Speaker 1 (00:14):

Welcome. I am David Carroll, I am president of a small business called Champagne-Urbana Aerospace, or CUA. Today I'll be talking about micro-propulsion for CubeSats.

First, we're going to talk about some of the different technologies and why micro-propulsion is even of interest in the first place. So today there's a lot of these small satellites called CubeSats, which are 10 centimeter cubes, and if you think about the technology you can pack in a cell phone, you can start to imagine that a spacecraft the size of a shoe box could actually hold a number of different capabilities that are quite useful.

So one of the issues is that with the proliferation of these small CubeSats, you're starting to grow the orbital debris problem, and so that is one of the primary reasons why micro-propulsion has become a big issue and is very important to include on these small CubeSats in the future. The micro-propulsion allows you to avoid collisions, it allows orbital maneuvering, and then at the end of life, it allows you to deorbit the satellite so that you don't have a shoebox flying around in space with no control.

So the different micro-propulsion technologies that are being built for CubeSats have a wide range of different trade offs, including thrust, exhaust velocity, volume, power, and cost. And one of the interesting things about these technologies is that they are being productized by small businesses like CUA, as opposed to the large companies like Boeing or Lockheed Martin.

So here is a snapshot of a variety of different technologies that are out there. The sort of base technology is just simple cold gas, which would typically just be some sort of gas plenum or refrigerant that's exhausted through nozzles that are just controlled by simple valves. And these systems are functional and quite useful, but with electrothermal, by heating that gas, for example, you can add some thrust to that system. In fact, you can increase the thrust by about 50% beyond a cold gas system. So we actually have multiple electrothermal technologies that I'll talk a little bit more about.

There's also electromagnetic, which is a fairly low thrust option, so it's a slow way to get around in orbit, but it has the capability to provide lots of total impulse allowing you to go long distances in space. So these technologies are also very important.

And then lastly, the other category is mono and bipropellant technologies. These tend to be very high thrust, rapid transit type technologies, but they have the disadvantage of having fairly high temperature, and when you think about a couple thousand degrees Fahrenheit thruster system at the end of a shoebox, well, then you can start to imagine that maybe there's a thermal management problem where you heat up the spacecraft pretty fast. So what that means is that these mono and bipropellants end up typically having sort of short burn times to manage the heat.

Now, this is just a sampling of a bunch of different technologies. There are other technologies that exist and are being produced around the world.

So now let me focus in on CUA specific micro-propulsion technologies. So the first one I'll talk about is the Propulsion Unit for CubeSats, or PUC. The big advantage to the PUC system is that the thruster is really very compact, it's only about a half inch long, and this is an image of a plume that is emitted from it. It uses a micro-plasma discharge technology. As I mentioned, it's very compact. Here on the right, you can see it's illustrated inside a 3U CubeSat frame, or a 30 by 10 by 10 centimeter CubeSat frame, and you can see how it tucks away quite nicely at one end.

And it also has an advantage where you can, if the user needs more propellant for more total thrust, for more total impulse, then you can just extend the tank size to a larger tank. And this technology was flight qualified to technology readiness level or TRL six back in 2014, when we delivered eight units to the air force.

This is some different images of the PUC system using different propellants. So the primary propellant that we've used is SO2, but you can see that you can also fire it with argon or krypton or xenon, and you can see the color changes, which is kind of interesting. And then with xenon, you even get this sort of glow around the discharge region.

The second system we developed was the CubeSat High Impulse Propulsion System that we call CHIPS. This also has a propellant tank, and in this case the technology is a micro-resistojet, and basically that is just a hot tube through which the gas flows and exhausts at higher temperature. This system also included some attitude control thrusters, which you can see these little side arrows. That allows you to provide pitch and yaw and even role maneuvers for the spacecraft. And again, the tank size can be scaled to meet customer needs, and we completed this system in 2017 and validated it through quite a bit of testing. At this point, that technology is ready for a final flight design, which could then be fabricated and then put in space for a demonstration.

