

I was sitting in a folding lawn chair, kicked back with a drink in my hand. The cooler to my right was full of cans of Coors, bottles of pineapple juice, and a few bottles of Malibu Coconut rum. If this was a movie, the camera would zoom out to let the viewer see another, similar chair, with a little camp table next to it. The older man in the chair, wearing shorts, flip flops and a flower print shirt, exchanged the tablet he was reading with the can of Coors on the table, then took a sip and pondered for a bit before speaking.

"It's not that far off, " he said, "but the Zuchai Crystals are part of the jump capacitors. And there's parts about how the Grid and Coils that are... not right. Considering the handicap the writer was under, it's really pretty amazing. "

I nodded, took a matching sip of the pineapple and rum, and let him settle his thoughts. We'd met before, a few times, and he'd told me stories. I knew that you had to let him gel his thoughts, so I sat back in my chair.

We were sitting in a failed housing development in rural Florida. The developer had paved the roads and cul de sacs, and then the 2008 housing bubble hit and nobody wanted to buy a house way out here in the middle of nowhere. I'd parked my car a street over, and when he parked it took up the whole cul de sac... but the shade was nice. And his ride had an icemaker, among other things, so we had cool drinks and snacks. That made waiting through his reading a bunch of emails and discussion, then waiting while it digested more tolerable.

He began speaking again, "And so... I'm not going to give you anything classified. Nor do you get the basic math behind any of it, and definitely not any of the really useful 'rule of thumb' math that lets you do things rather than understand how they work. All the science is going to be what you call 'high school level' , the level where people can discuss things with some relation to reality, rather than 'skill level' where it's actually useful knowledge."

He leaned forward and looked me dead in the eyes, very serious now, "You push for more than that, and you're breaking the agreement. I am not going to be responsible for messing up the flow of civilization in this weird variant timeline in which you live, especially since I don't want a second wave of Solomani figuring out how to follow me home."

As he leaned back in the chair, taking another sip of beer, he began..

"It comes down to certain key points in technological evolution. Magnetism - the first time some rube figured out that tying a piece of lodestone to a string and hanging it on his boat, there was a leap in transportation technology. Now you could cut straight across the sea, rather than having to hug the coast to figure out where you were. Interesting analogy to the Jump drive, heh? Out there in the middle of the ocean for a week, cut off from the rest of the world, and then boom! You're at a port it would have taken months to follow the coast to get to. "

“Then, later, someone figures out that there’s a relationship between rubbing a cat with a piece of amber, lightning, and combing your hair... which is nice and everything, but not really useful until they figure out that there’s a relationship between that and *magnetism*, which is a force that’s pretty well understood by that point. Suddenly, there’s generators and motors and telegraph and telephone and all that good stuff. You don’t really understand magnetism until you’ve got an understanding of electricity, and you get a grip on electromagnetic force. “

“And still, you fumble around and talk about ‘magnetic fields’ and eventually get the idea that they’re useful, and get radio. Time goes on, and eventually someone makes another leap and figures out that the photon carries EMF... which raises some weird questions about ‘is it a particle or a wave?’ and that gets people curious about quantum mechanics.”

He sipped at the can, realized his beer was empty and nodded toward the cooler. I tossed him another, freshened my drink, and kept taking notes. Part of the deal was I wasn’t allowed to record the conversation... and he had the equipment to make sure I kept that promise.

“QM leads, eventually, to speculation about gravitons. Your culture has detected gravity waves, so you’ve got some pretty strong hints they exist. But you’re still stuck at the ‘groom the cat with an amber comb’ stage.. No, really, you’re not even quite there. You’ve realized there is, in fact, a cat. “

“The really big steps that you’ve not taken yet is figuring out how gravitons work, and then the relationship between photons and gravitons. You can at least easily observe light, so puzzling out photons wasn’t that hard, until you got to wavelengths you can’t see... but detecting gravitons isn’t easy. The details of how gravitic detectors work is part of the off-limits part of this conversation. I will say that the first lab experiments for us that lead to breakthroughs involved very very small versions of the Cavendish experiment. Things done down at the Casimir effect scale. “

“High school physics time - the graviton is analogous to a photon, in that it exhibits particle/wave duality. Just as many things emit photons naturally, gravitons are pretty much continuously emitted and absorbed by... well.. Everything. “

“A graviton decays on impact with an object. That decay produces no detectable effect in the EM spectrum, but it does have a very tiny ‘denting’ effect on the fabric of space-time. If we’re going to use the classic *sheet of rubber* analogy, then a graviton leaves a planet, hits the bottom of the empty beer can, and makes a wee little dent in the space time between the two, and the can rolls toward the dent. “

He flicked the empty can on the table with his finger, and it rolled off onto the pile below. “Voila!”

