[Translation]

Prepared for and on behalf of Japan Exchange Group, Inc.

Investigation Report

November 30, 2020

The Investigation Committee of Independent Outside Directors in Relation to the System Failure

Contents

Chapter 1 Overview of the Committee and the Investigation

1 Background to the Establishing of the Committee

Due to a system failure that occurred on Thursday, October 1, 2020 (hereinafter "the System Failure") in the arrowhead cash equity trading system (hereinafter "arrowhead") of Tokyo Stock Exchange, Inc. (hereinafter "TSE"), a wholly owned subsidiary of Japan Exchange Group, Inc. (hereinafter "JPX"), auction trading on the cash equities market was suspended for the entire day, an event that had a tremendous impact on investors, market participants, and others.

At a meeting of the JPX Risk Policy Committee[1] that took place the day after the System Failure on Friday, October 2, 2020 it was agreed that, taking into account the importance of the matter, and the public interest element to JPX and TSE operations, it was essential to conduct an investigation into the causes of the system failure and the countermeasures taken at the time, and to raise the effectiveness of various countermeasures to prevent a recurrence based on the conclusions of this investigation. The Risk Policy Committee judged it important and necessary that the investigation be implemented from an independent, neutral and impartial standpoint, and accordingly proposed to the JPX Board of Directors that an Investigation Committee of Independent Outside Directors in Relation to the System Failure (hereinafter "the Committee") be established.

Accordingly, on Monday, October 5, 2020, the Board of Directors of JPX resolved unanimously to establish the Committee.

2 Objectives of the Committee and the Scope of Investigation

The Committee is independent of the executive of JPX and TSE, and includes technical and legal advisors as well as administrative staff. Its objective is to act from an independent, neutral and impartial standpoint to restore trust in JPX among all stakeholders of JPX and in the securities market.

The scope of the investigation is as follows.

(a) Causes of the System Failure

(b) Reasons for being unable to resume trading on the day the System Failure occurred

(c) Locus of responsibility

[1] A committee with at least five members of which a majority consist of independent outside directors, whose objective is to identify risks that JPX should prioritize as "significant risks," and to summarize the results in a comprehensive risk management statement for submission to the Board of Directors, amongst other activities.

(d) Measures to prevent a recurrence

It is not the main objective of the Committee to proactively investigate the course of events related to the System Failure to confirm facts and legal responsibility. For that reason, the descriptions in this report of the course of events related to the occurrence of the System Failure and of the response to it both rely on materials and information provided by JPX and TSE. The primary objective of the Committee's investigation was to evaluate, in response to the opinions and fact-finding of JPX and TSE in relation to the course of events and the cause of the occurrence, matters pertaining to the true cause of the System Failure, the reasonableness of JPX and TSE's handling of the situation before and after, and measures, etc. taken to prevent recurrence, and to make recommendations. The scope of the investigation also included the after-the-fact verification, evaluation and assessment of the methods and content of investigations carried out by JPX, TSE, and Fujitsu Limited (hereinafter "Fujitsu").[2]

Furthermore, although the Committee is not a so-called "independent committee," it complied as closely as possible to the Japan Federation of Bar Associations' "Guidelines for Independent Committees in Relation to Corporate Misconduct," and its approach during the investigation was that the client was the whole of society and the market mechanism itself.

3 Composition of the Committee

The core of the Committee is made up of independent outside directors[3] who are members of the JPX Risk Policy Committee and Audit Committee, which are particularly closely associated with the objective and subject of the Committee.

JPX has adopted the structure of a company with three committees (nomination, audit and compensation), and nine out of its 14 directors are independent outside directors who have expertise across a wide range of fields. The Board of Directors therefore judged that it would be possible for the investigation into the System Failure to be conducted from a neutral and objective standpoint,

[2] In addition to supplying products such as hardwares, Fujitsu, which was the development vendor of arrowhead, was entrusted with post-deployment development, maintenance, and service operations.

[3] Outside directors who are independent of company management and for whom there is no danger of a conflict of interests with general shareholders.

independent of the executive, in line with the intended role of the independent outside director,[4] and without entrusting the investigation to an external law firm, etc. Members were chosen in the expectation that their independence from the executive would be ensured and that independent outside directors who understand the operational details of JPX and TSE's business, as well as their purpose and vision, would be able to conduct a full investigation in a short period of time.

The composition of the Committee is as follows.

Committee chair	Kubori Hideaki	JPX independent outside director, member of JPX Nomination Committee, chairperson of JPX Risk Policy Committee (Attorney-at-Law, Representative, Hibiya Park Law Offices)
Committee member	Endo Nobuhiro	JPX independent outside director, member of JPX Nomination Committee (Chairman of the Board, NEC Corporation)
Committee member	Kohda Main	JPX independent outside director, member of JPX Audit Committee, member of JPX Risk Policy Committee (Novelist)
Committee member	Yoneda Tsuyoshi	JPX independent outside director, chairperson of JPX Audit Committee, member of JPX Risk Policy Committee (Former Commissioner General of the National Police Agency)

In addition, the Committee appointed the following individuals as technical and legal advisors to assist in the investigation.

Kamiyama Hiroshi (Attorney-at-Law, Patent Attorney, Partner, Hibiya Park Law Offices)

Ogawa Naofumi (Attorney-at-Law, Partner, Hibiya Park Law Offices)

4 Investigation methodology

The Committee's investigation was conducted using the following methodology.

(a) Consideration of relevant documents provided by JPX and TSE pertaining to the course of events

[4] In the Japan Federation of Bar Associations' "Guidelines for Outside Directors" (as revised on March 14, 2019), the role expected of outside directors when misconduct occurs is described as follows. "(1) To analyze the misconduct objectively, and to undertake an impartial and neutral investigation into the specific details of the misconduct and the causes of its occurrence from a different perspective to that of directors involved in execution of business, and to give an opinion on the same. (2) To make an impartial and neutral judgment on who should bear what responsibility in relation to the misconduct that occurred." The System Failure does not directly correspond to a so-called misconduct such as serious violations of laws and regulations or other improper or inappropriate acts, but because it was thought that the guidelines should be consulted in detail from the perspective of ensuring that independent outside directors play their expected role, the investigation was undertaken with that viewpoint in mind.

The Committee considered documents, forms, etc. associated with the System Failure, beginning with the reports submitted to the Financial Services Agency by JPX and TSE on October 16, 2020.

(b) Interviews with those involved

The Committee conducted interviews with the following involved individuals.[5]

Date & time	Interviewee	Position, etc.
Wednesday, October 7 10:00 - 11:00	A	Director, TSE IT Development Department (Trading System)
	B	Departmental Manager, TSE IT Development Department
As above 11:30 - 12:00	Yokoyama Ryusuke	JPX Senior Executive Officer & CIO (IT Planning) TSE Director & Senior Executive Officer (IT Administration, IT Development (Equities Trading, Information and Clearing) and IT Services)
Thursday, October 8 17:00 - 18:40	Kiyota Akira	Director & Representative Executive Officer, Group CEO TSE Director (part-time)
	Miyahara Koichiro	JPX Director & Representative Executive Officer, Group Co-COO (Management of Cash Equities Markets) TSE President & CEO
	Yokoyama Ryusuke	As above
	Kawai Hiroki	TSE Executive Officer (Equities, Equities Business Development and Financial Literacy Support)
Thursday, October 15 12:30 - 14:00	Kiyota Akira	As above
	Miyahara Koichiro	As above
	Yokoyama Ryusuke	As above
	Kawai Hiroki	As above
Tuesday, October 20 10:30 - 11:40	A	As above
	B	As above
Thursday, November 5 17:00 - 18:40	Kiyota Akira	As above
	Miyahara Koichiro	As above
	Yokoyama Ryusuke	As above
	Kawai Hiroki	As above
Tuesday, November 10 11:00 - 12:00	Kawai Hiroki	As above
As above 12:30 - 13:30	Miyahara Koichiro	As above
As above 13:40 - 14:40	Kiyota Akira	As above
As above	Yokoyama	As above

[5] Real names are not given here for interviewees who were not officers of JPX or TSE.

Date & time	Interviewee	Position, etc.
14:50 - 15:50	Ryusuke	

(c) Inspection of related departments and facilities

The Committee conducted inspections of related departments and facilities, as follows.

Equities Department/IT Development Department	Offices, system failure emergency headquarters, trading supervision terminals, operational supervision terminals, videoconferencing facilities
IT Development Department, Fujitsu development sites	Offices, system failure response area, operational supervision terminals, test facilities, videoconferencing facilities
IT Services Department operational sites /data center	Offices, Operations room (intensive system supervision), server room, videoconferencing facilities

5 Investigation expenses

Hitherto the expenses incurred by independent committees have almost never been disclosed in reports. Because the attorneys to which such work is entrusted tend to belong to large legal firms specializing in corporate law, with significant numbers of younger lawyers being committed to the project for long periods of time, there are said to be costs of up to ¥1 billion in some cases. In litigation to establish responsibility or class action suits brought by shareholders, the costs incurred by independent committees may be demanded as damages.[6] By using independent outside directors to undertake the investigation, consideration, and evaluation, and create the report, costs were controlled to the minimum level possible. The process of viewing and investigating recordings and documents, conducting interviews and drafting documents, etc., placed a tremendous burden on the directors serving as committee members, which was very different to the work ordinarily performed by directors. However, the total allowance for all committee members was set at ¥10 million (not including costs associated with technical and legal advisors).

Chapter 2 Overview of the cash equity trading system (arrowhead)

1 Background/history of arrowhead deployment

TSE had been working on the shift to electronic securities trading since before the closing of the trading floor, and operated an old system for trading shares, etc. to provide market functionality, but

[6] It was reported that in litigation that sought to establish the responsibility of executive officers at The Kansai Electric Power Co., Inc., ¥773 million was demanded as the portion relating to independent committee expenses.

the period between November 2005 and January 2006 saw the occurrence of significant system failures. With dramatic changes in the market environment and the expansion of electronic trading, such as the growing popularity of online trading for retail investors and the shift of the majority of institutional investor trading to systems, these difficulties provided a catalyst for the Financial Services Agency to set up in 2006 an Informal Round Table on Operations of Stock Exchanges. In response to proposals by the Round Table regarding the direction of rolling out trading systems, TSE committed to constructing a world-leading system with the objectives of "building trustworthy and attractive markets" and "strengthening competitiveness versus other international markets." TSE subsequently built the arrowhead system with Fujitsu as the development vendor.

