INTERVIEW: PHILIP M. LUBIN

DE-STAR: Laser Technology For Asteroid Vaporization

What brings you here today for the 2013 Planetary Defense Conference?

I was in Washington for a NASA review, and managed to get out and catch the last two days of the conference. We are here mostly to present an idea for asteroid mitigation. It's some work we've been doing for the last couple of years. It was a good opportunity. I didn't know the conference existed before I started this project. It's a great audience for this kind of work. It's ideal.

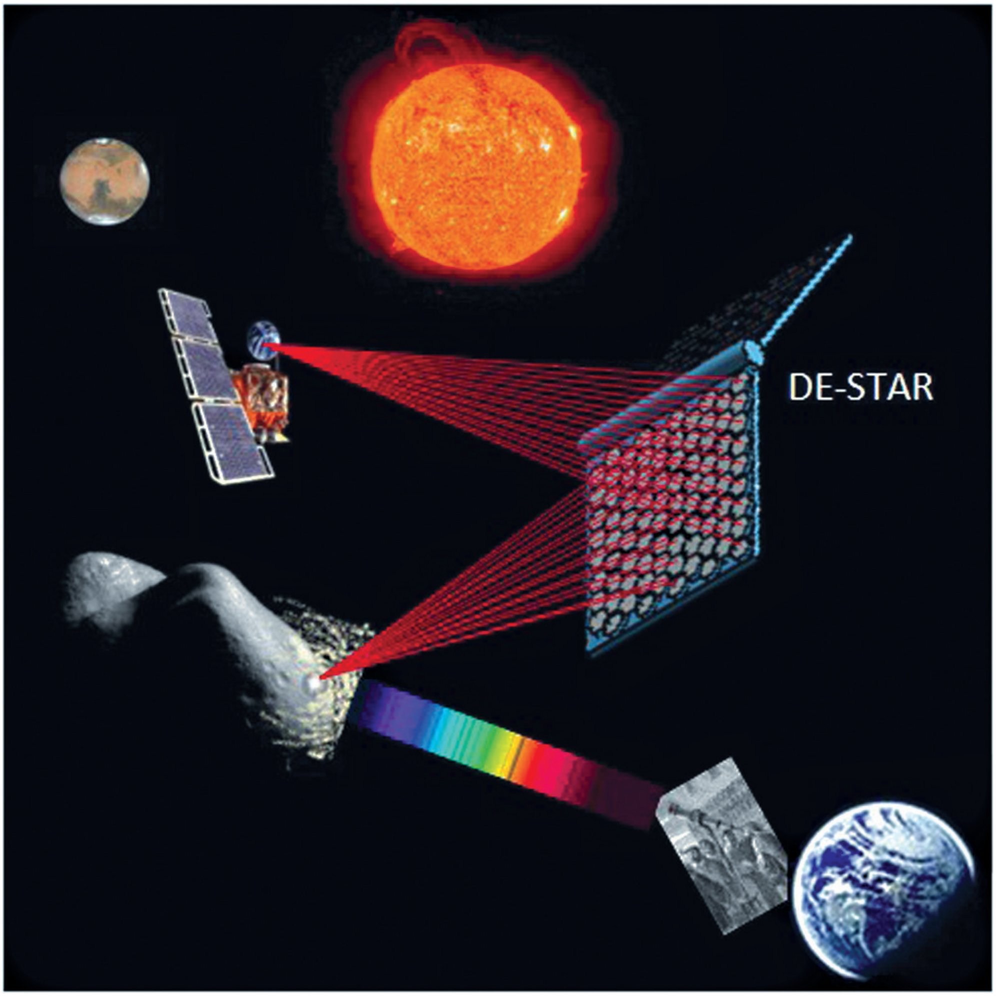
Can you describe your concept? It's called the DE-STAR system, and it's a laser-based system that could be used for asteroid deflection, correct?

It can be used for deflection of asteroids amongst other uses, but it was initially designed to allow us to evaporate asteroids up to 500 meters in diameter completely, in the course of approximately one year. Those were our intellectual marching orders. We said: here's our goal. How can we take some other things we have been doing, and apply it at a much higher level? Is it feasible to do this? So we set as a target 500 meters. We are looking at Apophis as a candidate, which is approximately 300 meters. We set a baseline requirement of approximately 500 meters over a year of complete evaporation, not just deflection, as an absolutely worst-case scenario.

Then we decided that we would like to begin to engage the asteroids and begin the evaporation process at greater than one AU. (One AU is the mean distance between the Earth and the Sun.) So these are very large distances to do something like this. But we set it as a goal to see if it was possible to do this, and that is what evolved into what you see here.

