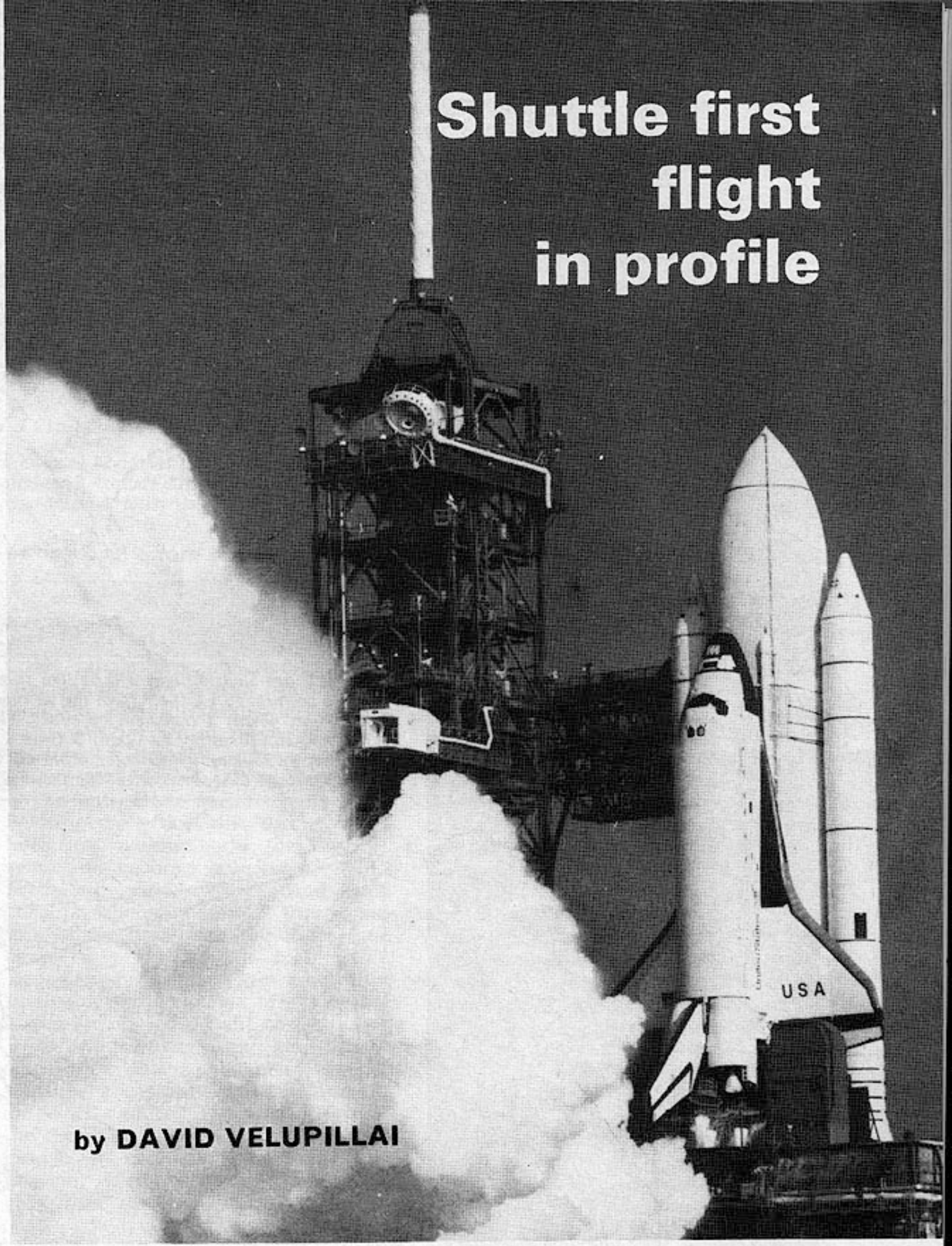

Nasa tests Columbia's engines during a 20sec flight readiness firing, which took place during February

Shuttle first flight in profile

by DAVID VELUPILLAI

WHEN Space Shuttle's Solid Rocket Boosters and main engines are finally lit, almost everything has to work correctly. The lives of Commander John Young and pilot Robert Crippen, as well as the future of American spaceflight, depend on it. Space Shuttle is the first re-usable rocket and none of it has flown unmanned tests in space—as happened with Mercury, Gemini and Apollo. It is the first time that solid-propellant boosters have been used on a manned spacecraft, the first bluff-shape rocket, the pioneer of throttleable engines, and will be the first US manned flight for almost six years.

