Dr. Frank Fernandez
1998-2001

Interview: January 4, 2007

Interviewer: Please, tell us your name and the dates of your tenure at DARPA.
Fernandez: Okay. My name's Frank Fernandez and I was at DARPA from, I believe it was May '98 through January '01.

I: How did you happen to become a Director at DARPA?
Fernandez: (Chuckles.) It's a funny story. I never was involved in anything in the government. I was told in '97, that there were some positions coming open. Would I be interested in submitting my name? I was told by a friend of mine who knew somebody who worked in the Secretary of Defense's office. So, I said, "Sure. I'll send my résumé."

Nothing happened, and then all of a sudden, I got a call. "Would you be interested in working for the Department of Commerce?"

I said, "To do what? As a technical person?"

"Well, to be an ombudsman."

I said, "No, I'm not interested."

Then, later, somebody said, "The DARPA Director job may be coming open. Would you be interested?

I said, "Yeah. That one I think I might be interested in."

So, I went, and they set up an interview for me with Hans Mark who was DDR&E at that time, and Jack Gansler, who was the Under Secretary for Technology and Acquisition. So, I went, and I talked to them. Then the next thing I got is a call saying, "Frank, we're going to put you on the short list. You've got to say you'll take it now."

So, that's when I went and talked to the boss here at home (chuckles), and I said, "Honey, would you like to go on an adventure for three years?" I said, "Only three years."

And she said, "What do you mean?"

I said, "Well, just go out there, live out there." And we figured that we would rent our home in California, so she said, "Yeah."

So, I called him up and said, "Fine."

The next thing that happened, a few weeks later, I got a call from a friend at DARPA congratulating me on being Director. (Chuckles.) It turns out the news had leaked, and I got the news from a friend at DARPA before the announcement was made by Secretary Cohen. (Chuckles) So, that's how it happened. And then I think a day later, I got a call from the Secretary's office saying, "Dr. Fernandez, congratulations..." - and things like that.

That was early in January or so of '98. Then it took months—four months or so—before I was able to become a government employee, so during that time I was a consultant at DARPA. And that's when Larry Lynn, a previous Director, really took me under his wing and showed me a lot of stuff that was going on, to try to make the transition as smooth as possible.

I had been a DARPA contractor for many years, but I had only worked in certain areas. And what really, really overwhelmed me was just the breadth and scope of activity that's going on in this place all the time. I knew something about the work they did for the Navy and the Air Force. I didn't have the slightest idea of what was going on in all the technology areas and stuff like that. So, that was overwhelming. It took almost a year to get up to speed on what was happening.

I: What was the state of DARPA when you walked into it?
Fernandez: It was functioning the way DARPA does. Like I said, I was a consultant for a few months so I was able to be at DARPA, watching things with Larry while he went over the programs he had, what their status was, which ones he thought were in some trouble, which ones looked like they were going well. So, when I walked into the office, once Larry left, I think that I was pretty well aware of what was going on at a superficial level. I hadn't done any reviews or stuff like that.

So, then the first thing that happened was that Lee Buchanan who was the Deputy and he helped me for a while, and then he moved off because he got the assignment to be Assistant Secretary of the Navy for Research, Development and Acquisitions. I had to get a Deputy, and that's when I picked Jane Alexander. She was a deputy director of one of the offices at the time. And she was pretty savvy, so she really helped me a lot on a lot of the procedural matters—the schedules and when we had to do things. Also, the Finance Director, Bill Lehr, sat down with me and gave me a really good rundown on what the schedules are for, when things have to happen, when things have to go to Congress, when things have to go to the Secretary, and all these other things that I really had not been aware of. So, I was kind of inundated in learning. (Chuckles.)

I: I hope you weren't overwhelmed by the minutiae there.
Fernandez: Uh, no. No, it's just that you have to learn about the process of how things become programs. There's a lot of stuff going on at DARPA, so as a result, there has to be a process. Otherwise, you will spend every hour of every

day trying to catch up on what's going on. Larry had done a pretty good job on that and I had to learn about the process he had and get up to speed on some of the things. So, it's not so much minutiae as just the breadth.

And some of the areas were areas I really had no knowledge about, so I had to learn the language. Some of the microelectronics—I mean what did I know about MEMS? (Chuckles.) I knew that they used them for airbags. That's about all I (chuckles) knew. So, there was quite a bit of work going on there, and some of the information technologies were areas where I hadn't really had much exposure. So, I had to do a quick learn.

One of the nice things that happen is when you're a Director at DARPA, wherever you go, people will spend time teaching you about what they're doing, because you're a funding source. So, there were a lot of very smart people who took time out to help me.

I: How were you able to figure out what the needs of Defense were and proceed? How did that process work?

Fernandez: Well, in my case, it really was the following. My boss, Hans Mark, was a very savvy person, and he could give me a lot of advice on what were some of the things that were happening that were important. And in addition, his boss, Under Secretary Jack Gansler, turned out to give me a lot more time than I deserved. So, they brought me up to speed on a lot of the issues that were pressing, both from the standpoint of acquisition and then also in some areas having to do with emerging problems—problems I really hadn't been aware of.

