EXECUTIVE SUMMARY OF INVESTIGATION REPORT INTO TRAIN COLLISION AT JOO KOON STATION WESTBOUND PLATFORM ON 15 NOVEMBER 2017 ("INCIDENT")

1. On 15 November 2017, Train 3535/3536 was launched into service at about 5.38am from Ulu Pandan Depot (UPD) heading east on the East-West Line (EWL) towards Pasir Ris MRT station. It was operating on the legacy signalling system with the new Communications-Based Train Control (CBTC) signalling system operating in the background in passive mode[1].

2. When launched for passenger service, Train 3535/3536's train-borne CBTC signalling equipment developed an abnormal condition which prevented it from communicating with the trackside CBTC signalling system. The safe operation of Train 3535/3536 was unaffected at this time as it was being controlled by the legacy signalling system. Nonetheless, in response to the abnormal condition, the CBTC system automatically applied a Non-Communicating Obstruction (NCO) protective "bubble" around the train to ensure its safety.

3. However, the NCO protective "bubble" was inadvertently disabled[2] when Train 3535/3536 passed over an existing trackside device (a track point labelled W210B located west of Clementi station) which had yet to be modified for compatibility with the CBTC system. From that moment onwards, each track circuit block that Train 3535/3536 entered automatically imposed a Temporary Speed Restriction (TSR) of 18 kilometres per hour (km/h). This is illustrated in **Figure 1** below. However, this did not affect the operation of Train 3535/3536 as it continued to travel eastbound towards Pasir Ris MRT station under the full control and protection of the legacy signalling system. After reaching Pasir Ris MRT station, Train 3535/3536 turned back westbound to Pioneer MRT station.

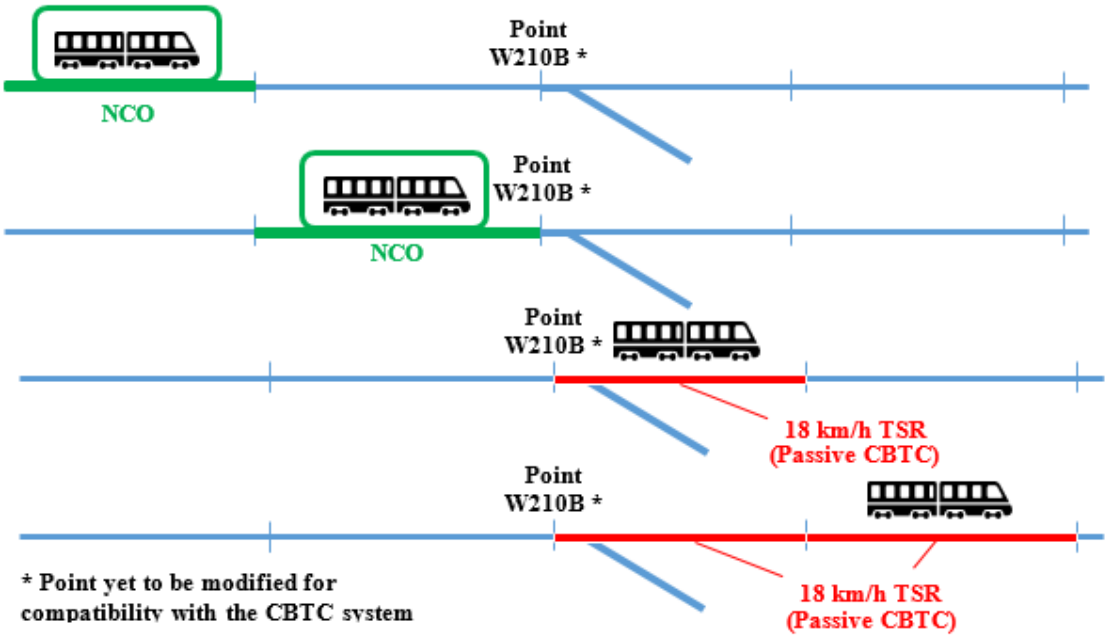

Figure 1: Sequence of events leading to disabling of the NCO protective "bubble" and imposing of TSR under CBTC passive mode operations

[1] CBTC passive mode refers to the mode where the train is controlled by the legacy signalling system but the CBTC system is monitoring in the background and collecting information for performance verification.
[2] The NCO failed to propagate with the train when it moved over track point W210B.

4. Pioneer MRT station is where westbound trains transition from operating on the legacy signalling system on the EWL to operating on the new CBTC signalling system on the Tuas West Extension (TWE), and vice versa for eastbound trains. When Train 3535/3536 arrived at Pioneer MRT station at about 8.03am, it transitioned to operating on the new CBTC signalling system. However, due to the abnormal condition that had developed on the train-borne CBTC signalling equipment, Train 3535/3536 was prevented by the CBTC system from travelling in Automatic Mode (AM). As a result of this abnormality, SMRT's Operations Control Centre made the decision to withdraw Train 3535/3536 from service via a centre siding after Joo Koon MRT station to Ulu Pandan Depot as shown in **Figure 2** below. To accomplish this, Train 3535/3536 was first routed in Restricted Manual (RM) mode to the Joo Koon westbound platform, where the passengers could be de-trained. In RM mode, the train's speed is limited to 18 km/h by the CBTC system.