The first-generation arrowhead was launched by TSE in January 2010, with its improved performance reducing the time required for order acceptance and execution processing from seconds to milliseconds, and more than doubling the order-processing capacity of the older system to 48 million transactions. This achieved the objective of delivering a more sophisticated system that was also able to deal with algorithmic trading, such as by allowing co-location.[7] Although rule changes, the addition of new functions, and the improvement of processing capabilities were implemented as needed while the first-generation arrowhead was in operation, TSE began development of a second-generation arrowhead, using completely new hardware, with the goal of responding to further changes in the market and market needs, and also in anticipation of the expiry of hardware warranties. In addition, following the establishment of JPX in 2013, the integration of the cash equity market systems of TSE and the former Osaka Securities Exchange was accomplished using arrowhead.

The second-generation arrowhead went into operation in September 2015, and while it inherited the same basic system structure and processing approach, it shortened order response time to 500 microseconds as well as increasing capacity, etc. In terms of operational aspects, it provided more risk management functions and added control functions for connections to trading participants and management.

The current iteration of arrowhead is the third generation, and as with the second generation it maintains the basic system structure and processing approach, while replacing hardware. It went into operation in November 2019. It achieves order response times of 200 microseconds, and provides capacity of over seven times that offered by the first-generation system. In terms of functionality, the third generation implements a fuller range of risk management functions, price displays that make it easier to preserve continuity, and more sophisticated handling of execution rules, etc. This is the

[7] A service enabling equipment, etc. for placing orders to be located in a customer area in the same data center as TSE. Direct connections from the co-location area to arrowhead are possible.

system currently in use.

2 arrowhead structure

arrowhead is a system in which “orders” are accepted from investors (securities companies), trades are executed, and the results are sent back, and in which “market data” such as order status and execution data is distributed to securities companies and data vendors.

In order to conduct clearing and settlement of executed orders, arrowhead not only links results to the clearing system, but is also equipped with supervisory and control functions to enable it to implement controls such as checks for the presence of misconduct, and mechanisms to suspend trading.

The basic configuration of the system is that of a cluster of several hundred tightly synchronized servers, with orders accepted at the participant gateway servers, matching processing conducted at the trading servers, and market data disseminated by information distribution gateway servers. In terms of the configuration of external links, each connection with securities companies and data vendors forms a closed network and is regulated and connected using a proprietary protocol (connection specification and process).

The distinctive features of the system are that, in order to maintain the speed and fairness[8] that support securities trading at the microsecond level, it avoids the use of cloud environments and also adopts an in-memory database (IMDB)[9] architecture for its primary processing method. Because data integrity is important when using an IMDB, the server cluster mentioned above is organized into three layers, with data synchronized between servers in order to improve reliability. Although an in-memory database is used to deal with data updated in real time, the structure takes into account differences in the application and non-functional requirements, such as by using a general-purpose database and non-volatile storage for ordinary files whose data is not updated either frequently or immediately.

3 arrowhead operational/maintenance structure, etc.

JPX separates system development and operation into different departments, using mutual checks and balances to improve system stability and quality. arrowhead is based on the same policy, with development and operations departments carrying out system operation and maintenance. For day-

[8] Because order processing and matching processing include functions used for time priority, price priority, price continuity and control of violent fluctuations, sequentiality and consistency are essential.

[9] Order data, etc. is stored in memory. Although unlike an ordinary database that uses hard disks an IMDB is capable of high-speed processing, this storage is volatile and so attention must be paid to storage of data.

to-day operations the operations department and the operations vendor have a 24/365 system in place. The operations department is responsible for operational and supervisory roles, while service and maintenance for equipment is performed by the maintenance vendor (Fujitsu).

4 Past system failures in arrowhead

Past system failures in arrowhead include the failure of part of the information distribution gateway server in February 2012 and a partial systemic failure of the participant gateway server in October 2018.

In the 2012 system failure, a hardware failure that occurred overnight in part of the three layers of servers led to market information distribution operations becoming impossible on the next trading day. As a result, for the morning session of the next trading day, trading was suspended for 241 issues on TSE related to these market distribution operations, and resumed in the afternoon session. This was caused by incomplete switching of software used to control the monitoring of server operations, and insufficient checking of the switch. The software was revised, and additional error/diagnostic information, etc. was added.

In the 2018 system failure, the instant the system came online a co-located user sent a huge number of messages to some of the participant gateways, putting the arrowhead sorting equipment under heavy load and causing the associated participant gateways to be cut off, which affected the connections of multiple securities companies. In response, TSE took measures such as reviewing control of the sorting equipment and raising the blocking level on the network side, in addition to communicating with securities companies regarding the impact on their operations, and implementing more substantial system failure tests.

Chapter 3 Course of events relating to the System Failure

According to JPX and TSE, the course of events on the day of the System Failure was as follows.

1 From detection of System Failure to suspension of trading

At 07:04 on October 1, 2020, a large number of messages were detected showing access irregularities for the No.1 shared disk device (hereinafter “NAS”).

At 07:10 it was found that in some cases it was impossible to log into the arrowhead trading supervision and operations management screens. In cases where market supervision operations that

make use of the trading supervision screens cannot be implemented there is an impact on the operations of the market for that day, but at that point in the Equities Department (where such operations are conducted), there was a mixture of terminals where login was possible and others where it was impossible. In addition to trading participants being unable to confirm connection status for virtual servers because the operations management screens were not in a usable state, the system failure diagnostic tools that check the status of the system ran for a considerable time without returning any diagnostic results.

At 07:10 Fujitsu was informed of the events occurring, and at 07:11 the managers responsible for the platform and for operations began working with TSE on isolating the impact on operations.

With regard to market data, at the same time that delays in issue information were discovered from 07:30 onwards, it became clear that data that are usually distributed at a fixed time, such as routing maintenance messages and communication start messages distributed from 7:00 onward, were not being sent. At 07:37, a “system failure emergency headquarters” was established, headed by CIO Yokoyama Ryusuke, and internal emails were sent from the systems operations department notifying others of the system failure.

Investigations into the impact on market information distribution and of measures to recover the situation were implemented in parallel, and while the cause was still unclear the impact on users had been confirmed, and so a notification was made at 08:01 to the effect that communication start messages could not be sent.

Subsequently, as it had been recognized that, regardless of the terminal, the trading supervision and operations management screens could not be used, and that in terms of market information distribution the information required for trading was being received correctly by almost no users, at 08:36 the system failure emergency headquarters, in accordance with the contingency plan, issued a notification to the effect that it had decided to suspend trading of all issues from the market open.

With regard to the order to suspend trading, because the NAS that constituted the location of the malfunction was unusable, the trading supervision and operations management screens could not be used, and so it was impossible to employ the normal means of suspending trading (through use of the trading supervision screen) and suspending the market (through use of the operations management screen). For that reason an emergency trading suspension order that did not use the trading supervision screen was attempted, but because this too was a process that used the data stored on the NAS, it was found to be impossible.

For that reason it was impossible to order a suspension of execution processing, and so the load balancer, which is the device used to distribute the load on the network that connects arrowhead to trading participants, was cut off from arrowhead and ToSTNet (the off-auction trading system) at 08:54 and 08:56 respectively.

(Reference) Types and overviews of orders suspending trading[1]

#	Type	Overview ([] = operational department)
1	Trading suspension	Order given using the trading supervision screen when implementing a normal trading suspension (where there is information that requires a suspension of trading, etc., such as news of a business merger). [Equities Department]
2	Market suspension	Order given using the operations management screen when the entire market or part of the market needs to be suspended due to a natural disaster or system failure, etc. [IT Services Department (systems operations department)]
3	Emergency trading suspension	On the assumption that a normal trading suspension cannot be used, a trading suspension order is given by execution of a job. [IT Development Department]
This incident	Load balancer cut-off	On the assumption that it is necessary to restrain orders due to a system failure with a specific server, etc., an order is given by issuing a command to cut off the network. [IT Development Department]

2 Restraining market information distribution

Order acceptance began as normal at 08:00, and real-time data on orders for individual issues was being distributed.

Because on this occasion the response did not involve suspending execution processing itself, the system implemented execution processing for orders accepted up to the load balancer cut-off. In order to prevent execution data from being distributed to market information users, a network cut-off was also implemented for market information distribution. However, mainly because priority was given to the load balancer cut-off, the timing with which the distribution of market data was cut off from the network straddled the market open at 09:00, and execution data was distributed for a period of approximately 1 minute after 09:00.

Accordingly, a notification was sent at 09:11 to the effect that the load balancer was cut off and the distributed execution data were invalid.

3 Response to NAS No.1

With regard to the messages detected from the NAS No.1 that constituted the location of the

malfunction, at 07: 55 a communication was received from Fujitsu to the effect that they indicated a breakdown of the control mechanism. If the specification had conformed to TSE expectations, it should have switched over automatically to NAS No.2, but because the switchover appeared to have malfunctioned, it was necessary to give the order to force the switchover from NAS No.1 to NAS No.2, with the aim of achieving an early recovery of the situation.

At 08:16 the order was given to forcibly cut off the power to NAS No.1, and at 08:26 the order was given to transfer control from NAS No.1 to NAS No.2, but both attempts failed. Next an attempt was made at 08:28 to create an interruption in communications between NAS No.1 and NAS No.2 by blocking ports. The attempt to block the ports was successful, but because NAS No.1 had already gone down, the switchover did not occur. At 08:42, the order given at 08:26 was executed with changed conditions, but this too failed.

