PLANETARY SCIENCE

7 MINUTES OF TERROR

The Curiosity rover prepares to plunge down to Mars.

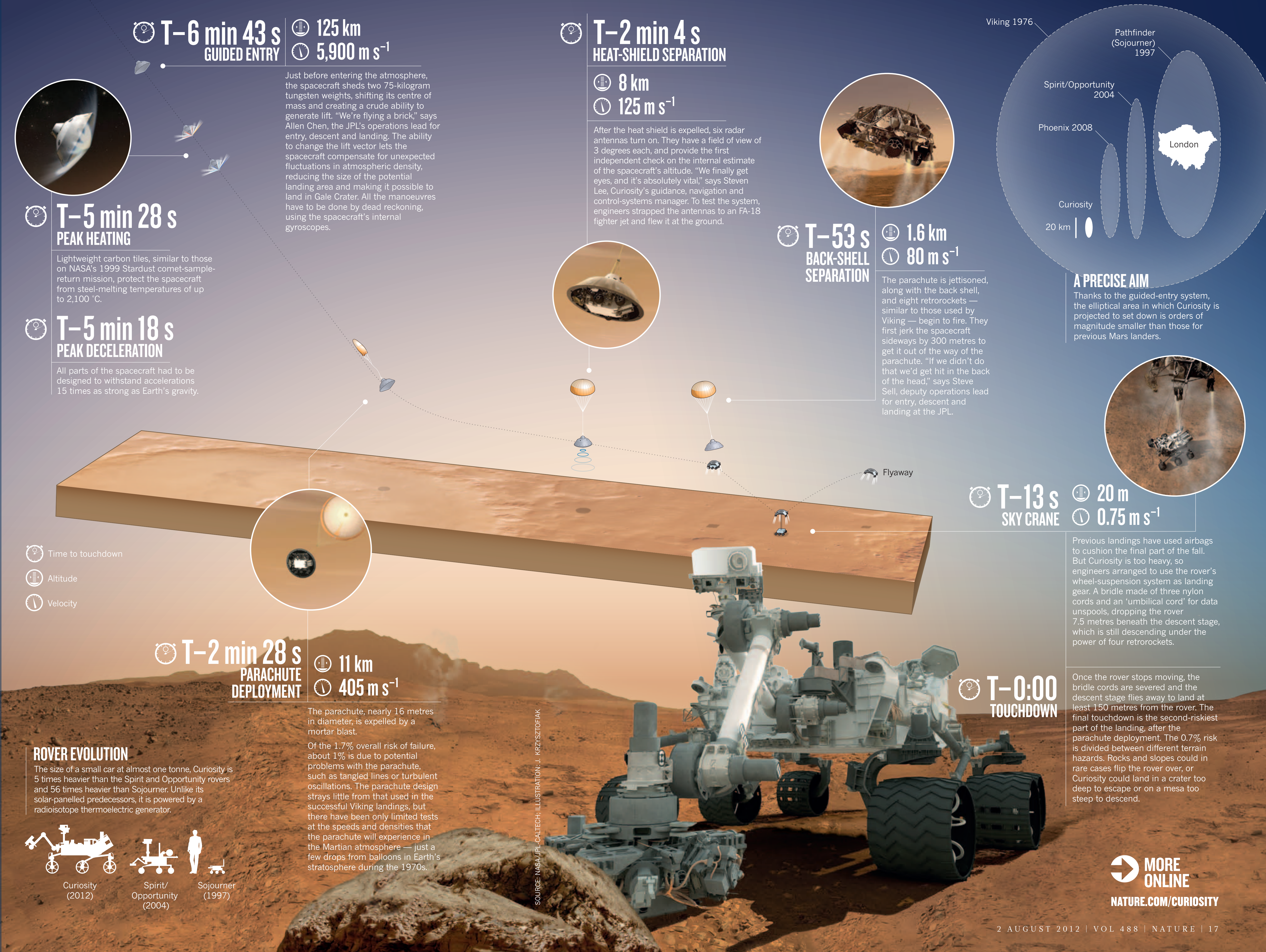
BY ERIC HAND

After an eight-month journey to Mars, success for NASA's Curiosity rover will hinge on a few crucial moments. The largest and most complicated piece of machinery ever sent to the red planet, Curiosity will begin its seven-minute fall through the wispy atmosphere at 05:24 UTC on 6 August. On Earth, mission scientists will be unable to do anything but wait and hope for the signal that the six-wheeled remote laboratory is resting safely in the feeble Martian sunlight.

If Curiosity lands successfully in Gale Crater, it will eventually trundle over to a 5.5-kilometre-tall stack of layered deposits ringed by water-altered minerals. Ascending the mound, the rover will chart hundreds of millions of years of geology and help researchers to deduce whether life could ever have existed on Mars.