And then, basically, what happened was at that time, the two major, national-level issues DARPA was involved with... we focused on bio-defense (defense against biological attack), and the second one was defense against cyber attack. Those were two major looming issues—programs that started at DARPA, and now have transitioned to other places in the government, which are solid organizations of their own. Not that DARPA doesn't do work in those areas, but nobody else would touch those areas at the time. And they were national problems.

In the military area, which was another area back then, precision strike against moving targets was a very hard problem. We knew how to hit fixed targets, but being able to hit moving targets that would rapidly relocate was a major problem. So, we spent a lot of effort on that problem.

Also at that time, our enemies had decided that they would go deep into bunkers—deep, underground bunkers. And trying to determine where to strike those bunkers—where was the place you wanted to hit—was a major problem that we started working on. So, those became issues.

On the technology side, which was pushing technologies, the major thrusts there were, at the time, learning how to do integration of multiple components on a chip, Okay? Integrating optics and electronics on one, single chip; putting a lot of transistors on a chip , numbers getting close to a billion transistors on a single chip; and trying to learn how to mesh organic and inorganic interfaces on a chip because that had all kinds of applications in the biomedical area. So, those were some of the areas that we started to work with.

The biggest frustration we had at the time was, first of all, the dot-com boom was on (chuckles), so we couldn't get the interest of any companies. And also, defense was not considered to be a very important issue in the United States at that time. It was something that was kind of you had to do it but it wasn't a prime concern, defense wasn't. So, Congress left us alone, but they also didn't pay much attention to what was going on at DARPA.

And the military at the time considered DARPA basically a competitor for their research moneys. It wasn't clear to them how much we added. And what I learned—and this I learned on my own—was that it really came down to, could you find people in the military of a fairly high rank who could essentially provide the staying power, or become the champion, for some innovation—which is what then we became focused on, innovation.

I: How did you find people to help you solve the problems?
Fernandez: Well, first of all, we had a very good lawyer who worked for us at DARPA, Rick Dunn. He was a very imaginative guy. He worked with Congress to get the law changed to allow us to get a hiring authority, so that we could go and offer a young person in industry a job without having them having to become a government employee. We got that authority, and I was able to use it so that I could get job offers out at short times, at reasonable salaries—still not competitive, but at reasonable salaries compared to what they would have gotten back then, working for the government. So, that was number one.

Number two, I made it a point every place I went to give a talk. The major purpose of that talk was really recruiting, to try to grab some person's attention to show them that, "Look, if you're at the point in your life where you want to make a change in your career, come to DARPA. You get a chance to do it, because you can run something where there are quite a bit of resources involved—money—and if you do well, you can talk to everybody." So, I was looking for those people who were at the point in their life where they wanted to build something, do something different. So, the recruiting was an incredible job. It never finished. I just keep on going. That's all there is. I think it's still a problem at DARPA, as best I can tell.

I: There are built-in incongruities in DARPA. You want to do revolutionary invention, and yet, your customer, the Defense Department, is conservative by nature.
Fernandez: Right. It's really a case of making a deal. Give you an example. Unmanned vehicles, the Global Hawk, which was started by Larry Lynn, became a reality for the Air Force while I was there. The next question, after surveillance was, "Could you build an unmanned vehicle to do combat?" Well, you're not going to let the vehicle go fight by itself. We don't quite know how to do that yet, but could you basically have one pilot commanding four vehicles, so that the strength of this one person could be multiplied up by a large factor? And what would this vehicle look like?

So, what happened was, at that time there was an office director who was very imaginative who worked for me, who wanted to push this very hard, and we

found a couple of people in the Air Force. And I knew the Navy quite well, because I had worked for them a lot, and I got the Chief of Naval Operations to back it at the Navy side, and we were able to spin up two programs—one naval program and one Air Force-oriented program—for unmanned combat air vehicles. First of all, to build the vehicle with some modern manufacturing techniques so that it would be much cheaper and still carry payloads and everything else; and so that it could do everything that a Cruise missile could to, but it could come back and reload and go back again. And more than that, that one pilot could command four of these vehicles. And we got it going.
I think the Air Force just this year killed their program because they didn't have enough money, but the Navy still has theirs. So, I think it's still going, as best I can tell.

There's a very interesting story. I left that program for my successor, Tony. He told me that by the time he came in, the vehicles were being built, and what they found out was, for the Navy, the most difficult problem of all was not landing on an aircraft carrier, which everybody thought would be really hard; that was easy to do, autonomously. The hardest part was taxiing around the deck to make room for other vehicles, because the deck of an aircraft carrier during operations is an incredibly crowded place, and there's oil on the ground, and things are slipping and sliding, and the ship is pitching and rolling. And that turned out to be much more of a problem than landing or taking off autonomously. So, we'll see what happens.

And it was Admiral Jay Johnson, the CNO, who was the one who made the Navy get involved with DARPA on that one, because he thought it would be a good idea to multiply human capability. He was an aviator, too, so it was very interesting. So, that's very hard, to find somebody in the military who wants change.

The other one we found, which was, again, by pure luck because I went for a courtesy call, was General Paul Kearn of the Army and then the Chief of Staff of the Army at that time, Shinseki. And they had to convince themselves that they had to do something with the armored force to make it more affordable and transportable. I mean I didn't know anything about tanks at the time, so the Army took me to Ft. Hood, Texas, and gave me a week of training on tanks, nighttime shooting and nighttime running of the tanks, and everything.

