability assessments must be conducted regularly.
- Safety reviews, evaluation, and certification of vendor products must be carried out where feasible.
- Penetration testing must be conducted regularly.
- Red teaming should be carried out periodically.
- Threat hunting must be considered.



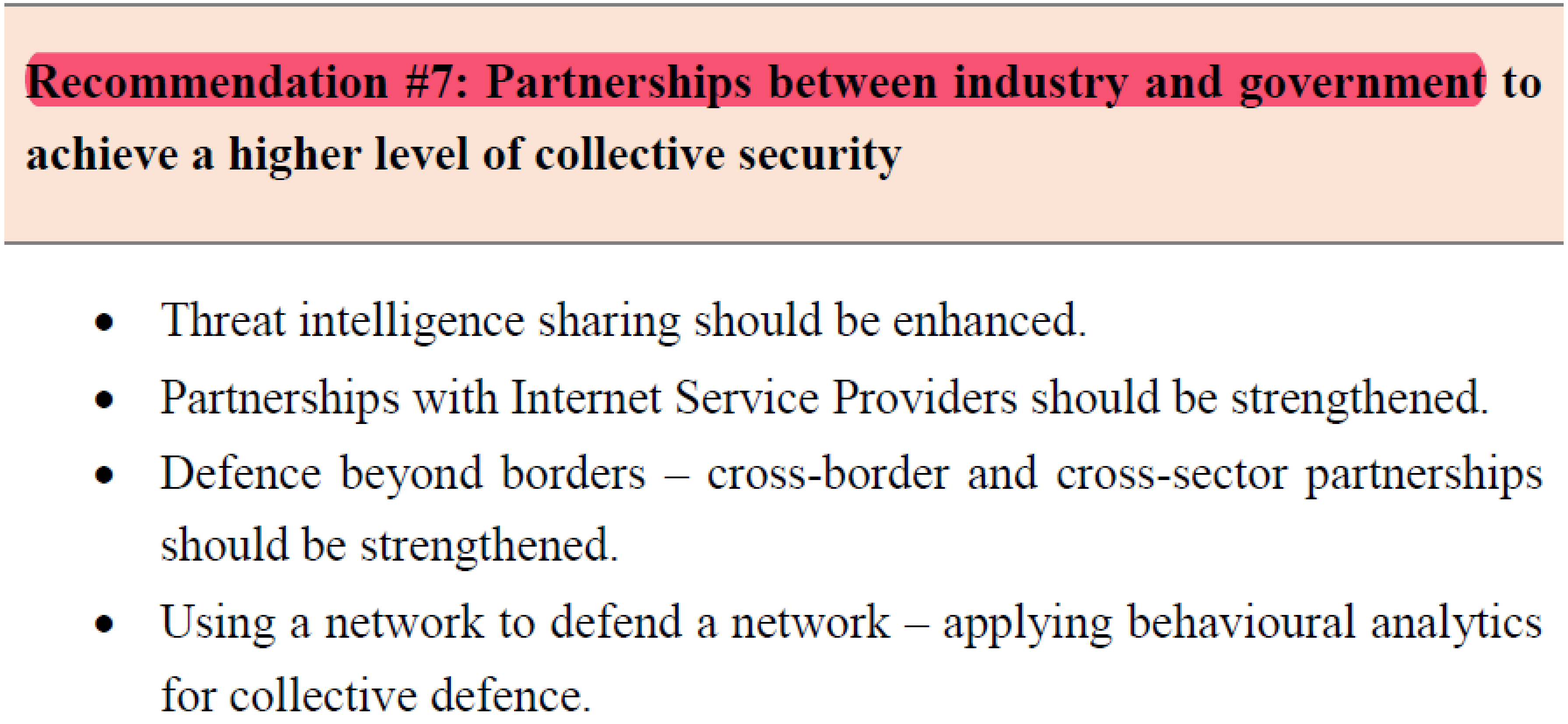
Recommendation #5: Privileged administrator accounts must be subject to tighter control and greater monitoring

- An inventory of administrative accounts should be created to facilitate rationalisation of such accounts.
- All administrators must use two-factor authentication when performing administrative tasks.
- Use of passphrases instead of passwords should be considered to reduce the risk of accounts being compromised.
- Password policies must be implemented and enforced across both domain and local accounts.
- Server local administrator accounts must be centrally managed across the IT network.
- Service accounts with high privileges must be managed and controlled.