"Of course, all the particles in the object - planet or beer can - are doing the same dance on a tinier scale, so there's a dent around the object, making the gravity well for the thing.. And in the case of planets, pulling them together to form in the first place."

"Now, I mentioned that graviton/particle interaction does not produce a detectable effect in the EM spectrum. The converse is not entirely true - it is possible to do things in EM which have detectable effects on gravitons. We are again straying into details of which I will not speak. No matter how many of these beers you give me. Although a hold full of them would sell pretty well when I get home, mind you. "

I shrugged, "Forty cubic meters of cans of Coors adds up to a lot of money, and unless you're willing to part with something *useful* rather than just story time..." "

"Anyway, " he changed the subject.

"The first useful thing when you figure out electrogravitics is just to be able to generate a field that interdicts gravitons from crossing it. That's contragrav, and it'll let you make floaters and grav sleds. You still need some kind of reaction drive to move it around, but at least it ignores the local gravity field. "

"The second useful thing is when you can get a sacrificial mass to give up more gravitons than it should. That leads to grav plates, which are nice, but more importantly it leads to being able to pull things along, and that's true antigrav. That gives you air/rafts, grav belts, and the first generation of M-Drives. M-Drives gulp down huge amounts of power, but that's ok, because convincing some hydrogen to be *much, much* more gravitational than it should be leads to fusion reactors that are small, cheap, and effective."

"The third useful thing is when you figure out that fields can be convinced to interact with each other. There's where you get Jump drive. "

"Now, all this conversation started because of an email about Jump drives, so we'll go there for a bit. "

"One thing you've learned about, especially you personally as a Ham, is Standing Waves. Two different waves in the same area, getting in the right kind of sync, leaves you with a wave that's fixed in space and doesn't go anywhere. In a radio, it builds up RF that burns out the finals because all the energy you're pushing won't leave the antenna."

"With gravitics, you get a zone of gravitons settling into an area of space time that keeps digging itself a deeper and deeper dent, until finally the *rubber sheet* gets fed up with it and goes **SPROING!**" He paused then, thought about it, and said," Might as well try going to another star with a trampoline, or some such rubbish, right?"

“There are, of course, issues - like, all the matter in your ship is going to be drawn toward that ditch. So you need a contragrav bubble around the ship so you don’t get destroyed by your own J-drive. Like you need sacrificial mass to provide the extra gravitics, so you need lots and lots of LHyd you can dump out, in addition to the lots and lots of LHyd to power it. And we’re talking power levels where even superconductors get hot, so you need more LHyd to cool that...although vented coolant is used as sacrificial mass too.”

“And you need to do it quickly, because a long slow pull on the *rubber sheet* leads to the Universe getting grumpy and things , for want of a better word, tearing rather than slingshotting. There’s some scientists who are pretty sure that the weird stuff the Ancients did with bubble universes were cases of a deliberately slow J-field build up and a controlled tear. We don’t know how to do that, and the experiments were... not pleasant. Not very survivable, either. There’s several Red Zones where experimental bases used to be ... never mind, not relevant, other than when you get to where you start trying to build a J-Drive, **do not** do it within 10 light seconds of anything you care about.”

“Beer, please?”

I passed him one, then showed him the cooler was running low. He took the opportunity to go aboard, empty himself, and fill another bucket with ice, while I walked to the car and got another case out of the back seat. We settled back into our chairs, and I smiled at the open cargo door above us, and realized he’d turned the enviro systems up. A steady breeze of cool, dry air came out, doing it’s best to mitigate the still, humid, hot air of a Florida afternoon over asphalt. We spent a few minutes settling back in before he picked the tablet back up, scrolled through, and continued speaking.

“Step one, course gets built up in the computer, yeah. Preplanning of navigational charges, yeah. Aligning Zuchai crystals, no.”