The third technology that we have been exploring quite heavily is called the Monofilament Vaporization Propulsion System, or MVP, and the primary motivation here was to replace the gas or refrigerant propellant with a simple plastic fiber. And in this case, you've got some sort of wound fiber spool, kind of like a fishing line spool. It's fed with 3d mechanical feed technology that then melts that plastic, and then we use our micro-resistojet to super heat and exhaust a hot gas from that nozzle.

So this system has the advantages of both completely eliminating the pressure vessel and any expensive valves, so that means that it ends up being a much lower cost system, and there's no range safety concerns since it's just a spool of fiber propellant. For example here the MVP system design, you can see in the sort of lower middle, and you can see this spool of fiber that has been wound around, and that just feeds into the back of this thruster area. And then the final flight like system that we delivered to NASA earlier this year is photographed here. So another thing that's of great interest here, I'll talk a little bit more about this spacecraft, but we are scheduled to launch the MVP in mid 2022 on our DUPLEX spacecraft.

The next technology that we have been working on is the Pulsed Plasma Thruster, and that's actually a technology we've been working on for over two decades. And you can see a variety of different versions of the Pulsed Plasma Thruster which just simply uses solid Teflon as the propellant, and what this has ultimately led to in the last couple of years is the fiber fed PPT, or FPPT, and again, this is using sort of 3d printer motor technology to feed the fiber right down the middle of a high voltage discharge. And we've also taken advantage of advances in electronics to have miniaturized capacitors for this. It's about an 800 volt discharge, runs across inside the thruster area. You can see here, an example photograph of an FPPT pulse, and then a flight design that we had. And again, in the backside here, you can see sort of the spool of fiber propellant in the back. This system is also scheduled to launch on the DUPLEX spacecraft, which I'll talk about in another couple of slides.

The fifth technology that we are working on is called the Monopropellant Propulsion Unit for CubeSats, or MPUC. And in this case, what we're using is what we call CMP-X, which stands for CUA Mono-propellant number 10. Now the advantage of mono-propellants is that they have much higher thrust, so you can have a spacecraft and move it from one orbit to another orbit much more rapidly than you could with some of these lower thrust technologies, like the FPPT. So it's more responsive, if you will. And there are some other very efficient mono-props out there, but they tend to burn pretty hot, as I mentioned earlier. So when you have something that's burning at a couple thousand Fahrenheit, you can create thermal control problems for a small spacecraft the size of a shoebox.

So CMP-X is actually designed to burn cooler by several hundred degrees, and it's a mixture of hydrogen peroxide and ethanol. It's extremely inexpensive, non detonable, so you can drop it, you can transport it on an airplane, but it still maintains a performance that's similar to some of these other mono-props.

Over here in the photographs you can see how its very reactive when you mix it with a catalyst. And then this is an image of the thruster head operating, so you see it's glowing red. And then this is an illustration or calculation of the exit velocity of the nozzle itself. So the nozzle is just this tiny little thing in the middle of this, the end of the thruster, but this says exit velocity of around two kilometers per second, which translates to about 4500 miles per hour. So it's pretty fast. Anyway, this system is in development now and we're hoping to get the first flight-like unit at around mid 2022.

So let me now talk about the Dual Propulsion Experiment, or DUPLEX CubeSat that I mentioned earlier. This is a 6U CubeSat, about the size of a boot box, and on one end, it will have an FPPT system. Now on the other side, it has an MVP system. So this is going to allow us to get what's called flight heritage for both of these technologies. And this program is funded by NASA Tipping Point program, and it is fully funded for fabrication, qualification, launch and in space operations.

We started it earlier this year and it's due to launch in the third quarter of 2022 at this point. So in summary, micro-propulsion is going to be really critical to include on future satellites to help prevent the escalation of orbital debris in low earth orbit. And it does that by the propulsion systems allowing collision avoidance, orbital maneuvering, and then when the satellite is done at the end of life, you can deorbit the satellite, it'll burn up in the atmosphere. There are many different options being developed by many companies around the world and the different options, of different characteristics, to best suit customer needs. So with that, if you have any questions, you can contact me at this email, and I thank you for your time.