The system is modular, in the sense that you could build small versions of it, not for taking out asteroids, but for testing. So it doesn't require you to build the whole system to validate it, which is one of the other things I wanted to do, to make sure that we didn't have to spend billions of dollars to build something and then find out we made some mistake along the way. So we proposed a system which is very logical and based on a number of existing technologies which are already very compelling. We don't require any technological miracle for this project, which is another requirement that I have. It should be something that's possible to do, even if difficult. And we wanted it to be modular so that we could test it without spending a lot of money, and then work our way up and find out what the problems are, and solve the problems, or find that they are not solvable in the near-term. So far we haven't found any problems that are not solvable. We do see technological challenges, but it does not require any completely new technology at this point. It does require a lot of engineering detail and it does require us to be able to launch and assemble, mostly assemble, large structures in

In this interview, UC Santa Barbara Professor of Physics Philip M. Lubin discusses his DE-STAR (Directed Energy Solar Targeting of Asteroids and exploRation) proposal, a space-based phased-array laser system which could be used to deflect threatening asteroids, remove space debris, analyze asteroid composition, propel spacecraft, and for other purposes. The system would be modular and scalable, offering a larger or smaller square array of lasers for different goals. A smaller DE-STAR 1 or DE-STAR 2 system (measuring 10 or 100 meters) could vaporize or de-orbit pesky space debris in Earth orbit. The proposed 10-km DE-STAR 4 could vaporize an entire asteroid. The large square array of lasers is required in order to tightly focus enough laser energy, and the photovoltaics provide the electrical power. Professor Lubin was interviewed in April, at the 2013 Planetary Defense Conference at Flagstaff, Arizona, by 21st Century Science & Technology *staff writer Benjamin Deniston.*



Courtesy Philip M. Lubin

Artist's conception of the DE-STAR system interrogating an asteroid and propelling a spacecraft.

space. The modularity allows you to send up sub-components that then are assembled into the larger components, so you don't have to send the whole thing up in space at all. You can send up very small things and robotically build it.

So this would be utilizing solar radiation, converting it into electricity and then converting it to a laser-based system which could potentially vaporize either the surface or even the entirety of an asteroid.

In a nutshell, the basic idea is that you want to form a spot on the asteroid and raise the effective temperature of that spot high enough that all known elements will evaporate. The way you do that is you have to have an optical system which is large enough—we'll worry about the phased array part later—to focus a beam at large enough distances so that it is intense enough to begin the evaporation process. That requires surface temperatures at the asteroid of roughly two to three thousands degrees Kelvin, hot enough to vaporize almost all known elements. Some elements we have to get up to four and five thousand degrees Kelvin. That would be if you had a solid carbon asteroid or a solid diamond asteroid, which would be interesting. Nothing that we know of exists like that, but we have the ability to vaporize basically every known element.

So once you do that, once you form a spot which is small enough and intense enough, then you have to ask yourself how you are going to power such a system, and, of course, how much power you need. The answer is that if you want to evaporate asteroids at about one AU or a little bit beyond, you need a system which is about between 1-10km in size. Ten km is six miles, so it is not a small structure. The International Space Station, for reference, is a tenth of a kilometer in size, approximately a hundred meters. This would be one hundred times larger in each dimension, and thus a formidable assembly project in space. Not impossible, but formidable.

The question of power then comes immediately into play because in order to do what we want, we need to be able to provide approximately 70 gigawatts of laser power. At the current efficiency of lasers, which is actually quite good, the type that we are using are already close to 50% efficient, between 35-50%, and there were some reports recently of 69%, so they are already amazingly efficient. So there is not much room left to go on that front with efficiency. There are other areas where we need to improve. But the size of the system that is required to form the small spot also turns out to be just about the right size to be powered by the Sun through converting sunlight into electricity via photovoltaics. So you don't need any other power source on board. You don't need any reactors. Nothing else, just solar photovoltaics. Those two together give you a system which is capable of powering the lasers and forming the spot on the asteroid.

You can completely evaporate, worst case analysis, completely bring it down to the atomic or molecular level, depending on composition, so that nothing is left of the asteroid except the vapor value which is in space. That is clearly the worst-case analysis. What actually happens along the way, in the process of forming the intense spot, which begins the vaporization process, is similar to boiling a pot of water. The water vapor coming off the pot is actually pushing down on the surface of water. Now you don't notice it because it's a small effect, but in this case, the amount of thrust on the asteroid, from the ejected material coming off the asteroid, which is therefore pushing back on the asteroid, just action and reaction, that thrust is approximately equivalent to the shuttle solid rocket booster (SRB)—*enormous* thrust, so you don't have to vaporize the asteroid completely, you can certainly push it off course dramatically, as compared to any of the other technologies that exist, including using gravity tractors, or attaching small ion engines, which are a few pounds of thrust. This thing puts on the order of a million pounds of thrust on the asteroid, so it's a phenomenal amount of thrust. That is one of the uses.