The M1-A1, the Abrams tank, is an awesome, awesome weapon. It weighs 75 tons, so that the only plane that you can transport it in is the C5-A, and you can only fit one per C5-A. So, it's not very easy to transport places. It uses about four gallons of fuel to the mile. It has a full 400-gallon gas tank, and with that, it gets about a 100 miles range, so the tank basically has a row of trucks behind it just (chuckles) waiting to supply it —which are vulnerabilities. The tank's invulnerable; it can take anything. It's just all this other stuff that it needs. So, the question was, "What can technology do to help solve this transportability and mobility problem?" And the only answer was, "We've got to get the people out of the tank," because the minute you put the person in the tank, you have to provide a certain amount of volume for the people to be able to live in and function. That volume has to be wrapped around with armor to protect the

people, and that determines 70 percent of the weight. And at that point, it gets heavy enough that you can't use wheels. You have to use treads, and that makes it even heavier, and on and on. So, the question was, "Could networking of some kind help us?" And that was the beginning of the Future Combat System program that DARPA started doing with the Army, and it was only because General Shinseki and General Kearn said, "I want to look to technology to see if it can help me solve some of these problems.
It had incredible impact. How it evolved in the future now and what's happened, I really don't know.

I: You told me an interesting story about how that problem came up in Bosnia—about tanks in Kosovo.
Fernandez: Kosovo. Yes. The story there was kind of the following: We wanted armor. We had lots of tanks in Germany. We could've gone through Hungary right into Kosovo, but the Hungarians essentially told us that they didn't want to have to deal with a bunch of angry Serbs on their border after the war was over. So, the tanks had to be taken from Germany to the ocean, down by ship, and then we had to find a port big enough to unload the tanks—I think it was Montenegro, and then you had to get the tanks from the port back up to the battle zone, and there were no roads that were capable of carrying—these tanks are transported on vehicles that with—with the tank on them weigh about 90 tons. So, it took special roads, and the roads were going to have to be built. And it took such a long time, that the heavy armor almost didn't get there in time to do anything.
And I think that was the time when the Army said, "We've got to go lighter. We've got to be able to get some place in a short time, and we can't do that carrying all that weight." There were no airports that could take a C5-A. And a C5-A is just one tank per plane, but then you have to have an airport capable of landing this plane, and it was a real problem. It was a real interesting problem.

I: So much for blitzkrieg.
Fernandez: (Chuckles.) Well, we pre-positioned everything. That was the way it had worked - it wasn't something where you had to transport everything all of a sudden, in a new way. So, that was when I think the Army said, "We've got to change some of the way we do

I: Tell me a little bit about the Predator.
Fernandez: Predator in Kosovo was a situation where we got a call from some operational people, saying, "We found out that Predator"—which was primarily an intelligence asset—is accurately tracking the movement of some of these people that we want to shoot at in real time." Predator had real-time feeds back to the command center. The problem was that the camera on Predator had to look out at very low angles, very low grazing angles, so there was a lot of distortion in the scene, and you couldn't register what you saw with accuracy enough to essentially use that to target a vehicle. So, the question was, could some software be built that would in do this job real time?

So, we funded some work, and some contractors went out there and pulled off a miracle and got this thing going in time to seriously affect the outcome of what happened. So, now the Predator could call for a shot and give coordinates to a GPS-guided munition.

I: What was interesting about these two stories is the ability of DARPA to be quick on its feet and adjust to changing conditions and changing requirements. Change seems to be the big element here.
Fernandez: Yes, DARPA is all about, I think, being the change agent for the Department of Defense. What it works on depends on the circumstances. In the'70s, anti-submarine warfare with us and the Soviets was a very big deal. DARPA led some very new things that went on there. As the '90s came along and then after that, 2000, the problems changed, and the emphasis that DARPA puts on different Services—or different agencies that it works with will continue to change. It's where the change is needed. And so I mean, that's what DARPA is, and that's why DARPA exists, as far as I'm concerned.

I: Can you talk a little bit about the difficulties DARPA may have in being the enabler of change, or the agent of change for the Department of Defense?
Fernandez: Yes. The question with change is that, first of all, the Services DARPA works with—the military Services, because they're the ones who train, equip and operate everything, the actual Services themselves are big organizations. Big organizations work very hard at making what they do as efficient as they can, and so that when you try to do an innovation, which is what the change part is all about, you're trying to change the way somebody does business. And the innovation doesn't take hold until you really change the way they do business, so it's a lot more than an invention.

A UCAV, unmanned combat air vehicle, might be an invention. Until the Air Force learns how to use that to change the way they strike targets, it will not become an innovation or a change in the way the Air Force does business. So, the most difficult part is this marriage of the invention and the "business" of war. DARPA is a technical organization, the challenge is to technically invent and make it part of an operational concept that then people are trained to do.

And quite often, what happens is organizations that have been operating successfully for a long time have their procedures down very, very pat. You bring in a new invention, or a new technical approach, the odds are that in the beginning, it won't work as well as the approach they've gotten used to using. It's got potential for a lot more, but in the beginning, it quite often doesn't work quite as well as the way the things that you do now.
Take, for example, the floppy disk. Back in the days where just more memory on disk drives was the story, nobody could figure out why anybody would want a floppy disk. It only has 750 kilobytes of memory, so what are you going to do with this kind of a thing? The fact that it was portable and you could move it around, to move information from laptop to laptop was something that all of a sudden became something the consumer wanted more than just more storage. So it took off, and became a new way of doing business, where you could just

pass information this way. If you had continued the old way, there would have never been a use for a technology such as this.