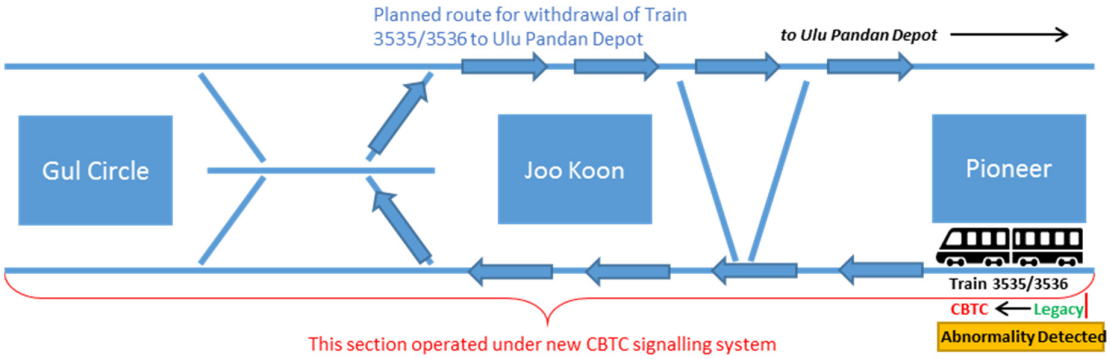

Figure 2: Legacy to CBTC transition at Pioneer and planned route for withdrawal of Train 3535/3536 to Ulu Pandan Depot

5. Approximately 3 minutes later, the following train, Train 3547/3548 departed Pioneer westbound platform after having successfully transitioned into AM under CBTC control. The speed of this train was limited to 18 km/h by the CBTC signalling system due to the TSRs that had been invoked by Train 3535/3536 ahead of it. Also, as part of route protection, as long as Train 3535/3536 had not completed the route that was set for it to move from Pioneer station west to the next Joo Koon station, Train 3547/3548 would not be allowed to catch up with Train 3535/3536.

6. When Train 3535/3536 arrived at Joo Koon westbound platform, the platform screen doors had to be opened manually with the Emergency Screen Door Control to allow passengers to de-train. This process created a "Closed Track" protection around Joo Koon westbound platform which prevented trains from entering or leaving the platform. As a result of the "Closed Track" protection, the following train, Train 3547/3548 came to a stop approximately 36 metres from the Joo Koon westbound platform tail-wall. This is illustrated in **Figure 3** below.

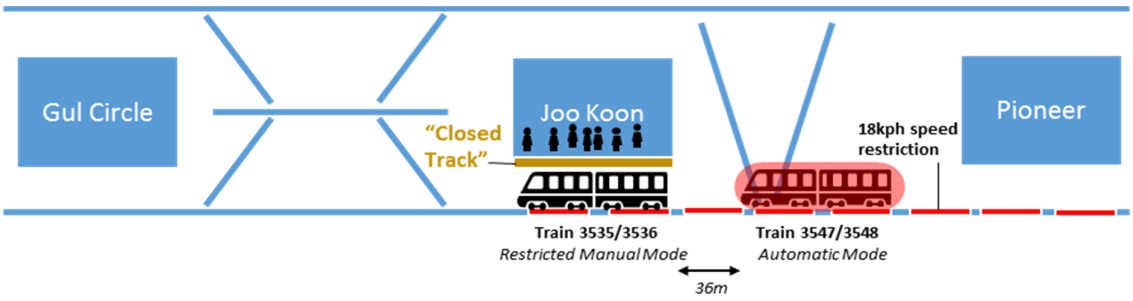

Figure 3: Creation of "Closed Track" protection at Joo Koon westbound platform

7. Once passengers had de-trained from Train 3535/3536, the platform screen doors were manually closed, and the "Closed Track" protection around the platform was lifted to allow Train 3535/3536 to move off. As the NCO protective "bubble" on Train 3535/3536 had earlier been inadvertently disabled, Train 3547/3548 could not detect the presence of Train 3535/3536 ahead, and moved forward in AM (but restricted to 18 km/h due to the TSRs invoked by Train 3535/3536). At 8.20am, Train 3547/3548 collided with the rear of Train 3535/3536 before the latter could depart from Joo Koon westbound platform, as shown in **Figure 4** below.

