Question 1:

Dear Cheap Astronomy – Can anyone intercept the information and images transmitted from spacecraft back to Earth?

Continuing a recent Dear Cheap Astronomy theme of cyber-hacking in space, we're now going to investigate straightforward cyber-theft. Again, we have no expertise in this area whatsoever and no-one is the space business goes out of their way to publish their security protocols, so here we're just reproducing information that's already out there.

So, firstly pretty much anyone can intercept a radio transmission. It is possible to beam a radio transmission from a dish – so the radio waves or the photons travel in straight lines, rather than radiate out in a sphere – a bit like how car headlights will beam optical light straight ahead of your car. But over any appreciable distance, that beam is going to spread and diffuse – and such spreading and diffusing is inevitable over spacecraft communication distances. So, as a general rule if you have line-of-sight of a spacecraft you can receive its radio transmissions. But of course how long you have that line of sight for will vary. A low orbiting spacecraft like the ISS might only be in view for a minute or so. Higher altitude ones will stay in view longer – and a geostationary satellite will always be in view.

But thinking beyond Earth orbit, the rotation of the Earth becomes the main issue in maintaining line-of-sight with spacecraft that have left orbit. Furthermore, to intercept the faint radio transmissions from spacecraft in deep space you start needing some kind of radio telescope to get the resolution needed to separate signal from noise and you will also need to know exactly where to point the telescope to gain a strong signal.

But OK, beyond those first-order practicalities, it's one thing to receive a radio signal – and quite another to be able to make sense of it. First, there's basic stuff like the frequency and modulation of the radio wave signal. Potentially you could scan the airwaves until you a find the signal you are after, but in the 21st century the airwaves are pretty packed with content. So, it could be a struggle to find what you are looking for unless you are in a radio-quiet area or you already know exactly what the content of the signal is.

To recap, if you want to intercept a deep space radio source you'll need a radio telescope, which involves some pretty serious infrastructure, plus staff to run it. If you've already got that, you probably won't have much trouble pinpointing a signal source along with its frequency and amplitude. Beyond that, there are still major issues around trying to interpret the data. Spacecraft generate a lot of data from purpose-built instruments with specific calibration settings – such data would be largely meaningless to a cyber-thief without the technical specs of the data collection instrument. But generic data like images probably could be interpreted by anyone. The only way to protect that data would be encryption. But, since agencies like NASA will generally release any images publicly within a day or so anyway, it's not worth their while taking on the time, effort and risk of data loss that would be involved in encrypting the data at the source. So, as far as our crack investigative research team can tell, no-one bothers to encrypt data that is transmitted from deep space missions.

The only publicized incident of data theft from deep space exploration was when the UK's Jodrell Bank radio observatory intercepted a data transmission from the Soviet Union's Luna 9 lander, which had just snapped the first-ever close-up images of the Moon's surface back in February 1966. So, England's media gazzumped Russia's media in publishing those first close-up images of the lunar surface. But, it's hard to say whose victory it really was since the Soviet Union had its technological triumph broadcast across the English-speaking world overnight without having to lift a finger – or hire an interpreter.

It's really in Earth orbit that cyber security starts to matter. All the warm fuzzy stuff about doing it for all of humankind tends to go out the window when you're this close to home. As we've discussed in a previous episode, there is a certain risk someone could take over someone else's satellite, although it's not a huge risk, since taking over a satellite effectively you would need fairly detailed knowledge of how to fly the thing – and enough fuel to fly it with. Of greater concern may be the risk of someone intercepting data downloads from someone else's satellite – and if someone can do that, they probably aren't going to make a public announcement of it. Instead they're more likely to continue surreptitiously monitoring those downloads – siphoning off any useful intellectual property, or waiting for some key military intelligence to filter through – which in an active conflict might mean seeing what an enemy is looking at, or what they haven't looked at. So, in the 21st century it does pay to be alert – and maybe a little alarmed.

Question 2:

Dear Cheap Astronomy – what do you think of the Drake equation?

