Aviation Safety Investigation Report 200102695

Boeing Company 737-476

18 June 2001

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FACTUAL INFORMATION

As the Boeing 737-476 (B737) operating a scheduled passenger service to Adelaide, accelerated during the take-off roll on runway 06 at Perth International Airport, the driver of a sweeper vehicle (see Fig. 1) operating on that runway saw the aircraft approaching in the vehicle's rear view mirror, turned right and vacated the runway. The crew of the B737 saw the vehicle vacating the runway and continued with the take off.

The *Manual of Air Traffic Services* (MATS) Part 4.5.1.1, stated that:

> Visual separation shall be achieved by the use of visual procedures.

MATS Part 6.3.1.6 stated:

> A visual check of the take-off or landing path on the runway-in-use shall be made to ensure no obstructions exist before clearing an aircraft for take-off and immediately before the take-off is commenced.

Paragraph 6.3.1.7 further stated that:

> The clearance shall be withheld or cancelled until an obstruction no longer exists, unless in the opinion of the controller:
>
> - no collision risk exists, and
> - there is reasonable assurance that separation will exist when:
>   - the aircraft commences take-off roll, or
>   - the aircraft crosses the runway threshold to land.

There was an infringement of separation standards.

FIGURE 1:
Runway sweeper vehicle

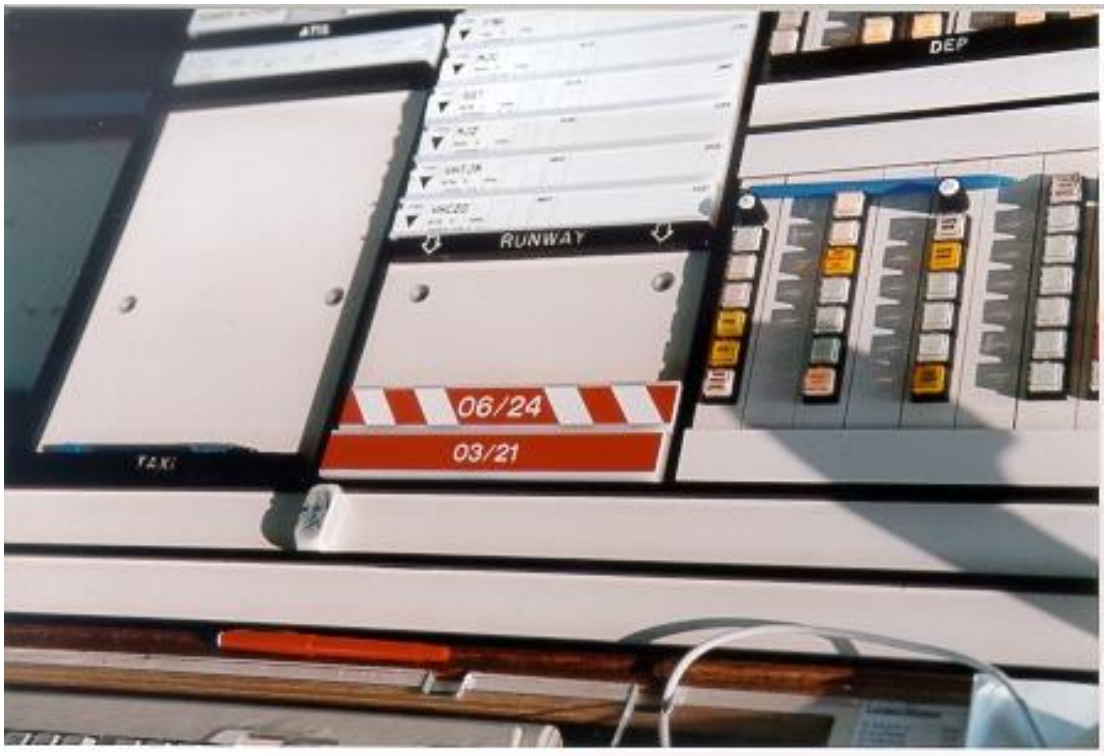
At about 10:59 Western Standard Time, the driver of the sweeper vehicle requested approval to enter runway 06. The vehicle had previously been operating on that runway but had been directed to vacate the runway due to arriving aircraft. The vehicle's rotating beacon and strobe light were operating. The surface movement controller, who was in radio communication with the sweeper driver, cleared the driver to re-enter the runway, after first asking the aerodrome controller for permission. The aerodrome controller approved the request. Both controllers then placed runway occupied strips in the relevant bays on their consoles in accordance with local instructions.