The focus then shifted to dealing with the situation by physically detaching cables. While making preparations for members of equipment maintenance staff to enter the server room, attempts were made in consultation with Fujitsu to repeatedly execute commands so as to force a switchover to NAS No.2 (i.e., to seize control irrespective of the status of NAS No.1). At 09:23 a command provided by the product manager for Fujitsu was executed, but this attempt also failed.

As a consequence, options were added to the command executed at 09:23 and the resulting command sequence was executed at 09:26, successfully forcing the switchover from NAS No.1 to NAS No.2. It was subsequently confirmed that processing of market information distribution had been restored, and that the trading supervision and operations management screens were usable.

4 Movement toward resumption of trading

In preparation for resuming trading that same day, the restoration of the system was considered from the perspectives of (1) rebooting arrowhead and resuming, and (2) resuming without rebooting. Given the state of the system, it was affirmed that (1) would be necessary for trading to be resumed. The specific details of system status were as follows.

Although trading had been suspended, in effect this had been achieved by cutting off the network and execution processing itself had not been suspended. Executions based on orders accepted up to the cut-off at 08:54 existed in arrowhead, but notifications of these executions had not been sent to trading participants due to the load balancer cut-off, and were retained in the system. Furthermore, as explained above, an external notification had been sent at 09:11 to the effect that executions associated with orders accepted up to 08:54 were invalid.

In addition, the rationale for aiming to resume trading based on (1) was as follows.

If a resumption based on (2) were to be implemented, there would be no means of using normal system processing to force the expiration of the retained and unnecessary execution notifications,

and so it would be impossible to avoid these being sent to trading participants. There were concerns that this could significantly impact the systems on the trading participant side. In addition, the base price for the day would have already moved on the back of these (unnecessary) executions. Having taken this into account, it was judged that resuming trading through the second plan of action would be difficult from the perspective of providing a properly fair and impartial market.

On the other hand, if a resumption based on (1) were to be implemented, it would be possible to reset all data for orders already accepted, execution data, and base prices for the day. Nevertheless, it was surmised that on the trading participant side, orders would have already been sent for the day, and that even if the orders were cleared from within arrowhead, systems on the trading participants' side that were operating normally would have difficulty in responding to such an event.

If aiming to resume trading the same day, the main approach was to be (1) above, but going by past cases of system failure, it was felt that this should be a comprehensive judgment that took the opinions of trading participants into account as much as possible. Accordingly, both the Equities Department, which is responsible for operations, and the IT Development Department, which is in charge of systems, gathered opinions from trading participants and vendors. As a result, having given comprehensive consideration to the high probability that trading participants who were able to respond after the resumption of trading on the same day would not fulfill the 50% share of trading value prescribed in the contingency plan, and to the handling of orders already accepted, an extraordinary meeting of the Risk Management Committee was held at 11:00, attended by JPX Group CEO Kiyota Akira and TSE President & CEO Miyahara Koichiro. Based on discussions by the Committee, TSE President & CEO Miyahara Koichiro made the decision at the system failure emergency headquarters to suspend trading for the entire day.

At 11:45 an external announcement to that effect was made on the JPX website, etc.

5 Movement toward resumption of trading the following day

In preparation for the resumption of trading on the following day, October 2, after repeated discussions with Fujitsu it was decided that the motherboard containing the malfunctioning memory in NAS No.1, which constituted the location of the malfunction, would be replaced in its entirety on October 1.

As a result of the replacement it was confirmed that the hardware that had caused the system failure had returned to normal status (active-active configuration) and that if a similar event should occur, procedures were in place to enable a prompt switch-over. TSE and Fujitsu both made monitoring arrangements, and at 17:00 an announcement was made on the JPX website, etc. to the effect that trading was expected to be able to resume the following day.

It was subsequently confirmed that processing in preparation for the following day had completed normally, and so at 19:25 a formal announcement to the effect that trading would be conducted as

normal on October 2 was made on the JPX website, etc.

The motherboard replacement for NAS No.1 was completed at 22:00, and trading on October 2 was completed without problems.

Chapter 4 Causes of the System Failure

1 JPX and TSE's views on the causes of the system failure

JPX and TSE's views on the causes of the System Failure are as follows.

The direct cause of this event was an erroneous value in the settings of the control mechanism running on the NAS, which led to a failure to execute the automatic switchover from NAS No.1 to No.2 when the memory card malfunctioned, resulting in incomplete operation of the various functions accessing the data stored on the NAS (trading suspension, market suspension, emergency trading suspension, etc.). An explanation of the structure of the system and the event that occurred is provided below.

(1) Memory card malfunction

At 07:04, a large number of warning messages were detected showing access irregularities for the NAS No.1 device, which is part of a dual-layer configuration. The investigation that was later performed showed that the memory card had malfunctioned.

In addition to Fujitsu's internal inspection organization, an inspection organization from the supplier of the NAS (hereinafter, "Company A") carried out a multifaceted validation, as a result of which it became clear that there had been a component failure that made it impossible to read or write from the memory card in question. In addition, the final report was received from Fujitsu to the effect that, given that the number of past malfunctions of the memory card installed in NAS devices of the same model type already sold in the market (including the malfunction in the System Failure) is within the parameters expected by Fujitsu internally, it is unlikely to be a defective production lot.

(2) Cause of the failure of the automatic switchover to NAS No.2 to work normally

The operating hours of the memory card that malfunctioned in this case were within the service life, but because equipment malfunctions cannot be completely eliminated, so as to enable business to continue in the event of failure a two-node approach is taken, with two NAS installed so that even if a defect were to occur in one, business could continue.

In the event of a defect occurring in one of the doubled-up devices, the other, non-defective NAS is configured to take over processing by means of an automatic switchover. The approach used by

the automatic switchover can be either “standard takeover” or “immediate takeover,” as follows.

- With the standard takeover approach, in the event that the messages that indicate life (hereinafter “heartbeat messages”) come to a stop, processing is taken over 15 seconds later.
- With the immediate takeover approach, in the event that a message is received from the other device informing the recipient of a suspension of functionality (hereinafter “panic notification message”), processing is taken over immediately.

This System Failure was caused by the “On Panic” setting, which specifies the takeover approach when a panic notification message is received, and which can be set to either True or False, not being set appropriately. TSE’s understanding of the setting in question was as follows.

- True = immediate takeover enabled
- False = immediate takeover disabled
- The standard takeover approach is always enabled, irrespective of True/False

The description in the product manual as of 2015 is congruent with TSE’s understanding as explained above, and it was thought that, irrespective of the “On Panic” setting, processing would be taken over using the standard takeover approach. For that reason, the False (disabled) setting value that had been set for the second-generation arrowhead was carried over as it was to the third-generation arrowhead settings.

However, the actual specification used when designing the third-generation arrowhead was as follows.

- True = immediate takeover enabled
- False = immediate takeover disabled + standard takeover also disabled in the event that a panic notification message is received before heartbeat messages come to a stop

Accordingly, in the event that a panic notification message is received with the parameter set to False (disabled), not only is immediate takeover disabled but standard takeover is not initiated either, leading to a state in which automatic switchover will not take place.

(a) Operation of the NAS when it malfunctioned on the day in question

In the TSE’s requirements definition document for the design of the third-generation arrowhead, with regard to NAS-related operational functionality it is requested that, in the event of an equipment malfunction, a switchover is completed and processing is continued within “30 seconds”.

However, because of the above-mentioned defect in the “On Panic” setting value, the specific

behavior of the system in relation to automatic switchover (takeover of processing) of the NAS on the day of the system failure was as follows.

- Due to the memory malfunction, a panic notification message was sent from NAS No.1 to NAS No.2.
- Because the arrowhead "On Panic" parameter was set to False, neither immediate takeover nor standard takeover was initiated.
- In addition, although the "dead or alive" monitoring to check the state of communications between NAS No.1 and NAS No.2 every 0.5 seconds then came to a stop, standard takeover was not initiated either due to the panic notification message having been sent in advance of this.
- For that reason the automatic switchover from NAS No.1, in which the memory failure took place, to NAS No.2 was not carried out, and both NAS became unusable.

(b) Background to the decision on the "On Panic" setting value

In the NAS product manual created by Fujitsu during the design process, there is a statement to the effect that even when the setting is set to False, when a panic notification message is received from the other device, standard takeover should be executed. Because no problems arose as a result of this setting during the operation of the second-generation arrowhead, the "On Panic" parameter was also set to False in the detailed design process.

This description was based on the specifications for an older model of the NAS, but despite the specification for the NAS used in the third-generation arrowhead having changed with regard to this point, the description in the manual in question had not been revised. For that reason, when compared to the product specification for the NAS used in the third-generation arrowhead the description can be seen to be erroneous. When the parameter is set to False, in the event that a panic notification message is received from the other device, the specification led to standard takeover not being implemented.

The settings for the third-generation arrowhead NAS were described by Fujitsu in the detailed design documents, which were reviewed by TSE, but because Fujitsu had not reported changes in the specification to TSE, TSE was not aware of the errors in the description in the manual in question, and did not discover the errors in the detailed design document.

(c) Reason for the defect in the "On Panic" setting value

The cause of the failure to understand the change in specifications with regard to the operation of the NAS in "On Panic" conditions, leading to the third-generation arrowhead having "On Panic" settings that were different to the specification prescribed by TSE in the requirements definition document, was that the settings checking process (in which the Fujitsu product manager was involved) and the test conditions implemented before the full-scale deployment of

the system were insufficient.

One reason was that even during the phase of deciding important settings, such as the design of switchover during system failures, those involved relied only on the product manual. An incompatibility survey was conducted, but the change in the “On Panic” functionality could not be picked up by checking the manual alone.

The second reason was that, with regard to the testing implemented by TSE and Fujitsu before full-scale deployment, the failure tests carried out did not reproduce the same conditions that occurred in the System Failure (verification of operation during “On Panic” conditions). TSE and Fujitsu assumed that even when the “On Panic” parameter was set to False as described in the manual, in the event of a panic notification message being sent due to a loss of functionality in the NAS unit processing would be taken over. Accordingly, because they believed that the heartbeat message cut-off test between NAS No.1 and NAS No.2 included checks for a loss of functionality in the NAS unit, they concluded that, since the operations were able to continue in the heartbeat message cut-off test, the overall design in relation to the taking over of processing during a failure was correct.

