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Ultra-high-capacity Aircraft Will Intensify Airport Safety Issues

The new generation of transports will likely cause further pressures on ground maneuvers and emergency evacuations at airports, and possibly increase wake vortex hazards.

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Introduction of ultra-high-capacity aircraft (UHCA) is likely to create safety challenges in airport operations. Affected areas include airport ground maneuvers and operations, the provision of airport rescue and fire fighting services and the emergency evacuation of passengers from aircraft. Ultimately, however, UHCA most likely will highlight current safety problems.

The discussion of any safety issue concerning an aircraft type that is still on the drawing board is fraught with difficulty and is made by analogy and experience with existing aircraft types. What has become apparent is the relationship among safety issues, aircraft design and the interface with airport infrastructure.

Many safety-related incidents, of course, are not a function of aircraft size. Nevertheless, should an accident occur, the public perception of air transport safety is affected by the number of people involved in that accident. For example, the loss of a microlight or a general aviation aircraft tends not to attract the national press unless the circumstances are particularly poignant; however, an emergency landing by an airliner followed by a less-than-successful evacuation of passengers is likely to be well publicized.

Larger Weight and Size Can Mean Larger Problems

UHCA raise new safety issues, including effects of increased weight and dimensions of the aircraft. The Boeing 747-400 has a maximum takeoff weight (MTOW) of 870,000 pounds (394,625 kilograms), a wingspan of 213 feet (65 meters) and an overall length of 231 feet (71 meters). By contrast, the world's largest aircraft is the Antonov An-225, with an MTOW of 1,322,000 pounds (600,000 kilograms), a wingspan of 290 feet (88 meters) and an overall length of 276 feet (84 meters). The weight and dimensions of UHCA remain subjective but for this discussion they will approximate the An-225.

The initial step is to identify those operational safety areas in which UHCA operations may result in an increased probability of a specific type of accident or incident. Certain incident types in which aircraft size is unlikely to be a factor can be eliminated. Using the *World Airline Accident Summary*, published by the U.K. Civil Aviation Authority (CAA), a summary of accident/incident types includes:

- Wake vortices;
- Ground maneuvers, including the transit of runways and taxiways; physical separation from other aircraft, structures and ground vehicles during ground operations;
- Deicing and fire and safety services;
- Ground operations while the aircraft is stationary, including damage to the aircraft by ground handling vehicles, and the safety of personnel; and,
- The safety of passengers and crew on board the aircraft during embarkation and disembarkation and in an emergency evacuation.

What wake vortex standards should be applied is of major concern. This issue is still being resolved for aircraft types operating today. Vortex generation is primarily a function of aircraft weight, speed and flap configuration, and the strength of the perturbation diminishes with time and distance.

The effects of wind and temperature on wake vortices is the subject of current research programs because meteorological conditions can affect the rate at which wake vortices disperse and the paths the vortices take during that dispersal. For example, high winds and turbulent conditions speed the dispersal of the vortices; calm conditions allow the vortices to remain for a longer period.

Larger Wake Vortices May Be Created

The UHCA will likely be 50 percent heavier than the Boeing 747-400, and if the wake vortices increase proportionally then separation for following aircraft on approach may have to be increased by up to 12 nautical miles (nm). Research is required to establish the necessity and magnitude of revisions to wake vortex separation standards. Boeing, for example, is exploring various means of reducing vortex effects, including specially configured winglets deployed in the landing configuration, or turbines designed to break up the vortices.

Despite current separation standards, incidents do occur when the vortices do not disperse or separation distances are degraded, often because of air traffic control (ATC) procedures. Some examples are:

- The Fokker F27 was on a scheduled flight to Heathrow, London, England. The aircraft was cleared for radar positioning to the instrument landing system (ILS) on Runway O9L. Immediately preceding the F27 was a B-747, also being positioned under radar direction to land on Runway O9L. The B-747 was then re-allocated to Runway O9R as the aircraft was parking at Terminal 4. This meant that the F27, while aligning on final approach to Runway O9L, would pass behind the B-747 and when the F27 actually crossed the O9R centerline, the horizontal separation was about three nm. The F27 encountered the wake vortex of the B-747. As a consequence of the wake vortex–induced turbulence, which only lasted a few seconds, one cabin attendant, who was closing the flight deck door, was thrown to the floor and broke her leg.
- At Heathrow, a Boeing 757-200 aborted the landing from 60 feet (18 meters) on the approach to Runway 23 because of severe turbulence on crossing the Runway 27R threshold. This was attributed to a B-747 taking off from Runway 27R. At present there are no specific separation rules because Runways 23 and 27R do not directly intersect. Nevertheless, normal ATC procedures require that, if an aircraft is on approach to Runway 23, then takeoff clearance for aircraft on Runway 27R should not be given until the landing aircraft has passed the centerline of Runway 27R.
- A de Havilland Dash 7, on final approach to Charles De Gaulle, Paris, France, Runway 27, was radar vectored for positioning as number 2 behind a B-747-400, with a left-hand turn to intercept the localizer given once the B-747 had descended through the level of the Dash 7. The Dash 7 noted the apparent closeness of the B-747 as the ATC-directed intercept heading turn was made, but continued until the B-747 wake hit the Dash 7 with a tremendous impact. The Dash 7 crew turned 90 degrees to the B-747 track, and as they turned they could see the vortices from the B-747 cutting a path through the broken cloud layer below. Speed was reduced and the rest of the approach was uneventful. The report indicated that this was the third such incident experienced by the airline and suggested that the arrival procedure is a causal factor of such incidents.

The introduction of the B-747-400, with an increase in wingspan of 16 feet (5 meters) compared with previous variants, resulted in the aircraft being restricted to specific taxiways and stands at some airports. The introduction of UHCA will result in a further dramatic increase in wingspan and fuselage length. Nevertheless, the safety of the aircraft during airport operations depends not only on the overall dimensions of the aircraft but also on other factors, such as undercarriage layout and the height of the fuselage above ground.

Some major airports believe that UHCA can be accommodated by limited additional investment in infrastructure and acceptance by aircraft operators that ground maneuvers and stand availability might be restricted. Nevertheless, alternate airports will require runway and taxiway infrastructure sufficient to allow UHCA to land, clear the runway, park, return to the runway and take off.

Within the runway and taxiway system, wingspan is the most critical dimension because of the requirement to have a minimum separation distance between maneuvering aircraft. Ground vehicles and fixed infrastructure (for example, terminal buildings) also have to be avoided. To minimize the effect on other aircraft operations, preferential routing for UHCA, such as there already is for some B-747 operations, is a possible option for accommodating UHCA.

More Passengers Will Require More Ground Support

Two markets are projected for UHCA: the Far East domestic and short-haul market, and long-haul operations. It is expected that the number of ground support vehicles on the apron will increase in proportion to the passenger capacity of the aircraft. For example, refueling vehicles on both sides of the aircraft and additional catering and baggage vehicles will be needed if current container and baggage-handling equipment is retained.

The overall length of the aircraft will reduce the clearance normally available at parking stands to allow the safe movement of ground support vehicles, and some stands might become unusable because of a reduction in stand taxi-lane clearance caused by a UHCA parked on one side of the apron.

The undercarriage layout, wheel base and wheel track may require additional paved areas in the taxiway system. International Civil Aviation Organization (ICAO) regulations for the largest commercial aircraft presently in operation recommend a standard runway width of 148 feet (45 meters); this allows for aircraft deviation from the runway centerline in the event of engine failure and, with the shoulders, protection to the engines from debris. The offset of the engines and undercarriage layout will determine if the present standards will still be sufficient for safety. Some taxiway maneuverability problems already occur with some heavy stretched-fuselage aircraft.

Finally, something as apparently innocuous as the vertical stabilizer height could infringe the obstacle clearance surface of the runways while the aircraft is parked.

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Runway Incursions Will Become More Dangerous

Collisions involving two aircraft, or one aircraft and a ground vehicle or an aircraft and an airport structure can also cause expensive hull damage and lost revenue. Fortunately, most of the collisions occur within the taxiway and apron system where the relative speeds of the vehicles concerned are low and the results are less serious than on the runway, where collisions are generally more serious in human casualties and aircraft damage.