Recommendation #6: Incident response processes must be improved for more effective response to cyber attacks

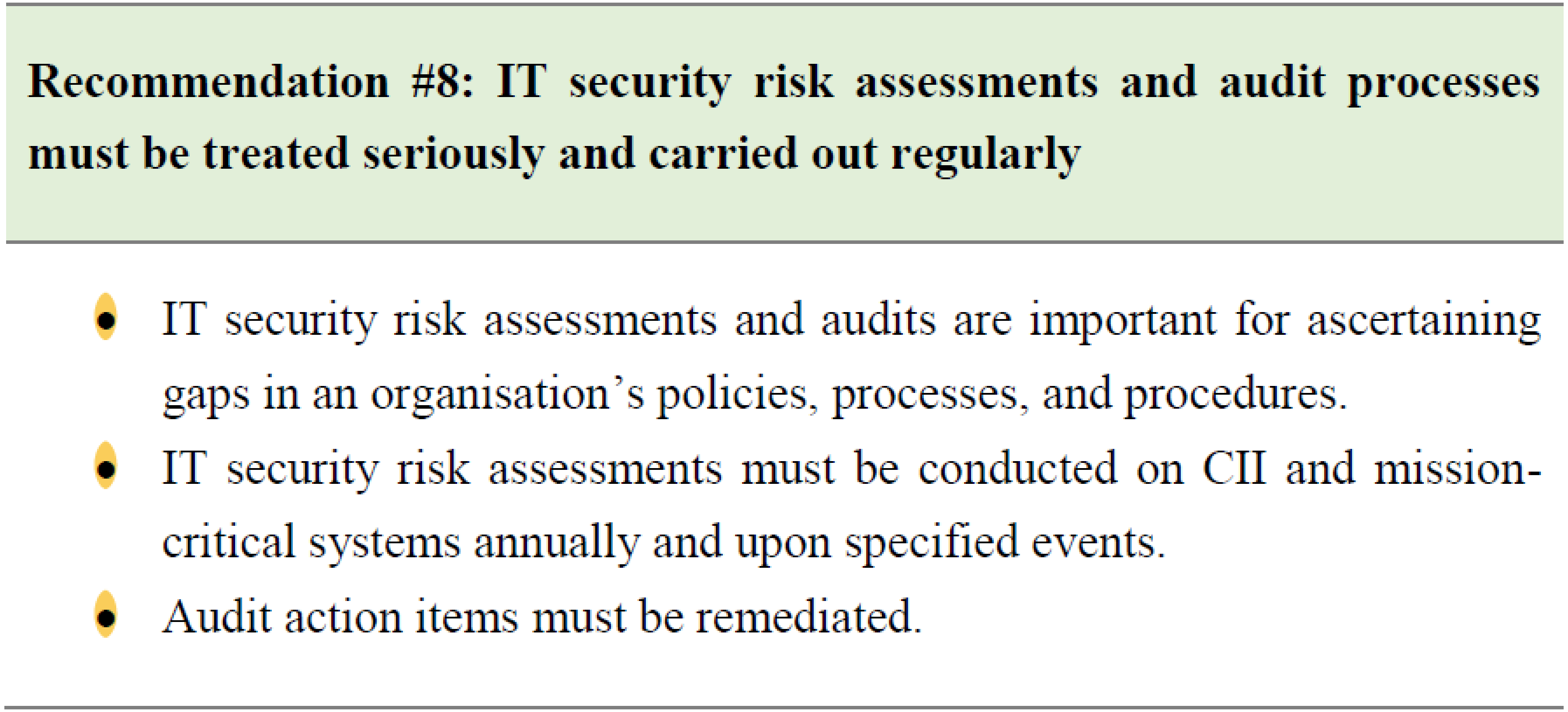
- To ensure that response plans are effective, they must be tested with regular frequency.
- Pre-defined modes of communication must be used during incident response.
- The correct balance must be struck between containment, remediation, and eradication, and the need to monitor an attacker and preserve critical evidence.
- Information and data necessary to investigate an incident must be readily available.
- An Advanced Security Operation Centre or Cyber Defence Centre should be established to improve the ability to detect and respond to intrusions.



Recommendation #7: Partnerships between industry and government to achieve a higher level of collective security