(d) Reason for the failure to apprehend the error in the manual description

The cause of the failure to apprehend the error in the manual description was insufficient checking of the specifications by the Fujitsu product manager.

The parties involved in the creation of the manual were Company A, which supplied the NAS (the NAS in question was an OEM product that was manufactured and sold by Company A, procured by Fujitsu, and supplied to TSE as a Fujitsu product) and the Fujitsu product manager. Those involved in the usage of the product were the Fujitsu system engineer (personnel responsible for TSE arrowhead) and TSE itself.

For the NAS supplied by Company A, the specification document was checked by the Fujitsu product manager by comparing the specification created by Company A to operation of the actual device. This was then sold as a Fujitsu product and supplied to TSE. The content of the specification document for which checks had been completed was then appended in its original form as the manual for supply to the customer. Subsequently, the Fujitsu system engineer performs a comparison of the TSE requirements to the manual, while adjusting the setting parameters to appropriate values so that the device behaves in accordance with the TSE requirements definition document, and tests to see whether the requirements have been fulfilled (whether the automatic switchover, etc. conforms to the TSE requirements definition document).

i. Checking of specifications by Fujitsu product manager

Under Fujitsu’s internal administrative rules relating to products supplied by other companies

(OEM products), which prescribe the main points to cover when the Fujitsu product manager checks specifications, it is stated that for each setting item, “Checks of the actual equipment” and “Checks for consistency of the description in the specification document” should be used together. Specifically, “initial setting values” for each setting item were checked against the actual equipment, while for “Other setting values,” the description in the specification document was checked for consistency with the specifications for initial setting values. A report was received from Fujitsu to the effect that this was based on the assumption that Company A was performing comprehensive checks of settings for conformity with the specification document as a matter of course for all setting items using actual equipment, and it is believed that this was caused by insufficient communication between Company A and the Fujitsu product manager with regard to test results. As a result, Fujitsu supplied the NAS to TSE without performing tests (specification checks) of the TSE setting value (False), leading to the setting of a value of False that was inappropriate to the third-generation arrowhead.

(Backgrounder 1) Checks during the development of first-generation arrowhead

The “On Panic” setting whose value caused the System Failure also existed in the generation of NAS products adopted for the development of the first-generation arrowhead.

However, the specification for the NAS of that time was different to the specification of the NAS used in the third-generation arrowhead that was the cause of the System Failure, and the specification for operation under “On Panic” conditions and the description in the manual were in agreement with each other (the manual description was correct). The Fujitsu product manager checked that automatic switchover was being carried out by setting the initial setting value of that time to False, and initiating a standard takeover.

(Backgrounder 2) Changes in the “On Panic” specification and initial setting value

For NAS that began to be manufactured and sold during the period in which the first-generation arrowhead was in operation, the specification changed in cases where “On Panic” was set to False. That is to say, the previous specification of “Standard takeover is initiated when there is a loss of functionality in the NAS unit” changed to “When a panic notification message is received before the heartbeat messages come to a stop, standard takeover is not initiated.” At the same time, the initial setting value was changed from False to True.

Company A stated that, in addition to revising the specification so that the initial setting value was changed to True based on the assumption that ordinary users would basically use this setting, False was retained for applications such as those used when verifying the implementation of failure tests.

However, the specification document created by Company A only described the changes to the initial setting values, and had not been revised to reflect the specifications mentioned above.

(Backgrounder 3) Fujitsu product manager's response after changes to specification and initial setting values

Based on the Fujitsu report, when developing the second-generation arrowhead, the Fujitsu product manager, in accordance with the above-mentioned administrative rules for product managers, caused a loss of functionality in the NAS unit with the value set to True, and confirmed using actual equipment that immediate takeover was initiated.

On the other hand, with regard to confirming operation when the NAS unit lost functionality with the value set to False, which was no longer the initial setting, there were no changes in the specification document in relation to operation. Because of this, and based on their understanding that "On Panic" was a function that determined whether or not immediate takeover should be initiated in the case of a loss of functionality in the NAS unit, Fujitsu assumed that with the value set to False the initiation of immediate takeover would be suppressed, and that standard takeover (standard functionality) would be initiated. The Fujitsu report states that since this assumption also matched the content of the specification document, no confirmation using actual equipment was performed, and based on checks of the documentation the issue was deemed not to be a problem.

Because the manual carried a statement to the effect that standard takeover would continue to be implemented with the value set to False, and because no problems had occurred using the same setting in the first-generation arrowhead, the Fujitsu system engineer maintained the False setting value as it was for the second-generation arrowhead. In TSE's review also, according to the description in the manual the specification was in conformity with the specification prescribed by the requirements definition document, and so the problem with the settings was not discovered.

In the same way, for the NAS selected during the development of the third-generation arrowhead, the Fujitsu product manager checked the specification document provided by Company A, but Fujitsu reported that because there had been no change in descriptions relating to "On Panic," the setting value in question was not verified all over again.

In other words, the manual provided by Fujitsu to TSE was based on the specification document provided by Company A, but because the specification document provided by Company A had not been revised to reflect the changed NAS product specification, the Fujitsu product manager did not understand that it was necessary to verify the operation of the NAS all over again to cover cases where the "On Panic" value was set to False.

ii. Tests by the Fujitsu system engineer

It was reported by Fujitsu that tests performed by the Fujitsu system engineer in the arrowhead system environment did not extend to incorporate variations in the conditions under which

takeover was initiated (verifying not only the cessation of heartbeat messages, but also operation during an occurrence of an “On Panic” state). It was explained that, with regard to the different takeovers initiated by NAS unit loss of functionality and by cessation of heartbeat monitoring, the product function had been verified on the Fujitsu product manager side and it was believed that the results were reflected appropriately in the product manual, and therefore the emphasis had been placed on confirming that the various operations of the arrowhead continued after the initiation of takeover.

Moreover, having looked into the situation with regard to cooperation and sharing of information between the Fujitsu system engineer and the Fujitsu product manager, Fujitsu reported that although the Fujitsu system engineer cooperated with the Fujitsu product manager with regard to the details of arrowhead setting values including the “On Panic” value, TSE requirements were not conveyed at that point. Rather than the operation of the equipment within the system, the checks implemented by the Fujitsu product manager went no further than checking the product specification for inconsistencies between settings for the equipment as a whole.

(3) Reason for the time taken to execute a manual switchover

The reason that it took time to execute a manual switchover was that, as noted in (2) (a), it was assumed that processing would be taken over in the event that a panic notification message was sent due to the NAS unit having lost functionality, even in cases where the “On Panic” value was set to False, and so insufficient consideration had been given to procedures for responding to a system failure caused by the NAS not switching over automatically, including preparing commands in advance to deal with cases in which takeover had not been performed correctly.

(4) Cause of market information distribution and trading suspension functions becoming unusable

In order to improve the efficiency of system design as well as ensure the integrity of data within the system, the system was designed to consolidate management of files used by multiple servers on the NAS wherever possible. Because the market information distribution and trading suspension functions use files that are stored on the NAS, until NAS No.2 had taken over processing from NAS No.1 and restored file access functionality, the system continued to wait for a response from the NAS, rendering these functions effectively unusable.

Trading suspension is an extraordinarily important part of market operations, and so multiple trading suspension functions had been put in place on the assumption that there would be situations in which the normal trading suspension function could not be used, but these also made use of files

stored on the NAS and therefore did not function.

2 The Committee's evaluation

(1) Memory card malfunction

The direct cause of the System Failure was deemed to be a malfunction in a memory card installed in the NAS, making it impossible to access the storage area of the memory card, causing the entire memory card to cease to function.

However, not only was the memory card malfunction an accident, but given that the operating hours of the memory card were within the service life, and that it was not a problem associated with a particular production lot, we do not perceive there to be a problem with TSE's response in relation to this point.

(2) Defect in the automatic switchover to NAS No.2

In order that operations might continue even at times of equipment failure, two NAS units were installed and configured so as to switch automatically in the event of an equipment malfunction in one NAS unit to the other unit, thus enabling business continuity. However, the automatic switchover to the other NAS was not performed, and as a result it was not until 09:26 that a manual switchover was accomplished. If the switchover had taken place immediately, this incident would arguably have not become such a major event, and so the defect in the automatic switchover is particularly important in the context of the System Failure.

The cause of the inability to switch over immediately was a discrepancy between the settings as described in the NAS manual created by Fujitsu and the actual specification, such that the NAS settings were implemented based on the erroneous details described in the manual.

The cause of and responsibility for the errors in the product manual description lie with the manual's creator, Fujitsu, and because it would be unreasonable to expect TSE to notice the errors in the description by itself, we do not perceive there to be a problem with TSE's response in relation to this point. In addition, Fujitsu had received a revised version of the NAS manual in November 2019, and it is reasonable to suppose that if it had made a detailed investigation of this manual and become aware of the erroneous settings, the settings could have been changed. Responsibility for this point must also therefore be laid at Fujitsu's door.

On the other hand, in the tests implemented jointly by Fujitsu and TSE before full-scale deployment, failure tests to reproduce a situation in which there was a loss of functionality in the NAS unit were not carried out. Had these been implemented, it is possible that the defect in the settings would have been noticed. Furthermore, had the values used in the arrowhead settings been tested before the product was shipped, it is possible that the defective setting would have been discovered. Given the importance of the NAS within arrowhead, one could say that TSE should

have required Fujitsu to perform such tests. Looked at from this perspective, it appears that TSE is responsible to a certain extent for its inability to recognize the defect in the NAS settings.

(3) Time required to manually switch to NAS No.2

Because the automatic switchover to NAS No.2 did not take place an attempt was made to perform the switch manually, but the manual switchover was not accomplished until 09:26. If the manual switchover had been accomplished earlier, the impact of the System Failure would likely have been more limited.