Some examples of runway incursion accidents/incidents are given below:

- A collision between a Boeing 727 and a Beechcraft King Air A100 at Atlanta, Georgia, U.S. (1990); the latter aircraft had not cleared the runway although other causal factors included conspicuity. The King Air was destroyed. The pilot was killed and the copilot was severely injured.[1]

- A near-miss between two McDonnell Douglas DC–l0s at Minneapolis-St. Paul, Minnesota, U.S. (1985), one taking off, the other taxiing across the same runway. The vertical clearance was estimated as being between 50 to 75 feet (15 to 23 meters).

- A collision between a B-727 and a McDonnell Douglas DC-9 at Detroit, Michigan, U.S. (1990). The DC-9 taxied onto an active runway. The DC-9 was destroyed and seven passengers and one flight attendant died.[2]

Aside from the problem of runway incursion, potential problems also arise during low-speed maneuvers within the taxiway and apron system. The following comments were made by a Boeing 737 pilot: "… taxiing is potentially one of the most hazardous parts of our operation, because of not only the proximity of other aircraft but also, at some airports, the sheer number of ground vehicles [and] complicated taxiing instructions. [Although] it is obviously essential for both pilots to be alert and to keep a continuous look-out, there is also the need to complete the taxi drills [and] monitor air traffic clearances … and possible changes to taxi instructions … . Add to this poor visibility or darkness, with taxiway markings unclear due to rain or other contamination [and construction] work in progress not very clearly marked, and you have a very heavy workload on two pilots."[3]

In many incidents, size and congestion have been identified as factors, which likely will be more critical for UHCA. Two examples highlight some typical causal factors:

- A Lockheed Tristar could not be correctly parked at the gate because of a stalled ground vehicle. Ramp control had not been advised of the vehicle and the control tower was not advised that the aircraft was parked out of position. A B-747 was then cleared to taxi past the gate at which the Tristar was parked. The left wingtip of the B-747 struck the right elevator of the Tristar. The incident was not reported and the B-747 took off. Subsequent inspection of both aircraft revealed minor damage.

- A B-757 developed a technical fault and returned to the parking stand. On the opposite side of the taxiway an Airbus A310 was being prepared for departure. Parking was nose-in for both aircraft with tug pushback. Ground control saw the B-757 pass behind the Airbus and, assuming that the aircraft would park normally, issued pushback clearance to the Airbus. Because of a malfunction to the parking guidance system, the B-757 stopped with its tail protruding into the taxiway by approximately 69 feet (21 meters). The left wingtip of the Airbus collided with the underside of the B-757's tailplane and rear right fuselage, causing substantial damage to the B-757 and damage to the wingtip and trailing edge of the Airbus.

Present and near-future technology can be expected to contribute to a reduction in airport ground operations incidents. Such technology will assist both air traffic controllers and flight deck crews. For example, controllers will have the benefit of improved surface movement radar and vehicle transponders that will display and identify aircraft and ground vehicles.

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For flight deck crews, research is being conducted for the use of on-board closed-circuit television (CCTV). CCTV trials by the U.K. CAA and British Airways have a number of objectives:

- To establish whether CCTV cameras could be fitted to a transport aircraft and function in the environment of worldwide operations;
- To integrate pictures from such a system into flight deck procedures;
- To determine whether there could be any safety benefit from external viewing systems and to investigate technology required to use the system under low-visibility conditions; and,
- To determine the requirements for infrared or thermal imagery to assist CCTV in low visibility or night operations.

As an extension of this, aircraft deviation from runway and taxiway centerlines might be reduced by the use of surface movement guidance technology and CCTV to monitor the location of the main gear and nose wheel.

In addition, improvements could be made to airport lighting systems: for example, "smart" lighting with red stop bars, amber flashing lights and green taxiway lights could coordinate aircraft and ground vehicular traffic and prevent runway incursions.

