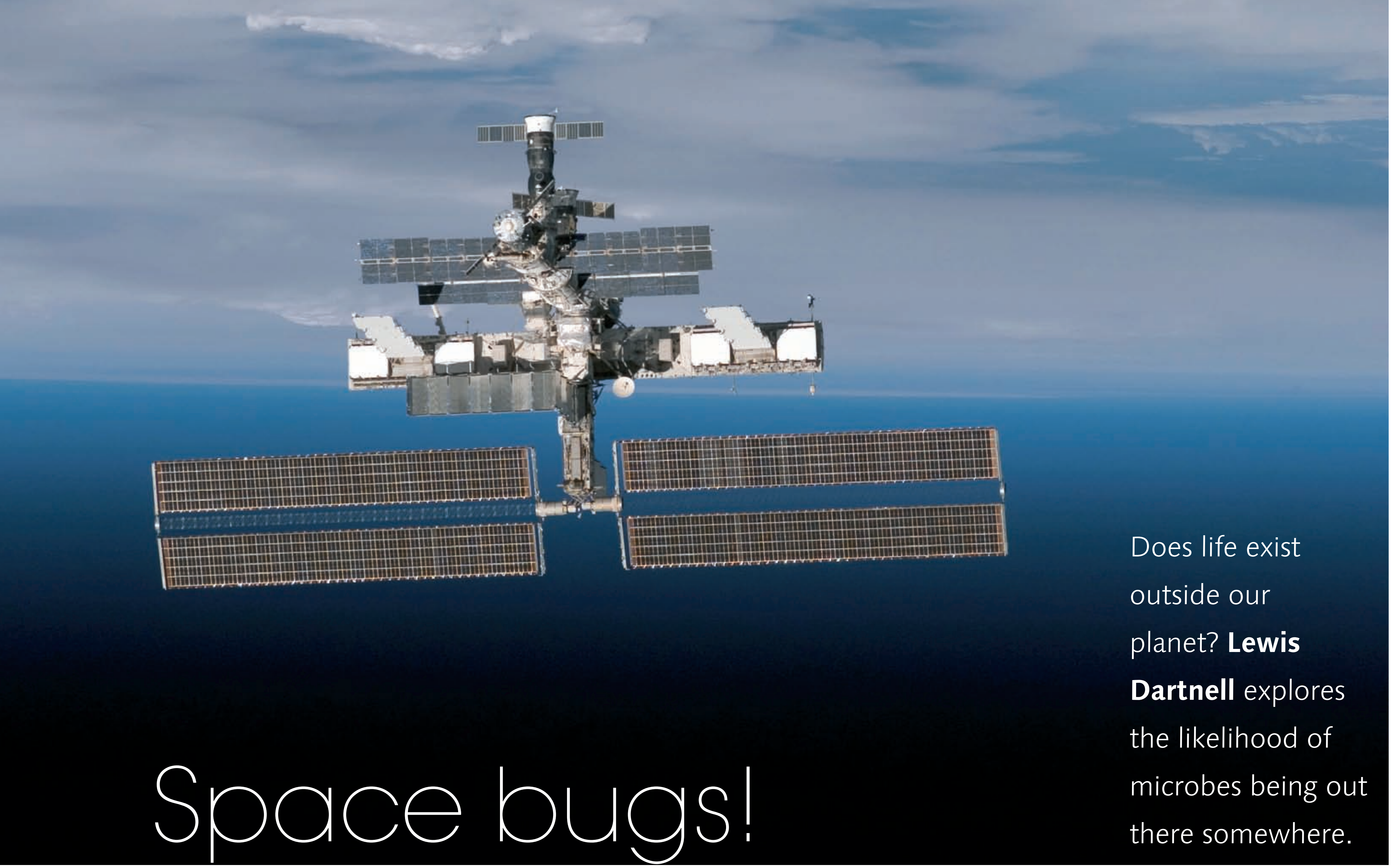

Space bugs!

Does life exist outside our planet? **Lewis Dartnell** explores the likelihood of microbes being out there somewhere.

On Earth, microbes get absolutely everywhere. Indeed, there seem to be very few completely sterile natural environments. But what about microbial colonization of locations beyond Earth? In this article we'll explore the realm of space bugs. There is a great deal of interest in the microbiology of the closed artificial environments created for human exploration of the cosmos, such as the International Space Station (ISS), as well as in minimizing the risks of inadvertently transporting terrestrial contamination elsewhere, and even the possibility of a natural mechanism spraying life between worlds over the history of the solar system.

