Implausible Engineering – Episode 5a: A telescope big enough to see alien life

Starting with the practicalities, to see life on another planet it first has to visible. So, for example, subterranean and nocturnal life may not be visible form ten metres away, let alone from across the galaxy. Similarly if the planet has dense cloud cover, forget it.

So let's try to refine the issue here. If it is possible to see an exoplanet's alien life forms from orbit, then yes we should be able to build a telescope big enough to see them from across the galaxy. Of course to see fine detail of the surface, you'd need to visualize the planet as a very high resolution image – so your telescope needs very high resolving power. At a simple level, the bigger your aperture – for example, the bigger the mirror of a reflector telescope – then the bigger the resolution you can achieve. That's not the full story though – you can also use magnification to resolve fine details – which you can achieve by increasing the telescope's focal length, but the more you do that the dimmer the image becomes. So to get around that you either have to further enlarge your aperture or you need a longer exposure to your target image. Since everything is moving in the universe, that's means your telescope needs the capability to track – that is, it needs to move to remain precisely locked on a moving target – noting that the further away your target is the faster it's going to slip out of your magnified and narrowed field of view, so more magnification requires more precise tracking.

All these things are pretty routine technology nowadays, but we haven't yet applied them to the huge scale apertures we may need to visualize details on the surface of a distant exoplanet. So for example a relatively detailed picture of the Earth has been captured by spacecraft that have left near-orbit, for example the Blue Marble image captured by Apollo 17. This was an unmagnified photo taken by a camera, where the resolution of that image was around 35 kilometers per pixel. It's been calculated that an alien in the Alpha Centauri system would need an aperture of 600 kilometers in diameter to achieve that same resolution of Earth from Alpha Centauri.

So, that's a 600 kilometre diameter mirror just to capture a high resolution image, over which you then apply magnification and tracking technologies to get a close-up view of what's happening on the surface. And that's just for an exoplanet 4 light years away. But with that much theoretically possible, there nothing to stop you theoretically scaling it up further to view more distant targets, there's just some pretty-extreme engineering challenges to overcome.

A dish of 600 kilometres in diameter would requires the land area of Ecuador or New Zealand, so it's probably better building it in space. This also helps in reducing issues with gravity affecting the mirror's geometry and structural integrity, plus you are not peering through Earth's atmosphere. Nonetheless, you still have problems in wanting it to track distant objects. With a dish of 600 kilometres in diameter, a force applied at one point will take time to work through the whole structure, so this dish will initially warp before it turns. So you really need actuators distributed at close intervals right across its structure that are all coordinated to work in unison. And one you go down that road, why not just forget about one big dish and instead build an array of hundreds of closely spaced mirror segments. This would be vastly simpler to maintain in the face of occasional micrometeorite collisions – so you just swap out a unit rather than having to repair and realign the whole structure. The architecture is also simpler since you could just have lots of small flat mirrors with their own independent thrusters so they could move around independently, organizing themselves into a the shape of a giant parabolic dish, which could track distant objects as though it was a single structure.

And you could choose between having very-closely spaced mirrors that make up one big mirror – versus spreading them further out, hence expanding the diameter of your apparent aperture. This makes the telescope more of an interferometer but with some clever image processing you would have yourself an even more powerful virtual telescope, sacrificing integrated image capture in favour of more raw data collection. Would it be insanely expensive, both to build and maintain? Heck yeah – but when has that ever got in the way of an episode of implausible engineering.

Implausible Engineering – Episode 5b: Seeding the cosmos with robots

Yep, it's robots again. As we've covered previously on Cheap Astronomy, flying people around the Universe is mostly impractical and it would be highly unpopular given the trip durations involved. Warp drive just isn't going to happen and even close to light speeds are problematic given collisions with dust grains are likely to substantially slow you down and possibly damage your spacecraft. So going anywhere interstellar will probably require trip durations measured in thousands of years.

Maybe it would be worth it if the destination was an Earth 2.0, but if we do have the technology to cross vast interstellar distances with generational starships, then we could probably just as easily build an Earth 2.0 in a Goldilocks orbit round the Sun. After all, a proper generational starship, pretty much has to be a small Earth 2.0 itself. You'd need a proper ecosystem to produce and recycle food and water over thousands of years and since it's a generational starship you need a big crew for genetic diversity, and you'd need maternity hospitals, schools and universities to produce future generations of competently skilled adult astronauts.

But no-one's going to embark on such a generational starship without the assurance that they are going to a place where at least their great, great grandchildren will be able to disembark and build a new home. So, long before the voyage is even considered, we'll be looking for candidate destinations with telescopes followed by close-up robotic exploration of any systems that might be candidates for colonization.

Such robotic exploration could be done by either getting something small and simple there fast or get something large and complex there gets there slow. Regular Cheap Astronomy listeners will be aware that we consider the latter option to be the only realistic one, despite the greater expense of both time and money. Sending a lightweight probe with no intrinsic maneuverability carries a huge risk of the probe completely missing its destination should there be the slightest deflection from its initial trajectory. And having its maneuverability controlled from Earth won't work since it could take years for a signal about a course deflection to reach Earth and then an equal number of years for Earth to send back a course correction maneuver, by which time it may be far too late to correct the probe's course. So the solution is to give the probe intrinsic decision-making control. This can just be in the form of if then commands – for example, if you veer left then fire the left thruster to put you back on course. To make that happen, the spacecraft to possess an energy source for electrical power, which in the cold blackness of deep space is going to be a nuclear reactor, and the craft will have to have its own sensors, to monitor its course against the external star field and to monitor its own internal systems. Taking it a step further, the craft should also have intrinsic machine learning capabilities – so when managing a course deflection maneuver, it will also capture feedback data, about the effect of a particular amount of thruster firing and the efficiency of the thruster, data which might then modify how the next thruster fire is managed.

As well as developing its own learning, the craft will remain in touch with Earth, meaning that Earth can provide software upgrades which might include thruster efficiency enhancements as well as some additional algorithms to enhance the craft's machine learning capability.

So on the basis of all that, Cheap Astronomy concludes that the light weight interstellar probe you send from Earth can't actually be very lightweight – since it needs a power source, fuel and propellant, transmitters, receivers and computing capability. On the positive side, with all that capability, when it does eventually arrive at its destination, it should be a more efficient and more capable spacecraft than it started off as.

But having established that there's no value in sending a lightweight probe on an interstellar journey, meaning that it will hence take thousands of years, you also have to consider that thousands of years is a long time. Even in the cold, dark vacuum of empty space things will start running down and wearing out. So you'll have to further add to the launch weight with various spare parts, but replacing old parts with new parts requires internal mechanisms that can move things out of storage take them to another part of the ship, undo and redo bolts, fastenings and connections – all of which starts sounding like what you really need is a team of maintenance droids.

So a ship with machine learning capability and crew of maintenance droids that are continually moving further away from contact with Earth in terms of both space and time sounds like a ship that's on a trajectory to independent, self-directed existence. Once a robotic explorer craft gets to another star system you don't want it just sitting there for years or decades waiting for instructions from Earth – we would have preprogrammed it with instructions to lay out solar, sorry stellar, panels for energy and start converting the mechanisms of the ship to new tasks including building 3d printers and ultimately building landers to start exploiting whatever resources are available on the exoplanets of that system. And once all that is happening, it's worth asking why the heck would you want to send people. Everything is so much easier without having to fiddle about with life support.