UHCA Will Require More Fire-fighting Resources

The availability of rescue and fire-fighting services at an airport is based on recommendations made by ICAO. Each airport is classified, on a numerical scale from 1 to 9, according to the overall length and fuselage width of the largest type of aircraft using the airport on a regular basis. The required quantities of water, foam and supplementary media are based on this classification.

ICAO currently allows a "remission factor" to a lower category based on the number of movements of the largest aircraft operating at the airport. In the United Kingdom, when the number of movements (landings and takeoffs) by aircraft in the largest size category totals less than 700 in the busiest three months of the year, the required level of protection is reduced to what is appropriate for the next lower category.

In anticipation of a commercial aircraft type significantly larger than the B-747-400, an interim ICAO Airport Category 10 has been introduced. Category 10 covers an overall aircraft length of up to 295 feet (90 meters) and a maximum fuselage width of 23 feet (7 meters), such as the Antonov 225, which already operates, although not for passenger transport.

Analysis of past incidents has revealed that minimum required quantities of foam/water might not be sufficient to control and extinguish aircraft fires.[4] For example, in the Detroit collision between a B-727 and a DC-9 referred to earlier, 1,515 U.S. gallons (40,000 liters) of water were used for foam production. This exceeded the recommended volume of water that should be available for foam production at airports having regular commercial operations of much larger, widebody aircraft.

Four factors have been identified that can influence the quantity of foam used: gross mass of the aircraft, fuel load, passenger capacity and the previous experience of rescue and fire-fighting crews. Accidents and incidents in recent years have led to recommendations in addition to the ICAO regulations. For example:

- The quantities of agent (water and foam) available should be similar to the quantities used in recent aircraft crash fires and not on tests carried out under artificial conditions;

- The quantities of agent should be computed for the longest aircraft in each category, instead of the median aircraft;
- A replenishment factor should be included and, based on recent experience, should be at least 100 percent of the basic quantity recommended for the specified category; and,
- The required quantity of available agent should be based on the largest commercial aircraft scheduled to use the airport, regardless of the number of operations.

The adoption of these recommendations may not be sufficient to deal with a collision between two heavy aircraft, and adding personnel and equipment are likely to cause airport authorities to be less than enthusiastic about having to provide rescue and fire fighting services to meet the requirement for UHCA operations.

Evacuation Procedures Will Need Rethinking

The issue of emergency evacuation from the UHCA is complex and, of all the issues discussed here, is possibly the most important.[5]

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Present aircraft certification procedures require the evacuation of all passengers from an aircraft within 90 seconds, using 50 percent of the available emergency exits. This is demonstrated by using volunteers in emergency evacuation trials.

The need for full-scale passenger evacuation trials in new airliners is now being questioned. It has been suggested that about 5 percent of the volunteers receive some sort of injury, usually minor, during the trials. Nevertheless, in 1991 the almost total paralysis of an elderly volunteer during a U.S. evacuation trial, and the specter of litigation costs, have led to a growing belief that the injury-risks to volunteers may outweigh the trials' value.

This leads to three safety questions. What are the present problems with emergency evacuations, and are they always necessary? Are evacuation trials realistic enough and, if they are not, what are the possible alternatives? Are there aspects of the UHCA design that will adversely affect emergency evacuations?

A recent report by the U.S. National Transportation Safety Board (NTSB) indicated that an increase in use of different types of aircraft, with emergency equipment stowed in different sections of the aircraft and with varied emergency procedures, showed the necessity for improved cabin crew training and also a need to improve communication between the cabin crew and the flight crew in emergencies.[6]

The NTSB report identified a number of problems:

- Inability of flight attendants to locate and properly operate emergency equipment;
- Opening of exit doors while aircraft were moving or with engines running;
- Inability of flight attendants to open doors properly; failure to inflate evacuation slides or allowing the slides to inflate before being fully deployed (blocking exits and escape routes);
- Evacuation slides not secured to the aircraft or allowed to separate from the aircraft, as on one occasion when the flight attendant inadvertently pulled the slide disconnect handle instead of the inflation handle;
- Failure to follow evacuation procedures; and,
- Pre-emptive evacuation by passengers (organized panic) as in a U.S. B-727 incident in New York (1990).

