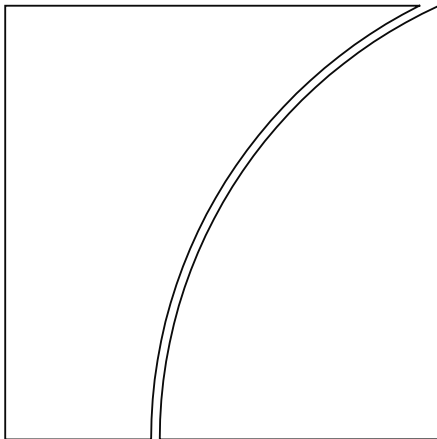


Committee on
Payments and Market
Infrastructures

Board of the International
Organization of Securities
Commissions



Guidance on cyber
resilience for financial
market infrastructures

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BANK FOR INTERNATIONAL SETTLEMENTS



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Executive summary¹

Background. The safe and efficient operation of financial market infrastructures (FMIs)² is essential to maintaining and promoting financial stability and economic growth. If not properly managed, FMIs can be sources of financial shocks, such as liquidity dislocations and credit losses, or a major channel through which these shocks are transmitted across domestic and international financial markets. In this context, the level of cyber resilience, which contributes to an FMI's operational resilience, can be a decisive factor in the overall resilience of the financial system and the broader economy.

Purpose. The purpose of this document (Guidance) is to provide guidance for FMIs to enhance their cyber resilience. Specifically, this document provides supplemental guidance to the CPMI-IOSCO Principles for Financial Market Infrastructures (PFMI), primarily in the context of governance (Principle 2), the framework for the comprehensive management of risks (Principle 3), settlement finality (Principle 8), operational risk (Principle 17) and FMI links (Principle 20). This guidance is not intended to impose additional standards on FMIs beyond those set out in the PFMI, but instead provides supplemental detail related to the preparations and measures that FMIs should undertake to enhance their cyber resilience capabilities with the objective of limiting the escalating risks that cyber threats pose to financial stability.

Outline. The Guidance is presented in chapters that outline five primary risk management categories and three overarching components that should be addressed across an FMI's cyber resilience framework. The risk management categories are: governance; identification; protection; detection; and response and recovery. The overarching components are: testing; situational awareness; and learning and evolving. In order to achieve resilience objectives, investments across these guidance categories can be mutually reinforcing and should be considered jointly.

Broad relevance. While the guidance is directly aimed at FMIs, it is important for FMIs to take on an active role in outreach to their participants and other relevant stakeholders to promote understanding and support of resilience objectives and their implementation. Given the extensive interconnections in the financial system, the cyber resilience of an FMI is in part dependent on that of interconnected FMIs, of service providers and of the participants.

Collaboration. Effective solutions may necessitate collaboration between FMIs and their stakeholders as they seek to strengthen their own cyber resilience. Efforts to coordinate the design of resilience solutions may bring enhanced strategies forward in a more timely and efficient way. The outcome of such collaboration should be considered in their individual and collective strategic planning. Because the cyber resilience of FMIs supports broader financial stability objectives and in light of significant interdependencies in clearing and settlement processes, it is important for authorities to cooperate, recognising that such cooperation may help authorities consider, where appropriate, consistency of direction in their oversight and supervision of both FMIs and their relevant stakeholders. Moreover, authorities and FMIs may need to call upon technology companies and other firms to help identify and develop efficient and effective solutions.

Governance. Consistent with effective management of other forms of risk faced by an FMI, sound governance is key. Cyber governance refers to the arrangements an FMI has put in place to establish, implement and review its approach to managing cyber risks. Effective governance should start with a clear and comprehensive cyber resilience framework that accords a high priority to the safety and efficiency of the FMI's operations while supporting broader financial stability objectives. The framework should be guided by a cyber resilience strategy, define how the FMI's cyber resilience objectives are determined and

¹ Technical terms are explained in the glossary in the Annex A.

² Consistent with the definition in the PFMI, the term "FMI" refers to systemically important payment systems, central securities depositories (CSDs), securities settlement systems (SSSs), central counterparties (CCPs) and trade repositories (TRs). Relevant authorities, however, may decide to apply this guidance to types of infrastructure not formally covered by this report.

outline its people, processes and technology requirements for managing cyber risks. This framework should include timely communication to enable effective collaboration with relevant stakeholders. It is essential that the framework is supported by clearly defined roles and responsibilities of the FMI's board (or equivalent) and its management, and it is incumbent upon its board and management to create a culture which recognises that staff at all levels, as well as interconnected service providers, have important responsibilities in ensuring the FMI's cyber resilience. The chapter on governance includes guidance on the basic elements of an FMI's cyber resilience framework and how an FMI's governance arrangements should support that framework.

Identification. Given that FMIs' operational failure can negatively impact financial stability, it is important that FMIs identify their critical business functions and supporting information assets that should be protected, in order of priority, against compromise. The chapter on identification outlines how an FMI should identify and classify business processes, information assets, system access and external dependencies. This helps the FMI to better understand its internal situation, the cyber risks that it bears from and poses to entities in its ecosystem, and how it can coordinate with relevant stakeholders when designing and implementing its cyber resilience efforts.

Protection. Cyber resilience depends on effective security controls that protect the confidentiality, integrity and availability of its assets and services. The chapter on protection urges FMIs to implement appropriate and effective controls and design systems and processes in line with leading cyber resilience and information security practices to prevent, limit and contain the impact of a potential cyber incident.

Detection. An FMI's ability to detect the occurrence of anomalies and events indicating a potential cyber incident is essential to strong cyber resilience. Early detection provides an FMI with useful lead time to mount appropriate countermeasures against a potential breach, and allows proactive containment of actual breaches. Given the stealthy and sophisticated nature of cyber attacks and the multiple entry points through which a compromise could take place, advanced capabilities to extensively monitor for anomalous activities are needed. The chapter on detection outlines monitoring and process tools to be used by an FMI for the detection of cyber incidents.

Resumption within two hours (ie two-hour RTO or 2hRTO). Financial stability may depend on the ability of an FMI to settle obligations when they are due, at a minimum by the end of the value date. An FMI should design and test its systems and processes to enable the safe resumption of critical operations within two hours of a disruption and to enable itself to complete settlement by the end of the day of the disruption, even in the case of extreme but plausible scenarios. Notwithstanding this capability to resume critical operations within two hours, when dealing with a disruption FMIs should exercise judgment in effecting resumption so that risks to itself or its ecosystem do not thereby escalate, whilst taking into account that completion of settlement by the end of day is crucial. FMIs should also plan for scenarios in which the resumption objective is not achieved. Although authorities recognise the challenges that FMIs face in achieving cyber resilience objectives, it is also recognised that current and emerging practices and technologies may serve as viable options to attain those objectives.³ Furthermore, the rationale for establishing this resumption objective stands irrespective of the challenge to achieve it. The chapter on response and recovery provides guidance on how an FMI should respond in order to contain, resume and recover from successful cyber attacks.

Testing. Once employed within an FMI, the elements of its cyber resilience framework should be rigorously tested to determine their overall effectiveness. Sound testing regimes produce findings that should be used to identify gaps against stated resilience objectives and provide credible and meaningful inputs to the FMI's management of cyber risks. The chapter on testing provides guidance on areas that should be

³ See CPMI, *Cyber resilience in financial market infrastructures*, Section 4.3.3, for potential solutions provided by FMIs during the CPMI industry interviews.

included in an FMI's testing programme and how results from testing can be used to improve its cyber resilience framework.

Situational awareness. Strong situational awareness can significantly enhance an FMI's ability to understand and pre-empt cyber events, and to effectively detect, respond to and recover from cyber attacks that are not prevented. Specifically, a solid understanding of the threat landscape can help an FMI better identify and understand the vulnerabilities in its critical business functions, and facilitate the adoption of appropriate risk mitigation strategies. The chapter on situational awareness provides guidance on how an FMI could proactively monitor the cyber threat landscape, and acquire and make effective use of actionable threat intelligence to validate its risk assessments, strategic direction, resource allocation, processes, procedures and controls with respect to building cyber resilience. This chapter also stresses the importance of an FMI's active participation in information-sharing arrangements and collaboration with trusted stakeholders within and outside the industry to enhance resilience of the FMI and its ecosystem.