Well, we like it and we think it's terrific that an eminent astronomer's back-of-an envelope scribblings have so captured the public imagination. Indeed, Drake's equation has been so meticulously documented and explained, that we'll do a cheaper version here that also deals with the Fermi paradox and makes a passing reference to Carl Sagan.

So, for anyone who needs the back story, the Drake equation attempts to calculate the number of intelligent species we should be able to communicate with by adding together a mixture of what are mostly probabilities about stars and planets and evolution. The Fermi paradox then states that here we are in this huge Universe with lots of stars and potentially life-bearing planets – so where the heck is everyone?

Anyhow, the first terms of the Drake equation seek quantification for how many stars there are and how many of those stars could have planets with habitability potential. Later terms of the equation then seek estimates of the likelihood of intelligent life developing on those planets and then what are the chances of those intelligences then developing interstellar-scale communications and then what is the period of time over which such intelligent civilisations might sustain that technology.

Drake equation commentators often wax lyrical over that last point, interpreting it as meaning that there's only a brief window period between an intelligence developing and it then destroying itself. The equation doesn't actually say that, it just proposes there's a certain window over which broadcasting is likely before it stops. So, rather than destroying itself, a civilisation might instead become smart enough not to rely on energy-inefficient broadcasting anymore and that civilisation might well decide that there's no point bothering to communicate with any primitives who have just recently stumbled across the whole broadcasting idea.

In reality it's unlikely that an advanced civilisation would just ignore a recently-emerged broadcaster like Earth. But, since the universal speed of light limit eliminates any likelihood of invasion, an advanced civilisation might just contact us to say, OK, we're not going to kill you, but if you want to swap ideas, well… what have you got? It's likely a flurry of international conferences, symposia and working groups would follow as the human race suddenly realised it has to justify its existence – and sending a bunch of poetry and religious texts probably won't cut it. We'll have to acknowledge that about 90 per cent of what we've done to date has involved digging stuff out of the ground and burning it to create electricity and we've wiped much of the planet's ecosystems in doing so. And sure, we went to the Moon – although once we'd done it, we kind of lost interest and although we've since landed some robots on Mars you'd have to say that interest is now waning there too.

As for the other parts of the Drake equation, they are all valid, it's just important to remember that to make an apple pie you not only need a Universe, but you need a Universe that's old enough to have shifted from a periodic table of hydrogen, helium and lithium to a much richer elemental mix that can support a wonderously aromatic mix of carbohydrates, polysaccharides and triglycerides.

It's also important to remember that our Solar System has only appeared in the last third of the Universe's lifetime – and it's taken well over 99% of our Solar System's lifetime for our broadcasting species to appear. So, in calculating the probabilities of receiving communications from other intelligences, we must also account for the relativistic truth that distance is time – in other words, the probability of detecting other intelligent communicators will drop quickly over galactic distances.

So, our best chance of finding an answer to Drake's equation probably lies within our galaxy, where you can scan for life that's emerged within the last 100,000 years or so. And within our galaxy it's probably only worth looking in places where evolution has been able to do its thing uninterrupted for several billions of years – that is, without being zapped to nothing by supernovae explosions or gamma ray bursts, or planetary-scale collisions - which probably means we should be focusing our searching on the galactic outskirts – and just in mature and stable stellar systems, like the one that we are in.

So, not only is the search just beginning, but, as the Drake equation implies, we should probably expect that there's slim-pickings out there – but to rebuke Fermi, the chances of finding anyone are certainly not zero, they're just slim and those chances will probably grow as the Universe gets older. And if do we find someone out there, we should celebrate with some freshly-baked apple pie.

DRAKE EQUATION

$$N = R \times f_s \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

R	average rate of star formation
f_s	fraction of good stars that have planetary systems
n_e	number of planets aound these stars within an "ecoshell"
f_l	fraction of those planets where life develops
f_i	fraction of living species that develop intelligence
f_c	fraction of intelligent species with communications technology
L	lifetime of the "communicative phase"