Interview: John Slough

Developing Fusion Rockets To Go to Mars

A round-trip human expedition to Mars, using current technology, would take two to three years. On such missions, astronauts would suffer deleterious health effects, including loss of both muscle and bone mass, and would be exposed to large doses of cosmic rays and solar energetic particles. The cargo required for such a mission would require 9 launches of the largest class rocket for a manned Mars mission. Professor John Slough's team of researchers at the University of Washington and MSNW, believe they have a unique solution to this problem by using nuclear fusion. The high energy density of fusion fuel means that such a rocket could reduce the trip time to 30 days, while requiring only a single rocket launch per Mars-bound spacecraft.

He was interviewed on his proposal by Jason Ross at the Fall 2012 NASA Innovative Advanced Concepts (NIAC) symposium, held Nov. 14-15, 2012 in Hampton, Virginia.

21st Century Science & Technology

Prof. John Slough (left) is interviewed at the NIAC conference by LPAC's Jason Ross.

21st Century: I was hoping you could just share with our readers a general idea of what your idea is, with your fusion rocket.

John Slough: We perceived that the problem with why we're not on Mars now, is that it costs too much, and it takes too long. So, the only way that those two problems can be addressed, is if we manage to have a rocket, where the ratio of the mass of the rocket to the power it delivers is very small. And at the same time, the exhaust velocity must be much higher than what we can achieve with chemical energy, in order to shorten the trip time.

So both of those are required to reduce the amount of material that you need to bring into space, and the time it takes to get there.

There's probably only one energy source that has that kind of energy density, if you want to call it that, and that is nuclear. And nuclear fission has been a problem for space transportation, because there, they can only use thermal energy that's derived from the fission due to the nature of the reactor/reactions itself. [But] fusion has always held the promise of being able to generate particles at very high energies, and we can then use these particles which have a very large exhaust velocity.

What we've decided is that the fusion process, can create a tremendous amount of energy, and that if it were surrounded by a different propellant, other than the fusion plasma itself, that we could transfer that energy to that material, and then achieve both the high velocity that we need for rapid transportation, and reduce the mass cost, because we actually use the propellant to compress the plasma to fusion conditions. So, we kind of do double duty there.

So the energy that's released by the fusion event goes directly into propulsive motion, rather than passing through some kind of an energy-conversion system, such as a boiling-water reactor, or a boiling-lithium reactor, or whatever you might imagine for space.

It's a very simple system. It is really kind of based on nuclear devices that were developed in the '50s for much different purposes, but the challenge was to not have high yields, like you would see in a hydrogen bomb, but to bring that down to a scale where essentially that energy could be created and transferred to the rocket ship without damage to it.

And we believe that we can do this for two reasons. One, we reduce the energy by about a factor of a billion over a hydrogen bomb—you may not even think that's quite enough, but actually it is. The other thing that's very important about the way we proceed to make the fusion event, is that we use a magnetic field to induce this lithium, the preferred material as the shell that implodes our plasma, and creates fusion conditions. We use magnetic fields to do that.

The good part of that is that after we've created this large burst of fusion energy, and transferred it to the lithium propellant, the lithium propellant becomes an ionized gas itself. And the magnetic field then guides it out the end, so that it can't restrike the rocket surface. All chemical rockets depend on the wall transmitting the impulse in the nozzle to exit in a specific direction, so here, we avoid the energy transfer to the rocket, and we protect the rocket, all done at the same time.

So, all these things coming together mean that we can now have a rocket ship mass that is, compared to the power produced, a very small number. So, we don't spend much mass in producing the energy. That's sort of the basis behind the fusion-driven rocket.

The Low-Hanging Fruit of Fusion Reactions

Okay. Let me ask you, in regards to the fusion process itself, your plan uses DT [deuterium-tritium] fusion.

That's right.

There was some talk about using helium-3 as a potential source for aneutronic fusion reactions. What are your thoughts on that, in space and here on Earth?

DT—is obviously the easiest and most energy-productive way to create fusion energy. The DT reaction has the largest cross section, has the lowest plasma temperature, so it's what I call the low-hanging fruit of all fusion reactions. And all conceptual designs for Earth-based reactors are always based on DT for that reason.

Now, helium-3 would be an interesting alternative propellant, but the problem there is, it doesn't exist naturally—it's only produced by the decay of tritium. Tritium itself is also only produced by man-made reactions, but the process that's required for making it aneutronic requires a much more difficult fuel to actually convert into fusion energy.

But having neutrons is only a problem in an Earth-based reactor, in that you need to shield it. In space, in all but the small direction that the spacecraft takes in terms of the solid angle, the neutrons just fly off into space, harmlessly.

