Hi, this is Duranee for Cheap Astronomy, www.cheapastro.com. This is SISS, Science on the ISS – and today's episode is *Exposed.*

As we've noted before in this podcast, science on the International Space Station is mostly about science in microgravity. But, there is still *some* ISS science that really is about science in space. A lot of that science is about protecting people and structural materials and also robots from the external space environment. But there is also a small branch of science where we investigate what happens to things when we don't protect them – that is, when we deliberately expose them to the external space environment.

Several ISS programs have now investigated how inanimate materials fare in space, including NASA's *Materials International Space Station Experiment*, the European Space Agency's *EXPOSE* program and JAXA, the Japanese space agency's *Exposed Facility*, which is like a small porch outside the Japanese *Kibo* module. All these programs follow much the same approach of exposing samples to outer space, recording data about them during their exposure and then bringing these samples back inside for a quick inspection by the astronauts before they're packed up back to Earth for more intensive investigation.

What we are learning from all these programs is that being in a vacuum isn't the worst thing about being in space. Sure, most living things will quickly die in a vacuum – and any inanimate material with significant moisture content will quickly desiccate in a vacuum. But for other things that aren't alive and don't have much water content, being exposed to a vacuum isn't a big deal. It's all the other things about being in space that cause real problems.

Since the ISS orbits Earth with one side always facing the Earth and with one edge always facing forwards, we can position exposed samples so they experience very different aspects of the space environment. Some samples can be exposed to direct sunlight, at least for half of the ISS's 90 minute orbits, while other samples can be kept in permanent shadow. Some samples can be made to face forward in the direction of the ISS's orbit and hence bear the brunt of any collisions with micrometeorites or high-atmosphere particles, while other samples facing backwards are relatively-protected.

After comparing the effects of all these different aspects of the space environment, it turns out that the most damaging thing of all is sunlight. Outside of the atmosphere, the Sun's light includes ionising ultraviolet and gamma ray radiation, which normally bounce off the atmosphere or the ozone layer. After sunlight, the second most damaging aspect of being in low Earth orbit is *atomic oxygen*. Atomic oxygen is what you get after *molecular* oxygen, which forms 21 per cent of our atmosphere, drifts up past the ozone layer and is then split by ionising solar radiation into its individual oxygen atoms. These isolated oxygen atoms are very chemically reactive and if they hit a surface at high speed, and become embedded within it, they will quickly initiate corrosive reactions, even in traditionally corrosive-resistant materials like aluminium.

Atomic oxygen is a problem peculiar to low Earth orbit. It's not something that standard aircraft in the denser atmosphere below have to worry about – and it's not something that spacecraft which leave Earth orbit will have to worry about either, since they are unlikely to encounter it anywhere else in the Solar System. But, given the amount of hardware that we are currently putting into low Earth orbit, the effect of atomic oxygen is something that we can't ignore.

Another thing about being in orbit is that a spacecraft like the ISS will spend half its time in sunlight and the other half in shadow – which creates large temperature fluctuations. This puts stress on structural materials which repeatedly expand and contract with swings in temperature from over 100 degrees Celsius in sunlight to under 100 degrees Celsius in shadow. This is why you often see spacecraft covered in white thermal blankets for insulation – the white to reflect as much heat as possible and the blankets to limit the temperature swings.

Of course, out in real space, like in interplanetary space, temperature fluctuations and atomic oxygen cease to be issues. Out there, space really is cold, dark and *almost* empty. But, out there, you face a new problem in the form of high energy extrasolar and extragalactic cosmic rays, which are normally deflected or at least weakened by the Earth's magnetosphere.

Nearly all astronauts who've been in space for any length of time have reported seeing flashes of light with their eyes open or closed. Lunar astronauts who were well outside the Earth's magnetosphere reported seeing flashes once every three minutes on average, while ISS, Shuttle and other astronauts in low Earth orbit report seeing a flash once every seven minutes on average. No-one is sure yet if the flash comes from a cosmic ray particle hitting the retina, some other part of the eye, or perhaps even the optical nerve itself. And all the while, other cosmic ray particles will be hitting other body parts undetected. Fortunately, no-one has turned into one of the Fantastic Four yet, but there is a general view that this can't be good for people and it can't be good for their spacecraft either.

In fact, in the face of high energy cosmic ray bombardment, a metal hull will not only degrade – but becomes a source of radiation itself, as high velocity cosmic ray collisions split the nuclei of atoms in the metal, creating fission products that includes gamma rays. Fortunately, no-one has turned into the Incredible Hulk yet, but there is a general view that we need to protect any Mars-bound crews from these effects, since a Mars-bound crew may be flying through real outer space for a cumulative period of up to two years.

To protect themselves, that Mars crew will need shielding composed of less complex atoms, like hydrogen and oxygen, that are less likely to undergo nuclear fission on impact. So, water should make for good shielding, where cosmic ray particles are more likely to just bounce around in the water, losing energy in the process but not initiating nuclear fission. Since the water would be held within the outer layers of the hull, it might freeze, but that won't affect its shielding ability – and it means it won't all leak out in a rush should a micrometeorite puncture the outer hull.

And yes, micrometeorites, not to mention full-size meteorites, are another space environment issue that we have to worry about. We tend to focus on micrometeorites as the bigger risk since there are a whole lot more of them – and, let's face it, if you are unlucky enough to collide with a real meteorite that will probably be your end-of-mission right there.

A lot of exposure research is also directed towards seeing how well organic materials might fare when they are exposed to space. And those organic materials generally don't do well. The half-lives of a wide range of organic compounds turned out to be less than one week after being exposed to space – and these were just basic organic compounds, like the amino acids glycine and serine.

However, some of the hardiest of *biological* structures we know about can better survive exposure to space. These hardiest of biological structures are bacterial endospores – which are not really spores, but a kind of escape pod that is jettisoned by some species of bacteria when they find themselves without the nutrients they need to survive. An escape pod endospore has no energy requirements and can just sit there for years – possibly for centuries, under the right conditions, until it once again finds itself in fertile conditions where it can germinate back into a bacterial cell. However, being exposed to the cold vacuum of space and to the unshielded radiation of a nearby star are most definitely not the right conditions and after a few weeks of exposure all the bacterial endospores we've tested couldn't be revived.

So, even our extremophiles have their limits. We get excited that these things can survive in nuclear fission reactors and hot geothermal springs, but the key thing is that they still have *water*. Take the water away and all the living things we know about either quickly die or they shut-down into some kind of biochemical stasis until some new water comes along. So anything we've got here on Earth would be very unlikely to survive an unprotected trip to Mars and even then they'd probably just die when they arrived. So, exposure research is making panspermia is look increasingly unlikely. But, we humans can certainly go to Mars, in appropriately-shielded spacecraft – and when we do, we will be taking all our internal bacteria and fungal biota with us.

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