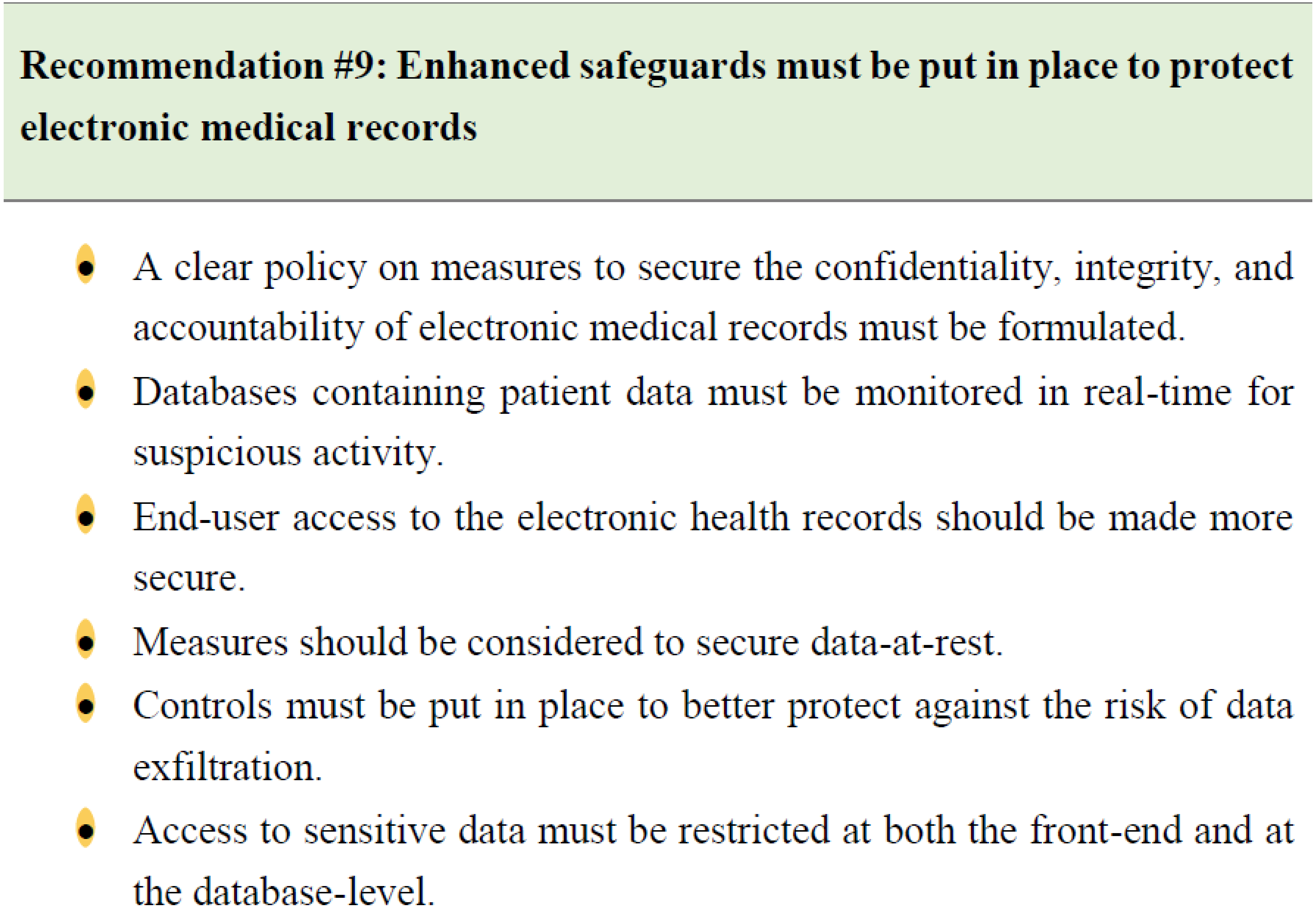
- Threat intelligence sharing should be enhanced.
- Partnerships with Internet Service Providers should be strengthened.
- Defence beyond borders – cross-border and cross-sector partnerships should be strengthened.
- Using a network to defend a network – applying behavioural analytics for collective defence.

Additional 9 Recommendations



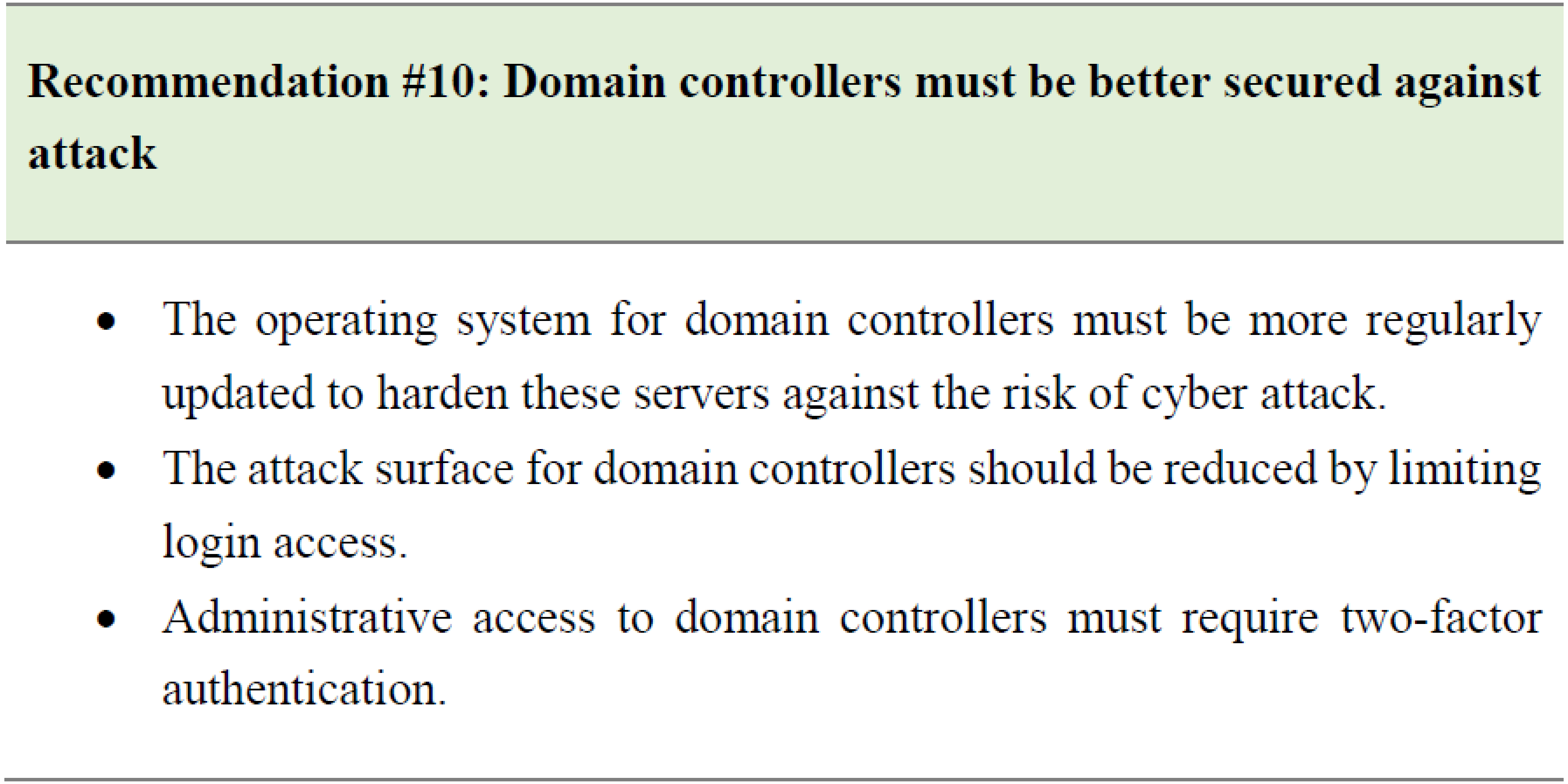
Recommendation #8: IT security risk assessments and audit processes must be treated seriously and carried out regularly