Dirty spaceships

Although limited microbiological research was carried out before the launch of the *Apollo* spacecraft that flew astronauts to the Moon and back in the late 1960s and early 1970s, the first extensive in-flight studies of microbial diversity were carried out on the Russian space station *Mir*. *Mir* was humanity's first long-term inhabited outpost in space, launched in 1986 and consisting of a five-port docking hub with connected resupply ships and habitation modules. Over the course of the station's almost 15 years of service, numerous studies were conducted on the biota surviving in different regions, such as the dining area, sleeping quarters and hygiene facilities. Widespread bacterial colonization was noted, but fungal levels typically remained low throughout space missions, probably due to the low humidity of the recycled air.

A unique discovery was made in 1998 when a NASA mission to the space station found several large free-floating blobs of water caught behind the service panels of one of the habitation modules. These had formed as water vapour in the air condensed into tiny droplets and coalesced in the microgravity environment of the station into sizeable drops. Samples from these 'free-floating condensates' were syringed into sterile bags and returned to the ground for extensive analysis.

The condensate samples were noted to be a cloudy white or brown colour, and culture studies were run to identify the micro-organisms inhabiting this unique wet environment. The bacterial isolates were predominantly Gram-negative and included many *Enterobacteriaceae* such as *Escherichia coli* and *Yersinia* species. These contaminants were almost certainly supplied by the human occupants of the station. Alongside the bacterial biota, fungi, amoebae and ciliated protozoa were recovered from the free-floating condensate, and even dust mites. Perhaps most worrying, however, the researchers isolated several opportunistic pathogens and what they suspected to be a *Legionella* species, although this identification could not be confirmed as subculturing failed. Some species of this genus cause Legionnaires' disease, an often fatal infection.

More recently, the ISS has been sampled for microbial abundance. Many contaminants from human occupation have been found, such as *Staphylococcus epidermidis*, which are also commonly found in other closed environments like nuclear submarines. On the whole, though, the ISS carries a much lower bioload than other space platforms. This has a lot to do with the lessons learned from previous missions, such as the installation of HEPA filters on air handling systems and a robust housekeeping programme of weekly cleaning and biweekly disinfection. Over its operational lifetime, *Mir* witnessed numerous crew exchanges, re-supply deliveries and biological experiments. More importantly, *Mir* had also suffered numerous malfunctions that led to raised temperatures and high humidity: ideal conditions for microbial growth. *Mir* was also much older when sampled, and the progression of microbial colonization of the ISS will be closely tracked.

The problems of microbial infection are particularly acute aboard space missions. Prolonged exposure to cosmic radiation and microgravity is believed to have a negative effect on the immune system, and disease transmission is enhanced within the closed environment of recycled air and water. Studies report that diseases, mainly respiratory infections, occur in a quarter of space shuttle flights. But the problem is not limited to that of infection, and adverse microbial effects also include allergies, toxicity of air and water supply, and biodegradation of critical spacecraft components.

For longer missions, such as the habitation of the Moon or a return trip to Mars, it will simply not be possible to supply sufficient consumables from Earth. Ingenious biologically based regenerative life support systems are being proposed, relying on plants and micro-organisms to provide food, oxygen production, waste recycling and water purification. In this case, a microbial outbreak might not only affect crew health, but crash the life support systems and endanger the viability of the entire mission.

It is clear then, that wherever man boldly goes his microbial fauna is sure to follow. As discussed above, if this is allowed to get out of control it may pose serious problems on long-term space missions. But in terms of our responsibility as explorers, perhaps even more serious is the possibility of inadvertently spreading our terrestrial contamination to the extraterrestrial locations we visit.

◀ International Space Station (ISS), seen from the Space Shuttle *Discovery* as it leaves towards the end of mission STS-121. Photographed on 15 July 2006. *NASA / Science Photo Library*

▼ Astronaut Terrence W. Wilcutt transports a water bag from the space shuttle *Atlantis* to the *Kristall* module of Russia's *Mir* space station. Photographed on mission STS-79 (6–26 September 1996). *NASA / Science Photo Library*

Planetary protection

Preventing the spread of microbial life between worlds of the solar system has been a top priority of NASA, and the other space agencies of the world, for decades now. This effort is known as planetary protection, and aims to not only limit the possibility of transporting terrestrial life to places like Mars, but also accidentally bringing something back home. Although the risks of this back contamination are decidedly minimal, they are not negligible, and even the *Apollo 11* astronauts were placed in quarantine for 3 weeks after returning from the 'magnificent desolation' of the Moon.