Learning and evolving. The last chapter emphasises the importance of implementing an adaptive cyber resilience framework that evolves with the dynamic nature of cyber risks to enable effective management of those risks. FMIs should aim to instil a culture of cyber risk awareness and demonstrate ongoing re-evaluation and improvement of their cyber resilience posture at every level within the organisation.

Application of the Guidance. In implementing the Guidance, FMIs are expected to use a risk-based approach. It is recognised that FMIs will need to implement the Guidance consistent with applicable laws and regulations. Together with institutional differences, these may determine how the guidance is adopted to achieve the intended results. FMIs should immediately take necessary steps in concert with relevant stakeholders to improve their cyber resilience, taking into account this Guidance. FMIs should also, within 12 months of the publication of this Guidance, have developed concrete plans to improve their capabilities in order to meet the two-hour RTO, as discussed in Chapter 6 of this Guidance.

1. Introduction

1.1 Purpose of the guidance

1.1.1 *Purpose.* The purpose of this document is to provide guidance for FMIs to enhance their cyber resilience. This guidance (Guidance) is not intended to impose additional standards on FMIs beyond those set out in the PFMI, but instead provides supplemental details related to the preparations and measures that FMIs should undertake to enhance their cyber resilience capabilities with the objective of limiting the escalating risks that cyber threats pose to financial stability. In the context of this guidance, “cyber resilience” is an FMI’s ability to anticipate, withstand, contain and rapidly recover from a cyber attack. FMIs, which facilitate the clearing, settlement and recording of monetary and other financial transactions, play a critical role in fostering financial stability.⁴ While safe and efficient FMIs contribute to maintaining and promoting financial stability and economic growth, FMIs may also concentrate risk. If not properly managed, FMIs can be sources of financial shocks, such as liquidity dislocations and credit losses, or a major channel through which these shocks are transmitted across domestic and international financial markets. In this context, the level of operational resilience of FMIs, including cyber resilience, can be a decisive factor in the overall resilience of the financial system and the broader economy.

1.1.2 *Cyber risks in the PFMI.* In April 2012, the Committee on Payment and Settlement Systems (CPSS (now CPMI)) and the Technical Committee of the International Organization of Securities Commissions (IOSCO) published the Principles for Financial Market Infrastructures (PFMI).⁵ The main public policy objectives were “to enhance safety and efficiency in payment, clearing, settlement, and recording arrangements, and more broadly, to limit systemic risk and foster transparency and financial stability”. The PFMI recognise operational risk, including cyber risk, as a specific key risk faced by FMIs, and state that an FMI should have governance arrangements and objectives to manage these risks within a comprehensive risk management framework.⁶ The management of cyber risks is included in the expectations outlined in Principle 17 and its supporting key considerations.

1.1.3 *Cyber risks are unique.* While cyber risks should be managed as part of an FMI’s overall operational risk management framework, some unique characteristics of cyber risk present challenges to FMIs’ traditional operational risk management frameworks:

- a. First, a distinguishing characteristic of sophisticated cyber attacks is the persistent nature of a campaign conducted by a motivated attacker. The presence of an active, persistent and sometimes sophisticated adversary in cyber attacks means that, unlike most other sources of risk, malicious cyber attacks are often difficult to identify or fully eradicate and the breadth of damage difficult to determine.
- b. Second, there is a broad range of entry points through which an FMI could be compromised. As a result of their interconnectedness, cyber attacks could come through an FMI’s participants, linked FMIs, service providers, vendors and vendor products. FMIs could themselves become a channel to further propagate cyber attacks – for example, via the distribution of malware to interconnected entities. Unlike physical operational disruptions, cyber risk posed by an interconnected entity is not necessarily related to the degree of that entity’s relevance to the FMI’s business. From a cyber perspective, the small-value/volume participant or a vendor providing non-critical services may be as risky as a major participant or a critical service provider.

⁴ See also PFMI, paragraphs 1.3 and 1.20.

⁵ See <http://www.bis.org/cpmi/publ/d101.htm>.

⁶ Section 2.0, “Overview of key risks in financial market infrastructures”; paragraph 2.9, “Operational risk”; and Principle 3, “Framework for the comprehensive management of risks”.

Internally, the risk of insider threat from rogue or careless employees opens up yet another avenue for possible compromises.

- c. Third, certain cyber attacks can render some risk management and business continuity arrangements ineffective. For example, automated system and data replication arrangements that are designed to help preserve sensitive data and software in the event of a physical disruptive event might in some instances fuel the propagation of malware and corrupted data to backup systems. Overall, a cyber attack's potential to cause significant service disruptions to the broader financial system dictates the urgency of having an effective approach in place to manage it, and to minimise the probability that service resumption will introduce additional risks to an FMI or the wider financial sector.
- d. Fourth, cyber attacks can be stealthy and propagate rapidly within a network of systems. For example, they can exploit unknown vulnerabilities and weak links in systems and protocols to cause disruptions and/or infiltrate an FMI's internal network. Malware designed to take advantage of such latent vulnerabilities may circumvent controls. To minimise the impact of such attacks, FMIs would require capabilities to swiftly detect, respond to, contain and recover from such attacks.

1.1.4 *The most relevant principles from the PFMI.* This document is intended to provide supplemental guidance to the PFMI regarding cyber resilience, primarily in the context of those principles listed in Box 1.

Box 1

Key PFMI principles informing the guidance

Principle 2: Governance – *An FMI should have governance arrangements that are clear and transparent, promote the safety and efficiency of the FMI, and support the stability of the broader financial system, other relevant public interest considerations, and the objectives of relevant stakeholders.*

Principle 3: Framework for the comprehensive management of risks – *An FMI should have a sound risk-management framework for comprehensively managing legal, credit, liquidity, operational, and other risks.*

Principle 8: Settlement finality – *An FMI should provide clear and certain final settlement, at a minimum by the end of the value date. Where necessary or preferable, an FMI should provide final settlement intraday or in real time.*

Principle 17: Operational risk – *An FMI should identify the plausible sources of operational risk, both internal and external, and mitigate their impact through the use of appropriate systems, policies, procedures, and controls. Systems should be designed to ensure a high degree of security and operational reliability and should have adequate, scalable capacity. Business continuity management should aim for timely recovery of operations and fulfilment of the FMI's obligations, including in the event of a wide-scale or major disruption.*

Principle 20: FMI links – *An FMI that establishes a link with one or more FMIs should identify, monitor, and manage link-related risks.*

1.1.5 *Settlement finality and resumption of critical operations.* This report is informed, in particular, by two important elements included in the PFMI relating to the systemic importance of FMIs: (i) the importance of assuring settlement when obligations are due and the finality of those transactions; and (ii) the ability of an FMI to resume operations within two hours following a disruption.

- a. Principle 8 on settlement finality states: "An FMI should provide clear and certain final settlement, at a minimum by the end of the value date. Where necessary or preferable, an FMI should provide

final settlement intraday or in real time.”⁷ The finality of settlement is important for the stability of the financial system. Credit, liquidity, market and legal risks are allocated among the parties to payments and securities transactions based on the principle of finality. The liquidity condition of financial institutions and their customers depends on the certainty of the assumption that transactions that are considered final will remain as such. In this guidance, the settlement finality principle is treated as a given.

- b. Since financial stability may indeed depend on FMIs to process transactions and settle obligations when they are due, the PFMI impose stringent expectations on FMIs in the area of operational risk. Of significant importance is an FMI’s ability to resume critical operations rapidly. Specifically, Key Consideration 6 of Principle 17 on operational risk establishes an expectation that an FMI’s business continuity plan “should be designed to ensure that” it can “resume operations within two hours following disruptive events and enable the FMI to complete settlement by the end of the day of the disruption, even in the case of extreme circumstances”.