- IT security risk assessments and audits are important for ascertaining gaps in an organisation's policies, processes, and procedures.
- IT security risk assessments must be conducted on CII and mission-critical systems annually and upon specified events.
- Audit action items must be remediated.



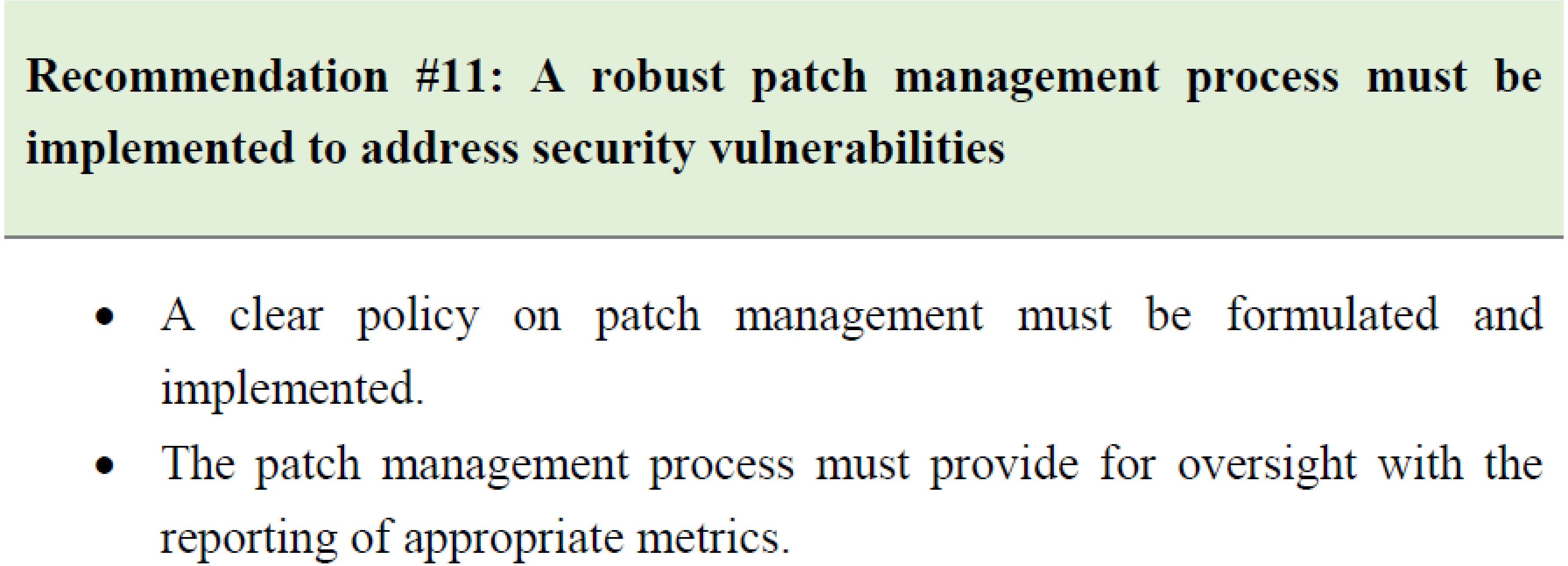
Recommendation #9: Enhanced safeguards must be put in place to protect electronic medical records

- A clear policy on measures to secure the confidentiality, integrity, and accountability of electronic medical records must be formulated.
- Databases containing patient data must be monitored in real-time for suspicious activity.
- End-user access to the electronic health records should be made more secure.
- Measures should be considered to secure data-at-rest.
- Controls must be put in place to better protect against the risk of data exfiltration.
- Access to sensitive data must be restricted at both the front-end and at the database-level.