The use of a runway occupied strip was a common practice among air traffic controllers. The runway occupied strips were brightly coloured to maximise their visibility from most control positions in control tower cabins. In the Perth control tower, the surface movement controller used a red flight progress strip that was divided into two sections. The left half of the strip was engraved with 03/21 in white. There was a dividing line engraved vertically at the centre of the strip and the right half of the strip was engraved with 06/24. There was space on both sides of the strip to write additional information, such as the vehicle callsign, with a chinograph pen. In addition, the surface movement controller used a white strip to write details of all other vehicles that were operating on the airfield that were using his frequency. If used, both the strips would normally be placed in the taxi bay of the surface movement controller's console (see Fig. 2). If an aircraft called for a taxi clearance, the aircraft's flight progress strip would be placed in the taxi bay and the strips, used as memory prompts, should alert the controller to the disposition of the traffic on the aerodrome.

FIGURE 2:
Example of surface movement controller's red runway occupied strip in the taxi bay

At Perth, the aerodrome controller used a red coloured strip with 03/21 engraved in white on the centre of the strip when runway 03/21 was occupied. For runway 06/24, the controller used a strip that was striped diagonally in bands of red and white, engraved in the centre with 06/24. When both runways were occupied, both runway occupied strips were placed in the runway bay (see Fig.3).

FIGURE 3:
Example of aerodrome controller's runway occupied strips in the runway bay



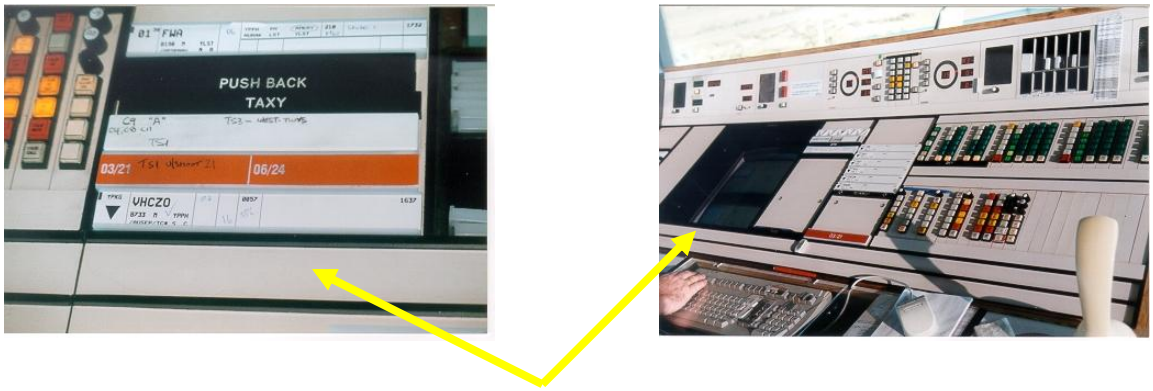
Flight progress strips were used to improve the controller's situational awareness by acting as a memory prompt. The action of placing the flight progress strip in the runway bay required direct interaction with the strip, which would enhance a memory trace. Further, the runway strip bay could be scanned allowing the controller to verify his/her situational awareness. Sweeper vehicles and other maintenance vehicles were frequently on the Perth runways.

When the aerodrome controller gave the surface movement controller permission for the sweeper to enter the runway, the aerodrome controller placed the striped runway occupied strip in the runway bay on the console. The aerodrome controller had no recollection of either giving approval or of placing the strip into the runway bay.

At about 11:02, the crew of the B737 requested a taxi clearance and was cleared to the holding point Juliet 1 by the surface movement controller. The Juliet 1 holding point was at the northern intersection of runway 06/24 with taxiway Juliet. Prior to the aircraft taxiing, the aircraft's flight progress strip was in the surface movement controller's pushback bay. The flight progress strip would then be placed in the top transfer slot when the aircraft taxied out (see Fig. 4). While the aircraft taxied, the surface movement controller would write the taxi time on the paper strip and ensure that any vehicles on the runway were moved clear of the runway before passing the strip via the transfer slot to the coordinator for reconciliation with the Eurocat system. The coordinator would ensure that the runway and standard instrument departure annotated on the flight progress strip matched the runway and standard instrument departure entered into the Eurocat system. The

strip would be ticked with a red pen and then moved along the transfer slot to the aerodrome controller, before the crew of the aircraft reported ready for departure.