1.2 Design and organisation of the Guidance

1.2.1 *Design.* This Guidance is presented in chapters that outline five primary risk management categories and three overarching components that should be addressed across an FMI’s cyber resilience framework. The risk management categories are: (i) governance; (ii) identification; (iii) protection; (iv) detection; and (v) response and recovery. The overarching components are: (i) testing; (ii) situational awareness; and (iii) learning and evolving. Categories similar to those used in leading cyber resilience standards, guidelines, and frameworks have been used as a logical way to organise and articulate related expectations. Figure 1 below depicts the relationship among these cyber resilience guidance categories.

⁷ See PFMI, paragraph 2.9, “Operational risk”; Principle 3, “Framework for the comprehensive management of risks”; and Principle 8, “Settlement finality”.



1.2.2 *Principles-based.* The guidance is principles-based, recognising that the dynamic nature of cyber threats requires evolving methods to mitigate these threats. Guidance requiring specific measures today may quickly become ineffective in the future. In some cases, however, specific examples are used to illustrate and clarify certain points.

1.2.3 *ICT controls should be present.* Importantly, the guidance is not intended to replace existing information and communication technology (ICT) control guidance. A strong ICT control environment is fundamental and a critical component of an FMI's overall cyber resilience. Key Consideration 5 of Principle 17 of the PFMI states that "an FMI should have comprehensive physical and information security policies that address all potential vulnerabilities and threats". In practice, in the context of cyber risk management, FMIs should maintain robust ICT controls and consistently demonstrate effective control environments. This point is particularly important as many successful cyber attacks have been attributed to weak or inadequate ICT controls, even basic ones.

1.3 Expected usage

1.3.1 *Target group.* This guidance is first and foremost directed to FMIs as defined in the PFMI, namely: systemically important payment systems, central securities depositories (CSDs), securities settlement systems (SSSs), central counterparties (CCPs) and trade repositories (TRs). Relevant authorities, however, may decide to apply this guidance to types of infrastructure not formally covered by this report.⁸

⁸ In some cases, exchanges or other market infrastructures may own or operate entities or functions that perform centralised clearing and settlement processes that are covered by the guidance in this report. In general, however, this guidance is not addressed to market infrastructures such as trading exchanges, trade execution facilities or multilateral trade compression systems.

1.3.2 *Role of the board and senior management.* The guidance should be considered an important reference for an FMI's board of directors and senior management, given that active involvement on the part of the board and senior management is instrumental in ensuring cyber resilience. The Guidance should also be regarded as a reference by all FMI personnel responsible for designing, implementing or overseeing elements of the FMI's cyber resilience framework.

1.3.3 *Stakeholder considerations.* While the guidance is directly aimed at FMIs, it is important for FMIs to promote among their participants, service providers and other relevant stakeholders an understanding of the FMIs' resilience objectives, and to require appropriate action to support their implementation. Given the extensive interconnections in the financial system, the cyber resilience of an FMI is in part dependent on that of interconnected FMIs, of service providers and of the participants. Achieving effective solutions may require FMIs to collaborate with their stakeholders as they seek to strengthen their own cyber resilience. Efforts to coordinate the design of resilience solutions may bring enhanced strategies forward in a more timely and efficient way. The outcome of such collaboration should be considered in their individual and collective strategic planning. Because the cyber resilience of FMIs supports broader financial stability objectives and in light of significant interdependencies in clearing and settlement processes, it is important for authorities to cooperate, recognising that such cooperation may help authorities consider, where appropriate, consistency of direction in their oversight and supervision of both FMIs and their relevant stakeholders. Moreover, authorities and FMIs may need to call upon technology companies and other firms to help identify and develop efficient and effective solutions.

1.3.4 *Swift and sustained actions to enhance cyber resilience.* The escalating cyber threat environment makes it important for FMIs to apply this Guidance immediately after its publication. Given FMIs' systemic importance and extensive interconnections, and hence potential for risk contagion between FMIs and entities within their ecosystems, FMIs should take appropriate, swift and sustained actions to enhance their cyber resilience. Nonetheless, it is recognised that FMIs may be at different levels of cyber resilience capability, and enhancing resilience could take time. Particularly in the area of resuming operations within two hours (2hRTO) following extreme cyber attacks, concerted redesign strategies with relevant stakeholders over a reasonable and definite time period may be needed to achieve the necessary improvements. Therefore, within twelve months of the publication of this Guidance, FMIs should develop concrete plans to improve their capabilities in order to meet the two-hour RTO, consistent with the PFMI and as discussed in Chapter 6 of this Guidance.

1.3.5 *Ongoing efforts to improve FMIs' cyber resilience.* Observing this Guidance is not a once only undertaking. On the contrary, FMIs should make ongoing efforts to adapt, evolve and improve their cyber resilience, to increase the level of difficulty for perpetrators to carry out exploits, and to improve the FMIs' capabilities to resume critical operations and recover from successful cyber attacks (see Chapter 9, "Learning and evolving"). In order to achieve resilience objectives, investments across the guidance categories included in this document can be mutually reinforcing and should be considered jointly.

1.3.6 *Risk-based approach.* Components of an FMI's ICT environment and entities within its ecosystem are not of equal criticality to its operations. Each component of an FMI's ICT environment may be impacted to varying degrees by different cyber risk types. The cyber risks posed by an FMI's participants, linked FMIs, service providers, and vendors will vary, and not necessarily related to the degree of that entity's relevance to the FMI's business. As such, an FMI should adopt a risk-based approach in applying this guidance, and prioritise its risk mitigation efforts such that risk mitigating measures implemented are commensurate with the various levels of cyber risk it faces.

1.3.7 *Guidance implementation in the context of the relevant legal framework.* The guidance is also pertinent to relevant regulatory, supervisory and oversight authorities as they carry out their responsibilities. It is recognised that FMIs will need to implement the Guidance consistent with applicable laws and regulations. Together with institutional differences, this may determine how the Guidance is adopted to achieve the intended results.

2. Governance

2.1 Preamble

Cyber governance refers to the arrangements an FMI has put in place to establish, implement and review its approach to managing cyber risks. Effective cyber governance should start with a clear and comprehensive cyber resilience framework that prioritises the security and efficiency of the FMI's operations, and supports financial stability objectives. The framework should be guided by an FMI's cyber resilience strategy, define how the FMI's cyber resilience objectives are determined, and outline its people, processes and technology requirements for managing cyber risks and timely communication, in order to enable an FMI to collaborate with relevant stakeholders to effectively respond to and recover from cyber attacks. It is essential that the framework is supported by clearly defined roles and responsibilities of the FMI's board (or equivalent) and its management, and it is incumbent upon its board and management to create a culture which recognises that staff at all levels have important responsibilities in ensuring the FMI's cyber resilience.

Strong cyber governance is essential to an FMI's implementation of a systematic and proactive approach to managing the prevailing and emerging cyber threats that it faces. It also supports efforts to appropriately consider and manage cyber risks at all levels within the organisation and to provide appropriate resources and expertise to deal with these risks. This chapter provides guidance on what basic elements an FMI's cyber resilience framework should include and how an FMI's governance arrangements should support that framework.

2.2 Cyber resilience framework

2.2.1 *Cyber resilience framework.* An FMI should have a framework that clearly articulates how it determines its cyber resilience objectives and cyber risk tolerance, as well as how it effectively identifies, mitigates, and manages its cyber risks to support its objectives. The FMI's board should endorse this framework, ensuring it is aligned with the FMI's formulated cyber resilience strategy. The FMI's cyber resilience framework should support financial stability objectives while ensuring the ongoing efficiency, effectiveness and economic viability of its services to its users. Therefore, framework objectives should aim to maintain and promote the FMI's ability to anticipate, withstand, contain and recover from cyber attacks, so as to limit the likelihood or impact of a successful cyber attack on its operations or on the broader financial system. The FMI's cyber resilience framework should be reviewed and updated periodically to ensure that it remains relevant.

