iron and volatile material also ending up in the iron- and volatile-poor Moon. However, most of the simulations Cameron relied on to constrain the possible range of impacts involved only 3,000 particles. Canup and Asphaug[4], using a much denser array of particles, now find that an impact on a fully formed Earth, some 50 million to 70 million years after the first meteorites, can loft enough mass to account for the present Moon, thus evading the problems inherent in the early-Moon scheme of events.

Encouraging as these new results[4] are, they are not the final word. One of the pillars on which any shock-physics computer code rests is the equation of state, a thermodynamic relation between internal energy, density and pressure. Unfortunately this equation is not well known for the complex silicates of which the Earth and Moon are mainly composed. Several difficulties have recently appeared in the most sophisticated equation of state in common use, a computer program called ANEOS[10]. Canup and Asphaug[4] sidestepped these difficulties by using a more primitive equation devised by J. H. Tillotson[11]. Although it was constructed for impact computations, this equation of state has many drawbacks, including the lack of a clear distinction between solid, melt and vapour phases. So, although vapour pressure seems to have been involved in boosting vaporized Earth material into orbit, Canup and Asphaug can only evaluate its role by a kind of average over the melt and vapour states. This is an area needing refinements.

Although we have not yet arrived at a definitive simulation of the Moon-forming impact, the signs are encouraging. Thanks to the coevolution of modern computers and simulation algorithms, the means to model events of this kind can now be found on the desk of nearly any scientist. I look forward to the entry of more new players into this fertile scientific arena. ■

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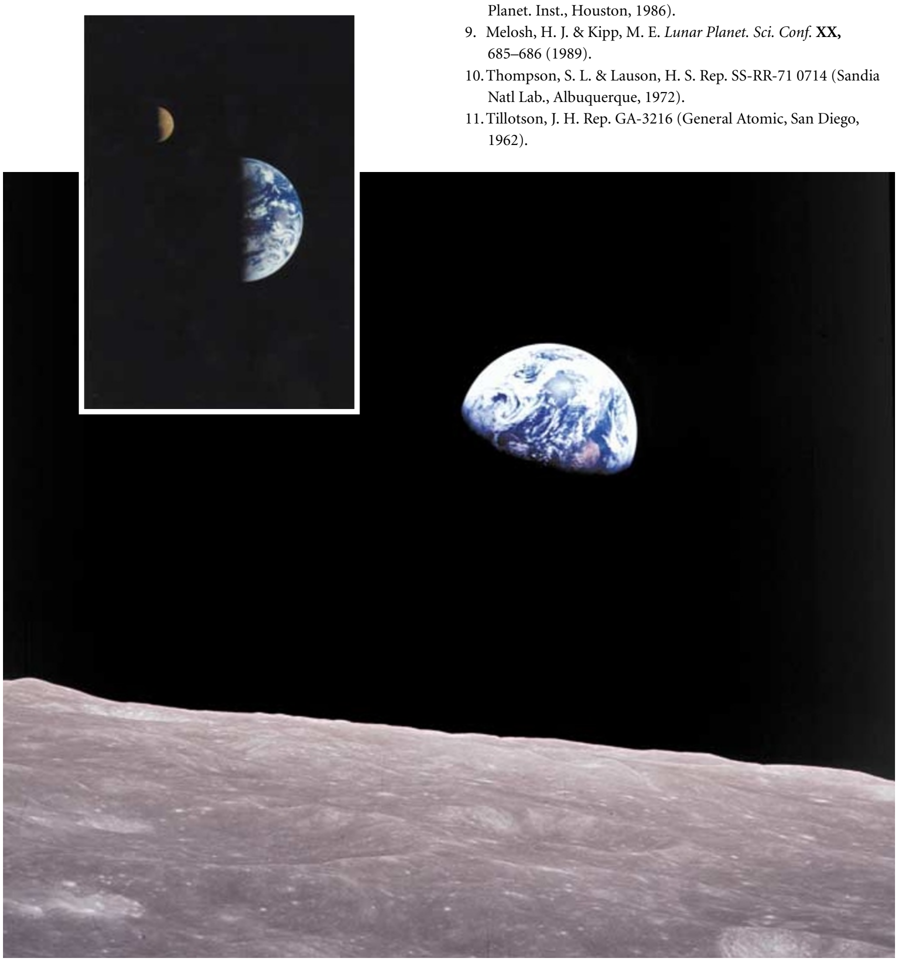

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Figure 1 **Earth and Moon — shock simulation.**

Daedalus

Blood and iron

Blood, says Daedalus, gives a lot of trouble. The heart has the job of pumping it round the body all the time, and can fail or underperform in many ways. Replacement valves and pacemakers help out, as do complete replacement pumps. Sadly, artificial materials tend to encourage the blood to clot. Human hearts from donors are perhaps the best way to overcome this type of heart inadequacy, but have many problems of their own. Daedalus has a new idea.

Blood, he points out, is itself a magnetic fluid. It contains iron-loaded red blood cells, so it could be pumped around the body by a magnetic linear motor. In fact only the red cells really need to be moved, for they provide oxygen. But a fluid loaded with magnetic particles would be pumped as a whole, just as the heart pumps it. The best way of driving the blood around would use coils or magnetic linear motors attached to the arms or legs. Our limbs have central arteries taking blood outwards, and veins near the surface bringing it back in. The veins would be engaged by the motors; the arteries are too deep. One problem will be calibrating the whole system, to establish the correct rate of flow. Daedalus reckons that the carotid arteries in the neck, used as calibrators by the heart itself, could do this job. They will be given calibration coils to check that circulation is maintained. Indeed, the blood pressure could be held at a youthful 120/80 millimetres of mercury, even in very tense moments.

This arrangement has several advantages. No skin need be broken. Even a very inadequate heart can help the arrangement along. Indeed, all patients must have a functioning heart of some sort before inviting surgical help, and it would be a pity not to use it. Even a heart that can only maintain a resting body will still be doing most of the work needed most of the time. The carotid sensors will enable the magnetic accelerators to add just the extra capacity needed from moment to moment. Sadly, the motors on arms and legs will be heavy, even if DREADCO's engineers make the minimal use of copper and iron, and they will need a lot of power. The user will spend a great deal of time changing or recharging batteries. But thousands of customers will be very happy just to have a bit of extra heart-power available when needed. And surgeons will welcome any reduction in the long burden of seeking donors.

David Jones

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