Surfaces

(Intro)

In Larry Niven's 1970 novel *Ringworld*, a number of space-faring species travel around the galaxy in spacecraft with General Products hulls. General Products hulls are impenetrable to projectiles or other things that the hull might incidentally collide with. General Products hulls are also impenetrable to all wavelengths of electromagnetic radiation excepting, somewhat conveniently, visible light. This means that a spacecraft's surfaces generally had to be painted over, for privacy and security reasons, except in those places where you wanted windows.

Of course today, there is no such thing as a General Products hull. Astronauts have landed on the Moon in spacecraft with hulls that you could poke a hole through with a sharp pencil. You couldn't do that on the ISS so easily, but its hull could be punctured by a high-speed micro-meteor, or by a loose bolt left behind in low Earth orbit from a previous space mission. Anything that is in low Earth orbit is there by virtue of it moving at 8 kilometres a second, that is, around 30,000 kilometres an hour. Any objects moving faster than that are flung out of Earth orbit and any objects moving slower than that will fall to Earth, if they are not first incinerated in their descent through the atmosphere.

To protect the ISS from 8 kilometres per second collisions with other things in low Earth orbit, critical areas do actually have shields – called Whipple shields. These are not something out of Star Trek, they are just layered sheets of metal, facing into the ISS's orbital path. Whipple shields aren't deflector shields either, they are designed to take the full impact of a high speed object – absorbing all of its kinetic energy before it can come into contact with a pressurised bulkhead. So, their function is much the same as a bumper bar or a crumple zone on a car. This might sound a bit low-tech for space, but when their lives depend on it, astronauts prefer to put their trust in hard-core physics rather than science fiction.

But impacts by orbiting debris are only part of the problem faced by an orbiting space vehicle. The material used to make a spacecraft hull also has to withstand temperature swings from 120 degrees centigrade in sunlight to minus 150 degrees centigrade in the shade. In sunlight, the hull is also exposed to harsh UV light, as well as higher-energy X rays and gamma rays that the Earth's atmosphere normally insulates us from.

On top of all that is a problem peculiar to low Earth orbit – atomic oxygen. Atomic oxygen just means a single atom of oxygen, but a single atom of oxygen is an unusual thing. Normally, oxygen loves company. Across the Universe, it is most often found bound to the most common element in the Universe – hydrogen. Indeed, it is most often found bound to two of them, in the form of water.

But if it doesn't meet some hydrogen first, oxygen will bind to almost any other atom that happens to be around, including itself. The O_2 in our atmosphere is constantly being produced from photosynthesis and then, in the upper reaches of the atmosphere, that O_2 is constantly being broken down, mainly by UV radiation, into individual oxygen atoms. Normally these atoms would not persist for any length of time without reacting with, that is *oxidising*, another atom. But in the rarefied exosphere of low Earth orbit, an oxygen atom may remain isolated for long periods of time until it does fortuitously does come into contact with something else – like, for example, a passing space station.

Unfortunately for the ISS, atomic oxygen is not kind to the materials that it comes into contact with. On Earth, oxygen makes iron oxidise to rust and makes a carbon-based material like wood burst into flame if it's hot enough. If an oxygen atom in low Earth orbit collides with a space station at 8 kilometres a second, the kinetic energy of that collision has a heat equivalence that can drive some very energetic oxidation reactions. And although one single oxygen atom collision may just create a little pockmark on an ISS panel, the cumulative effect of lots of oxygen atoms, colliding relentlessly over days and weeks and months, does start adding up to some significant surface erosion.

So, with all that going on, you might not be surprised to hear that the ISS has been running a long-term, multi-staged experiment called Missy – that is, the *Materials International Space Station Experiment* (MISSE) – which involves embedding a range of different surface materials on a set of panels that are constantly exposed to space. These MISSE panels are generally two-sided. Some have one side facing away from Earth, while the other side faces towards Earth. These panels enable comparison of the effects of radiation from deep space, compared with the other side of the panel which is shadowed by the Earth. Other MISSE panels are positioned to face the orbital direction of the ISS, while their opposite sides face away. The panels facing into the ISS's orbit bear the full brunt of collisions with atomic oxygen and orbiting micro-debris, while the ones facing away do not.

The MISSE panels primarily measure the particular harshness of the space environment in Low Earth Orbit, at around 400 kilometres altitude. If you go higher, the likelihood of colliding with atomic oxygen diminishes. From about 1,000 kilometres altitude up to about 60,000 kilometres altitude you are in the midst of the van Allen belts, which is where all the subatomic particles deflected by our magnetosphere are congregated into channelled flows around the planet. So, the higher you go, the higher the risk of surface erosion from solar wind and cosmic ray particles. Indeed, the concentration of these particles within the Van Allen belts, makes them a bigger problem in the belts than they are out in deeper space.

Out in deeper space, where only the Apollo missions and our plucky robot explorers have yet ventured, things are different again. Outside the magnetosphere, but still in the region of Earth's heliocentric orbit, damage from solar wind particles and UV radiation are the big issues, issues that get worse if you move closer to the Sun. But of course, if you move away from the Sun, these issues diminish. Out past the orbit of Mars, the solar wind and the UV radiation from the Sun cease to be much of a problem – and your spaceship hull is less challenged by thermal swings between light and shadow, everything just becomes uniformly cold.

However, in the outer Solar System you will still continue to be exposed to cosmic rays arising from other parts of the galaxy, as well as cosmic rays from outside the galaxy. Although less numerous than solar wind particles, these extrasolar cosmic ray particles are generally much more powerful, being the distant echoes of supernovae or even colliding black holes. And since they are more powerful, they are also more damaging.

So, space isn't just space and your choice of which material you decide to make your spacecraft hull out of may depend upon the particular extra-terrestrial environment that you want your spacecraft to operate in.

Also, you can't just depend on adding more layers of shielding in order to go anywhere you want. For example, your solar panels need to be exposed to space as much as possible, since if you shield them with protective coverings, they will cease doing their job. And of course it's the same with radiator panels.

Oh… what are radiator panels? Well, if you look closely at a photo of the ISS – you will see the huge, extended solar array panels, but you will also see a few collections of smaller rectangular panels, that just seem to just sit there. These curious structures are the radiator panels. Each 2 by 3 metre panel is connected to a system that circulates liquid ammonia coolant around the station, transporting heat from internal ISS systems out to the panels, from where that heat can slowly radiate away into space. So, on a spacecraft there are at least two critical systems, stellar energy absorption and waste heat disposal, that depend upon the integrity of unshielded surfaces.

This is where the MISSE experiments are helping to identify what materials stand up best to high-speed collisions with micro-debris, what stand up best to bombardment by high-energy sub-atomic particles and what stand up best to ionising electromagnetic radiation.

Doing all this now makes a lot of sense. We don't want to embark on a five year mission to explore strange new worlds and find the hull has started leaking two weeks into the voyage. If we really want our future to be Star Trek, we need to start now. And fortunately, we are starting now.

(Outro)