And I think the same thing with unmanned vehicles. I don't think unmanned vehicles can do things that human beings do as well as human beings can do them. What they can do, I think, is multiply the effectiveness of people. Human beings are incredibly good at reactive situations. I guess all of our evolution, in order to survive, has taught us how to do this. We're very good. We're very bad at efficiently transferring what we know to other human beings. Training takes a long time. Every new generation has to be trained up, and it takes a long time.

Machines, computers are just the opposite. They're extremely limited as to what they can do reactively, but their knowledge and capability can be transferred instantly, because that's called software, to a million other machines. So, the real question is—how do you mix man and machine to get a situation that works best? It means you're going to have to change the way you do business, because we are now optimized towards only people-oriented activities.

And I think that's what the major future areas are going to be for the military. We see it on air vehicles. I think we're going to start to see it on ground vehicles. We'll start to see it on naval vehicles, on surface vehicles, and underwater vehicles. And, I think that will be a revolutionary change as we learn to get the machines to be more cognizant of their environment—because that's the hardest part. How do you teach a machine to understand its environment so that it can then make a decision—the things we do very, very well?

I: Let's talk a little bit more about that interface between biological and physical.
Fernandez: Well, I think that a very exciting area is the man/machine/computer interface for the future, and we being one particular form of biological matter—I mean, think that's the most exciting thing of all. I don't know if I'll see it, but I think the time has to come when we'll be doing something other than tapping keyboards to talk to a computer. (Chuckles.) I mean, we haven't changed for a long time about how we interface with a computer. We tap keys. Little by little, the machines are starting to get smart enough that I'll be able to talk to it, and maybe it'll start to know my intention after a while, and I won't have to say as much—the same way that we talk to each other. So, that whole question of the interface between silicon and carbon-based systems, or biological systems is going to be a very exciting one.

Fundamentally, I think taking that down to the very small levels where we can make small machines—micro-electrical mechanical devices, nano devices which are molecular-sized some very exciting, new things that are going to happen there that I can't begin to predict. And it'll involve us—let me just give you an example. When you look at something and you look at the scene, you process data, but we know that we do not process data at the rate that a fast computer processes. We run data at only about 150 hertz. A hundred fifty times a second, we can update what's going on, an event; yet, we're very good at seeing the smallest differences in somebody's makeup or something like that. How does that happen? How is the human computer working that allows us to do those kinds of things, and how would we make a machine learn how to do that kind of recognition?

Still unsolved problems—and why are they important? Because as long as we have to put human beings to look at pictures and determine that there's something important about that picture, as the numbers of pictures grows, we have to increase the number of trained human beings, and that problem does not scale. So, someplace we have to learn how to automate these incredible functions that people have, and I think that's where some of these interfaces are going to come in. Or, maybe one person can be looking at multiple pictures but only paying attention when alerted by the computer. Basically, what theory says is that you're always getting data coming in, and we have a big memory system. That we do have. We have fast-access memory.

And, for example, think about it—when somebody goes to hit a pitched ball with a bat, he doesn't compute the trajectory of that ball. He can't. He doesn't have the computing power to compute it. That's all i would do if I was going to program a computer. I'd say, "Okay. Get fixes on the ball, compute the trajectory and solve Newton's laws and everything else." Because it's a curveball, or whatever, but you're cranking before the ball leaves the pitcher's hand. Because you anticipate based on things that you've got in your memory, when his arm comes that way that probably means he's throwing a fastball and not a curveball. And that's how we do it.

Think about it. A lot of things, when you walk into a room and you look at the wall, what you look for are changes as compared to what you remember that it used to look like. Now, the first time you walk into a room, you scan a lot slower. The second time, you don't spend much time looking at anything. What your eye picks up is there used to be a picture there. What? The picture's missing. Then what happens is your brain tells your eyes, "Look at that place. Spend a little more time there, because that's not what I'm used to seeing in that corner."

Or, that somebody's wearing makeup that's different. It's only different because it's different from what you've seen before. And so instantly your brain says, "Spend more time on that particular thing. Focus over there and start looking." It's very interesting. Is that how we do our thinking? And I don't know the answer, but I think once we learn some of that theoretically, then augmenting that to do robotics, then we'll see breakthroughs in real robotics.

I: Before we get into MEMS and things like that, I want to ask you about "operational dominance." What did you mean by that?
Fernandez: Operational dominance is our military's ability to go anywhere in the world and fundamentally strike at the enemy effectively. Now, at that time, we were not contemplating anywhere near the kind of ground, close-in conflict that, for example, exists in Iraq today on an ongoing, daily basis. We were talking about more surgical strikes where we would have Special Forces that would go in, set up targets, and then we could just dominate the situation that way against another adversary who was a military adversary. At that time, we weren't dealing much with the question of an asymmetric adversary of the kind that we have

now.

