Dawn of the computer age
Andrew Charlton looks at ATM development from 1939 until 1990 – a period that saw progress in radio, radar and computers transform the industry.

The Second World War saw enormous step-changes in the size and reliability of airframes and of course, the jet propulsion engine. But without the quantum leaps made by air traffic control technology and procedures, modern aviation would look considerably different today.

The changes to ATM resulted from huge technological breakthroughs in radio communications and radar technology spurred on by the war effort, but based on technologies developed in the 1930s.

Radio waves

By the start of the Second World War, airport controllers were able to talk to approaching aircraft by radio. Approaching aircraft were required to report their location, speed and altitude and were given instructions accordingly. But it was crude, and required the pilot to know the approximate location of the aircraft in the first place – effectively limiting air transport to visual conditions and light beacons.

In the United States, a number of airports used radio to control approaching aircraft. Aeronautical Radio, Incorporated (ARINC) was established by the four major US airlines of the day and was delegated the task of managing the aviation industry’s use of radio waves in 1927. They expanded that role during the 1930s to take responsibility for all ground-based, aeronautical radio stations as well, before being nationalised as part of President Roosevelt’s New Deal. The Civil Aeronautical Bureau was established, setting in place the foundations that would become the FAA as we know it today. ARINC continued to exist, as a member cooperative, officially delegated as holder of the radio allocations until recently.

Radio beacons replaced light beacons immediately after the war. Radio beacons, positioned along standard routings, extended airline networks to the limits of the range of these Non Directional Beacons. This, in turn, provided the tools for airspace divisions. The first Flight Information Regions were created in the UK in 1946.

Radio Detection and Ranging equipment (radar), on the other hand, was experimental at the start of the war. The technology dates from the end of the previous century. A standard beam, of known velocity, is sent out. If the beam hits a metal object the distance between the source of the beam and the object
is measured by noting the difference in the time before the beam returns. The first radar stations, set up to monitor aircraft movements during the Battle of Britain, needed huge areas of land for the equipment. The information was analysed by a team of three, situated in a hut in the middle of two vast arrays. In 1943, the invention of the magnetron allowed transmitting and receiving from the same equipment. This made the development of the revolving radar unit possible, essentially the unit still in use today.

The Chicago Convention – signed in 1944 and continuing to govern civil aviation – agreed a number of principles, two which were especially crucial to ATM development. First, each State is responsible for the regulation of safe civil aviation within its airspace. Secondly, States that undertake to provide radio, meteorological and air navigation facilities should do so, as far as practicably, in accordance with standards and procedures agreed within ICAO. The role ICAO plays in coordinating and regulating ATM standards and procedures is little changed today.

Post-war, these new technologies were incorporated into civil aviation. Heathrow, for example, installed ground approach (GCA) radar in 1947. Two fixed radars were used to measure the horizontal and the vertical, creating a ‘cone’ of signal at the end of the runway. The controller used the on-board radio to talk the pilot down the cone to two miles from the runway threshold. For final approach, visual conditions applied. This was replaced in the late 1950s by radio-based Instrument Landing Systems (ILS). ILS provide signals positioning the aircraft relative to the horizontal and vertical path, accurate to a few metres from the runway threshold. It can also be linked to the aircraft’s autopilot.

Maintaining separation
Rotating antennae radar was introduced in the late 1940s. It allows for monitoring of flights within range. The display, on a radio-scope, is of the echoes of each aircraft the transmitting beam detects. Again, to get a true position and the identity of each aircraft the pilot communicated by radio. The controller had to remember the details. By 1951, these terminal radars had a range of 60-80 nautical miles. Approach as a standalone unit within an ATC centre came into being.

As the volume of air traffic increased, ICAO realised that it needed to establish standards such as separation minima to keep the airspace safe and efficiently managed. In 1955, it established 1,000 feet vertical, 120 nautical mile lateral and 30 minute longitudinal minima for trans-Atlantic flights. In the absence of fixed radio beacons and given the limited range of radar these international standards were vital for safe aviation.

The introduction of VHH omni-directional radar range (VOR) and distance measuring equipment (DME) equipment in the late 1950s, coupled with a shift to higher frequency radio, increased range and accuracy, allowing further improvements in ATM and reduced separations, necessary as the volume of traffic increased further.

The next big technological leap was Secondary Surveillance Radar (SSR), allowing for the aircraft to identify itself and its altitude. It was introduced in the 1960s. This increased the amount of information the controllers had available.

Coupled with the need to transfer traffic information, write paper strips and calculate speeds, distances and times, the industry was ready for the introduction of computers. The first basic software allowed clear printing and the calculation and distribution of paper strips to the appropriate sectors. As the 1970s and 1980s progressed, computers became standard.

Software took care of linking the radio transmissions and ground messages between the various sectors of control. Soon the need to expand radar coverage to larger area control centres introduced multi-radar coverage. Computers were necessary to combine the echoes received from multiple radar sites.

By the 1990s, computers had changed the tools available to controllers yet again. Paper strips were replaced by electronic flight information displays. The sole SSR code number on the screens has been replaced with the full flight number and the Short Term Conflict Alert introduced.

Given the growth in air traffic, without these innovations, modern aviation would have been impossible. At the same time, without significant further innovation and change, the industry would not be ready to face the future.