With regard to this point, TSE recognizes that its preparation of commands in advance to deal with cases in which takeover had not been performed correctly was inadequate. That is to say, it did not properly anticipate a situation in which the automatic switchover was not performed correctly and a manual switchover became unavoidable, which can be interpreted as having given insufficient advance consideration to such countermeasures.

It may have been difficult to anticipate the specific situation in which an automatic switchover was not performed due to erroneous settings, as in the case of the System Failure, but there have been media reports of significant and prolonged system failures occurring at other companies due to the malfunction of (automatic) switchover in redundant devices. Based on this, the assessment must be that insufficient consideration was given by Fujitsu to countermeasures to be used in cases where manual switchover became necessary.

(4) Summary

As per the above, from the perspective of the technical causes of the System Failure, the most significant problem was a malfunction caused by errors in the manual in relation to the NAS automatic switchover settings, which came into effect due to the accidental failure of a memory card, which is unavoidable at a certain frequency. Fujitsu bears a heavy responsibility in this regard.

In addition, because it should have been possible to mitigate the impact of the System Failure if adequate preparations had been made in regard to the methods and procedures for manual switchover in the event of a failure of the automatic switchover to operate properly, it appears that measures put in place in advance by Fujitsu were also insufficient.

Chapter 5 Reasons for being unable to resume trading on the day the System Failure occurred

1 JPX and TSE's views on the reasons for being unable to resume trading on the same day

JPX and TSE's views on the reasons for being unable to resume trading on the day the System

Failure occurred are as follows.

(1) Basic approach to trading suspensions

In arrowhead there are two types of trading suspension. In the “orders accepted” type, orders are accepted from trading participants during the trading suspension, while in the “orders not accepted” type, not only is trading suspended but the acceptance of orders from trading participants is also suspended. As a rule, “orders accepted” trading suspensions are used in practice.

This is because in the case of “orders not accepted,” as far as trading participants are concerned, orders received from their customers during the trading suspension cannot be sent to the exchange and so get backed up (if an order is placed an error occurs), which results in more time being required after trading has resumed to send orders to the exchange and makes it difficult to resume promptly. On this point, when the information distribution gateway server failure occurred in 2012 an “orders not accepted” trading suspension was implemented, but there were requests from trading participants for orders from them to be accepted during the trading suspension.

Based on these circumstances, the current policy is to use “orders accepted” whenever possible if a trading suspension is implemented. However, when a system failure occurs that makes it impossible for orders from trading participants to be processed appropriately, such as a malfunction in the trading server that implements execution processing, or such as when order capacity is under pressure and orders (including cancel orders) should not be accepted, an “orders not accepted” trading suspension will be implemented because the process of accepting orders from trading participants is in itself considered inappropriate.

(2) Decision to suspend trading at 08:36, load balancer cut-off

At 07:37 the Equities Department was notified by the systems operations department that some operations management terminals could not be used. It was also told that, amongst other issues, communications problems between arrowhead and the market information distribution system were preventing data connections. Just around the time of this contact, the Equities Department itself had detected a phenomenon whereby some trading supervision terminals were not starting, and was making this known within the Department.

At this point it was judged that because the IT Development Department was investigating the cause of the system failure and the scope of its impact, and because only some of the terminals were not starting, and because normal trading supervision operations were thought to be possible, and because measures for restoring distribution of market data were being considered, it was not necessary to suspend trading before the system began accepting orders.

However, there was no subsequent improvement in the situation with regard to market information distribution, and before 08:00 all the activated trading supervision terminals had become unusable. The IT Development Department continued to investigate the restoration of the

trading supervision terminals and of market information distribution in preparation for continuing trading. Nevertheless, it was thought that if no recovery was achieved then the situation would correspond to “II. In the event of a failure in the TSE Market Information System” in the contingency plan, and that because the impact of the system failure was not confined only to some issues it would be necessary to suspend trading for all issues.

Not only does implementing a trading suspension for all issues have a significant effect on investors and market participants, but at the point at which the situation had been confirmed the cause of the system failure had not yet been identified, and there was no firm prospect of recovery. Accordingly, the approach taken was to continue to work on restoring arrowhead so as to be able to conduct normal trading and, if that proved to be impossible, to come to a decision on the trading suspension as quickly as possible. From the viewpoint of leaving time to publicize this, the system failure emergency headquarters scheduled the decision for 08:30, planning to implement a trading suspension of all issues in the event that the Market Information System had not recovered by that time. In addition, because the aim was to achieve a smooth resumption after the trading suspension, and because at that point it still appeared possible to process orders appropriately, the plan was for the trading suspension to be of the “orders accepted” type, as described below in 2 (1).

Subsequently, because market information distribution had not recovered by 08:30, after preparing an external announcement, trading participants were notified of the implementation of a trading suspension under Rule 29, Item 4 of the Business Regulations, etc. at 08:36, and a trading suspension was effectively achieved through the load balancer cut-off at 08:54.

(3) Gathering opinions from trading participants

As described in 1 (1) above, the trading suspension implemented at 08:54 was out of necessity performed by cutting off the network between arrowhead and trading participants, and the trading server implementing execution processing had not been suspended. For that reason, from 09:00 onwards the system performed execution processing for orders that had already been sent, and the results of that processing (execution notifications) were also created.

In addition to market information distribution not working correctly, as a result of carrying out executions in this way, if the network between arrowhead and trading participants were to be restored and trading were resumed without any other action being taken, it was believed that the following problems would occur.

- Because the execution notifications are sent to trading participants, in addition to the possibility that orders that were not actually executed in the system might be perceived by trading participants to have been executed, leading to subsequent system processing, etc., confusion might arise from investors looking at the order screen, etc., arriving at the mistaken understanding that execution had taken place, and on that assumption proceeding

with further investment activities.

- As well as measures being required to prevent the execution notifications received by trading participants resulting in the above-mentioned system processing, etc. at the trading participant end, it is necessary for trading participants to restore the internally managed status of orders for which execution processing had already been performed to their original condition, in order to allow the orders to be resent to TSE, and then to actually perform the work of resending the orders.
- For trading participants who operate on a "payment received in advance" system, it is also necessary for them to prevent the result of execution notifications received from being reflected in the amount of funds available to their customers and in customer balances, etc.
- As a result of execution processing having proceeded, base prices at the time of resuming trading would change, leading to discontinuities in pricing.
- There would be risks such as being unable to form order book information at the user end due to defects in the data distributed through market information distribution.

On the other hand, if arrowhead were to be rebooted before the restoration of the network between arrowhead and trading participants, the data that underwent execution processing would be deleted and execution notifications would not be sent to trading participants, which would mean that recipients would be less likely to mistakenly believe that orders that should not have been executed had been executed.

On top of this, by rebooting arrowhead base prices would revert to the values they had held on the morning of the day in question, and distribution of market data would also begin from scratch. Because rebooting would have a smaller effect, it was decided that the approach taken would be to implement a reboot of arrowhead.

However, in trading participants' systems (although this varies according to the approach taken to build the system) the updating of statuses for orders sent is generally managed on an order-by-order basis. Particularly in the case of TSE, orders are not normally handled on the trading participants' side after the orders have been sent, and statuses are changed upon receipt of order acceptance notifications or expiry notifications sent by TSE. For that reason, although it is possible to resend an order with details identical to that of an order for which an expiry notification has been received from TSE, irregular handling would be required to resend an order from a trading participant system without having first received an expiry notification for that order and with the order status unchanged at "sent to TSE."

In cases where such irregular handling were not possible, it was believed that even if arrowhead were rebooted there would be a confusing situation in which orders from investors were not reflected in trading for that day, putting investors at a disadvantage and preventing appropriate price formation.

Taking into account the time required to reboot arrowhead, opinions were then gathered from the major securities companies, online brokers, overseas securities companies, and vendors, etc. with regard to the feasibility of resending orders, bearing in mind differences in business models, systems, and customer bases, etc., and with the objective of completing before 11:00.

(4) Reasons for the decision to suspend trading for the entire day

The market includes a wide range of participants, such as institutional investors, retail investors, hedge funds, day traders, and high-frequency traders, which leads to a combination of diverse investment judgments and investment motivations, and works to facilitate price formation and improve liquidity, enabling the market to function at its best.

Based on such concepts, in order to prevent price formation driven by supply and demand that is distorted by one group of investors after a system failure, "I. In the event of a failure in TSE trading systems" in the contingency plan mandates that decisions regarding trading suspensions be rooted in comprehensive consideration of the past market share of trading value held by trading participants unable to participate in trading, and the number and attributes, etc. of trading participants unable to participate in trading. In the case of resuming trading after the System Failure, there were trading participants who could prepare for a resumption, and trading participants who could not prepare for a resumption, and the decision as to whether or not to resume was made after taking these factors into account.

The following points became clear through the opinion gathering mentioned in (3).

- Some trading participants responded that they would be able to resend orders in the event of a trading resumption, but their share of trading value was no more than 38% or so, and in terms of their attributes they were limited to overseas securities companies.
- A vendor of systems used by many medium-sized and second-tier securities companies responded that they had never performed tests on this and did not know whether it was possible to handle the situation, and so it was unclear whether the numerous trading participants using the system in question would be able to handle the situation.
- The online brokers from which opinions were gathered responded that they would be unable to handle such a process, and so it seemed likely that most retail investors would not be able to participate.

Integrating these responses, it appeared likely that even if trading were to resume, only certain overseas securities companies and their customers (which probably included a large number of high-frequency traders) would be able to participate. In addition, as shown by the trading participants and vendors saying that they did not know whether they would be able to handle the situation or not, there was no agreement with market participants with regard to the procedure for rebooting

arrowhead and resuming trading. Given that no tests had been undertaken, this course of action would have been simply too unpredictable, and it was decided that, as the market operator, an approach that risked such instability could not be adopted.