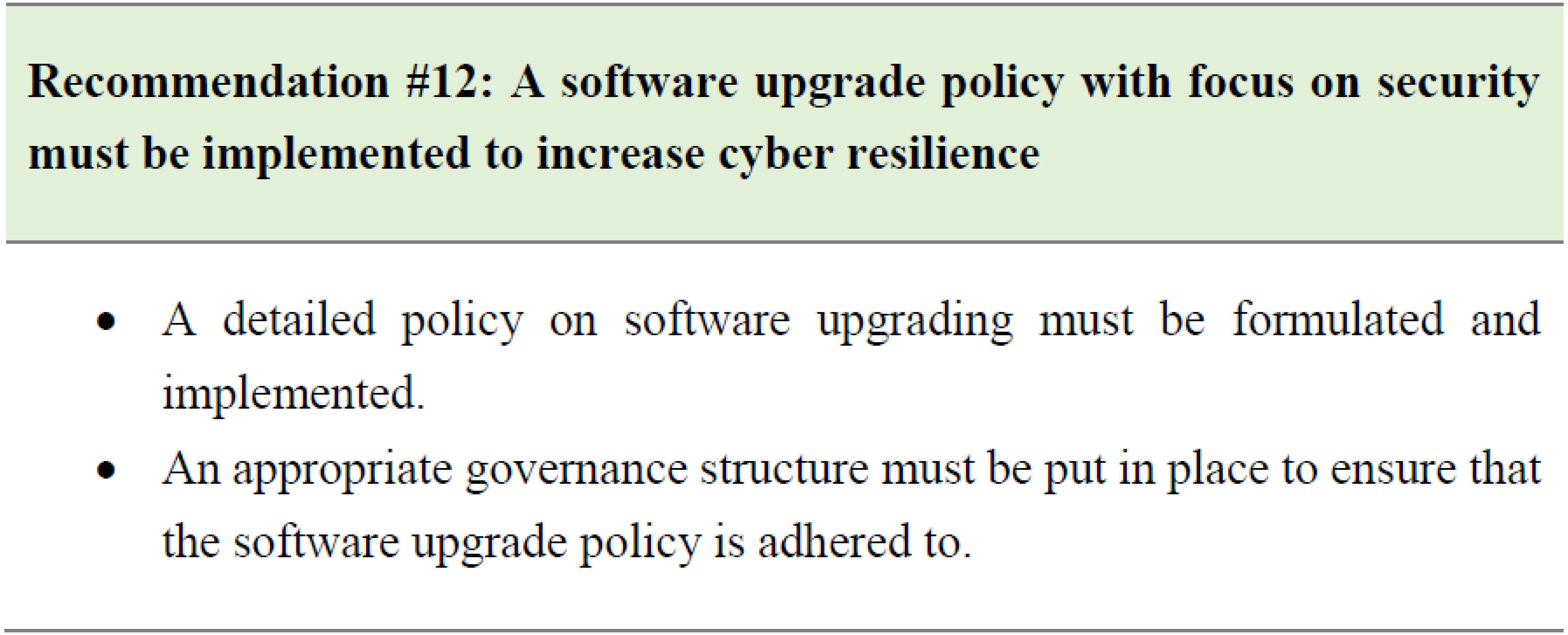
Recommendation #10: Domain controllers must be better secured against attack

- The operating system for domain controllers must be more regularly updated to harden these servers against the risk of cyber attack.
- The attack surface for domain controllers should be reduced by limiting login access.
- Administrative access to domain controllers must require two-factor authentication.



