

PRESS RELEASE

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Tokyo Stock Exchange, Inc.

Report on the Cash Equity Trading System Failure on Oct. 1

We would like to once again deeply apologize for the inconvenience caused to many investors and other market users due to the failure in the arrowhead cash equity trading system on October 1, 2020.

Below is a report on the sequence of events surrounding the incident, the cause of the failure, and measures we will put in place to prevent a recurrence.

1. Sequence of Events

(1) From incident occurrence to trading halt

At 7:04 a.m. JST on October 1, a large number of messages were detected showing some difficulties in accessing Device 1 of the Shared Disk Device¹ (hereinafter referred to as "NAS"). After this, TSE's in-house trading control screens became unavailable and a portion of market information, which is normally disseminated to users after 7:00 a.m., was not disseminated.

On confirming the situation with the system development vendor Fujitsu, at 7:55 a.m. we became aware that a memory module failure had caused the control unit of Device 1 to fail, and a failure of the automated switch to Device 2 had caused the whole NAS to become unavailable.

Although we continued working to enable a switchover to Device 2, we were unable to guarantee a schedule for this to happen, and since the correct market data was not being disseminated, at 8:36 a.m. we decided to halt trading of all listed issues from market open (9:00 a.m.) and made an announcement to this effect.

¹ NAS (Network Attached Storage) stores files containing issue information, user information and other data that are used across different devices.

Under normal operations, trading is halted using TSE's in-house trading control screens. However, this process requires access to NAS, so we decided to take an alternative approach to halt trading by shutting down the connection of the network connecting arrowhead and trading participants. This instruction was given at 8:54 a.m.

(2) From trading resumption discussions to whole-day trading halt

At 9:26 a.m., we succeeded in a manual switchover to Device 2 of NAS, which returned all functions back to normal.

We then began discussions aimed at rebooting the system in order to resume trading within the day. Although the network had been shut down, orders that were received before 8:54 a.m. had been matched and execution notifications had accumulated within arrowhead without being sent to trading participants. Given this situation, from the perspective of handling orders, handling the accumulated executions, and price continuity, we concluded that it would be appropriate to reboot arrowhead.

We then contacted trading participants and vendors to check the possibility of their resending orders and other necessary actions, and how much time they may need. As a result, we found that only a limited number of trading participants would be able to take these actions, with a limited scope and share in trading value. As a result, it was likely that we could not guarantee the fairness and reliability of price formation in the market.

Furthermore, a resumption of trading was predicted to cause confusion, for example in the handling by trading participants of orders that they had already received. As such, at 11:45 a.m., we decided to halt trading for the whole day and made an announcement of this decision.

(3) Until resumption of trading on the next day

The motherboard² that held the faulty memory³ of Device 1 of NAS was replaced

² A motherboard holds memory, the CPU and other components

³ As a result of an investigation at the factory, the fault was determined to be a component failure which disabled reading or writing on the memory card. It was also confirmed that the defect was not

within the same day. Trading was conducted as usual the next day.

2. Cause of Failure

(1) Reason why automatic switchover to Device 2 of NAS did not function normally

TSE has a system requirement that operations should continue in the case of a NAS failure by switching over to another device within 30 seconds. When we developed the current version of arrowhead⁴, we discussed with Fujitsu what NAS setting would be appropriate with reference to the Fujitsu product manual. Since the product manual said the automatic switchover would function regardless of the NAS setting, we decided on the NAS setting taking into account the past performance of arrowhead with the same setting. This decision was also confirmed by Fujitsu.

However, the investigation after the failure on October 1 revealed that with NAS at said setting, the current product specifications are such that the automatic switchover would not function in the case of a memory module failure. The deficiency in the product manual prevented a proper understanding of the product specifications^{5 6}.

Usually, Fujitsu conducts testing with default settings to check a product functions as described in the manual prior to shipment. This time, however, since the arrowhead settings were not the default settings, the production specifications were checked on paper but no actual testing was conducted at the time of shipment. TSE did conduct NAS switchover testing, but this focused on checking business continuity after the switchover. Since our understanding was that the consistency between actual settings and those in the manual had been verified by Fujitsu during the shipment process, our testing involved creating a mock network failure to check whether the switchover functioned properly and that operations could continue normally.

The reason why it took some time to complete the manual switchover of NAS is because the failure response procedures were developed on the basis that the switchover would be

common to the production lot.

⁴ The current version of arrowhead launched in November 2019.

⁵ There was a deficiency in the production manual at the time of development of the second generation of arrowhead, which launched in September 2015.

⁶ For NAS settings over time, please see the attached "(Supplementary Material) NAS settings."

conducted automatically.

(2) Reasons why trading could not be resumed on the same day

a. IT-related issues

Although the network was shut down to halt trading, processes such as matching had continued within arrowhead, and as a result, the number of necessary procedures and things to confirm in order to resume trading was very large. We recognize that there was an issue in that, although we had multiple contingency plans to halt trading in the case of unexpected circumstances, we had not prepared a contingency plan to halt trading in the case of the NAS becoming unavailable.

b. System operation-related issues

As we had no agreement with trading participants on rebooting arrowhead, and had not carried out any tests, we judged that rebooting arrowhead to resume trading would be too risky to justify in our position as market operator. We recognize that there was an issue in our lack of rules on how to handle trade resumption after a trading halt in the event of a system failure.

3. Recurrence Prevention Measures

We have put in place various measures to enhance the reliability of arrowhead until now, under the slogan "Never Stop." Going forward, in order to build speedier and more appropriate recovery procedures, we will place the same level of importance on "Resilience" (the ability to recover from a failure).

Recurrence Prevention Measures	Contents
(1) System Responses and Comprehensive Checks (Response to 2. (1))	- Correction of NAS switchover setting (Completed on Oct. 5) - Comprehensive check of NAS settings (By the end of Oct.) - Examination and development of measures to ensure successful switchover (By the end of Nov.) - Switchover tests and drills (by Jan. 2021 for NAS; ongoing)
(2) Enhancement of	- Confirmation of whether there are any past cases of failure

Recurrence Prevention Measures	Contents
<p>procedures for failsafe trading halts (Response to 2. (2) a.)</p>	<p>to halt trading (by the end of Oct.)</p> <ul style="list-style-type: none"> - (If there are any such cases) Preparation of necessary instructions and operation procedures (By the end of Nov.) - Development of a function which halts trading without using NAS (By the end of Nov.)
<p>(3) Development of rules for trading halts and resumptions (Response to 2. (2) b.)</p>	<p>Establishment of a "Council for Recurrence Prevention Measures" comprised of market users such as trading participants, investors, and system vendors, and development of necessary rules, etc. based on the discussions of the Council. (By around the end of Mar. 2021)</p> <ul style="list-style-type: none"> - Development of rules necessary to resume trading on the same day; - Development of procedures for trading resumptions; -Clarification of standards for trading halts/resumptions; - Discussion on ideal information provision; and so on.