Actually, when we started, the other thing we wanted in such a system was not only to be able to interdict asteroids, but to able to go out and deflect them or vaporize them as needed, but we want something which would also be useful for other purposes, so that the money spent on it would be returned in other ways.

We looked at spacecraft propulsion, for example. It turns out that the photon pressure on the reflector of the spacecraft is such that you get roughly from here to Mars in approximately three days with a hundred-kilogram-class robotic spacecraft—a small spacecraft, a couple hundred pounds.

So that's basically having this thing in orbit around the Earth and then beaming the power to the spacecraft?

Correct, so it pushes on the spacecraft, and because it pushes on the spacecraft continuously, it's not like a chemical rocket. What normally happens in the mission, say to Mars or to the Moon, is you fire your chemical rocket to get off the Earth. Most of it is gone by the time you get up into orbit. Then if you want to get to the Moon, you fire up, and you fire for a little while. You don't leave it on the whole time. You don't have enough fuel. This system is on, basically, all the time if you want.

Now, there are issues as we discussed earlier. What do you do when you get to Mars in such a system, because it's going at a phenomenal speed. By the time you get to Mars, for a hundred-kilogram-class robotic system, it's going over four thousands kilometers per second: amazing speeds. In fact, it's high enough to exit the galaxy. It's actually higher than the escape velocity of the galaxy. You blow right through the Solar System. Now it takes a while to get out of the Solar System, but you're going at phenomenal speeds compared to any chemical propulsion system that we have envisioned.

So it has applications. I think the whole idea of propelling spacecraft by this technique is something to look at. You have to understand you want to do more than just go past Mars, you want to actually orbit Mars and land. So there are issues that one has to deal with in terms of how to slow down once you get there. Do you carry an ion engine on board that you power from this thing? Because, this is a phenomenal power source. You'd basically have a plug and a long power chord. You just don't have any mass in the power chord that you are dragging around with you. So it has uses. If you think about anything where you want massive amounts if power, this might have some uses for that purpose.

For example, picture the Space Shuttle. How much of the mass of the rocket you see leaving the Earth is actually the Shuttle you want to get out to your location, versus fuel you have to take with you to get off the Earth and then to get to your destination? So, you are saying that we would not have to take that power source with us and be able to provide even more power throughout the whole travel process, correct?

Correct. There are applications where this is appropriate and there are applications where this is not appropriate. One has to carefully analyze where you would use this. But, basically that's correct. If you calculate the amount of power in the Shuttle's solid rocket boosters—those are the two solid rockets on the side—they have approximately 10 to 20 gigawatts of power each. Now we don't normally think about them in terms of power; we think about them in terms of thrust, but if you calculate the power, they are roughly 10-20 gigawatts.

The power of this system, the baseline system, DE-STAR 4, is 70 gigawatts of photon power, so it's not surprising then that one might conclude that the thrust equivalent that you might be able to induce on the asteroid would be comparable to the Shuttle. Now, this does not have an optimal nozzle design on the asteroid. No one designed a nozzle on the asteroid for us, so we lose a factor there in terms of efficiency, but we still have very large thrust on the asteroid. But in terms of propelling a space craft, you don't use the thrust from the ablation of the spacecraft. You could, so that is possible. There is a mode where you use the system to drive an on-board propellant, but not in the sense of a normal propellant as simply being used as a mass you eject.

In that sense it is somewhat akin to an ion engine, except you don't carry the power with you for the ion engine, you send it by this technique. It has vastly higher power per unit area then sunlight, so therefore you don't need to carry a large amount of mass like solar panels with you on the spacecraft. There may be some interesting applications there. We've been looking at some of those.

Another one is to be able to look at the composition of asteroids, by using the start of the evaporation process, which ejects material. In the ejection process you have a very hot surface on the asteroid, so you can see that hot surface through a telescope. So when you have a backlight, and you have material which is being ejected, we have been looking at the possibility of analyzing ejected material. This might be useful for people who want to mine asteroids and want to know what they are made out of. So this might be a stand-off solution for that, to determine the composition. You can also change the trajectory of asteroids, so if you want to harvest them, this allows you to do that in some applications.

What seems so incredible about this, is that you are talking about speed of light action, basically. To go out and figure out what an asteroid is made of, we would currently have to send a whole mission out there, which would take a long time to get there, and it would be very expensive to build the system to get to it. Here you could have a capability already existing, and then from that capability, through speed of light action, you could decipher what that one's made out of, or move that one around. It seems like an incredible capability.