“Step two, Big Honking Handwavium Reactor goes gonzo, yeah. Funny thing here... Normal long-duration reactors have one set of gravitics, and one set of sacrificial masses that get replaced during annuals. The one for the jump drive uses some of the fuel going in as much more sacrificial mass, sacrificed at a higher ratio than normal, as well as using the normal sacrifice systems. So there’s two graviton sources, overlaid on each other and producing a very strong field. That there’s two sources means the technical term for this kind of reactor is ‘Binary Hyperdense Hydrogen Reactor’, so he got the acronym right even if he got the words wrong. “

“Step three and four is where things are off the rails, which means we need to talk about Zuchai crystals”

“Capacitors ... normal caps have layers of conductor and non-conductor, and the electrons ‘pile up’ in the space between them. Massively gross oversimplification. But you can make a capacitor from foil and paper, and it’ll hold a charge. More paper, more foil, better materials, and

you still have electrons piling up between atoms. At some point though, you get so much charge that the dielectric - the paper - doesn't hold up any more. With normal electronics, there's a pop sound, the smoke comes out, and the device doesn't work any more. "

"At the power levels for jump drives...well... the pop sound is much louder, destructively so. Work around is to work in parallel, have more caps. The size of a capacitor bank needed for the *Snipe* to jump, using even superconducting and superinsulating materials would be... probably about double the size of the jump drive now. Maybe triple."

"Zuchai crystals have a feature in the crystal lattice between the atoms that lets them store electrons in additional electron shells. Sort of like the way you'd pump the shells in a free electron laser, the electrons just move up a shell. What's special about Zuchai is it will then let you fill in the lower shell too, and let that pop up to another electron shell. The other atoms in the lattice have a lot of protons and they kind of force everything to behave even though the thing is ionized to hell and gone. On the other hand, the outer shell is 'full' , so you don't get the acid/base effect you'd expect, and the whole thing doesn't just eat itself."

"For a while, anyway. Leave the crystals charged for too long, and you get random electrons in the outer shells that decide to wander, and then things get ugly fast."

"So, then the power from the Caps - the Zuchai Crystals inside the capacitors - is dumped into two sets of gravitic generators. The so-called 'Jump Coils'. These are going to produce gravitons by the lorry load, and dump them outside the ship in very specific patterns to produce that standing wave effect we talked about earlier. This gives you a spherical jump field. Now, there is a set of antennas on the hull to release those gravitons, and one meaning of the words 'jump grid' is those antennas. It's kind of like people saying 'wheels' on a car, when they mean the rim and the tire, as opposed to 'wheel' as just the rim."

"The first jump drives just used the Coils and a spherical jump field. A lot of ships still do that - The Service likes it better, since you can get by with damage to the surface antennas and still Jump. There's also the advantage that with a ship with a drive capable of over-norm mass you can clamp a pod on the outside of the ship and still make your normal jump."

"The disadvantage to a spherical field is that if you get unexpected masses in it, then you're going to misjump. No ifs, ands or buts. Have some unexpected space rock go shooting by just as the computer closes the switch, and you have a problem. The Service has a *lot* of sensors on our ships, so it's not such an issue, just know the rock is coming through, delay the jump a few milliseconds, and then go. Merchants will head out to known 'quiet places' where there's not much in the way of dust or debris."

"Jump Grids, in the proper use of the term, are a specialized phased array antenna system that let you deform the jump bubble to make it conform more closely to the ship. The advantage here is that stray mass - ie, the sand you dumped overboard an hour ago that's still on your vector -

is not in the field. You go where you were planning to go, regardless of what's under your feet when you hit the trampoline. On the other hand, that hinges on having enough of the redundant grid of antennas intact, so ships which use this method and have taken a lot of surface hits have a problem. The Navy likes this system, because they like sand, and they like lots and lots of surface armor with multiple layers of redundant antennas."

He rolled his eyes at the mention of The Navy, but then looked back down to the tablet resting on his tummy, scrolled a bit while muttering, "where was..."

"Ok, so that covers three, four, five... yeah, the caps dump into the coils, that's six..."

"BHHR steps down - well, yeah, it goes non-binary and behaves like a normal reactor, but a big part of that is not maintaining the jump grid or the coils, because they've done their job. The *rubber sheet* has been twanged like a rubber band, and you're outside normal space. He is right about making sure the jump bubble is intact, and that's mostly handled by the equilibrium between the last of the sacrificial LHyd outside the ship being drawn to the only mass in this pocket universe - the ship - and the inner contragrav field that first shielded you from the Jump field forming keeping it from falling all the way in. You realize that in this pocket universe, your ship is like 99% of the mass of the whole universe? So the LHyd falling in would make you into a star. "

"Pulses... yeah, you can pulse the grid. Not commonly done, you should have had your bubble and trajectory right when you first made the jump. "

"Jump complete - that's going to happen no matter what. The universe gets tired of having a piece stretched all out of the norm, and it snaps back into place. Not the *same* place, mind you, which was the whole point of the exercise."