FIGURE 4:
Arrow highlighting position of top transfer slots



After the crew of the B737 was issued the taxi clearance, the surface movement controller took the flight progress strip directly to the coordinator position as the controller was performing the combined duties of the surface movement controller and coordinator (the rostered coordinator had taken a short break). That action allowed the surface movement controller to bypass moving the flight progress strip under the taxi bay and noticing the runway occupied strip. According to a Perth Tower Memo [TWR/00/02 effective 17 May 2000], the surface movement controller had the responsibility to be proactive by ensuring a runway that was to be used by taxiing aircraft was vacated.

At about 11:05, the B737 crew reported to air traffic control on the aerodrome control frequency that they were ready for departure. The aircraft was on taxiway Juliet approaching runway 06 (see Fig. 5). At the time, the aerodrome controller was coordinating an overhead transit of a light aircraft with approach control. He instructed the B737 crew to enter and backtrack on runway 06 and line up.

The aerodrome controller continued the coordination with the approach controller. The air traffic situation involved an overflying Cessna 172 Skyhawk (C172) tracking from the east and on descent from 3,000 ft to 1,500 ft via Perth aerodrome before heading west to Cottesloe. The aerodrome controller had earlier approved the descent clearance for the C172. The C172 was under the control of the approach controller and on the approach control frequency. The sighting of that aircraft by the tower controller was essential to facilitate the application of visual separation with any departing aircraft.

FIGURE 5:
View from aircraft of sweeper vehicle from taxiway Juliet

The airport sweeper driver observed the B737 at taxiway Juliet but did not see it enter the runway. He had turned the sweeper at taxiway Charlie 1 to head in the opposite direction towards the upwind end of runway 06. The sweeper commenced travelling down the right side of the runway. The driver was monitoring the surface movement control frequency in accordance with local procedures and did not hear the crew's transmissions with the aerodrome controller. The crew of the B737 did not notice the sweeper prior to turning their aircraft onto the runway. The sweeper and the B737 were now on the same runway but moving in opposite directions away from each other.

The aerodrome controller was finding it difficult to sight the C172. He walked to the rear of the tower to see if the aircraft was overhead and often looked on the radar display in an attempt to determine the position of the C172. At about 11:06, the aerodrome controller then coordinated an unrestricted departure instruction for the B737 with departures control as he could visually separate the B737 with the C172. The aerodrome controller then instructed the crew to contact the departures controller when airborne and cleared the B737 to take off. The crew read back the take-off clearance to the aerodrome controller. The aerodrome controller then continued coordination with approach control regarding the overflying C172 aircraft.

At the time that the B737 was cleared for take off, the aircraft was approaching the runway threshold and taxiing along the southern edge of the runway. The crew turned the aircraft clockwise through 180 degrees to align with runway 06. The elapsed time between the aerodrome controller issuing the take-off clearance until the aircraft was aligned with the runway was about 30 seconds.

About 10 seconds later, at 11:06:40, the crew of the B737 had completed the pre-takeoff checklist and commenced the take-off roll. The pilot in command was the handling pilot and the co-pilot was looking down adjusting the thrust controls. Neither of the flight crew saw the sweeper on the runway (see Fig.6).

FIGURE 6:
View from aircraft of sweeper from runway 06 threshold

The sweeper was still travelling in a north-easterly direction on the southern edge of the runway facing away from the aircraft. The sweeper observed the lights and heat plumes of the aircraft in his rear vision mirror accelerating towards him. He immediately turned the sweeper to the right and vacated the runway at a position approximately 1,470 m from the runway threshold.

When clear of the runway, the sweeper driver applied the brakes and disengaged the sweeper from the sweeping mode. He then drove towards the access road and contacted the control tower by radio. He advised the surface movement controller that the sweeper was clear of runway 24. There was no response from the tower for about 20 seconds.

The pilot in command of the B737 reported that he sighted the sweeper when the aircraft was travelling at approximately 100 kts and was about 200 m from the sweeper. The B737 was on the runway centreline and the sweeper was turning right at the runway edge. The pilot in command estimated that there was sufficient clearance between the aircraft's wingtip and the position of the sweeper, to continue without making evasive manoeuvres. The aircraft rotated and became airborne at 11:07:14 after it passed the sweeper's position.