2.2.2 *Cyber is more than just ICT.* The strategies and measures in an FMI's cyber resilience framework should not be restricted to securing the viability of its information technology operations alone, but should also cover people and processes. The framework should, in addition, include timely communication to enable the FMI to collaborate with relevant stakeholders to effectively respond to and recover from cyber attacks, whether on the FMI or on the financial system as a whole.

2.2.3 *Enterprise risk management.* At the broader level, the FMI's cyber resilience framework should be consistent with its enterprise operational risk management framework. Such consistency is important, and recognises that an FMI's cyber resilience framework is likely to share common elements with the policies, procedures and controls that it has established to manage other areas of risks. For example, limiting physical access can be a key control to address the risk to critical ICT infrastructure.

2.2.4 *An FMI's ecosystem.* An FMI should take an integrated and comprehensive view of the potential cyber threats it faces. In particular, an FMI's cyber resilience framework should consider how the FMI would regularly review and actively mitigate the cyber risks that it bears from and poses to its participants, other

FMI, vendors, vendor products and its service providers, which are collectively referred to in this document as an FMI's ecosystem.

2.2.5 *International and national standards.* There are many relevant international, national and industry-level standards, guidelines or recommendations that an FMI could use as a benchmark in designing its cyber resilience framework. Given FMIs' systemic importance, they should align themselves with leading standards, guidelines or recommendations, reflecting current industry best approaches in managing cyber threats, and incorporate the most effective cyber resilience solutions.

2.2.6 *Risk management governance.* An FMI's cyber resilience framework should clearly define the roles and responsibilities including accountability for decision making within the organisation for managing cyber risk, including in emergencies and in a crisis.

2.2.7 *Audits and compliance.* An FMI's internal processes should help the board and senior management assess and measure the adequacy and effectiveness of the FMI's cyber resilience framework. The adequacy of and adherence to an FMI's cyber resilience framework should be assessed and measured regularly through independent compliance programmes and audits carried out by qualified individuals. To assess and measure the effectiveness of its cyber resilience framework, an FMI is encouraged to use relevant metrics and maturity models as well as the results of its testing programme.⁹

2.3 Role of the board and senior management

2.3.1 *Board and senior management responsibilities.* An FMI's board is ultimately responsible for setting the cyber resilience framework and ensuring that cyber risk is effectively managed. The Board should endorse the FMI's cyber resilience framework, and set the FMI's tolerance for cyber risk. The board should be regularly apprised of the FMI's cyber risk profile to ensure that it remains consistent with the FMI's risk tolerance as well as the FMI's overall business objectives. As part of this responsibility, the board should consider how material changes to the FMI's products, services, policies or practices, and the threat landscape affect its cyber risk profile. Senior management should closely oversee the FMI's implementation of its cyber resilience framework, and the policies, procedures and controls that support it.

2.3.2 *Culture.* An FMI's board and senior management should cultivate a strong level of awareness of and commitment to cyber resilience. To that end, an FMI's board and management should promote a culture that recognises that staff at all levels have important responsibilities in ensuring the FMI's cyber resilience, and lead by example.

2.3.3 *Skills.* In order for the board and senior management to have effective oversight of the FMI's cyber resilience framework and cyber risk profile, both groups should contain members with the appropriate skills and knowledge to understand and manage the risks posed by cyber threats, while ensuring that those skills remain current.

2.3.4 *Accountability.* In view of FMIs' growing reliance on ICT systems to support their businesses and operations, and the increasing cyber threat, FMIs should designate a senior executive to be responsible and accountable for executing the cyber resilience framework within the organisation. This role should have sufficient authority, independence, resources and access to the board. The senior executive performing this role should possess the requisite expertise and knowledge to competently plan and execute the cyber resilience initiatives.

⁹ See Chapter 7, "Testing", and paragraph 9.3.1 in the "Learning and evolving" chapter.

3. Identification

3.1 Preamble

Given that an FMI's operational failure can negatively impact financial stability, it is crucial that FMIs identify which of their critical operations and supporting information assets should, in order of priority, be protected against compromise. The ability of an FMI to understand its internal situation and external dependencies is key to being able to effectively respond to potential cyber threats that might occur. This requires an FMI to know its information assets and understand its processes, procedures, systems and other dependencies to strengthen its overall cyber resilience posture. This chapter outlines areas where an FMI should identify and classify business processes and information assets as well as external dependencies.

3.2 Identification and classification¹⁰

3.2.1 *Identification of business functions and processes.* An FMI should identify its business functions and supporting processes and conduct a risk assessment in order to ensure that it thoroughly understands the importance of each function and supporting processes, and their interdependencies, in performing its functions. Identified business functions and processes should then be classified in terms of criticality, which in turn should guide the FMI's prioritisation of its protective, detective, response and recovery efforts.

3.2.2 *Identification of information assets and related access.* Similarly, an FMI should identify and maintain a current inventory of its information assets and system configurations, including interconnections with other internal and external systems, in order to know at all times the assets that support its business functions and processes. An FMI should carry out a risk assessment of those assets and classify them in terms of criticality. It should identify and maintain a current log of both individual and system credentials to know the access rights to information assets and their supporting systems, and should use this information to facilitate identification and investigation of anomalous activities.

3.2.3 *Regular review and update.* An FMI should integrate identification efforts with other relevant processes, such as acquisition and change management, in order to facilitate a regular review of its list of critical business processes, functions, individual and system credentials and its inventory of information assets so that that they remain current, accurate and complete.

3.3 Interconnections

Impact from and on an FMI's ecosystem. An FMI's systems and processes are directly or indirectly interconnected with the systems and processes of the entities within its ecosystem, eg participants, linked FMIs, settlement banks, liquidity providers, service providers, critical infrastructure such as energy and telecommunications, vendors and vendor products. Consequently, the cyber resilience of those entities could have significant implications in terms of the cyber risk that the FMI faces, particularly since the significance of the risks they may pose is not necessarily proportionate to the criticality of their business relationship with the FMI. Therefore, an FMI should identify the cyber risks that it bears from and poses to entities in its ecosystem and coordinate with relevant entities, as appropriate, as they design and implement resilience efforts with the objective of improving the overall resilience of the ecosystem.

¹⁰ See PFMI 3, Key Consideration 1.

4. Protection

4.1 Preamble

Cyber resilience depends on effective security controls and system and process design that protect the confidentiality, integrity and availability of an FMI's assets and services. These measures should be proportionate to an FMI's threat landscape and systemic role in the financial system, and consistent with its risk tolerance. This chapter provides guidance on how FMIs should implement appropriate and effective measures in line with leading cyber resilience and information security practices to prevent, limit or contain the impact of a potential cyber event.

4.2 Protection of processes and assets

4.2.1 *Controls.* An FMI should implement appropriate protective controls that are in line with leading-practice cyber resilience standards to minimise the likelihood and impact of a successful cyber attack on identified critical business functions, information assets and data. Protective controls should be proportionate to the FMI's threat landscape and systemic role in the financial system, and consistent with its risk tolerance.

4.2.2 *Resilience by design.* An FMI should consider cyber resilience from the ground up during system, process, and product design. A process to instil resilience by design should ensure that, among other measures, software, network configurations, and hardware supporting or connected to critical systems are subject to rigorous testing against related security standards, that attack surfaces are limited to the extent practicable, and that common information security principles relating to confidentiality, integrity and availability are adhered to (eg, ensuring that access to systems is restricted to those with a legitimate business requirement).

4.2.3 *Strong ICT controls.* FMIs should consistently maintain a strong ICT control environment, this being a fundamental and critical component of an FMI's overall cyber resilience. While ICT controls are not the focus of this guidance, a few important but non-exhaustive examples are provided below:

- a. Protecting information. Implementing appropriate measures to protect information (both in transit and at rest), commensurate with the criticality and sensitivity of the information held by and transmitted through the FMI. This should include, but not be restricted to, appropriate encryption (eg, end-to-end encryption), authentication (eg, multifactor authentication) and access control.
- b. Change management. Ensuring that the FMI has a comprehensive change management process that explicitly considers cyber risks, in terms of residual cyber risks identified both prior to and during a change, and of any new cyber risk created post-change. Ensuring that a process exists to identify patches to technology and software assets, evaluate the patch criticality and risk, and test and apply the patch within an appropriate time frame.
- c. Security settings consistent with levels of protection. Configuring ICT systems and devices with security settings that are consistent with the expected level of protection. FMIs should establish baseline system security configuration standards to facilitate consistent application of security settings to operating systems, databases, network devices and enterprise mobile devices within the ICT environment. Regular enforcement checks should also be performed to ensure that non-compliance with such standards is promptly rectified.

