Question 1:

Dear Cheap Astronomy – Can you talk us through the recent Falcon rocket landing on water?

Yes, we can. On Friday 8th of April 2016, a two stage SpaceX Falcon 9 rocket launched from Cape Canaveral in Florida. As with any launch from Florida, the rocket flew east in a parabolic arc, since, near the equator, the Earth is rotating towards the east at nearly 1700 kilometres an hour – so it makes no sense to fly west and subtract that advantage from your launch. And, of course flying east from Florida takes you right over the Atlantic Ocean.

The first stage booster of a Falcon 9 raises the rocket to about 80 kilometres at which point it is travelling at about as Mach 10 – which is over 12,000 km/h. The first stage then separates, at around 2 and a half minutes after launch. If that was that, the first stage would then continue passively following a descending parabolic arc until it hit the ocean about 1,000 kilometres offshore.

But that doesn't have to be that. Space X has been running Falcon 9 booster landing tests since 2013, the first of which involved setting the booster down to a soft landing on the ocean's surface – after which it just sank – but it was those tests that established and refined the booster return process, which is as follows.

At the point of stage 1 separation, the rocket has already left most of the atmosphere behind, so the separated stage 1 booster cannot manoeuvre aerodynamically. Instead it uses cold gas thrusters to turn itself around. From there it can either coast back down to Earth on its parabolic trajectory – or do a 'boostback' burn to shorten its return trajectory. This boostback burn just uses three of the nine Merlin engines. Then, just before it re-enters the atmosphere proper, it undertakes what's called the re-entry burn to further slow its decent and further modify its trajectory and it's about then that the grid fins are deployed.

Grid fins are used to help steer a range of long tubular craft which fly at supersonic speeds – and which are mostly missiles. Grid fins are generally squarish and are they really are grids – like a metallic lattice– allowing air to flow through them, so they don't get ripped off a rocket travelling at supersonic speeds, but they are still able to create some aerodynamic drag. The Falcon 9 first stage booster has four grid fins – which are folded against the rocket at launch to minimise drag and then later deployed on descent. Each grid fin is a bit less than 2 metres square and can open right out to 90 degrees or more, as well as being able to be turned back and forth. The combined action of four grid fins gives the booster allows roll, pitch and yaw control up to 20 degrees from its general direction of motion, once it's flying in dense atmosphere.

While all that is happening, the rockets target, the ASDS or Autonomous spaceport drone ship is waiting in the expected landing zone and can maintain an exact GPS-determined position using a set of azimuth-mounted engines.

On final approach to the ASDS, the stage 1 booster is usually firing just one of its Merlin engines to further reduce its velocity (eventually to zero), as well as providing further steering via gimbaling of the engine – that is, the engine is able to pivot around slightly to alter its direction of thrust and hence help guide the booster to a pin point landing. On its final approach the booster also deploys its four landing legs, which, like the grid fins, were folded up against the side of the rocket at launch. And so – about nine minutes after launch, the stage 1 booster is able to settle down gently on a hard surface.

The rationale for this retrieval process is that it costs about $60 million to build a Falcon 9 rocket, but it only costs about $200,000 to refuel it. So, if you could reuse a spent booster, after some appropriate refurbishment – that may reduce the total build and launch costs of a Falcon 9 by around 30%. We are yet to see a Falcon 9 stage 1 booster re-used. One of the retrieved boosters has undergone static launch tests – that is, not actually launching it, but firing up its engines as though it were going to launch. This was partially successful – and like all tests before it collected some valuable data that will make future attempts work better.

For now, the booster retrieval process remains cutting-edge engineering. Space X's Elon Musk anticipates a few more RUDs before they've ironed all the bugs out. RUD stands for Rapid Unscheduled Disassembly – an engineering euphemism for explosion.

Question 2:

Dear Cheap Astronomy – Is the Milner Hawking mission to Alpha Centauri technically-feasible?

The announcement of Breakthrough Starshot, a mission to send a 'gram-scale' spacecraft to Alpha Centauri at 20 per cent of the speed of light, is a good example of describing what's technically-feasible versus what's technically-practical.

Gram-scale means something that weighs a gram or so – some of which is payload, although most of it will be its light sail. The idea of the mission is to hyper-accelerate a low mass light sail craft with high power lasers up to around 20 per cent of light speed – which is about 60,000 kilometres a second. For reference Voyager 1, currently the furthest human-made spacecraft out there, is travelling at about 17 kilometres a second. At 60,000 kilometres a second a spacecraft could get to the Alpha Centauri system in about 20 years.

So yes, that much is technically-feasible. But, it is doubtful we could achieve pin-point accuracy when aiming a spacecraft at a target that is 4.3 light years away, using what's going to be a single-thrust manoeuvre.

Even with a hugely-powerful and tightly-focused laser array, the power and the push provided by the laser beam will still attenuate over astronomical distances, so the spacecraft will be largely relying on an early push to get it up to speed, leaving it to then hopefully coast on a direct line to its target. If it does veer off course at all – well, that's probably that. It's not intended that a gram-scale spacecraft will have any on-board propulsion per se. There is talk of adding photon thrusters, although, since these haven't been invented yet, it's a little unclear what they actually are – and let's face it photons just don't have the momentum required to significantly alter the course of an object with a forward vector of 60,000 kilometres a second.

And that brings us to another non-trivial problem. The darn thing is travelling 60,000 kilometres a second. Space is not a perfect vacuum and hitting a small dust particle at 60,000 kilometres a second would probably spell the end of your gram-scale spacecraft. And even if it did somehow survive the collision, there's no way it would remain on course.

And even, putting all that to one side, there are also issues at the Alpha Centauri end. Having got up to 60,000 kilometres a second and coasted the remaining distance at a constant velocity in a vacuum – there are no mechanisms available to slow the light sail down as it approaches its destination. The light pressure of the Alpha Centauri stars would have a minor effect at best – so the spacecraft will be whizzing through the system very, very fast, covering around 200 million kilometres every hour. At that speed it would take just over a day to cross a distance equal to the full diameter of Pluto's orbit around our Sun. There may be opportunities to gather some science data at that speed, but there's no way it would be capturing high resolution imagery of an exoplanet's surface – assuming it was lucky enough to be flying anywhere near an exoplanet during its brief transit of the system.

And, of course, this raises some more problems with this plan. Firstly, what sort of data collection instruments could a gram-scale spacecraft be able to carry and secondly – and perhaps most importantly of all – how would the spacecraft get any of the data it collects back to Earth?

Here, the project proponents appeal to Moore's law – anticipating exponential technological advances in the years to come that will overcome any of the cheap naysaying you might hear today. So, a gram-scale spacecraft will have its own power supply, cameras, photon-thrusters and a deep-space data transmission system – all apparently based on photonics and a bit of hand-waving.

While it's certainly not out of the question that such advances may come – it does beg the question as to why we don't make that the primary objective of the project. That is, why not start by developing a gram-scale spacecraft that really could do something useful when it gets to Alpha Centauri – because there is a lot of useful work that such a spacecraft could do locally. And this might help pass the time while we work out how exactly we are going to get the darn thing to Alpha Centauri.