Based on the above points, it was concluded that it would be inappropriate to resume trading when it was anticipated that almost no domestic investors (primarily retail investors) would be able to participate, which would result in price formation being driven by only one distorted area of supply and demand.

Putting the focus on investors, it was hypothesized that if arrowhead were rebooted there would be investors who, despite having sent orders on or after 08:00 that day, would have lost their opportunity to trade and would have to watch the price fluctuate in the market. Also, it was anticipated that, even if trading were resumed, if the resumption resulted in a situation where only one group of trading participants was able to participate, this would lead to disputes between trading participants who had been unable to prepare for the resumption, and customers of such trading participants, in relation to the way orders had been handled.

Furthermore, resuming trading after rebooting arrowhead had not been carried out even in the test environment, and it was therefore impossible to predict what would happen. Having taken these issues into account, it was decided that, as the market operator, operating the market in an unstable fashion should be avoided.

Accordingly, based on the above-mentioned contingency plan, the decision to suspend trading for the entire day was made under Rule 29, Item 4 of the Business Regulations, etc., and an announcement to that effect was made available on the JPX website, etc. at 11:45.

2 The Committee's evaluation

(1) Accepting orders from 08:00 (measures taken in advance in relation to judging whether or not orders should be accepted)

Judging by the background to and causes of the inability to resume trading on the same day even after performing the switchover to NAS No.2 when the System Failure occurred, it is likely that if orders had not been accepted from 08:00 onward, the situation would not have progressed as far as it did, and the impact of the System Failure would have been mitigated.

With regard to this point, based on the background of having received requests on the occasion of past previous system failures to accept orders even during trading suspensions, trading suspensions of the "orders accepted" type were implemented as a rule, and the decision not to accept orders had not been made as of 08:00.

In reality, given that: (a) before 08:00 on the day in question the details of the System Failure and

the scope of its effects were not fully understood; (b) because neither the trading supervision nor the operations management screens could be used at the time, it was necessary to use methods such as the load balancer cut-off in order to suspend acceptance of orders from 08:00; and (c) it was believed that if normal trading suspension and emergency trading suspension measures could be used there would be no problem arising from accepting orders, and that as of 08:00 the situation had not progressed to the point that a normal trading suspension was assumed to be impossible, the Committee's assessment is that TSE's acceptance of orders from 08:00 did not constitute a significant problem in this matter.

On the other hand, with regard to the point that, as a rule, TSE implements trading suspensions of the "orders accepted" type, TSE cannot be said to have given sufficient consideration as to whether there are any cases in which the "orders accepted" type should not be implemented as an exception, and as to when and how such a decision should be made. With regard to this point, it would have been desirable for TSE to have set out rules in relation to whether or not to accept orders in the event of a system failure, and in relation to procedures for taking such a decision, etc., and to have made these rules known to those involved in trading.

(2) Taking the decision at 08:30 to suspend trading (measures taken in advance in relation to procedures for deciding to suspend trading)

While moving ahead with work in preparation for restoring arrowhead in order to perform trading as normal, the approach decided on by TSE was to suspend trading of all issues in the event that the Market Information System had not recovered by 08:30, and when the Market Information System did not in fact recover by 08:30, TSE notified trading participants at 08:36 that a trading suspension would be implemented. Work on suspending trading was implemented at around 08:30, and a trading suspension was effectively achieved by means of the load balancer cut-off at 08:54. In addition, because the cutting-off from the network of market information distribution straddled the market open at 09:00, execution data was distributed for a period of approximately one minute after 09:00.

When premised on the course of events leading up to the System Failure, neither TSE's decision to take the approach of suspending trading in the event that the Market Information System had not recovered by 08:30, nor its decision to implement work to actually suspend trading at 08:30 appear unreasonable.

This resulted in the cutting-off from the network of market information distribution straddling the market open at 09:00, but this was because although an emergency trading suspension order was attempted between around 08:30 and 08:40, since this was a process that used the NAS that was the location of the malfunction the order did not succeed. It was only from around 08:40 that the focus shifted to the approach of cutting off the load balancer, and the Committee does not believe that TSE's responses and decisions in this regard should be considered a problem.

On the other hand, TSE appears to have given insufficient advance consideration to procedures and processes for making decisions regarding trading suspensions when failures such as the System Failure occur, such as for example what time should be the cut-off in terms of waiting for a recovery in the system before taking the decision to suspend trading. It would have been desirable for TSE to have set out rules in relation to procedures for making a decision on trading suspensions, such as for example making it a rule that if the system does not recover by 08:30 then the decision to suspend trading should be taken and measures implemented (as was the case in this incident), and to have made these rules known to those involved in trading.

(3) Failure to implement a trading suspension, including an emergency trading suspension, and the unavoidable use of the load balancer cut-off (advance consideration of the approach to processing emergency trading suspension functions)

In this incident, because the trading supervision and operations management screens were unusable it was impossible to order a normal trading suspension (through the trading supervision screen) or market suspension (through the operations management screen), and although an attempt was made to order an emergency trading suspension this could not be achieved because the process used the NAS that was the location of the malfunction, and so ultimately TSE was forced to take the load balancer cut-off approach.

The reasons for not being able to resume trading on the same day after implementing the switchover to NAS No.2 were that TSE was forced to use the load balancer cut-off approach, and that (a) in the event that the network that had been cut off were to be restored as it was, execution notifications would be sent to trading participants, and (b) conversely in the event that trading were to resume after arrowhead had been rebooted, expiry notifications would not be sent to trading participants, who would be required to implement special handling in order to resend orders, and both approach (a) and approach (b) would have been difficult to implement.

Accordingly, it can be said that the direct cause of not being able to achieve the resumption of trading on the same day was the use of the load balancer cut-off approach, and the problem is how to assess the fact that normal trading suspension, market suspension and emergency trading suspension orders could not be executed.

The emergency trading suspension is a function used in cases where neither the trading supervision nor the operations management screen can be used, and normal trading suspension and market suspension are both impossible to implement. It is configured by means of a file designating the issues subject to trading suspension, which is stored on the NAS and so could not be used when the System Failure occurred. Emergency trading suspension is a function designed for dealing with situations in which malfunctions in other equipment or system failures make it impossible to use the normal trading suspension or market suspension functions, and should have been set up so that

it could be executed with complete reliability in any situation. In conclusion, it can be said that at the arrowhead design stage TSE did not give sufficient consideration to the extent to which it could be affected by a NAS failure (such as becoming unable to use the emergency trading suspension function), or to initiatives to address this issue in the design. Furthermore, although it can also be seen as the consequence of not anticipating the possibility that the (automatic) NAS switchover might not be implemented, it should be assessed as a separate problem of the insufficient consideration given to the configuration and processing of the emergency trading suspension function.

(4) Decision to suspend trading for the entire day

As explained above, TSE decided to suspend trading for the entire day because (a) in the event that the network that had been cut off were to be restored as it was, execution notifications would be sent to trading participants, and (b) conversely in the event that trading were to resume after arrowhead had been rebooted, expiry notifications would not be sent to trading participants, who would be required to implement special handling in order to resend orders, and both approach (a) and approach (b) would have been difficult to implement.

As a result of gathering opinions from trading participants on the basis that devising measures for (b) was deemed to be difficult, it was found that in the case of this approach, no more than about 38% of trading participants by share of trading value would be able to resend orders after trading resumed, and that, in terms of attributes, these participants were limited to overseas securities companies.

Furthermore, resuming trading after rebooting arrowhead (approach (b) above) had not been carried out even in the test environment, and it was therefore impossible to predict what would occur.

When premised on the course of events leading up to the System Failure, approaches (a) and (b), if implemented, would have both involved a significant risk of causing further confusion among trading participants, and the Committee therefore perceives the substance of the decision to suspend trading for the entire day to have been reasonable. In addition, no problems were perceived with the consideration of procedures and the gathering of information during the process leading up to the decision.

(5) Measures taken in advance in relation to procedures, etc. aimed at resuming trading after an abnormal trading suspension

On the other hand, TSE failed to sufficiently anticipate a situation in which it would be unable to implement a normal trading suspension, market suspension, or emergency trading suspension, and would be forced to use the load balancer cut-off approach and to resume trading thereafter, had not conducted tests with regard to resuming trading after rebooting arrowhead, nor had it set out

procedures for resuming trading (including procedures for gathering the opinions of trading participants when coming to a decision on resuming trading).

If TSE had anticipated a situation in which trading resumed after an abnormal trading suspension, and devised measures such as drawing up procedures, making them known to trading participants, and implementing tests that took this scenario into account, it is possible that trading could have resumed on the same day even in the event of an incident such as this one.

Accordingly, it cannot be said that TSE gave sufficient consideration in advance to decision criteria and procedures aimed at resuming trading after an abnormal trading suspension. It would have been desirable for TSE to have set out rules in relation to procedures, etc. for resuming trading after an abnormal trading suspension in the event of a system failure, and to have made these rules known to those involved in trading.

(6) Summary

As explained above, with regard to the causes of not being able to resume trading on the same day after the System Failure occurred, TSE: (a) made the decision to suspend trading at 08:36; (b) subsequently began preparations to suspend trading, and eventually devised the load balancer cut-off measure; and (c) judged that resuming trading after rebooting arrowhead would be difficult and accordingly made the decision to suspend trading for the entire day. When premised on the course of events leading up to the System Failure, none of these decisions appear unreasonable.

On the other hand, in addition to (a) the problem of insufficient consideration being given to the possibility that the emergency trading suspension function would not be usable in the event of a failure of the NAS, there were inadequacies in relation to (b) the procedure for making decisions about whether or not to accept orders in the event of a system failure; the procedure for making decisions about trading suspensions; whether sufficient advance consideration was given to procedures, etc. for resuming trading after an abnormal trading suspension and the formation of related rules; and making these rules known to those involved, including participants.

Chapter 6 Measures to prevent a recurrence

1 Overview of measures being considered by JPX and TSE to prevent a recurrence

After the experience of the System Failure, JPX and TSE are moving forward with the consideration of measures to prevent a recurrence. As at the time of writing, the following matters had been finalized.