We should have known enough to figure out that somebody's got a brain in their head, once we had this dominance, they weren't going to go up against us that way; they'd go up against us another way. I mean the minute our Air Force got as awesome as it was, nobody sends up fighters against our Air Force any longer. That's crazy. What they'll do, perhaps, is try and do some other things, like putting surface-to-air missiles that keeps them out at an altitude where they can't be very precise any longer when they bomb and stuff like that. So, I think that that's what's happened. Our dominance has forced the enemy to change the ways they do things, and now we've got to change to accommodate that change—and this will go on forever. That's what's been going on in wars since man started doing war (chuckles).

I: Well, changes in steady state becomes faster and faster, doesn't it?
Fernandez: Yes, and I think the second it comes faster and faster, and I think, secondly, the change that's made available or enabled by technology happens faster and faster, because things based on technology are changing faster and faster in the world, because technology really has gone global. So, one of the problems now is we can't control the rate, nor the actual technologies. If you could control the rate of evolution of technology, then you could plan a lot better, but not possible anymore. So of these things are just out of control.

I: Aren't technologies—the knowledge of the technologies, out, accessible, and portable to anyone?
Fernandez: That's right. So, what the U.S. has got to do is, first of all, how do you exploit that? I mean how do you exploit the fact that those things are out there and use them to your own advantage? I mean one way was don't let them get out. Well, Pandora's Box is open. You know, the genie's out of the bottle. Which things don't you let get out there that you still know you own? And how do you do that and not fall behind? Because there are so few things now that are in modern weapons that are not part of something else at the same time, that I guess it would be a very difficult one.

So, that's where, I think, the model of a DARPA, whose job it is to look for opportunities and to be allowed to fail, has room in the DOD. I think the people who set up DARPA and who, hopefully, were just so smart –It's a small part of the budget. It's less than a percent of the DOD budget. And by the way, DARPA's budget seems to go up and down as the DOD budget goes up and down, keeping it at a fraction of a percent—a large fraction of a percent. So now, the Director's budget at DARPA is bigger, but the DOD budget is quite big. And when it goes down, the DARPA budget will go down again. And I think putting a small amount of resources like that aside to allow for a place where smart people can come and try to do things that would never fit into a business plan anyplace else is just the thing to have.

It's a case where they agree. Some of that money may be wasted. The day DARPA is asked to become efficient, DARPA dies, because you can't be efficient and be a place where you expect breakthroughs. I mean those two things just don't work together.

I: We talked about this Global War on Terror, how the enemy has much the same technology you have; that seems like a huge DARPA-kind of problem.
Fernandez: Yes, I think it's a DARPA-kind of problem because, first of all, if you're going to combat this enemy, you've got to know where he is and where he's going and what he's doing. So, in traditional warfare, we did that by tracking platforms. We watched tanks run around. We watched trucks run around. We watched airplanes run around, and based on that, we could get a pretty good idea of what the enemy was going to plan on doing.

Now, with this new asymmetric warfare, you've got to be able to do that with individuals. Now, forgetting personal security constraints, forgetting that for now, which is a very important issue, but just forgetting it—the scale of the problem has just grown exponentially because the number of individuals and small groups you to have to look at to determine if they're the ones you should track or not is exponentially larger than the number of airplanes anybody owns. That's number one.

Number two, the resolution with which you have to look at people, as compared to tanks or airplanes, is just enormously higher. And the Earth hasn't gotten any smaller, so all of a sudden, the sensor demands are incredible. And then what do you do with this information to not overwhelm yourself with false alarms? Because the worst thing in the world is if you're crying wolf every time there's a group of guys with black hair or beards- Okay?- sitting in a corner together, because after a while, you're crying wolf so often, nobody pays attention. So, how do you figure out which are the guys you have to track, and then how do you get the resources to track them, and surveil them, and everything else? And that's a major part of it. How are you going to do this kind of work that we got so good at in the Cold War in this new kind of asymmetric war?

This new kind of enemy operates on a much shorter time cycle, so he can get inside our decision loops, time-wise, and that's one of the asymmetric things he does. So, you have to figure out how to beat that.

I think some automation is going to be the only way. If you've got to have a new technology, it should be something they can't get right now, like automating some of these surveillance techniques so that you don't have to have a body looking at a camera—okay—for every camera that's running a video, so that things can be done near real time automatically, that then cue trained operators and essentially magnify their capability. If we try to do it the way we do it now, which is just putting more analysts in more rooms, we can't get there from here. The thing just overloads; it doesn't scale.

I: As Director, how did you maintain the flexibility of DARPA? Did you have to shed some projects?
Fernandez: Well, we had in place a situation where we shed about 25 percent of our budget every year, so that if a reason didn't come up for a project to be renewed, it went away. That provided the money for the new starts, and that was

about as much as you could handle. Starting up 25 percent of your business activity new every year really put a load on recruiting program managers who would invent these programs, because everything at DARPA was bottoms up when I was at DARPA. All the programs were invented by the program managers—maybe with a little guidance from the Director—but it was the program manager who put together the program and sold it. Sold it to the Director. First, sold it to his Office Director and then to the Director, and then at that time got the ability to manage it. And $500 million a year of new activity takes a while to review and buy, so that was enough for one Director (chuckles) at the time. So, we had enough.

And every program got reviewed every year, and the ground rules are simple. The first review, if there was a problem, the program manager was told, "You've got problems. This program's in trouble," and that program got reviewed again six months later. And if it didn't make it out of its problems by the second time, it was gone.