He took another sip of his beer, then said, "Lunch? "

I got the other cooler from my backseat, and pulled out the subs I'd picked up on the way over. We ate, talked about other things for a bit. I went aboard and used the fresher, while he scrolled through the emails, and as I came out and sat down, he was grinning.

"This other thread - about skills and licenses and such. They're focussing on the technology and the type of drive, and not thinking about how they're actually used."

"Ship's Boat - what's that guy doing with his life? He's either a commercial pilot, and eight out of ten that means he's shuttling from Highport to Downport. Or he's a fighter pilot. Or he's a long-run insystem pilot."

"Nine out of ten, the guy has a mission time of less than two hours. All of its hands-on."

He paused - "When I say hands-on, do you savvy? I'm saying he actually has hands on a stick and throttle, he's looking and making decisions based on what he sees outside. He's got a destination he can actually look out the window and see, like the Highport above or the Zho he's chasing. Might be that the HUD is helping him see it, but it's still a line of sight that doesn't involve much planning about flying to where it's going to be in a few days, or flying to a particular spot in space."

"He's making decisions about the last 200 meters to a landing pad or docking port, and he's doing it with more instinct and feel and training than he's doing it by instrument and computer. He's doing it in a craft that's very responsive to the helm. "

"And he's doing it 40 hours a week. For a guy doing the High/Down run, that's four up and four down a day. He's almost all stick-time."

"Compare that to a guy in a Type-A. In half his work-weeks, he's stepping in every few hours and checking the Jump field. In the other half, he's set the autopilot, and he does one lift and one drop. Nothing fancy, and for a big part of his atmo time, he's limited in what moves he can do by the aerodynamics of the ship and his approach protocols. Yeah, the contragrav gets rid of the pull from the planet, but the ship still has inertia, and the aerodynamics are pushing on it, so it can't make the tight turns a 20 ton fighter can. "

"So the difference is like being the pilot of an F-16, and the pilot of a 747 for an airline. The fighter pilot spends all his time sharpening his skills for tight, fast moves. The airline pilot takes off, sets the autopilot, kills time, then lands. "

"And then they look at grav pilots, like an air/raft. That is, in some ways, the worst of both worlds. Anyplace that has a traffic grid, you're probably never going to fly manual. Just tell it where you want to go. "

"If you are out in the hinterlands, " he said, waving a dismissive hand around, "then you're probably going to be going low and slow to stay off the local's sensors. Or you're going low and slow to look for something. Or because you're using the air/raft as a tractor to lift something from one place to another. Very rarely are you doing the all-day-climb-to-orbit."

"So... the skills in your 'game' reflect what people get into the habit of doing as they do their jobs, and that does in some ways balance into what happens when you go and get tested to get certified that you know how to use that hardware. A guy with level two certs on small craft has probably spent a huge number of hours doing hands-on flying. A guy with level two certs as a starship pilot probably has spent 25 weeks of the year not having his hands on a stick, and when he does his habits are straight, sensible approaches to starports, not the turn-and-burn 6G that a Rampart jockey does."

“Which means that if you put a starship pilot in the cockpit of a Rampart, he’s not got the practice, habits or temperament to do what the guy who does it every day does. “

“On the other hand, if you ask a Rampart jockey or a High/Down operator to set a ship up for jump, they’re going to look at you like you’re nuts. Or if you ask them to land it, they’re going to see it as a huge, lumbering elephant of a thing, and not feel comfy trying it, because the normal come in fast, then pull 4G’s decel does not work in a Type-A... and they have that nagging feeling that if they forget that they’ll end up lithobraking.”

We talked a bit more, rambling about other things. Personal lives, my spouse, his series of girlfriends, that sort of thing. And then the inevitable came - the beer ran out. His ability to consume it with no ill effect was impressive, and it had been spaced out over the long day. It was dusk when I packed up my lawn chair and cooler, and he packed his lawn chair and cooler. We shook hands, he boarded and I drove off a few blocks. Then that odd mirage effect made the stars that were coming out ripple as the contragrav field encircled (ensphered?) the *Snipe*, and it fell into the sky above me.