When considering measures to prevent a recurrence, JPX and TSE shall strive to implement highly

effective methods that fully take into account an in-depth analysis of the causes of the failure, to enable the operation of a market where trading can be conducted with confidence.

In addition, TSE shall move forward with these measures to prevent recurrence in cooperation with other stock exchanges that use arrowhead (Nagoya, Fukuoka, and Sapporo).

Hitherto arrowhead has operated under the slogan of "Never Stop" and emphasized initiatives to improve reliability, but going forward it shall focus in the same way on improving resilience, to further ensure that its recovery measures are prompt and appropriate.

With regard to this incident, specific measures to prevent recurrence will be considered in relation to the problem points listed below.

Problem 1: the error in the settings related to switchover operation was not noticed

Problem 2: there was no completely reliable means of executing a trading suspension

Problem 3: rules for handling trading suspension/resumption after the occurrence of a system failure were inadequate and did not have the agreement of the industry

In order to achieve stable operation of markets, as explained above, rather than focusing only on improving arrowhead reliability, it is important to strengthen business continuity and resilience in the event of a systems failure.

This requires consideration and coordination, not in relation to arrowhead alone, but also with systems at the trading participant end, and of trading participant customer systems that connect to those trading participant systems.

(1) Preventing recurrence through system-level responses

(a) Correcting the NAS setting value

The location of the setting value for the NAS switchover function that was the direct cause of the system failure was identified on October 2. Subsequently, after having confirmed using tests on actual equipment that, even if a similar event were to occur, correct switchover would be achieved, the "On Panic" on the production system was set to True on October 4. The system has been operating using the correct setting value since October 5.

(b) Overall inspection of NAS setting values

The Fujitsu system engineer and product manager have both confirmed that all settings are in conformance with the required specifications and match the product operational specification. This was completed by October 23. In addition, for areas where the settings are found to have different values when actual equipment is verified at the time of shipment, the Fujitsu product manager has checked, using actual equipment, that the specification is as expected. This process of confirmation was completed by the end of October.

(c) Putting in place measures to allow a completely reliable switchover

Because there remains the possibility of a switchover malfunction caused by hardware failure, etc., in addition to checking the implementation of switchover tests and the results thereof, the existence of procedures for ordering enforced switchover (on the assumption of a malfunction in the switchover) and the effectiveness of such procedures had been confirmed by the end of October. As a result of these confirmations, with regard to equipment that incorporates a switchover mechanism, new procedures to use in the event of the equipment switchover malfunctioning shall be put in place and a list of procedures to apply depending on the state of the equipment shall be provided by the end of November, with particular attention being paid to the need for the procedure to be quick and completely reliable in operation.

(d) Implementing ongoing tests/drills

In addition to implementing tests related to the NAS switchover, ongoing failure tests and drills including market participants shall be planned and implemented. Specifically, NAS switchover tests and drills shall be implemented by January 2021, and failure tests, which will include other equipment, shall be planned and implemented in stages.

(2) Enhanced measures for implementing trading suspensions

(a) Organization of routes and statuses for trading suspension instructions

By the end of October it had been checked whether the system in its current form no longer runs the risk of a trading suspension order not functioning as a result of the failure of a single piece of equipment or a single function. It has been confirmed that it will be necessary to decide on some procedures related to manual operation, and so it has been decided that this shall be implemented at the same time as (b) below.

(b) Changes to the emergency trading suspension function

In order to ensure that trading suspension orders function even in the event of a NAS switchover malfunction, methods for implementing trading suspension orders that do not pass through the NAS were considered with Fujitsu. Development has already begun, and is expected to be completed by the end of November.

(3) Putting in place rules for market suspensions and resumptions

The inclusion of a wide range of investors in the market facilitates price formation and improves liquidity, which works in the interests of investors by reducing trading costs, etc. For that reason, participation by a variety of investors is necessary, such as institutional investors, retail investors, hedge funds, day traders, and high-frequency traders.

TSE has set out connection condition documents and contingency plans for responding to a range of risks as part of its business continuity planning, and has identified criteria and factors to bear in mind when making the decision to suspend trading. However, with regard to resumption of trading, except in the handling of cases where a suspension appears likely to be prolonged, there has been no clarification such as establishing separate criteria. In addition, there is also a lack of established procedures for resuming trading in cases such as this one, in which the function prepared for suspending trading became unusable, and an abnormal procedure was performed to suspend trading. As a result, the formation of common understanding that is required between market participants for a resumption of trading has been inadequate. Finally, when applying the contingency plan, procedures for gathering the opinions of trading participants with regard to their status, and their ability to resume trading, only exist internally, and have not been systemized. It was because such a situation existed that on this occasion it became difficult to resume trading on the same day, resulting in a situation in which it remained unclear whether trading would resume or not, and causing confusion among trading participants and investors.

Based on the above points, work will begin on the following countermeasures, and after discussions with market participants on the Council for Recurrence Prevention Measures, rules, etc. will be put in place by the end of March 2021.

(a) Putting in place the necessary rules for handling orders that have already been sent, etc. so as to enable the resumption of trading on the same day instead of suspending trading for the entire day in the event of a system failure occurring

Because the fact that orders were accepted was one of the reasons that trading could not be resumed on this occasion, the issue of in which circumstances orders should not be accepted shall be put in order and given consideration, after having sorted cases of system failure by the time at which the failure occurs and the type of failure, etc. Consideration shall also be given to creating prescriptions, in the form of rules, to ensure that the grounds for not accepting orders in the event of a system failure, etc. are clarified.

At the same time, in the event that a system failure occurs that requires arrowhead to be rebooted, the issue of whether or not orders entrusted by customers need to be resent shall be discussed and, where necessary, clarified in rules and contingency plans, etc.

(b) Putting in place procedures aimed at the resumption of trading in cases where an abnormal trading suspension has been performed

In preparation for a system failure of the kind that involves the unavoidable rebooting of arrowhead after an abnormal trading suspension has been performed, in addition to both TSE and trading participants establishing system/operating procedures for the resumption of trading after a reboot of arrowhead, consideration shall be given to measures to enable more efficient use of

the time required for such a reboot.

(c) Implementing drills based on the above procedures

After the above-mentioned procedures have been agreed with trading participants, drills for resuming trading on the assumption that arrowhead has been rebooted shall be conducted within TSE, as well as being carried out in conjunction with trading participants and market information users. Drills based on a resumption of trading, etc. shall be conducted at regular intervals thereafter.

(d) Clarifying criteria in the contingency plan for a resumption of trading

Given that there are currently no statements in the contingency plan that focus on the criteria for resuming trading, new consideration shall be given to the criteria for resuming trading, taking into account the criteria for suspending trading, and these shall be clarified in the contingency plan.

(e) Putting in place procedures for gathering the opinions of trading participants when making the decision to resume trading under the contingency plan

With regards to procedures for gathering the opinions of trading participants, to increase transparency, these will be decided by holding discussions with trading participants in relation to which trading participants (for example, a certain proportion of the largest by share of trading value), and which individuals (the persons responsible for securities trading, etc.) should be asked to share their opinions.

At the same time, rule-based changes (revisions to regulations and contingency plans, etc.) shall be conducted as required for the functioning of this mechanism, such as making a response compulsory for certain trading participants.

(f) Clarification etc., of applicability in cases where comprehensive consideration must be given to trading value share, the occurrence of natural disaster or system failure, and societal expectation, in order to improve the predictability of trading suspensions and resumptions in the contingency plan

(g) Putting in place a system for the timely and appropriate provision of information in the event of an unexpected event such as a system failure

A system shall be put in place to enable a broad range of investors and market participants to obtain information on system failures, and in addition to providing information as quickly as possible in relation to known events and causes, information shall also be provided at regular intervals. Specifically, an “Information Provision Policy in the Event of a System Failure”

(provisional name) shall be established, and in addition to organizing which information should be provided when a system failure takes place, and enhancing channels for information provision, measures shall be taken to enable effective provision of information that more fully takes into account the standpoint of those who require such information at times of system failure. This includes efforts to improve the collation of provided information in one place so that it can be easily confirmed by investors and market participants.

With regard to the above measures, it is a precondition that feasibility, in terms of operations and systems, has been ensured for those involved in the market, and trading participants in particular. For that reason, in order to give more specific consideration to the above-mentioned points for response going forward, a Council for Recurrence Prevention Measures, consisting primarily of trading participants, has been set up and has begun discussions. At such times, depending on the type of the system failure and the effects it generates, it is anticipated that in some cases a full-scale response will be required, and so the approach taken may involve dividing the response into phases in accordance with the period of time required for the response.

(4) Enhancing the reliability of JPX systems as a whole

Aside from TSE, JPX Group includes multiple companies responsible for market functions. As a holding company, JPX is required to enhance the reliability of the major market functions to a similar level. As an issue related to communications with those involved in the markets, it also reported on the status of failures and rules for resuming trading in the derivatives market operated by Osaka Exchange to the Financial Services Agency.

As part of its responsibility as a market operator with a mission to provide highly reliable systems and to operate stable markets, when updating its systems JPX Group implements tests, including tests for switchover at times of system failure, to confirm that the behavior of the system being built conforms with the design. However, based on the possibility that systems may exhibit unexpected behavior, JPX believes that an even more committed response must be implemented.

Furthermore, when making a decision about resuming trading after a system failure has occurred, as the market operator JPX is keenly aware that it must communicate fully with those involved in the market, including trading participants, and that it is essential that decisions are made based on rules that have been agreed beforehand.

Given the above, it is believed that the following two points constitute system reliability issues for JPX.

Firstly, with regard to this event, tests that assumed a switchover after an equipment malfunction were implemented, but based on the fact that the behavior of the switching mechanism of said

equipment did not conform to assumptions when there was a malfunction in a specific area, and in addition to minimizing the scope of the effects of an equipment malfunction, specifically by conducting thorough checks of the impact when the system is upgraded, and from the perspective also of minimizing the extent of the effects of an equipment malfunction so as to enable trading in the market to continue to the extent possible, we perceive it to be essential to clarify measures to enable the equipment to be switched over with complete reliability even when the automatic switchover of the equipment does not function as expected, so that functionality may be restored quickly.