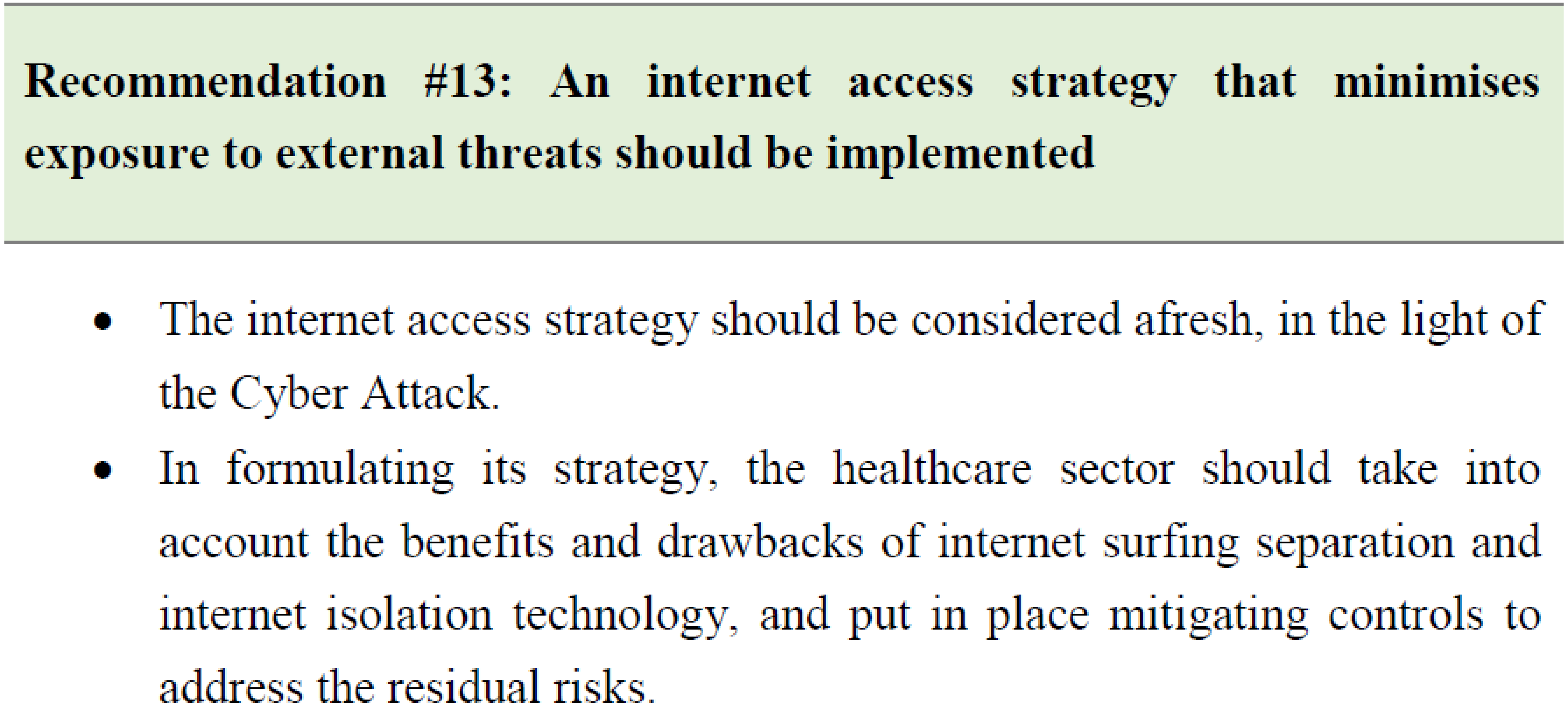
Recommendation #11: A robust patch management process must be implemented to address security vulnerabilities

- A clear policy on patch management must be formulated and implemented.
- The patch management process must provide for oversight with the reporting of appropriate metrics.