4.2.4 *Layered protection that facilitates response and recovery.* An FMI's protective controls should enable the monitoring and detection of anomalous activity across multiple layers of the FMI's infrastructure, which requires a baseline profile of system activity. Controls should be implemented in a

way that will assist in monitoring for, detecting, containing and analysing anomalous activities should protective measures fail. For example, (re-)designing processes to introduce more segmentation, intermediate checkpoints and intermediate reconciliations may allow quicker detection, identification and repair/recovery from a disruption. Similarly, segmenting networks in a manner that segregates systems and data of varying criticality may have multiple benefits, both by helping the FMI to insulate systems in one segment from a security compromise in other segments, and by facilitating more efficient recovery of services. The latter benefit is achieved because, in the event of such a compromise, only the affected segments have to be restored, rather than the entire ICT infrastructure and all data sets.

4.3 Interconnections

4.3.1 *Risks from interconnections.* An FMI should implement protective measures to mitigate risks arising from the entities within its ecosystem. The appropriate controls for each entity will depend on the risk that arises from the connected entity and the nature of the relationship with the entity. In view of its systemic importance and unique position in the financial system, an FMI should implement measures to mitigate effectively the risk arising from its connected entities, including the following:

- a. An FMI's participation requirements should be designed to ensure that they adequately support its cyber resilience framework.
- b. The FMI's framework to manage its relationship with service providers should address and be designed to mitigate cyber risks. At a minimum, an FMI should ensure that its outsourced services are accorded the same level of cyber resilience needed if their services were provided by the FMI itself. Cyber considerations should be integral part of the FMI's arrangements for managing vendors and vendor products in the areas of contracts, performance, relationships and risk. Contractual agreements between the FMI and its service providers should ensure that the FMI and relevant authorities are provided with or have full access to the information necessary to assess the cyber risk arising from the service provider.

4.4 Insider threats

4.4.1 *Security analytics.* An FMI should implement measures to capture and analyse anomalous behaviour by persons with access to its systems. Data loss identification and prevention techniques should be employed to protect against the removal of confidential data from the FMI's network.

4.4.2 *Changes in employment status.* An FMI should conduct screening/background checks on new employees to mitigate insider threats. Similar checks should be conducted on all staff at regular intervals throughout their employment, commensurate with staff's access to critical systems. FMIs also should establish processes and controls to mitigate risks related to employees terminating employment or changing responsibilities.

4.4.3 *Access control.* Physical and logical access to systems should be permitted only for individuals who are authorised, and authorisation should be limited to individuals who are appropriately trained and monitored. FMIs should institute controls that reliably restrict such access to systems to those with a legitimate business requirement. In particular, FMIs should institute strong controls over privileged system access by strictly limiting and closely supervising staff with elevated system access entitlements. Controls such as roles-based access, logging and reviewing of the systems activities of privileged users, strong authentication, and monitoring for anomalies should be implemented.

4.5 Training

4.5.1 *FMI staff.* An FMI should ensure that all relevant staff, be they permanent or temporary, receive training to develop and maintain appropriate awareness of and competencies for detecting and addressing cyber-related risks. They should also be trained on how to report any unusual activity and incidents.

4.5.2 *High-risk groups.* High-risk groups, such as those with privileged system access or in sensitive business functions, should be identified and should receive targeted information security training.

5. Detection

5.1 Preamble

An FMI's ability to recognise signs of a potential cyber incident, or detect that an actual breach has taken place, is essential to strong cyber resilience. Early detection provides an FMI with useful lead time to mount appropriate countermeasures against a potential breach, and allows proactive containment of actual breaches. In the latter case, early containment could effectively mitigate the impact of the attack – for example, by preventing an intruder from gaining access to confidential data or exfiltration of such data. Given the stealthy and sophisticated nature of cyber attacks and the multiple entry points through which a compromise could take place, an FMI should maintain effective capabilities to extensively monitor for anomalous activities. This chapter outlines monitoring- and process-related guidance aimed at helping FMIs detect cyber incidents.

5.2 Detecting a cyber attack

5.2.1 *Continuous monitoring.* An FMI should establish capabilities to continuously monitor (in real time or near real time) and detect anomalous activities and events. One practice that may help to accomplish this is to set up what is commonly referred to as a "security operations centre". These capabilities should be adaptively maintained and tested.

5.2.2 *Comprehensive scope of monitoring.* An FMI should monitor relevant internal and external factors, including business line and administrative functions and transactions. The FMI should seek to detect both publicly known vulnerabilities and vulnerabilities that are not yet publicly known, such as so-called zero-day exploits, through a combination of signature monitoring for known vulnerabilities and behaviourally based detection mechanisms. Detection capabilities should also address misuse of access by service providers or other trusted agents, potential insider threats and other advanced threat activity. These processes should be informed by and integrated with a strong cyber threat intelligence programme (see paragraphs 8.2.1 and 8.2.2 below).

5.2.3 *Layered detection.* The ability to detect an intrusion early is critical for swift containment and recovery. FMIs should take a defence-in-depth approach by instituting multi-layered detection controls covering people, processes and technology, with each layer serving as a safety net for preceding layers. As a cyber attack typically progresses in a sequence of stages before attaining its end objective, FMIs should also apply approaches that enable them to delay or disrupt the attackers' ability to advance within the attack sequence. In addition, an effective intrusion detection capability could assist FMIs in identifying deficiencies in their protective measures for early remediation.

5.2.4 *Incident response.* An FMI's monitoring and detection capabilities should facilitate its incident response process and support information collection for the forensic investigation process.

5.2.5 *Security analytics.* An FMI should implement measures to capture and analyse anomalous behaviour by persons with access to the corporate network.

6. Response and recovery

6.1 Preamble

Financial stability may depend on an FMI's ability to settle obligations when they are due. Therefore, an FMI's arrangements should be designed to enable it to resume critical operations rapidly, safely and with accurate data in order to mitigate the potentially systemic risks of failure to meet such obligations when participants are expecting it to meet them. Continuity planning is essential in meeting related objectives. This chapter provides guidance on an FMI's capabilities to respond to and recover from cyber attacks.

6.2 Incident response, resumption and recovery

6.2.1 *Incident response planning.* Upon detection of a successful cyber attack or an attack attempt, FMIs should perform a thorough investigation to determine its nature and extent as well as the damage inflicted. While the investigation is ongoing, FMIs should also take immediate actions to contain the situation to prevent further damage and commence recovery efforts to restore operations based on their response planning.

6.2.2 *Resumption within two hours (ie two-hour RTO).* Objectives for resuming operations set goals for, ultimately, the sound functioning of the financial system, which should be planned for and tested against. In line with Key Consideration 17.6 of the PFMI, an FMI should, design and test its systems and processes to enable the safe resumption of critical operations within two hours of a disruption and to enable itself to complete settlement by the end of the day of the disruption, even in the case of extreme but plausible scenarios. Notwithstanding this capability to resume critical operations within two hours, FMIs should exercise judgment in effecting resumption so that risks to itself or its ecosystem do not thereby escalate, while taking into account that completion of settlement by the end of day is crucial.

6.2.3 *Contingency planning.* While FMIs should plan to safely resume critical operations within two hours of a disruption, they should also plan for scenarios in which this objective is not achieved. FMIs should analyse critical functions, transactions and interdependencies to prioritise resumption and recovery actions, which may, depending on the design of the FMI, facilitate the processing of critical transactions, for example, while remediation efforts continue. FMIs should also plan for situations where critical people, processes or systems may be unavailable for significant periods – for example, by potentially reverting, where feasible, safe and practicable, to manual processing if automated systems are unavailable.