That's correct: this is designed to be a multi-tasking system. It doesn't even have to point in one direction only. It could simultaneously send out multi-directional beams. Because it's a phased array, it could simultaneously send out essentially as many beams as you want, propelling a spacecraft, analyzing the composition of an asteroid, evaporating another asteroid, and sending power to a lunar base. The way the system is built, it can do many things at once.

What you are saying is basically correct. You are not taking with you your power system: you are leaving it at home, and you're sending it at the speed of light. It takes approximately eight minutes to get from Earth to one AU, which is the amount of time it takes sunlight to get to Earth, so eight minutes after you turn the thing on you can begin to intercept an asteroid at 1 AU. Similarly, you can propel a spacecraft by using the light to push on it. You don't have to carry the propulsion system. But again, there are limits of this technology if you want to apply it appropriately, like any technology.

One interesting thing is that we don't require a miracle to get this to go: any anti-matter drives, any warp drives. We don't need even fusion drives, although we hope that those will come someday. Using technologies which both exist now, and are rapidly evolving, we could not only imagine such a system, but actually build small versions of such a system, and then work our way up to the final, larger system.

One last broader question: We are here at the 2013 Planetary Defense Conference, where there have been a lot of discussions on the role of asteroids and comets impacting Earth and affecting life on Earth. There is also growing attention to space weather, such as solar activity potentially affecting life on Earth. It seems that mankind is more and more being confronted with the fact that the Earth is a small part of the whole Solar System, which is a small part of the galaxy. If we're going to continue to progress and exist, we have to be thinking about the Solar System first, then Earth: broader pictures first, then Earth. Do you have any comment on that view that mankind seems to be moving towards?

Yes, I would hope that we could put aside our petty squabbles, and truly deal with things that are meaningful in life. And working together to place ourselves on the Moon as a near-term mission, to have a base on the Moon, is a laudable mission. To do the same with Mars, and then to work our way out, hopefully, to eventually make our way out of the Solar System.

I draw the distinction between things that are realistic to come to fruition, say in a lifetime, versus those things which are perhaps several lifetimes out. One of the things you could ask yourself is, suppose you go further than simply wanting to deal with asteroids or propel spacecraft within our Solar System, what could you do? If you stepped up, and asked, what would happen if you scale this up even larger, could you build a system which could propel a spacecraft to the nearest stars? We spent some of our time in our papers looking at this issue, and you can in theory, and I'm not saying that this is practical at the moment—it's not. But if you follow the same evolutionary approach, and again you don't need new technology here: you need to be able to assemble things in space which are very large. That requires an evolutionary approach to our ability to both launch and assemble in space. So those are areas we need to work on, but if one scales up, you can conclude that if you go to a DE-STAR 6, you can propel a 10,000-kilogram spacecraft, which is basically ten tons, at near the speed of light, so that you could imagine an interstellar probe someday without warp drive or fusion drive.

Now, we have the same problems, what do we do when we get there? How do you slow down, because you are going really fast. But it brings up some fascinating capabilities. I wouldn't advocate sending people there in the beginning. Send out robotic probes, instead. I am very much an advocate of sending out probes into the Solar System and beyond, and we can decide what we want to do with those probes, but I think what you said before is key to one of the differences between this and other approaches. In many other approaches in dealing with asteroids, one sends a mission to an asteroid to deflect the asteroid. One sends a mission to analyze the material. One sends a mission to put an ion engine on the asteroid to change its orbit. In our approach, we don't do that: we stand off and by staying on the Earth or on the Moon or at a Lagrange point, at the different places we can put this, and we say, let's travel with our energy at the speed of light. Let us work on a system that way, rather than having to mount a mission to every asteroid that might be a threat.

In the long run, in the analysis, this is a much cheaper way to do it, because you don't have to launch a mission which, using chemical propulsion systems, could take years to get to an asteroid. And then what do you do when you get there? So this is a different approach altogether.

I appreciate you taking the time to explain this interesting concept for us. Do you have anything else you'd like to add?

I think maybe one way to think about things that are related to what we are doing. If you go to the hardware store and look at an LED light bulb, and ask yourself what went into making this LED light bulb so much better than any incandescent light bulb, and why should I buy this light bulb instead of a compact fluorescent or an incandescent? I agree, that at the moment, the choice between buying an LED and a compact fluorescent is a tough choice, because it is an economic choice. But the economy of that is changing very rapidly. The same technological revolution, the same photonics and electronic revolution, which makes the LED possible in your laser pointer, in the LED light bulb in your flashlight, in the LED light bulb you buy for your home, that same technology is in fact driving what's making this a reality. It is the conversion of electricity to light at high efficiency, and that has now gotten to a point where one can not only *envision* something like this, but one can *build* something like this.

That's very exciting, thank you very much!

You're very welcome!