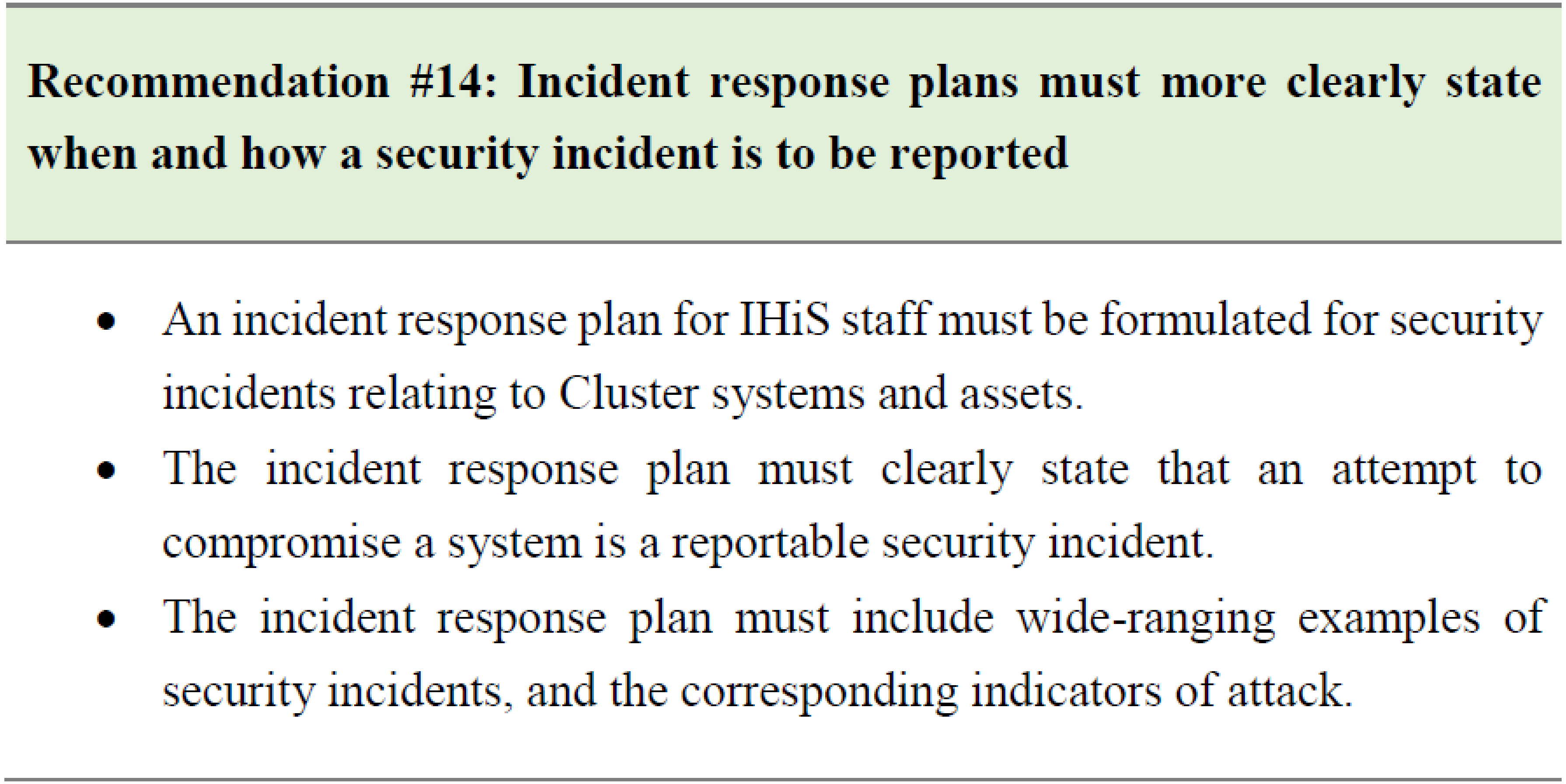
Recommendation #12: A software upgrade policy with focus on security must be implemented to increase cyber resilience

- A detailed policy on software upgrading must be formulated and implemented.
- An appropriate governance structure must be put in place to ensure that the software upgrade policy is adhered to.



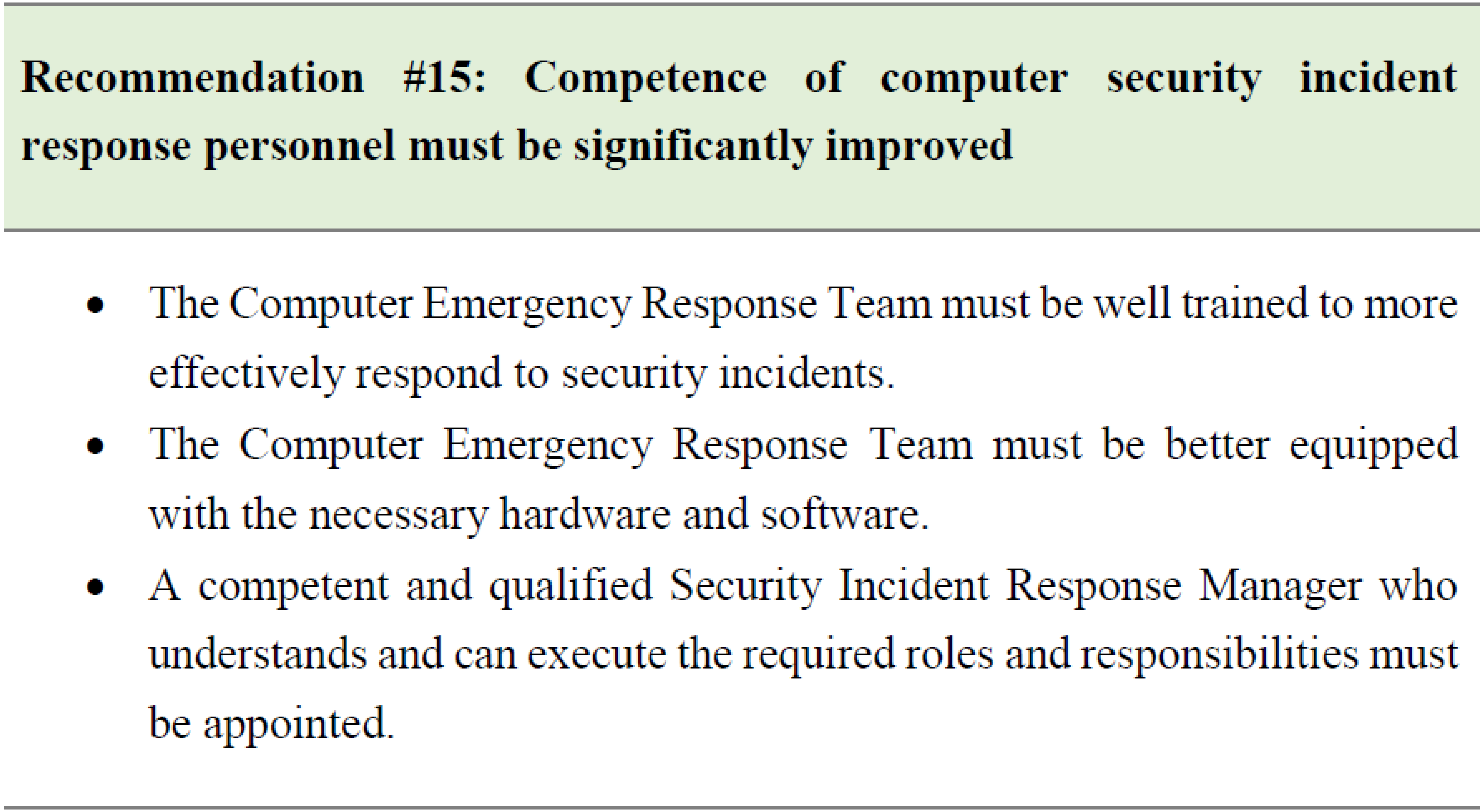
Recommendation #13: An internet access strategy that minimises exposure to external threats should be implemented