I: So, there are a couple of ways to shed a program. You transition it somehow into the real world, or just drop it?

Fernandez: Yes. DARPA does a lot of the latter. They declare victory and move on. (Chuckles.) A lot of the things that DARPA does don't go into application for quite a while. DARPA will do a demonstration of something, say, at a systems level, that works really well, but the military's just not ready. It doesn't have the resources, it's not high priority. So, it'll just go away and maybe get picked up five years later—unfortunately, or something like that.

So, the best deals at DARPA are if DARPA can make—and the word is "deal"—with somebody in the military who wants this kind of change, and who inside the military has the ability to get the resources programmed into the future for something that's very immature. Let me give you an example of one that didn't work. And I wasn't at DARPA at the time.

I was working for the Chief of Naval Operations as an advisor for about 15 years. The next-to-the-last one I worked for was Admiral Mike Borda. The Admiral came to his advisors and said, "I have no way to get a 120-ship Navy," which is what he needed, "with the money I've got, unless I have only frigates. And," he said, "I don't want an all-frigate navy; I want some ships that can carry a lot of weapons and shoot things." So, this idea of essentially building a weapons barge cropped up. It later got the name "arsenal ship" as a way to allow the Navy to build a big weapons platform at a cost that was a factor of ten cheaper than it would cost to build the conventional way. And I was an advisor to the Navy, and I was one of the group that convinced Admiral Borda that DARPA was the place he should go to get this program started. And Larry Lynn turned out to be the Director of DARPA at the time.

So, DARPA started a program called Arsenal Ship, and they assigned some Navy personnel to work at DARPA to get the program going, and it started to go. And the Navy's job, of course, was to provide the backup. After several years, then the Navy would provide the money to manufacture this thing and take it into operation.

Well, what happens? It was the late 90s, and Admiral Borda dies. Admiral Borda dies, and he'd gotten the money by slowing down the construction of an aircraft carrier. The Navy has money, Borda's Deputy, Admiral Jay Johnson, who's—guess what—an aviator who flies off carrier. So he takes over, and the first thing that happens to that money in the Navy is it disappears and goes (chuckles) back into the construction for the aircraft carrier, and the deal died. The deal died as suddenly as it got started, because a champion disappeared in the Services.

Turns out that's not so unusual. In every case in big industry where you've seen something that's really been revolutionarily innovative happen there's always been a champion. There's always an advocate who bets his or her career on it; who's the proponent, and there's usually at a very high level some champion who keeps it going while all the other people peck away at it. I think Motorola built some of the first cell phones. The only reason those things ever happened back then was because the chairman of the board thought it was a nifty idea, and it became his program. And everybody said, "Oh, we'd better leave it alone, because this is the boss' program," (chuckling) you know.

So, those two things are required, and this first one is very important: an advocate. I mean some advocate who bets their career on this being the thing that happens. And that's what you need for program managers at DARPA.

I: Did you say the phrase it was "revolutionary innovation"?
Fernandez: Yes. This is stuff that changes the way you do business and that are going to fundamentally alter the business itself—as compared to what they call "evolutionary innovation," which is planned product improvement; okay—the things you do that you know you should do to incrementally change the way you do business, but you're always building on the stuff you've got before. Personal computers are an example of revolutionary innovation. It did not fit in with mainframes at all. It couldn't compute as fast, couldn't do as much, and nobody could figure out, "What do you do with this?" Well, it turns out it created a whole new business, called personal computing, for these devices because they never had a place, as long as you said, "Computing is with big machines on big problems." That was an example.

I: Now, what was your relationship with the Services?
Fernandez: It was good. It varied, for example. I knew Admiral Johnson, because I'd worked for him, so I was able to get him to be the champion for the Naval Unmanned Combat Vehicle. Now, in doing that, I got crossed up with another admiral who was the head of Naval Air, who worked with Johnson, because he didn't want to do it, but he did it because Admiral Johnson told him to—his boss. (Chuckles) Okay? So, it was always kind of spotty.

With the Air Force, the Navy, the Services are really very different in their cultures. The Navy really doesn't like to work partnerships with anybody. They like to kind of do things themselves. The Marine Corps is different. With them we had a lot of good relationships, because they were a small force, and they love to do experimentation. We could use them as ways to learn if things worked—also Special Forces.

The Air Force loves to deal with everybody. They have a totally different mind-set as a service. The problem is sometimes after they've cut a deal, they tend to welsh on it. (Chuckles.) With the Navy, once you got a deal with the Navy, it was usually a deal. It took a death, like Borda's, for it not to happen. But it was a heck of a job getting the deal in place. With the Air Force, everything was easy, but sometimes, you know, a couple of years later, you'd say, "What happened? A deal is a deal."

The Army has just got so much of everything that organization trumps everything in the Army. So, it took me a while to learn that in the Army, you have to deal with the Army organization if anything is going to happen, because there's so much of everything. When you're doing networking for the Air Force, you're talking about networking a squadron of planes -even, ten planes—no big deal. When you're talking about networking ships, you might network a battle group of 25 ships. When you talk about networking the Army, you're talking thousands of nodes just to begin with. So, everything, all of sudden, the numbers get to be much different, and you have to understand that that's part of their culture. It's very different from the Navy or the Air Force culture- the numbers- where cost-per-unit is really important to them, because the Army just has so many units. So, that was just different.