While the B737 was rolling down the runway, the focus of the aerodrome controller's attention was on the C172 whose pilot had unexpectedly called up on the aerodrome control frequency. The controller had just sighted the C172 prior to that call. The C172 was supposed to be tracking directly to the city in a westerly direction but was observed by the aerodrome controller to be heading in a south-westerly direction. That concerned the controller as there was a British Aerospace 146 (BAe146) tracking for a left base to runway 03. The aerodrome controller instructed the C172 pilot to turn right and to track to the city. The aerodrome controller did not notice the B737 pass the sweeper on the runway and become airborne.

The surface movement controller did not observe the B737 take off. At the time the B737 was commencing the take-off roll, the controller was coordinating the Flight Data Record of an Airbus Industrie A320 (A320) within the Eurocat system. That process was the tower coordinator's function. Coordination of the Flight Data Record changes the electronic flight progress strip from a pre-active to an announced state. The process required the controller to interact with the Eurocat system using an electronic mouse.

A trace of the controller's interactive input with the Eurocat system indicated that the surface movement controller changed the A320's electronic flight progress strip from a pre-active to an announced state at 11:06:35. The surface movement controller then advised the terminal area electronically that another A320 became pre-active at 11:07:24 by inputting the runway and standard instrument departure on the electronic flight progress strip.

The first indication the controllers received of the incident was when the crew of the B737 advised that a vehicle had infringed the active runway during the take-off roll in front of their aircraft. Both controllers looked at their console displays and noted that the runway occupied strips were correctly placed in the appropriate bays indicating runway occupancy by the sweeper. It was during the transmission made by the B737 flight crew that the sweeper driver reported clear of runway 24. The surface movement controller later made a transmission to the sweeper driver to confirm that the sweeper was clear of the runway.

About one month prior to the incident, the surface movement controller, in his capacity as team leader, had carried out a performance check on the aerodrome controller. The performance check identified areas of the aerodrome controller's performance that needed improvement. Of note, the comment was made that his use of mandated memory prompts with regard to vehicles was not always up to date. The aerodrome controller disagreed with the performance check.

The visual acuity required to detect the sweeper from the tower was within the range for normal vision. The colour of the sweeper (white with black hoses) meant that the sweeper blended with the grey runway providing limited perceptual contrast. From the controller's perspective the sweeper was in the shade, given the position of the sweeper, runway and sun at the time of the incident, although the hazard beacon and strobe light were unobstructed. At the position from where the B737 commenced its take-off roll, the flight crew was looking at the smaller surface area of the rear of the sweeper truck. Due to the position of the sun at the time of the incident, the rear of the sweeper was in the shade, reducing visual contrast. The rotating beacon and strobe were in partial alignment. Tests during the investigation showed that it was possible to observe the sweeper vehicle from the runway 06 threshold and from the air traffic control tower, despite the unfavourable lighting conditions and the vehicle's colour scheme that made observation more difficult.

FIGURE 7:
View of sweeper from the control tower

ANALYSIS

Because the surface movement controller was working in the combined position of surface movement controller and tower coordinator, he was able to skip steps in the operating procedure. Skipping these steps removed some of the checks that were in the system to minimise the likelihood of an aircraft being cleared for departure on an occupied runway. As indicated in the Perth Tower Memo (TWR/00/02), the surface movement controller had a responsibility to be proactive in vacating the runway. The surface movement controller did not realise that the runway was still occupied and that the sweeper was still on the runway.

The aerodrome controller was unable to recall placing the runway occupied strip in his runway bay. The use of the runway occupied strip should have facilitated the aerodrome controller's situational awareness and consequent knowledge that the sweeper was occupying the runway. Given the frequency of sweepers and other vehicles on the runways at Perth airport, it was possible that the controller placed the runway occupied strip in his runway bay as an automated action, not consciously processing that the runway was occupied.

The aerodrome controller did not detect the sweeper on the runway when he carried out his runway scan. Despite limited perceptual contrast, the calculated visual acuity required to detect the sweeper from the tower indicated that the sweeper was sufficiently large enough to be visible, particularly as the strobe and rotating beacon were operating.

The pilot in command and co-pilot would not have been able to scan the length of the runway when the aerodrome controller issued the take-off clearance. The take-off clearance was issued prior to the aircraft turning 180 degrees to line up for the departure. The flight crew would not have been

unable to carry out their runway scans until the aircraft had lined up. Both the pilot in command and co-pilot of the B737 did not observe the sweeper on the runway when they carried out their runway scans prior to take off.