In an accident in 1980 at Riyadh, Saudi Arabia, a Lockheed Tristar returned to Riyadh with an uncontrolled fire in the cargo compartment. The aircraft landed safely and came to a stop on taxiway. While parked, the aircraft was destroyed by fire. Factors contributing to the 301 fatalities — everyone aboard the aircraft — included:

- Failure to prepare cabin crew for immediate evacuation on landing;
- Failure to stop on the runway with immediate evacuation; and,
- Inadequate training for emergencies.

It has been suggested that up to 80 percent of emergency evacuations are not actually necessary and that in some incidents the emergency evacuation created more problems. Considering the large number of passengers that would be carried on a UHCA, the reduction of emergency evacuations to an absolute minimum has obvious benefits but the techniques for achieving this have yet to be determined. Nevertheless, the following two incidents show that few emergency evacuations are straightforward.

- An incident involving a B-757-200 (1993) when, during passenger boarding, there was an aft cargo hold fire warning. The fire bottle was discharged, the drills were carried out and an evacuation was completed. Passengers at the forward and rear of the aircraft used the jetty and aircraft steps, but during the evacuation it was not possible to open the No. 3L door, which was jammed. Approximately 25 passengers exited via the escape slide at door 3R. Of these, three passengers received minor injuries.

- An incident involving a DC-10 (1978) where an external fire did not immediately threaten the occupants of the aircraft, but the radiant heat from the fire rendered the available escape slides unusable before the evacuation was completed.

Evacuation Trials May Yield To Simulation Models

The second issue is whether present evacuation trials are realistic and what the alternatives are. Generally, evacuation trials are selective in terms of volunteers: for example, no young children, elderly or handicapped persons are involved in the tests. It has been suggested that volunteers be allowed to run down exit ramps rather than using the slides where most of the injuries occur. Nevertheless, in real life an emergency evacuation is not a "nice" event and, in theory, more realistic conditions should exist during trials. The aircraft, for example, could come to rest in a nonlevel attitude, the cabin filled with smoke, darkness, loss of communication between the cabin crew and flight deck and passenger hand luggage hampering passenger movement toward the emergency exits.

The introduction of heavy jets, such as the B-747, presented challenges to airport operations not unlike those expected with the introduction of UHCA.

Existing evacuation trial data, together with safer partial tests (for example, using a variable seat pitch and specifying flow rates through emergency exits), could substitute for full-scale tests in conventional aircraft designs. This is supported by the fact that since the introduction of the B-747, other widebodies have selected similar passenger cabin configurations; preliminary UHCA designs are also similar.

One development that has generated considerable interest in recent years is the use of models to simulate the evacuation process and their application to aircraft evacuation studies. Although existing models can simulate passenger movement within the aircraft cabin, no such tool has apparently been developed to simulate movement down the slides and dispersion from the foot of the slides. In view of the costs of physical experimentation, this technique appears to have potential benefits in realism and in allowing more "experiments" to occur.

The UHCA will have door exits with sill heights similar that of the B-747-400 for both the upper decks and lower decks. Therefore, the certification process for the escape slides and escape/raft systems is expected to be similar to that for the B-747. But airworthiness and design requirements limit the distance between exits and, with a full-length double deck, the number of slides deployed on each side of the aircraft will double. This will result in congestion, both for the physical location of the slides, particularly in the vicinity of the wing area, and for the dispersion of evacuees from the foot of the slides.

The certification requirements for ditching require the provision of a suitable number of life rafts. Internal transfer from upper to lower decks is possible under such circumstances, which may eliminate the need for upper deck slides and rafts. Nevertheless, this requires supplemental life rafts to be carried on the aircraft.

The introduction of heavy jets, such as the B-747, presented challenges to airport operations not unlike those expected with the introduction of UHCA. This past experience, coupled with new technology and human factors awareness, will help to ensure a safe transition for UHCA. There likely will be few safety issues unique to UHCA; for the most part, introduction of UHCA will amplify current safety issues.♦

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