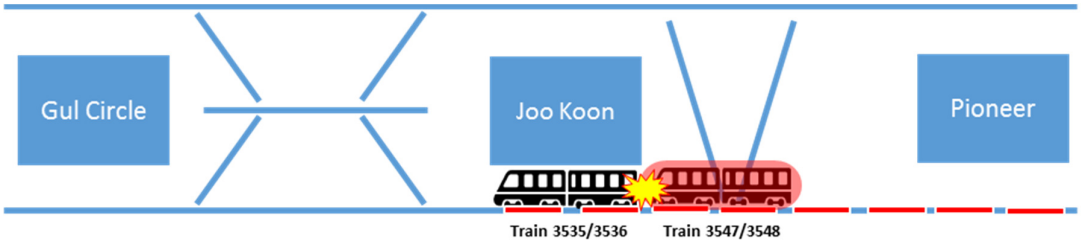

Figure 4: Lifting of "Closed Track" protection at Joo Koon MRT Station and collision

8. 38 people were injured as a result of the collision. In addition, about 12,930 commuters were affected by the service disruption caused by this Incident.

CAUSE OF THE COLLISION

9. The root cause of the Incident was a software logic issue with the CBTC system which was not configured to cater for the failure conditions that occurred on 15 November 2017. Further extensive tests and analysis by LTA, SMRT and Thales, including on-site re-enactments (see **Annex A**), have confirmed that a confluence of the following failure conditions contributed to the Incident:

a. Train 3535/3536 had developed an abnormal condition with its train-borne CBTC equipment which prevented it from communicating with the trackside CBTC signalling equipment. This prevented the CBTC system from tracking the location of Train 3535/3536 accurately. When such an abnormality occurs, the CBTC system will, by design, apply an NCO protective "bubble" around the affected train to ensure its safety. This was the requisite start state for the Incident; and

b. Train 3535/3536 crossed over track point W210B which was the only track point that had not yet been fully modified for compatibility with the CBTC signalling

system for trains operating in CBTC passive mode. Because of this, the status of point W210B could not be properly detected by the CBTC system, and was registered by the CBTC passive mode as 'moving' indefinitely; and

c. The CBTC signalling system configured in passive mode had not accounted for the possibility of a point registering as "moving" indefinitely. As a result, the CBTC signalling system did not propagate the NCO protective "bubble" for Train 3535/3536 through point W210B.

10. Analysis and tests conducted by Thales on the 'moving' point scenario (Refer to Test 3 in **Annex A**) have also confirmed that trains operating in the CBTC active mode, such as those on the North-South Line (NSL) and TWE, would have correctly handled the 'moving' point scenario and propagated the NCO across the point. Thus, operations in CBTC active mode on the NSL and TWE continue to be safe.

REMEDIAL MEASURES

Separation of TWE and EWL

11. Since 20 November 2017, operations on the TWE (which operates on the CBTC signalling system) from Joo Koon to Tuas Link MRT stations have been separated from the rest of the EWL (which operates on the legacy signalling system) to minimise the complications of operating two different signalling systems concurrently on a single line. This will eliminate the possibility of a recurrence of the events of 15 November 2017. The separation will continue until EWL re-signalling works are completed next year and the entire EWL, including the TWE, can be operated continuously on the new CBTC signalling system.

System Modification

12. Thales completed the circuit modification at point W210B on 16 November 2017. Thales will also modify the software logic to ensure propagation of the NCO protective "bubble" across points regardless of the status of the point for both the CBTC active and passive modes. This will prevent future disabling of the NCO protective "bubble".

SUMMARY

13. The train collision incident was the result of complications from operating two signalling systems concurrently on a single line. Since then, as a precautionary measure, operations on the TWE have been separated from the rest of the EWL. Thales has given its full assurance that the CBTC signalling system used on the NSL and TWE are safe and robust, and that CBTC works will not impact the continued operation of the legacy signalling system.

ANNEX A

Table 1 below shows the on-site tests, checks and re-enactments that have been carried out on the CBTC signalling system following the 15 November 2017 incident:

S/No.	Test	Findings
1	Recreation of NCO removal at point W210B before point circuit modification with CBTC in passive mode	A test was conducted in order to re-create the NCO removal on 15 November 2017. This proved that the cause of removal of the NCO protection had been properly identified by the investigating team.
2	NCO behaviour across W210B after point circuit modification with CBTC in passive mode	A test was conducted to confirm that with point wired to be compatible with passive CBTC operation, the NCO is properly propagated across W210B. This reaffirms the cause as identified in Test 1 above.
3	Demonstration of NCO behaviour with full CBTC control	A similar scenario to the one on 15 Nov 2017 was recreated but at a zone with full active CBTC control. The NCO was correctly propagated by the CBTC system after the train had traversed through the point.
4	EWL point detection relay status check	The results of the check determined that all points on the EWL (other than point W210B) had been wired for compatibility with CBTC operation.

Table 1: Summary of tests and findings