Secondly, with regard to this event, when reaching a decision in accordance with the contingency plan drawn up by TSE, in addition to forming a consensus with JPX Group as a whole TSE succeeded in establishing a certain level of communications with some trading participants, but because there had been inadequate formation of common understanding among market participants in relation to the resumption of trading, this caused confusion among trading participants and investors, based on which it is believed that a review of the entire Group's approach to achieving omnidirectional communications is required.

2 The Committee's evaluation

(1) System-level response

The direct cause of the System Failure was a malfunction of the automatic switchover to NAS No.2 caused by an error in the settings, and the most important initiatives are those taken to prevent a recurrence at the system level, such as checking whether there are errors in NAS setting values, enhancing and checking measures to implement switchover with complete reliability, and implementing tests that assume a comprehensive range of cases in order to confirm that there are no errors in settings and no areas where measures have not been put in place.

According to TSE, system-level measures put in place to prevent a recurrence include: (a) revisions to NAS setting values, (b) overall inspection of NAS setting values, (c) the putting in place of measures to allow completely reliable switchover, and (d) implementing and organizing ongoing tests/drills.

These details are rational in the light of the causes of the System Failure (see Chapter 4), and based on the details of the System Failure there do not appear to be any areas where the measures to prevent a recurrence are inadequate.

(2) Enhanced measures for trading suspensions

The cause of the expanded effect of the System Failure was the inability to implement an emergency trading suspension and the enforced use of the load balancer cut-off method, and so it is important that a completely reliable means of implementing a trading suspension is devised for the

future.

At TSE, responses aimed at enhancing measures for suspending trading are organized as (a) organization of routes and statuses for trading suspension instructions and (b) making changes to the emergency trading suspension function.

These measures are intended to implement trading suspensions (emergency trading suspensions) with complete reliability after a system failure has occurred, and to avoid giving rise to a situation in which an abnormal trading suspension, such as the load balancer cut-off employed in the System Failure, is used. Based on the details of the System Failure, they appear to be rational measures for preventing a recurrence.

(3) Putting in place rules for trading suspension and suspension of order acceptance

We do not perceive that errors of judgment were made by TSE with regard to the trading suspension and the acceptance of orders during the System Failure, but there were inadequacies in the provision of procedures, etc. in relation to the trading suspension and the suspension of order acceptance during the System Failure.

According to TSE, to guard against the occurrence of a system failure, TSE will put in place the necessary rules such as those for handling orders that have already been sent, and they include rules that determine whether orders should be accepted or not depending on the time at which the system failure occurs, and the type of the system failure.

These details seek to clarify procedures and rules after full consideration of trading suspensions and the suspension of order acceptance, and they appear to be rational measures for preventing a recurrence based on the details of the System Failure.

(4) Putting in place rules for market resumptions

We do not perceive that errors of judgment were made by TSE with regard to the suspension of trading for the entire day during the System Failure, but there were inadequacies in relation to putting procedures in place, drawing up rules for resuming the market and resuming trading, making these known to trading participants, and in relation to drills.

According to TSE, measures aimed at resuming the market and trading after a system failure include (a) the clarification of rules, etc. in relation to the handling of orders entrusted by customers in the event that a system failure occurs that requires arrowhead to be rebooted, and (b) drills for resuming trading on the assumption that arrowhead has been rebooted, which will be conducted within TSE as well as in conjunction with trading participants and market information users.

These details seek to clarify procedures and rules after full consideration of trading resumption and to conduct drills with trading participants, and they appear to be rational measures for preventing a recurrence based on the details of the System Failure. To add to this, when clarifying procedures and rules it will also be necessary for the impact on investors to be clarified, and it

should be recognized that cooperation and a change in awareness of those involved in the market, including securities companies, are also absolutely indispensable.

(5) Enhancing the reliability of JPX systems as a whole

According to JPX, system reliability issues for JPX include (a) further minimizing the scope of the effects of an equipment malfunction (clarifying measures to enable the equipment to be switched over with complete reliability even when the automatic switchover of the equipment does not function), and (b) a review of the entire Group's approach to achieving omnidirectional communications, based on the inadequate formation of common understanding among market participants in relation to the resumption of trading.

These seem to be reasonable issues to tackle with the aim of enhancing the reliability of systems at JPX, the parent company of TSE.

(6) Summary

As stated above, the measures being considered by TSE to prevent a recurrence in the light of the System Failure case are rational and based on the causes of the System Failure, the causes of the inability to resume trading on the same day after the System Failure had occurred, etc., and there appear to be no points of inadequacy.

Chapter 7 Proposals aimed at the future

1 Consideration of ways to guard against "unexpected" failures and difficulties

The direct cause of the System Failure was a mistake in the settings of the NAS resulting from an error in the manual, which led to a malfunction in the NAS switchover, but we do not perceive there to be a problem with TSE's response in relation to these points. In addition, the decisions made by TSE in response to the System Failure in the form of the acceptance of orders from 08:00, the suspension of trading at 08:36, the use of the load balancer cut-off method to effectively suspend trading, and the suspension of trading for the entire day, all appear reasonable when predicated on the situation at the time.

However, if TSE had given fuller advance consideration to: (a) the procedure for making decisions about whether or not to accept orders, (b) the procedure for making decisions about trading suspensions, (c) the procedure for resuming trading after an abnormal trading suspension, and (d) the processing of the emergency trading suspension function, the impact of the System Failure would probably have been more limited.

Even for the points to which, in our assessment, TSE gave insufficient advance consideration can all be said to have been related to, or caused by, the lack of specific assumptions about the event in

which the automatic switchover was not performed due to a mistake in the NAS settings. The measures to prevent a recurrence currently being considered by JPX and TSE are sufficiently rational as responses to the System Failure that recently occurred, but the possibility of other, “unexpected” failures and difficulties occurring in systems, including arrowhead, cannot be denied.

Based on the severity and scale of the impact resulting from the suspension of trading for the entire day caused by the System Failure, adequate countermeasures should naturally be devised to prevent a similar failure from occurring, but sufficient and necessary steps must be taken to address all aspects, including those at the system level, the drawing up of procedures for countermeasures, and the implementing of tests, including those conducted by related parties, so that failures and the like caused by "unexpected" events do not occur again. Vendors must also be required to implement comprehensive tests that assume a wide range of scenarios.

It is only after such countermeasures have been implemented that they will be assessed to be effective and rational mechanisms from a medium- to long-term perspective, rather than being an approach that simply addresses the symptoms.

2 Considering responses based on the assumption that a certain level of failures is unavoidable

In addition, although the cash equity trading system should naturally aim to live up to its slogan of “Never Stop,” by overemphasizing this slogan, even after the system failure occurred, it was taken as an absolute that orders should be accepted from 08:00, and trading should begin at 09:00. As a result of this “putting the cart before the horse” response, it became impossible to smoothly resume trading even after recovering from the system failure. On the assumption that system failures occur unavoidably at a certain ratio or frequency, when a system failure occurs and leads to the risk that trading will be impeded, countermeasures must also be considered from the perspective of limiting as much of the impact as possible, while resuming quickly and safely.

In addition, with regard to the advance consideration of procedures, etc. for use when resuming trading after an abnormal trading suspension resulting from a system failure, a fully committed approach should be adopted in which it is anticipated that a trading suspension, however unwelcome, is unavoidable. Given the realistic assumption that unacceptable events will always occur, the vital issue is that we do not fall into paralysis when we encounter them.

3 Timely and appropriate information provision in the event of difficulties such as a system failure

TSE provided details of the event via the website, but it is reported that trading participants and investors made comments such as “I was unable to understand the cause and the timetable for

recovery," "There were delays in the provision of information, depending on the company," and "Information should be provided simultaneously in English."

The timely and appropriate provision of information when a system failure occurs is a matter of great concern to trading participants, investors and others involved. When an emergency arises, TSE must respond by considering what information to provide and by what means, determine procedures, and make them known to those involved. In addition, because the parties involved are diverse in nature and spread over a wide range, consideration should be given to using a larger number of channels for information provision.

4 Strengthening internal structures for response in times of emergency

When an emergency such as the System Failure occurs, countermeasures to deal with the system failure must be considered and implemented in a short period of time. Moreover, depending on the status of the system failure, it is also necessary to make important decisions such as suspending or resuming trading in a short period of time. For that reason, it is important that when an emergency occurs the person responsible for the system and the person with authority to make decisions on important matters communicate with each other immediately, and that an adequate internal response structure is established in advance to enable sufficient consideration and dialogue to take place.

Also, while telephone, email, and websites are effective means of communication, in order to grasp the most recent information in an appropriate and timely manner, and to enable large numbers of those involved to hold discussions and determine reasonable countermeasures, etc., it is desirable that as many involved parties as possible be present in the system failure emergency headquarters and other headquarters involved in considering the matter. In order to enable the person responsible for the system and the person with authority to make decisions on important matters to gather at the headquarters involving considering the issue without delay, the securing of emergency means of transport and provision of accommodation should be considered and implemented with a sense of urgency at an early stage.

As the operator of Japan's main market for securities, TSE and its parent company JPX must remain keenly aware of the importance of their role and of the significant influence it confers, and make constant efforts to strengthen their internal response systems.

5 Committing even more management resources to system-related issues

It is not an exaggeration to say that the financial instruments exchanges markets sector is a systems/IT device industry. Taking into account the importance of the markets operated by JPX and TSE, it is arguably necessary to consider further enhancements to their in-house system development capabilities, design supervision skills, and maintenance capacity. Then, over the medium to long

term, one desirable option that JPX Group should consider is enhancing in-house system design and supervision capabilities, establishing IT/system research departments, expanding capacity/adding headcount to the IT department, and systematically increasing investments so as to drive bottom-up reform of IT structures.