The countdown for the first flight begins roughly 73hr before lift-off (T-73hr). The launch window is dictated by the need for good light during ascent and landing in normal flight, or during an abort. It opens at sunrise plus 45min and is more than 6hr long. Nasa is currently aiming for launch on April 10, for which the window opens at 06.48hr Eastern daylight time.

Young and Crippen will enter *Columbia's* cockpit about two hours before lift-off. They will be wired-up with sensors to measure heart-beat and respiration, and will be wearing g-suits and ejection suits. *Columbia's* ejection seats are intended for use in the four Shuttle test flights at speeds of up to Mach 2·7 and a height of 30,480m, and the suits are worn during launch and entry. An independent air supply to the suit provides protection against loss of cabin pressure.

During lift-off the astronauts are in a supine sitting position. Their main task during launch will be to monitor the computer-controlled flight of the Shuttle—intervening only when something goes wrong.

Space Shuttle Main Engine (SSME) ignition begins 3·5sec before lift-off, but a shutdown will occur if any engine fails to develop at least 90 per cent power—each should be producing 100 per cent. If the SSMEs are go, the SRBs are lit and their hold-down clamps released. Roughly 0·3sec later the Space Shuttle thrust/weight ratio becomes greater than one and lift-off occurs. It takes 6sec for *Columbia's* SSMEs to clear the anti-lightning tower atop pad 39A, during which the Shuttle rises vertically (a list of important events and times appears on page 1040).

As soon as the tower is clear a gradual pitch-over begins to point the astronaut's heads toward Earth, so that by the time they reach orbit they are hanging upside-down in their seats. (Pitch-over is necessary with any orbital attempt, to build up horizontal speed by the time injection height is reached). Nasa has chosen to make the Shuttle pitch over on to its back rather than its front for two main reasons—loads between the Orbiter and ET are lower, and the crew can see the Earth better.

The next major event is a reduction in SSME thrust from 100 to 65 per cent to minimise the maximum dynamic pressure—the aerodynamic load caused as the craft builds up speed in the comparatively thick lower atmosphere. SRB separation happens automatically just over two minutes after lift-off. By this time *Columbia's* three SSMEs are capable of powering it and the ET on their own—much of the liquid oxygen and hydrogen originally in the ET having been consumed.

The spent SRBs follow a parabolic trajectory toward the Atlantic Ocean. Parachutes are deployed when the SRBs have fallen to a height of about 4,700m, slowing their fall to a gentle splash in the sea 255km downrange. The SRBs carry beacons which help Nasa's two recovery ships to find them, and the ships then retrieve the parachutes and tow the empty SRBs back to the Kennedy Space Centre (KSC), Florida. When the SRBs arrive they will be washed and sent back to the manufacturer, who will refurbish them for another flight.

At almost eight minutes into the flight SSME thrust is again reduced. This time the reduction is to limit accelerations to 3g, which is one of the Shuttle-design criteria. Shortly afterward thrust is reduced to its minimum value of 65 per cent and the SSMEs are shut down.

ET separation occurs a few seconds later—provided that valves in the liquid oxygen and hydrogen pipes between *Columbia* and the ET are shut, and that pitch, roll and yaw-rate are less than 0·5°/sec. These conditions are necessary to avoid the ET hitting *Columbia* when they part. *Columbia* is nudged clear of the ET by its reaction control system (RCS) a fraction of a second after separation. A further evasive manœuvre is then