- The internet access strategy should be considered afresh, in the light of the Cyber Attack.
- In formulating its strategy, the healthcare sector should take into account the benefits and drawbacks of internet surfing separation and internet isolation technology, and put in place mitigating controls to address the residual risks.



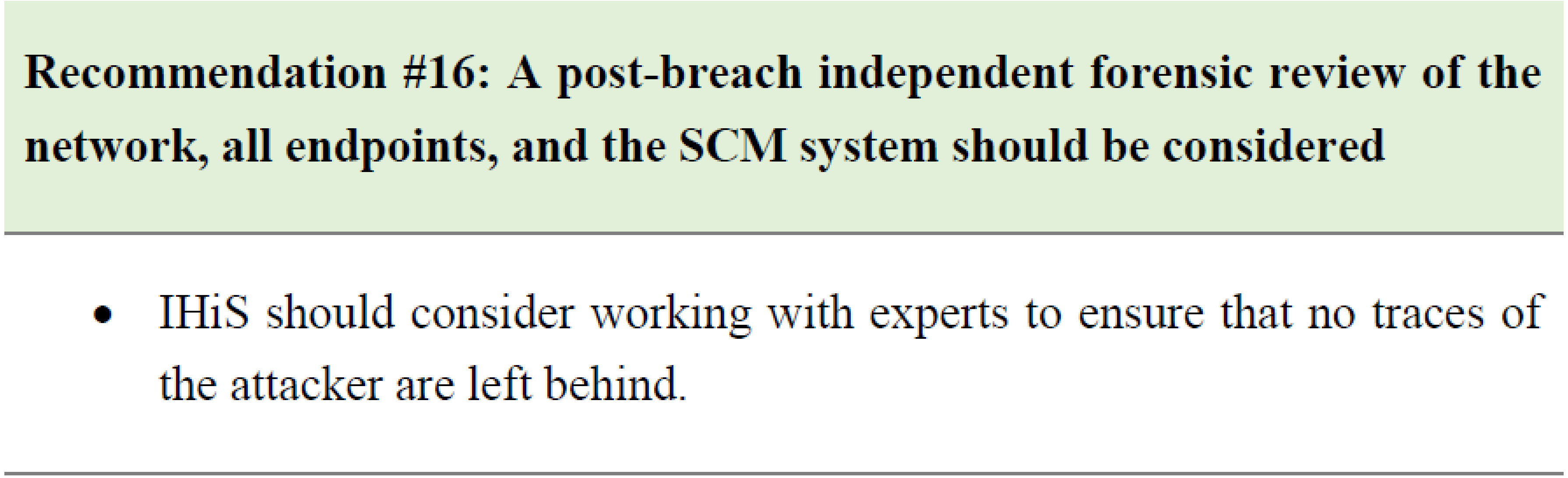
Recommendation #14: Incident response plans must more clearly state when and how a security incident is to be reported

- An incident response plan for IHiS staff must be formulated for security incidents relating to Cluster systems and assets.
- The incident response plan must clearly state that an attempt to compromise a system is a reportable security incident.
- The incident response plan must include wide-ranging examples of security incidents, and the corresponding indicators of attack.



Recommendation #15: Competence of computer security incident response personnel must be significantly improved

- The Computer Emergency Response Team must be well trained to more effectively respond to security incidents.
- The Computer Emergency Response Team must be better equipped with the necessary hardware and software.
- A competent and qualified Security Incident Response Manager who understands and can execute the required roles and responsibilities must be appointed.



Recommendation #16: A post-breach independent forensic review of the network, all endpoints, and the SCM system should be considered

- IHiS should consider working with experts to ensure that no traces of the attacker are left behind.