Sterilizing robotic probes before launch is a relatively simple measure. The *Viking* landers sent to the Martian surface in the late 1970s were baked in an autoclave for over 2 days. This is a prohibitively expensive enterprise, however, and is especially problematic for the delicate modern instruments, so in general only the parts of spacecraft expected to come in contact with potentially inhabitable regions are sterilized so thoroughly. For example, NASA's latest Mars probe, the *Phoenix* lander, will touch-down in the Arctic plains this May and dig beneath the frozen surface to hopefully make the first ever direct measurements of Martian water and organic molecules. The robotic arm will excavate up to 50 cm underground and deliver samples to a suite of analysis instruments atop the lander. To guarantee the cleanliness of this arm, and thus the validity of any organic detection, it has been enclosed in a biobarrier bag – effectively an interplanetary condom – and will only be unsheathed once on the Martian surface.

Once the political will arises to send the first human pioneers to Mars, however, such biological containment will be nigh-on impossible. As we've seen already, humans and the inhabitable sections of our spaceships are inherently dirty, and once we arrive to plant flags and footprints in the rusty soil, our microbial entourage will inevitably begin leaking out onto Mars. Terrestrial life may not survive the hazards of the Martian surface for long, but it can be spread far and wide by winds. Once humans have visited the red planet, how could we ever be totally certain that any subsequent biological discoveries weren't simply signs of our own dirty sleeves?

There is the increasing realization, however, that our best efforts at planetary protection may never ensure the biological isolation of the planets – there may exist a natural process that has been transporting life between neighbouring worlds since the birth of the solar system.

Spreading the seed of life

The idea that life can spread between different planets and moons to ensure a constant cross-fertilization of worlds, known as panspermia, has been knocking around for well over a century now, but has been recently gathering a great deal of momentum with mounting evidence.

There are essentially three main hurdles that must be passed in order for life to be expelled from one world and arrive safely upon the surface of another. The first is in ejection from the home world. Encouragingly, studies show that lumps of surface rock could quite easily be flung off a planet fast enough to escape its gravity by the shock wave of a near-by asteroid strike. Secondly, microbial stowaways within these exiled meteorites must survive the ravishes of the space environment for an interplanetary voyage lasting perhaps several million years. The major hazards include desiccation by the hard vacuum, the sterilizing glare of solar ultraviolet light and the constant trickle of cosmic radiation. But again, combinations of modelling and experimental research suggest that provided microbes are buried deep enough within the protective interior of their host boulder they could persist for substantial periods of time. Finally, life must survive the heat blast of re-entry into the atmosphere of the destination planet and the shock of slamming into the ground, essentially the mirror image of the original ejection process.

Some researchers believe they have already found fossilized microbial emigrants from another world – signs of Martian nanobacteria within the meteorite ALH84001 – although this remains a hotly contested claim. The theory of panspermia is rapidly gaining support, and this cross-fertilization mechanism may even explain the apparently rapid emergence of life upon our own planet as soon as conditions became appropriate, perhaps from Venus or Mars.

One recent study has produced exciting results demonstrating just how plausible panspermia really is. Earlier this year, researchers at Humboldt University in Berlin tested the feasibility of microbial cells surviving being ejected off a planet's surface by the shock of a nearby asteroid impact. Three types of micro-organism, *Bacillus* spores, *Chroococcidiopsis* (a cyanobacterium) and *Xanthoria* (a lichen), were loaded into pellets of rock and fired from a specially adapted gun. This generated an enormous pressure pulse in the life-laden rock and temperatures briefly approaching 1,000 °C – recreating the conditions that microbes would be subjected to if blasted off their home planet by a nearby asteroid strike. The surprising outcome was that under these conditions, significant proportions of all three test organisms survived, showing that such organisms really could survive forced departure from their home world.

Lewis Dartnell
CoMPLEX (Centre for Mathematics and Physics in the Life Sciences and Experimental Biology), University College London, Wolfson House (2nd Floor), 4 Stephenson Way, London NW1 2HE, UK (e l.dartnell@ucl.ac.uk)

Lewis Dartnell researches the possibility of life on Mars at University College London. His new book, Life in the Universe: A Beginner's Guide*, is reviewed on p. 98 of this issue.*