So, neutrons aren't bad. Neutrons are actually good, in that they're volumetrically absorbed, meaning that when we try to heat our propellant, in this case the imploding shell that surrounds our plasma to bring it to the fusion condition, the whole body of that absorbs it, and so we can heat the entire mass, and that way convert it all into an ionized gas. If it were trapped in the form of charged particles, the particles themselves would be retained in the plasma, and then you have the problem of, how do you get the heat out? So, maybe for a terrestrial reactor, it might have some benefit—I'm not sure about that either. So, neutrons are good as far as I'm concerned.

Okay, so they're overly maligned.

Yes, that's right. Well, they obviously can modify and transform materials, and that is good, because that means you can create the fuel that you need, the tritium fuel, from the reaction itself. The other reason people fear neutrons is that they are the means by which a chain-reaction occurs in a fission reactor, so I think they've gotten a bad reputation from fission, but not so much from fusion. So, we'll see.

But transforming materials could be another application, using waste from fission reactors.

The Orion Project

Right. Your proposed design uses a pulse-propulsion technique similar to, say, the Orion project that was studied earlier in the U.S. What could you say about Orion as an inspiration, or about international work on nuclear rockets of this sort?

It's true: There was a lot of time and energy spent in trying to use nuclear energy in a way that they knew would produce the copious amounts of energy required for space travel. And the Orion project, unfortunately, at that time, was too close to the concept of an atomic bomb to find any widespread acceptance. In fact, it was banned by all countries.

But the main problem with fission is that, in order to get enough fissile material together to have a chain-reaction that will produce these sort of energies, it requires a very large amount of mass, and therefore a very high amount of energy release. So, the amount of energy release couldn't be reduced by a billion the way we'd like to do with the fusion reaction.

A fusion reaction can really occur at any scale, and that means it's scalable down to a level that we can use it. The only successful demonstration of fusion has been with the pulse systems, so we felt like it's got a firm grounding in the fact that at least there are several countries that know the process.

Now this is slightly different in that we intend to use a magnetic field to confine it, and that allows us technologically to make it much simpler. So, there have been studies done in other countries, in terms of the implosion technique that we intend to use with magnetic fields, particularly back in the Cold War days. So a lot of that information, I think, is now lost, because of the retirement and death of the Soviet physicists, but also, just simply, these things were not written down. But there's a great body of knowledge, worldwide, on how to maybe do this.

So, I think if we can have a demonstration of its potential, through a successful implosion, which we can do in our laboratory, that we'd probably find worldwide interest increased in this process. Because you could also use it for terrestrial energy generation.

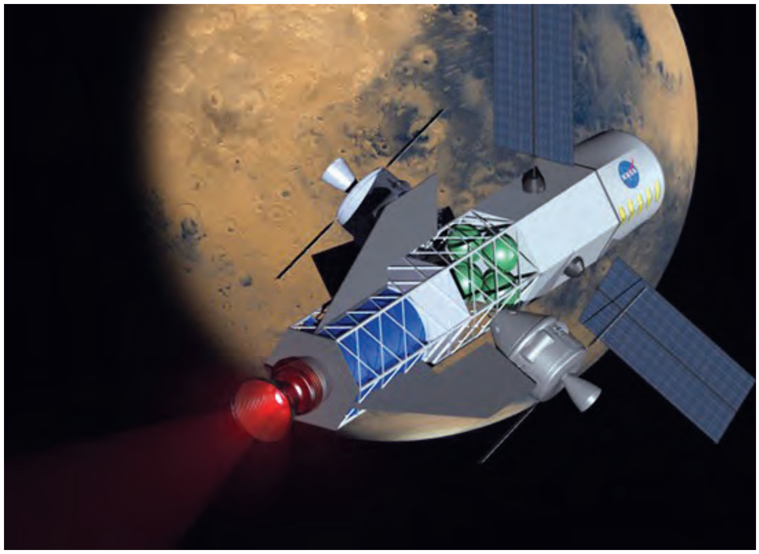
Under the Radar

Let me ask you one last thing, then. Sometimes these projects are discussed, as to whether it's a question of the scientific feasibility versus the political will, which means funding.

That's right.

Those might not actually be different questions, since scientific breakthroughs occur when you have funding, but what do you think about the political climate around all this?

I think we're under the radar right now, in regards to what we can demonstrate. So I think that we have, fortunately, from other fusion experiments that I've conducted in the past, a large amount of equipment that we can apply to this particular task. That allows us to actually get much further along in this process. We were even thinking that we might be able to achieve breakeven, which is something that hasn't occurred yet in controlled nuclear fusion—even with a simple experiment conducted by very few people, in this manner.



MSNW

The only reason we are not on Mars now, Slough said, "is that it costs too much, and it takes too long." His firm, MSNW, is developing a fusion-powered rocket, shown here in a artist's concept, to solve that problem.

So, that part of it is fortunate for us, that we can achieve that. But obviously, future development, and particularly with the sophistication and the repeatability rating and all the other aspects of space travel, will require significant investment by NASA. But we hope we can interest the world with the fact that fusion isn't always 40 years away, and doesn't always cost $2 billion.