



## TAPPR

### Terminal Area Parallel Procedures Research

#### What is the problem?

Airport runways and the limitations in their arrival rates are a primary hindrance to the growth of the current airspace system's capacity. In order to accommodate the flight demand of the future, major changes in today's current air travel operations, including runway procedures, will need to occur.

#### What is the solution?

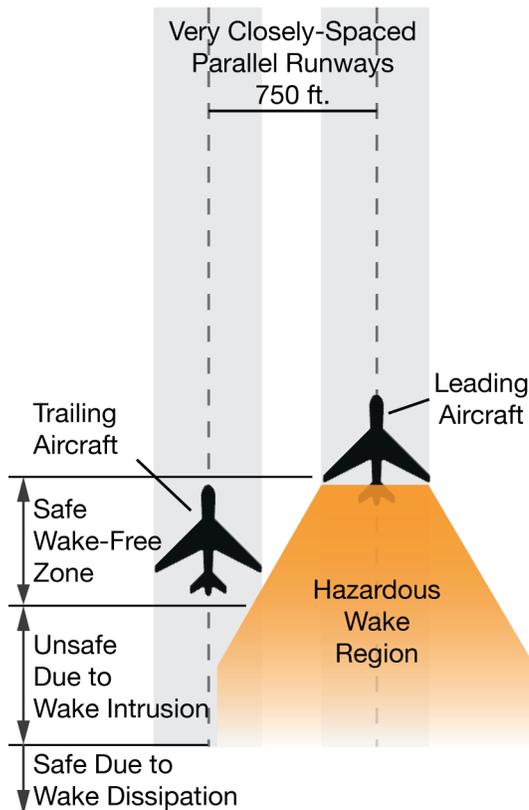
Building additional runways is one way to increase capacity at airports in order to accommodate higher levels of traffic. Airport expansion, however, is often difficult due to the limited availability of land and the impact that expansion would have on the surrounding communities. Instead, the building of new runways between existing runways is being investigated and is a promising alternative to expanding the airport's footprint. Building runways between existing ones, however, increases the risk of safe spacing violations and wake vortex hazards.

Under today's air traffic control operations and regulations, an all-weather parallel runway pair must be separated by at least 4300 ft. between centerlines. While some airports, like San Francisco International (SFO), can already support safe arrivals on parallel runways that are only 750 ft. apart, this is only achieved during clear weather conditions. In such clear visibility, peak arrival capacity at SFO is about 60 aircraft per hour, as aircraft can land simultaneously on the two parallel runways. To safely perform simultaneous approaches on runways spaced this closely together, the pilot of the trailing aircraft is required to obtain a visual sighting of the leading aircraft to ensure adequate separation. In low visibility conditions, such as fog, a pilot's inability to visually sight the aircraft on the nearby runway prohibits the use of simultaneous approaches. As a result, only one of the parallel runways can be used, effectively cutting the number of aircraft arrivals in half.

To increase capacity by adding runways between existing runways reduces separation significantly. Therefore, the technical challenge is to enable approaches on very closely spaced parallel runways in all visibility conditions in order to maintain higher airport arrival rates.

#### What is NASA doing to help?

NASA's current work on advanced tools and operational procedures, called **Terminal Area Parallel Procedures Research (or TAPPR)**, will allow maximum use of very closely spaced parallel runways even in poor visibility. Instead of positioning all



Terminal Area Parallel Procedures Research (TAPPR) involves positioning the trailing aircraft within a wake-free zone, close to the leading aircraft, on very closely spaced parallel runways in order to achieve maximum runway throughput.



Experienced air traffic controllers participate in a simulation using Terminal Area Parallel Procedures Research (TAPPR) automation in NASA's Air Traffic Control Simulation Lab. *Photo credit: NASA/Dominic Hart*

aircraft single file, TAPPR procedures create pairs of aircraft, positioning the following aircraft inside of a wake-safe zone (see figure). Wake-safe zones are regions slightly behind and to the side of an aircraft where its wake vortices pose no threat to the following aircraft.

TAPPR provides procedures, automation, and decision support to both pilots and air traffic controllers. TAPPR's advanced automation monitors incoming traffic streams and suggests compatible pairs of aircraft to air traffic controllers in the terminal area. The aircraft are selected for pairing based on several parameters, such as aircraft performance and wake characteristics. Once the aircraft are matched, automation helps the controllers interact with the pilots and manage the pairs. The pilots are provided with sophisticated automation to help achieve and maintain the correct relative spacing as the aircraft approach the runways. Enhanced cockpit displays show the optimized approach and landing trajectory as well as provide the pilots in the trailing aircraft with the position, path, and wake of the leading aircraft on the adjacent runway, thereby enabling closely spaced parallel approaches even in poor visibility conditions.

The TAPPR concept includes procedures for handling off-nominal situations, such as unexpected wake vortex behavior and lead aircraft blunders. TAPPR automation detects when wind causes the wake of the leading aircraft to drift too closely to the trailing aircraft or when



NASA researchers participate as pilots in a simulation of the Terminal Area Parallel Procedures Research (TAPPR) concept in NASA's Advanced Concepts Flight Simulator. *Photo credit: NASA/Dominic Hart*

one aircraft veers off course, intruding into the arrival path of the other. The automation then alerts the pilot and generates an emergency breakout maneuver to guide the trailing aircraft safely away. Although such events are rare, the ability to handle such events is critical to the feasibility of the concept.

NASA conducted human-in-the-loop simulations to study the effectiveness of TAPPR automation and procedures that involved both experienced air traffic controllers and commercial airline pilots in the same simulation. The experiments were conducted in the NASA Ames Air Traffic Control Simulation Lab and the Advanced Concepts Flight Simulator integrated with the new TAPPR tools. Valuable feedback was collected that will be used to improve the controller and cockpit interfaces and the predictive automation. Workload, situation awareness, and response times were also measured to study the effects of different levels of automation on the participants' performance. The results are being analyzed to determine the ideal mix of automation. Preliminary results support the potential of the TAPPR concept to allow airports in densely populated areas to build new runways within their existing footprints, and to use these runways to maximum benefit even in poor visibility conditions.

For more information on Terminal Area Parallel Procedures Research (TAPPR), please visit [www.aviationsystems.arc.nasa.gov](http://www.aviationsystems.arc.nasa.gov).

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