I: Did you find yourself having to answer the question from the different Services—"Why DARPA?"

Fernandez: Yes. I would say the S&T folks would ask, "Why do I need a DARPA? We could do it ourselves. Just give us the money." Then you'd sit down and talk to them and say, "But you can't do this because they won't let you, because you have to respond to requirements." We're the only place in the DOD where something can be done that doesn't respond to a stated requirements—and that's with a capital "R". A capital "R" means it's part of an acquisition plan, which means there's a schedule that says by the year 2008, or '07, or '10, that technology has to be there for me to put it into something else. DARPA doesn't have to work that way. Most of the work that goes on in the 6.3 arena—the S&T community has to respond to requirements, so they can't do some of the things that DARPA does. They just can't, because they're not organized to do it.

The military at that time saw our budget as being something they'd like to have for their own purposes. Congress was an incredible supporter of DARPA when I was there. I mean they were just incredibly supportive. The only problem we always had was they would ask us to show them results, and it was very hard to convince them that there was nothing to show them because what we were working on wouldn't happen for several more (chuckles) years. So you'd have to show them the stuff that other guys had done before you and hope that they wouldn't pick up on that too much, because virtually nothing really gets built that causes any innovation that doesn't take time.

You remember back in that time in '98, we had the dot com mentality where people felt that all technology could be invented and matured in 18 months, because companies were doing that. What they didn't know was that there had been 20 years of subsidy by places like DARPA and the National Science Foundation that built up the knowledge in these companies in the IT world, you know.

I: To stick with the budget questions here for a minute, didn't it also have to do with the peace dividend?
Fernandez: Oh, the peace dividend. DARPA's budget had come down somewhat. It was about $2 billion a year when I was there, and it went up a little bit while I was there. Towards the latter part of Clinton's administration, it went up about 10 percent. So, people were starting to get a little nervous, I think. Some of the things that were happening, you know, the bombing of the Cole and the first World Trade Center—people were starting to say, "There's something is coming along. We'd better start putting some money into things that are different." And that's why DARPA was called on to start working on some of the biodefense and some of these other—

In fact, one of the programs that I started at DARPA was—I still think it was a good idea. Unfortunately, Tony, Dr. Tether got stuck with, called the Total Information Awareness Program, and that was a case where the contractors got out of control, started advertising what they were doing, and it got to Congress, and everything happened. It was a very, very bad thing.

It was actually a good idea. The idea was the following hypothesis: the target that somebody is going to go after and the weapon that he, or she, plans to use will dictate the tactics. If people are smart, they will optimize their tactics about the weapons that they have and the target characteristics. So, whatever the target is and the weapon that you've got at your disposal, if you're smart, you're going to optimize your tactics to exploit that. Well, what that means you can make a model, because if the number of targets that you have to defend is big, but finite, you can now list the targets. If the kinds of weapons that people would use against those targets is something you get pretty good Intel on, because there are only a certain number of weapons, then you could say, "How's that person going to approach this target?" "How're they going to case it?" Okay? "If they are going to case it, how are they going to talk to each other?" Otherwise, they can't get the thing planned and organized, and then they have to rehearse someplace before they do it the first time for real.

So, the idea was, you could use those transactions that would have to take place to help sift through information to let you predict that "there's a good probability that target is going to be here tomorrow, because these things are falling into place." And I don't know to what extent it's being worked on now, or not, but the idea was a strong idea. And it was called Evidence Extraction and Link Determination—just connecting dots, how do you connect the dots.

And then it started getting advertised a lot. People went crazy. (Chuckles.)

I: Wasn't connecting Poindexter to the dots the problem?
Fernandez: Well, that was a decision that was made. John Poindexter, he was a contractor working for us at the time, and then, after Dr. Tether came in, he got

a job at DARPA, and he became a kind of lightning rod to attract a lot of old enemies.

I: That represents the kind of thinking and the kind of empirical backgrounding I think is unique to DARPA and the Services.
Fernandez: Yes. DARPA requires that everybody build things that can be tested, regardless of what the area is. If they do it in mathematics, they'd better write a code at the end to show that this algorithm works. And then run the code with data running through the code to show how it works and how it breaks. In virtually every area. If it's a piece of electronics, I need a breadboard. Okay? If it's a manufacturing technique, I need a small version of a factory built to do something.

But that's the heritage DARPA got from the people who were at DARPA in the beginning, a lot of them who had participated in the Manhattan Project and things like that, where the idea was to get really smart people together and build something, and then test it. And then it gets transferred to somebody else to use.

I: How do you move from a "Gee whiz" to, "Okay, what's the practical use of this thing?" I'm thinking of MEMS, now.
Fernandez: Yes, the thing that plagued MEMS for the most part was "gee whiz, they're neat, but what can we do with (chuckles) them?" "What can we use them for?" For the longest time, the only application that existed for MEMS was a nonmilitary one. It was the sensor, the accelerometer that's used to activate your airbags, and that's what kept the companies going, making those things for the automobile companies. And very cleverly, first, there used to be one. Then there were two, and now there are eight in every car, so every time you up the number of airbags, you up the number of sensors you have to build in the airbags.