6.2.4 *Planning and preparation.* FMIs should develop and test response, resumption and recovery plans. These plans should support objectives to protect and, if necessary, re-establish integrity and availability of its operations, and the confidentiality of its information assets. Plans should be actively updated based on current cyber threat intelligence, information-sharing and lessons learned from previous events, as well as analysis of operationally and technically plausible scenarios that have not yet occurred. The FMI should consult and coordinate with relevant internal and external stakeholders during the establishment of its response, resumption and recovery plans.

6.3 Design elements

6.3.1 *Design and business integration.* System and process design and controls for critical functions and operations should support incident response activities to the extent possible. FMIs should design systems and processes to limit the impact of any cyber incident, resume critical operations within two hours of a disruption, complete settlement by day-end and preserve transaction integrity. The possibility to resume critical operations in a system that is technically different from the primary system or in a system that performs those operations and completes settlement in a non-standardised way may be among the

options for an FMI to consider. An FMI's incident response, resumption and recovery processes should be closely integrated with crisis management, business continuity and disaster recovery planning and recovery operations, and coordinated with relevant internal and external stakeholders.

6.3.2 *Data integrity.* FMIs should have plans to identify, in a timely manner, the status of all transactions and member positions at the time of a disruption, supported by corresponding recovery point objectives. Therefore, FMIs should design and test their systems and processes to enable recovery of accurate data following a breach. Data instances should be safeguarded by stringent protective and detective controls. In addition, the FMI's cyber resilience framework should include data recovery measures, such as keeping a copy of all received and processed data (including the original intent of instructions being sent to the FMI for processing), maintaining transaction replay capability and conducting frequent periodic independent reconciliation of participants' positions. Recovery point objectives to support data integrity efforts should be consistent with the FMI's resumption time objective for critical operations. FMI's should consider diverse approaches to achieving these objectives.

6.4 Interconnections

6.4.1 *Data-sharing agreements.* In the event of a successful cyber attack that compromises the integrity of an FMI's data, a successful recovery may require obtaining uncorrupted data from third parties and/or participants. FMIs should consider setting up data-sharing agreements with relevant third parties or participants in advance in order to enable such uncorrupted data to be received in a timely manner once a successful cyber attack has been identified.

6.4.2 *Contagion.* Because an FMI's systems and processes are often interconnected with the systems and processes of other entities within its ecosystem, in the event of a large-scale cyber incident it is possible for an FMI to pose contagion risk (ie, propagation of malware or corrupted data) to, or be exposed to contagion risk from, its ecosystem. An FMI should work together with its interconnected entities to enable the resumption of operations (the first priority being its critical services) as soon as it is safe and practicable to do so without causing unnecessary risk to the wider sector or further detriment to financial stability.

6.4.3 *Crisis communication.* FMIs should plan in advance for communications with participants, interdependent FMIs, authorities and others (such as service providers and, where relevant, the media). Communication plans should be developed through an adaptive process informed by scenario-based planning and analysis as well as prior experience. Because rapid escalation of cyber incidents may be necessary, FMIs should determine decision-making responsibilities for incident response in advance, and implement clearly defined escalation and decision-making procedures. FMIs should inform relevant oversight and regulatory authorities promptly of potentially material or systemic events.

6.4.4 *Responsible disclosure policy.* FMIs should have a policy and procedure to enable the responsible disclosure of potential vulnerabilities. . In particular, FMIs should prioritise disclosures that could facilitate early response and risk mitigation by stakeholders for the benefit of the ecosystem and broader financial stability, following the possible approaches outlined in paragraph 8.3.2 below.

6.4.5 *Forensic readiness.* FMIs should have the capability to assist in or conduct forensic investigations of cyber incidents and engineer protective and detective controls to facilitate the investigative process. In this regard, FMIs should establish relevant system logging policies that include the types of logs to be maintained and their retention periods. While forensic analysis may need to be postponed, eg in the event of contagion giving rise to financial stability concerns, and ICT resources may be focused on recovering critical systems, FMIs should take appropriate steps so that investigations can still be performed post-event to the extent possible, eg through preservation of necessary system logs and evidence.

7. Testing

7.1 Preamble

Testing is an integral component of any cyber resilience framework. All elements of a cyber resilience framework should be rigorously tested to determine their overall effectiveness before being deployed within an FMI, and regularly thereafter. This includes the extent to which the framework is implemented correctly, operating as intended and producing desired outcomes. Understanding the overall effectiveness of the cyber resilience framework in the FMI and its environment is essential in determining the residual cyber risk to the FMI's operations, assets, and ecosystem.

Sound testing regimes produce findings that are used to identify gaps in stated resilience objectives and provide credible and meaningful inputs to the FMI's cyber risk management process. Analysis of testing results provides direction on how to correct weaknesses or deficiencies in the cyber resilience posture and reduce or eliminate identified gaps. This chapter provides guidance on areas that should be included in an FMI's testing and how results from testing can be used to improve the FMI's cyber resilience posture on an ongoing basis. The scope of testing for the purpose of this guidance includes vulnerability assessments, scenario-based testing, penetration tests and tests using red teams.

7.2 Comprehensive testing programme

7.2.1 *Testing programme.* An FMI should establish a comprehensive testing programme to validate the effectiveness of its cyber resilience framework on a regular and frequent basis. It should employ appropriate cyber threat intelligence to inform its testing methods – for example, by designing tests to simulate advanced threat agent capabilities and extreme but plausible scenarios. The results of the testing programme should be used by the FMI to support the ongoing improvement of its cyber resilience. Where applicable, these tests should include both internal and external stakeholders such as business line management including business continuity, incident and crisis response teams, and the relevant entities in its ecosystem. An FMI should involve its board and senior management appropriately (eg, as part of crisis management teams) and inform them of test results.

7.2.2 *Methodologies and practices.* FMIs should employ a variety of effective testing methodologies and practices, including the following (which may partly overlap or be combined):

- a. *Vulnerability assessment (VA).* FMIs should regularly perform vulnerability assessments to identify and assess security vulnerabilities in their systems and processes. FMIs should establish a process to prioritise and remedy issues identified in VAs and perform subsequent validation to assess whether gaps have been fully addressed.
- b. *Scenario-based testing.* An FMI's response, resumption and recovery plans should be subject to periodic review and testing. Tests should address an appropriately broad scope of scenarios, including simulation of extreme but plausible cyber attacks, and should be designed to challenge the assumptions of response, resumption and recovery practices, including governance arrangements and communication plans. FMIs should use cyber threat intelligence and cyber threat modelling to the extent possible to imitate the unique characteristics of cyber threats. They should also conduct exercises to test the ability of their staff and processes to respond to unfamiliar scenarios, with a view to achieving stronger operational resilience.
- c. *Penetration tests.* FMIs should carry out penetration tests to identify vulnerabilities that may affect their systems, networks, people or processes. To provide an in-depth evaluation of the security of FMIs' systems, those tests should simulate actual attacks on the systems. Penetration tests on internet-facing systems should be conducted regularly and whenever systems are updated or deployed. Where applicable, the tests could include other internal and external

stakeholders, such as those involved in business continuity, incident and crisis response teams, as well as third parties, such as service providers and participants.

- d. *Red team tests.* FMIs should challenge their own organisations and ecosystems through the use of so-called red teams to introduce an adversary perspective in a controlled setting. Red teams serve to test for possible vulnerabilities and the effectiveness of an FMI's mitigating controls. A red team may consist of an FMI's own employees and/or outside experts, who are in either case independent of the function being tested.

7.3 Coordination

7.3.1 *Coordination.* An FMI should, to the extent practicable and possible, promote, design, organise and manage exercises designed to test its response, resumption and recovery plans and processes. Such exercises should include FMI participants, critical service providers and linked FMIs. Where appropriate, FMIs should participate in exercises organised by relevant authorities and in industry-wide tests. Achieving market-wide timely recovery of operations calls for an added dimension to testing exercises. Traditional isolated testing implicitly assumes that all other players operate as usual. Removing that hypothesis helps an FMI to identify plausible complexities, dependencies and weaknesses that may have been overlooked in its recovery plans. Accordingly, testing should include scenarios that cover breaches affecting multiple portions of the FMI's ecosystem.