But first it has to arrive. On its way down, the spacecraft will fire 76 charges, adopt 6 configurations and slow from 6 kilometres per second to a standstill. It will be the first craft since the Apollo Moon programme of the 1960s and 1970s to use a guided-entry system, and the final leg of the descent will mark the first use of a 'sky crane'. At 900 kilograms, Curiosity is too heavy to land in airbags like earlier rovers, and retrorockets like those used in the Viking Mars landings of the 1970s would kick up damaging dust. Instead, a hovering platform will unspool the rover. "All sorts of things can go wrong," said NASA administrator Charles Bolden at a meeting of the NASA Advisory Council on 25 July. "That's what makes it a real nail-biter."

NASA officials told the Jet Propulsion Laboratory (JPL) in Pasadena, California, to ensure a 95% chance of landing success. Engineers say they have surpassed that: the current assessment, based on millions of simulations, finds only a 1.7% risk of failure. But that holds only if the models have assessed every possible vagary of environment and machine. What's worrisome are the unknown unknowns, says Steven Lee, the mission's guidance, navigation and control-systems manager at the JPL. "Probably the overall biggest risk is our lack of imagination." ■



T–6 min 43 s GUIDED ENTRY

125 km
5,900 m s⁻¹

Just before entering the atmosphere, the spacecraft sheds two 75-kilogram tungsten weights, shifting its centre of mass and creating a crude ability to generate lift. "We're flying a brick," says Allen Chen, the JPL's operations lead for entry, descent and landing. The ability to change the lift vector lets the spacecraft compensate for unexpected fluctuations in atmospheric density, reducing the size of the potential landing area and making it possible to land in Gale Crater. All the manoeuvres have to be done by dead reckoning, using the spacecraft's internal gyroscopes.

T–5 min 28 s PEAK HEATING

Lightweight carbon tiles, similar to those on NASA's 1999 Stardust comet-sample-return mission, protect the spacecraft from steel-melting temperatures of up to 2,100 °C.

T–5 min 18 s PEAK DECELERATION

All parts of the spacecraft had to be designed to withstand accelerations 15 times as strong as Earth's gravity.

T–2 min 28 s PARACHUTE DEPLOYMENT

11 km
405 m s^{-1}

The parachute, nearly 16 metres in diameter, is expelled by a mortar blast.

Of the 1.7% overall risk of failure, about 1% is due to potential problems with the parachute, such as tangled lines or turbulent oscillations. The parachute design strays little from that used in the successful Viking landings, but there have been only limited tests at the speeds and densities that the parachute will experience in the Martian atmosphere — just a few drops from balloons in Earth's stratosphere during the 1970s.

T–2 min 4 s HEAT-SHIELD SEPARATION

8 km
125 m s^{-1}

After the heat shield is expelled, six radar antennas turn on. They have a field of view of 3 degrees each, and provide the first independent check on the internal estimate of the spacecraft's altitude. "We finally get eyes, and it's absolutely vital," says Steven Lee, Curiosity's guidance, navigation and control-systems manager. To test the system, engineers strapped the antennas to an FA-18 fighter jet and flew it at the ground.

T–53 s BACK-SHELL SEPARATION

1.6 km
80 m s^{-1}

The parachute is jettisoned, along with the back shell, and eight retrorockets — similar to those used by Viking — begin to fire. They first jerk the spacecraft sideways by 300 metres to get it out of the way of the parachute. "If we didn't do that we'd get hit in the back of the head," says Steve Sell, deputy operations lead for entry, descent and landing at the JPL.

T–13 s SKY CRANE

20 m
0.75 m s^{-1}

Previous landings have used airbags to cushion the final part of the fall. But Curiosity is too heavy, so engineers arranged to use the rover's wheel-suspension system as landing gear. A bridle made of three nylon cords and an 'umbilical cord' for data unspools, dropping the rover 7.5 metres beneath the descent stage, which is still descending under the power of four retrorockets.

T–0:00 TOUCHDOWN

Once the rover stops moving, the bridle cords are severed and the descent stage flies away to land at least 150 metres from the rover. The final touchdown is the second-riskiest part of the landing, after the parachute deployment. The 0.7% risk is divided between different terrain hazards. Rocks and slopes could in rare cases flip the rover over, or Curiosity could land in a crater too deep to escape or on a mesa too steep to descend.

A PRECISE AIM

Thanks to the guided-entry system, the elliptical area in which Curiosity is projected to set down is orders of magnitude smaller than those for previous Mars landers.

ROVER EVOLUTION

The size of a small car at almost one tonne, Curiosity is 5 times heavier than the Spirit and Opportunity rovers and 56 times heavier than Sojourner. Unlike its solar-panelled predecessors, it is powered by a radioisotope thermoelectric generator.

MORE ONLINE NATURE.COM/CURIOSITY