At the time of the incident, the external lights active on the sweeper were the rotating beacon and strobe on the top of the cabin and body (see Fig. 8). Although these lighting devices were operating, neither the aircraft nor the tower crew observed them during their runway scans. The sweeper did not have, nor was it required to have, its vehicle hazard lights or any other external lights activated. The use of flashing or rotating lights increases the visual detection of objects, especially when illumination is reduced due to poor lighting or shade. The use of those additional lights may have improved the likelihood that the sweeper was detected in runway scans. The use of flashing or rotating lights on the rear of the vehicle may have increased the contrast of the sweeper against its surroundings, improving the likelihood of the B737 flight crew detecting the sweeper on the runway.

FIGURE 8.
Close up view of sweeper from the rear. Lighting conditions similar to those occurring on the day of the incident. Note the alignment of the rotating beacon and strobe

Although the situational awareness of the sweeper driver was most satisfactory, the equipment and procedures did not provide the driver with the opportunity to monitor the aerodrome control frequency. If the driver had been able to monitor the aerodrome control frequency, the driver may have realised that the B737 had been mistakenly cleared for take-off while the sweeper was occupying the runway and vacated sooner, or made a radio broadcast querying the clearance.

The performance check carried out by the surface movement controller on the aerodrome controller may have caused animosity between the two controllers, which would inhibit teamwork among the tower controllers. The investigation was unable to determine the extent to which that may have affected the performance of either controller.

SIGNIFICANT FACTORS

1. The surface movement controller did not adequately scan the console display or the runway prior to releasing the flight progress strip to the aerodrome controller.

2. The aerodrome controller did not adequately scan the runway bay or the runway prior to issuing a take-off clearance to the crew of the B737.

3. When performing their checks, the pilot in command and co-pilot of the B737 did not adequately scan the runway and see the sweeper vehicle on the runway.

4. The ambient lighting, vehicle colour scheme and position of the sweeper vehicle made it more difficult to see from the perspective of the B737 flight crew and the control tower, despite the operation of the vehicle's rotating beacon and strobe light.

5. The sweeper driver was unable to monitor the aerodrome control frequency from the sweeper vehicle.

SAFETY ACTION

Local safety action

As a result of the investigation, Airservices Australia advised that air traffic control has implemented the following changes:

Changes to ATC Local Instructions:

- Posting of Flight Progress Strips by Surface Movement Control.

  The FPS for a taxiing departure aircraft must be placed under the "TAXI" designator (where the Runway Occupied Strip is located) until vehicle/s have been instructed by SMC to vacate the runway.

- Additional note:

  It remains the aerodrome controller's responsibility to ensure that the vehicle/s have vacated the runway.

Westralia Airports Corporation (WAC) advised that as a result of the incident, some measures could be adopted immediately to reduce risks when driving on runways. Procedures and guidelines were published (*Safety Bulletin*, Issue: 1, dated 27 July 2001) that re-stated some existing practices and also introduced some new ones. WAC planned to incorporate these measures into a future issue of the Airside Drivers Handbook for Code 4 drivers.

The measures were detailed under the sub-headings as follows:

- Maximise vehicle visibility;

- Scan for aircraft;

- Reduce ATC workload; and

- Situational awareness.

In addition, a trial period was introduced with one vehicle painted red. Local ATC suggested that that colour was far more prominent and WAC have elected to introduce red coloured safety vehicles for a longer trial.

For the main safety officer vehicle, which spends more time on the runways than any other vehicle, WAC installed headlight flashers similar to that used by many police and ambulance vehicles. WAC drivers use the headlight flashers in the daytime, usually on high beam, with each light flashing alternately. WAC advised that when facing oncoming traffic, the "wig-wag" type flashing helped visual acquisition.

Australian Transport Safety Bureau (ATSB) safety action

As a result of the investigation, the Australian Transport Safety Bureau issues the following recommendations:

Recommendation 20020036

That Airservices Australia, in conjunction with airport owners, review the adequacy of equipment and procedures that allow drivers of all vehicles using airport runways to monitor the aerodrome controller radio frequency.

Recommendation 20020040

That Airservices Australia, the Civil Aviation Safety Authority and the Australian Airports Association should jointly review airside vehicle operation with a view to establishing national operating standards and procedures (including vehicle colour, lights and procedures).