8. Situational awareness

8.1 Preamble

Situational awareness refers to an FMI's understanding of the cyber threat environment within which it operates, and the implications of being in that environment for its business and the adequacy of its cyber risk mitigation measures. Strong situational awareness, acquired through an effective cyber threat intelligence process can make a significant difference in the FMI's ability to pre-empt cyber events or respond rapidly and effectively to them. Specifically, a keen appreciation of the threat landscape can help an FMI better understand the vulnerabilities in its critical business functions, and facilitate the adoption of appropriate risk mitigation strategies. It can also enable an FMI to validate its strategic direction, resource allocation, processes, procedures and controls with respect to building its cyber resilience. A key means of achieving situational awareness for an FMI and its ecosystem is an FMI's active participation in information-sharing arrangements and collaboration with trusted stakeholders within and outside the industry. This chapter provides guidance for FMIs to establish a cyber threat intelligence process, analysis and sharing processes.

8.2 Cyber threat intelligence

8.2.1 *Identification of potential cyber threats.* An FMI should identify cyber threats that could materially affect its ability to perform or to provide services as expected, or that could have a significant impact on its ability to meet its own obligations or have knock-on effects within its ecosystem. In doing so, an FMI should consider threats to the confidentiality, integrity and availability of the FMI's business processes and to its reputation that could arise from internal and external sources. In addition, an FMI should include in its threat analysis those threats which could trigger extreme but plausible cyber events, even if they are considered unlikely to occur or have never occurred in the past. The FMI should regularly review and update this analysis.

8.2.2 *Threat intelligence process.* An FMI should establish a process to gather and analyse relevant cyber threat information. Its analysis should be in conjunction with other sources of internal and external business and system information so as to provide business-specific context, turning the information into usable cyber threat intelligence that provides timely insights and informs enhanced decision-making by enabling the FMI to anticipate a cyber attacker's capabilities, intentions and modus operandi.

8.2.3 *Scope of cyber threat intelligence gathering.* The scope of cyber threat intelligence gathering should include the capability to gather and interpret information about relevant cyber threats arising from the FMI's participants, service and utility providers and other FMIs, and to interpret this information in ways that allow the FMI to identify, assess and manage security threats and vulnerabilities for the purpose of implementing appropriate safeguards in its systems.¹¹ In this context, relevant cyber threat intelligence could include information on geopolitical developments that may trigger cyber attacks on any entity within the FMI's ecosystem.

8.2.4 *Effective use of information.* FMIs should ensure that cyber threat intelligence is made available to appropriate staff with responsibility for the mitigation of cyber risks at the strategic, tactical and operational levels within the FMI. Cyber threat intelligence should be used to ensure that the implementation of any cyber resilience measures is threat-informed. When properly contextualised, cyber threat information enables an FMI to validate and inform the prioritisation of resources, risk mitigation strategies and training programmes.

¹¹ See PFMI 17, Key Consideration 7: "An FMI should identify, monitor, and manage the risks that key participants, other FMIs, and service and utility providers might pose to its operations."

8.3 Information-sharing

8.3.1 *Planning ahead.* To facilitate sector-wide response to large-scale incidents, FMIs should plan for information-sharing through trusted channels in the event of an incident, collecting and exchanging timely information that could facilitate the detection, response, resumption and recovery of its own systems and those of other sector participants during and following a cyber attack. FMIs should, as part of their response programmes, determine beforehand which types of information will be shared, with whom, and how information provided to the FMI will be acted upon. Reporting requirements and capabilities should be consistent with information-sharing arrangements within the FMI's communities and the financial sector.

8.3.2 *Information-sharing groups.* FMIs should participate actively in information-sharing groups and collectives, including cross-industry, cross-government and cross-border groups to gather, distribute and assess information about cyber practices, cyber threats and early warning indicators relating to cyber threats. FMIs should, where appropriate, share information both bilaterally and multilaterally. As appropriate, an FMI should consider exchanging information on its cyber resilience framework bilaterally with trusted stakeholders so as to promote understanding of each other's approach to securing systems that are linked or interfaced. Such information exchange would facilitate an FMI's and its stakeholders' efforts at dovetailing their respective security measures to achieve greater cyber resilience. Multilateral information-sharing arrangements should be designed to facilitate a sector-wide response to large-scale incidents.

9. Learning and evolving

9.1 Preamble

An FMI's cyber resilience framework needs to achieve continuous cyber resilience amid a changing threat environment. To be effective in keeping pace with the rapid evolution of cyber threats, an FMI should implement an adaptive cyber resilience framework that evolves with the dynamic nature of cyber risks and allows the FMI to identify, assess and manage security threats and vulnerabilities for the purpose of implementing appropriate safeguards into its systems.¹² An FMI should aim to instil a culture of cyber risk awareness whereby its resilience posture, at every level, is regularly and frequently re-evaluated.

9.2 Ongoing learning

9.2.1 *Lessons from cyber events.* An FMI should systematically identify and distil key lessons from cyber events that have occurred within and outside the organisation in order to advance its resilience capabilities. Useful learning points can often be gleaned from successful cyber intrusions and near misses in terms of the methods used and vulnerabilities exploited by cyber attackers.

9.2.2 *Acquiring new knowledge and capabilities.* An FMI should actively monitor technological developments and keep abreast of new cyber risk management processes that can effectively counter existing and newly developed forms of cyber attack. An FMI should consider acquiring such technology and know-how to maintain its cyber resilience.

9.2.3 *Predictive capacity.* FMIs' cyber risk management practices should go beyond reactive controls and include proactive protection against future cyber events. Predictive capabilities and anticipation of future cyber events are based on analysing activity that deviates from the baseline. FMIs should work towards achieving predictive capabilities, capturing data from multiple internal and external sources, and defining a baseline for behavioural and system activity.

9.3 Cyber resilience benchmarking

9.3.1 *Metrics.* Metrics and maturity models allow an FMI to assess its cyber resilience maturity against a set of predefined criteria, typically its operational reliability objectives. This benchmarking requires an FMI to analyse and correlate findings from audits, management reviews, incidents, near misses, tests and exercises as well as external and internal intelligence gathered. The use of metrics can help an FMI to identify gaps in its cyber resilience framework for remediation, and allow an FMI to systematically evolve and achieve more mature states of cyber resilience.

¹² See PFMI 17, Key Consideration 7: "An FMI should identify, monitor, and manage the risks that key participants, other FMIs, and service and utility providers might pose to its operations."

Annex A - Glossary¹³

actionable intelligence	Information that can be acted upon to address, prevent or mitigate a cyber threat.
attack surface	<p>The sum of an information system's characteristics in the broad categories (software, hardware, network, processes and human) which allows an attacker to probe, enter, attack or maintain a presence in the system and potentially cause damage to an FMI. A smaller attack surface means that the FMI is less exploitable and an attack less likely.¹⁴</p> <p>However, reducing attack surfaces does not necessarily reduce the damage an attack can inflict.¹⁵</p>
availability	The property of being accessible and usable as expected upon demand. ¹⁶
business process	<p>A collection of linked activities that takes one or more kinds of input and creates an output that is of value to an FMI's stakeholders. A business process may comprise several assets, including information, ICT resources, personnel, logistics and organisational structure, which contribute either directly or indirectly to the added value of the service.</p> <p>Any activity, function, process, or service, the loss of which, for even a short period of time, would materially affect the continued operation of an FMI, its participants, the market it serves, and/or the broader financial system.</p>
critical operations	
cyber	Refers to the interconnected information infrastructure of interactions among persons, processes, data, and information and communications technologies, along with the environment and conditions that influence those interactions. ¹⁷
cyber attack	The use of an exploit by an adversary to take advantage of a weakness(es) with the intent of achieving an adverse effect on the ICT environment. ¹⁸
cyber event	An observable occurrence in an information system or network. ¹⁹
cyber governance	Arrangements an organisation puts in place to establish, implement and review its approach to managing cyber risks.
cyber maturity model	A mechanism to have cyber resilience controls, methods and processes assessed according to management best practice, against a clear set of external benchmarks. ²⁰

¹³ For general definitions of terms not found in this glossary, please see CPMI, *Glossary of payments and market infrastructure terminology*, <https://www.bis.org/cpmi/publ/d00b.htm>; CPSS, *A glossary of terms used in payments and settlement systems*, March 2003; and European Central Bank and Eurosystem, *Glossary of terms related to payment, clearing, and settlement systems*, December 2009.

¹⁴ NICCS, *Glossary of common cybersecurity terminology*, <http://niccs.us-cert.gov/glossary>.

¹⁵ CPMI, *Cyber resilience in financial market infrastructures*, November 2014.

¹⁶ NICCS, *Glossary of common cybersecurity terminology*, <http://niccs.us-cert.gov/glossary>.

¹⁷ NICCS, *Glossary of common cybersecurity terminology*, <http://niccs.us-cert.gov/glossary>.

¹⁸ Adapted from MITRE definition of "attack". <https://capec.mitre.org/about/glossary.html>

¹⁹ NICCS, *Glossary of common cybersecurity terminology*, <http://niccs.us-cert.gov/glossary>.

²⁰ Adapted from APMG International Definition, <http://www.apmg-international.com/en/consulting/what-maturity-model.aspx>.

cyber resilience	An FMI's ability to anticipate, withstand, contain and rapidly recover from a cyber attack.
cyber resilience framework	Consists of the policies, procedures and controls an FMI has established to identify, protect, detect, respond to and recover from the plausible sources of cyber risks it faces.
cyber resilience strategy	An FMI's high level principles and medium term plans to achieve its objective of managing cyber risks.
cyber risk	The combination of the probability of an event occurring within the realm of an organisation's information assets, computer and communication resources and the consequences of that event for an organisation.
cyber risk management	The process used by an FMI to establish an enterprise-wide framework to manage the likelihood of a cyber attack and develop strategies to mitigate, respond to, learn from and coordinate its response to the impact of a cyber attack. The management of an FMI's cyber risk should support the business processes and be integrated in the FMI's overall risk management framework.
cyber risk profile	The cyber risk actually assumed, measured at a given point in time.
cyber risk tolerance	The propensity to incur cyber risk, being the level of cyber risk that an FMI intends to assume in pursuing its strategic objectives.
cyber threat	A circumstance or event with the potential to intentionally or unintentionally exploit one or more vulnerabilities in an FMI's systems, resulting in a loss of confidentiality, integrity or availability.
cyber threat intelligence	Information that provides relevant and sufficient understanding for mitigating the impact of a potentially harmful event (may also be referred to as "cyber threat information"). ²¹
defence in depth	The security controls deployed throughout the various layers of the network to provide for resiliency in the event of the failure or the exploitation of a vulnerability of another control (may also be referred to as "layered protection").
detection	Development and implementation of the appropriate activities in order to identify the occurrence of a cyber event. ²²
disruption	A disruption is an event affecting an organisation's ability to perform its critical operations.
ecosystem	A system or group of interconnected elements, formed linkages and dependencies. For an FMI, this may include participants, linked FMIs, service providers, vendors and vendor products.
financial market infrastructure	A multilateral system among participating institutions, including the operator of the system, used for the purposes of clearing, settling or recording payments, securities, derivatives or other financial transactions.
forensic investigation	The application of investigative and analytical techniques to gather and preserve evidence from a digital device impacted by a cyber attack.

²¹ Bank of England – CBEST, *Qualities of a threat intelligence provider*.

²² NIST, *Framework for improving critical infrastructure cybersecurity*, <http://www.nist.gov/cyberframework/upload/cybersecurity-framework-021214.pdf>.

forensic readiness	The ability of an FMI to maximise the use of digital evidence to identify the nature of a cyber attack.
ICT	Information and communications technologies. ICT can also be read as IT (information technology) in this document.
identification	To develop the organisational understanding required to manage cyber risk to systems, assets, data and capabilities. ²³
indicator	An occurrence or sign which reveals that an incident may have occurred or be in progress. ²⁴
information asset	Any piece of data, device or other component of the environment that supports information-related activities. In the context of this report, information assets include data, hardware and software. ²⁵ Information assets are not limited to those that are owned by the entity. They also include those that are rented or leased, and those that are used by service providers to deliver their services.
integrity	With reference to information, an information system or a component of a system, the property of not having been modified or destroyed in an unauthorised manner. ²⁶
layered protection	As relying on any single defence against a cyber threat may be inadequate, an FMI can use a series of different defences to cover the gaps in and reinforce other protective measures. For example, the use of firewalls, intrusion detection systems, malware scanners, integrity auditing procedures and local storage encryption tools can serve to protect information assets in a complementary and mutually reinforcing manner. May also be referred to as “defence in depth”.
leading standards, guidelines and practices	Standards, guidelines and practices which reflect industry best approaches to managing cyber threats, and which incorporate what are generally regarded as the most effective cyber resilience solutions.
malware	Malicious software used to disrupt the normal operation of an information system in a manner that adversely impacts its confidentiality, availability or integrity.
operational resilience	The ability of an FMI to: (i) maintain essential operational capabilities under adverse conditions or stress, even if in a degraded or debilitated state; and (ii) recover to effective operational capability in a time frame consistent with the provision of critical economic services.
protection	Development and implementation of appropriate safeguards, controls and measures to enable reliable delivery of critical infrastructure services.
recover	To restore any capabilities or services that have been impaired due to a cyber event.

²³ NIST, *Framework for improving critical infrastructure cybersecurity*, <http://www.nist.gov/cyberframework/upload/cybersecurity-framework-021214.pdf>.

²⁴ NICCS, *Glossary of common cybersecurity terminology*, <http://niccs.us-cert.gov/glossary>.

²⁵ UK National Archives, *What is an information asset?*, <http://www.nationalarchives.gov.uk/documents/information-management/information-assets-factsheet.pdf>.

²⁶ NICCS, *Glossary of common cybersecurity terminology*, <http://niccs.us-cert.gov/glossary>.

red team	An independent group that challenges the cyber resilience of an organisation to test its defences and improve its effectiveness. A red team views the cyber resilience of an FMI from an adversary's perspective.
resilience by design	The embedding of security in technology and system development from the earliest stages of conceptualisation and design.
respond	Of an FMI, to develop and implement appropriate activities to be able to take action when it detects a cyber event.
resume	To recommence functions following a cyber incident. An FMI should resume critical services as soon as it is safe and practicable to do so without causing unnecessary risk to the wider sector or further detriment to financial stability. The plan of action should incorporate the use of a secondary site and be designed to ensure that critical ICT systems can resume operations within two hours following a disruptive event.
risk-based approach	An approach whereby FMIs identify, assess and understand the risks to which they are exposed to and take measures commensurate with these risks.
risk tolerance	The amount and type of risk that an organisation is willing to take in order to meet its strategic objectives (may also be referred to as "risk appetite").
security operations centre	A function or service responsible for monitoring, detecting and isolating incidents.
situational awareness	The ability to identify, process and comprehend the critical elements of information through a cyber threat intelligence process that provides a level of understanding that is relevant to act upon to mitigate the impact of a potentially harmful event.
threat	A circumstance or event that has or indicates the potential to exploit vulnerabilities and to adversely impact (create adverse consequences for) organisational operations, organisational assets (including information and information systems), individuals, other organisations or society in general. ²⁷
vulnerability	A weakness, susceptibility or flaw in a system that an attacker can access and exploit to compromise system security. Vulnerability arises from the confluence of three elements: the presence of a susceptibility or flaw in a system; an attacker's access to that flaw; and an attacker's capability to exploit the flaw.

²⁷ NICCS, <http://niccs.us-cert.gov/glossary#letter t>.

Annex B – Members of the Working Group on Cyber Resilience (WGCR)

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