As time went on, we started doing better on building MEMS gyroscopes, and on building MEMS switches for building radars. . Now, those, when they start to work well—and there're still manufacturing issues—will have a serious impact on military operations. The accelerometers and the gyroscopes now, they're being put in missiles. I mean, they already work. The stuff for radars are being now prototyped and built, and they may change. What they promise to do, if they work, is drive the cost of phased-array radar down to very, very low levels. And that's really the future, in a radar that you can just program it anywhere you want to; where it's going to look and how fast it's going to look, and how fast it's going to update how it looks, as compared to an antenna that you have to move around mechanically. But they're very expensive. So, that's a case where MEMS may come into its own someday.

I: How big is a MEMS gyroscope?
Fernandez: Oh, golly. I'm trying to remember—10, 20 microns, the functioning part.

I: Which is smaller than a human hair?
Fernandez: I don't know. I forget exactly. It must be the same width. I don't know exactly the size of a human hair.

But the big problem with MEMS, by the way, which most people don't understand—is the fact that you build this electromechanical device that's exquisitely small, about a millionth of a meter or 10- millionths of a meter. It's not molecule size, but it's still pretty small, and very sensitive. And the hardest problem is how you package it. How do you put it in a package that separates it from all the random things that take place in the environment that could be making this thing go off—heat, vibration and all the other things that can cause problems? And that's where all the money goes, in designing the packaging for the MEMS. The MEMS itself is fairly straightforward to design and build, and then there are the production facilities, which are the old etching things that you can use to build it. But the packaging is a major issue, and continues to be a major cost issue. I mean, how do you package the device?

I: And how do you interface from something that's micro to macro?
Fernandez: Well, you have to package it in something that can take (chuckles) a plug. That's exactly the package that does that transition. So, it's kind of interesting. It's a very, very interesting problem that just gets harder by a factor of about a thousand when you go to nanotechnology, because now you're talking one-thousandth of a millionth of a micron. So, the packaging gets to be even tougher.

I: You can make the neatest, little molecular electrical generator, but—
Fernandez: (Laughs.) Ganging together 10,000 of them might be a little hard.

I: How do you test the nano and MEMS, devices for reliability?
Fernandez: Well, testing in this nano world of a very, very large number of devices gets to be very, very difficult. An example that people can relate to, perhaps, is the transistor. Our chips, when I left DARPA, we were routinely putting 40 million transistors on a chip, and the goal was that by now we'll have a billion transistor switches—transistors on a chip. So, now you build a chip with a billion transistors (chuckles) and you say, "I want to test the chip to see how many transistors are working." And how do you test a billion transistors? You'll spend the rest of your life testing it.

So, it's not testable. So, now what you have to do is you have to build this chip in a way that agrees that some of the switches are not going to work and has smart enough software that it programs around the ones that it finds out isn't working as it's trying to work. And that's a whole paradigm change. That just changes everything from the day where you had three transistors and you made sure it worked—vacuum tubes or whatever, and you made sure that they worked.

So, this whole world of the small just brings in a whole new aspect to how do you test things to see that they're going to work. First is the very large numbers of them. Second is what do you use as a probe to test something? You're almost stuck with using very, very high-frequency electromagnetics or something like that—something like a very small wavelength so you can probe in there to see what's going on. So, it's a whole new world of things that have to open up. You have a self-assembling set of molecules that are all supposed to be the same, but you know, what happens if one of them doesn't quite assemble like all the other ones did. Do you have to throw the whole thing out? Or, what do you do? So, it's a very interesting problem.

I: The mutation theory of systems development...
Fernandez: (Laughs.) You have to let them die.

I: Now, were MEMS ramping up during your tenure?
Fernandez: No, MEMS had ramped up before I got there. They were earlier. Bio was the new thing that started to ramp up. Bio started a year or two before I got there. Larry Lynn started it, and one of the DARPA Deputy Office Directors, Dr. Jane Alexander. She then became my Deputy after I became Director of DARPA. She taught herself biology and educated a lot of the other people, including myself, at DARPA, so that became the basis of us being able to know who to go to, and how to start the programs. And then while I was there, the biodefense area grew quite a bit. It tripled or quadrupled, so it was a big area by the time I left.

I: How did DARPA go about defining biodefense as a DARPA problem?
Fernandez: I think the initial definition came with Larry based on intelligence, and the fact that the Soviet Union had collapsed. The Soviet Union had had a very significant bio program, and a lot of these people were out of work, so they wanted to sell their capabilities and their skills to anybody who could pay them. So, trips were made to the Soviet Union—the former Soviet Union—by Dr. Alexander and Dr. Lynn, and the idea was to see if we could start programs to start looking at things that might be a defense against them. We had nothing really going on, because there was no threat. There wasn't much. There was a chemical threat. That had been around, chemical agents, but some of these biological agents the Soviets may have been engineering to make weapons of them, we had nothing significant going on.

So, DARPA started up some areas, new ideas for vaccines; innovative ways to try to detect agents remotely and things like that. And then they grew, and started to work, and then they moved over. There's a whole office in the Department of Defense now that does biologic and biodefense. It's a good-size office. It's an agency of its own.

I: I think the keynote speaker at the 2000 DARPA-Tech was a geneticist or biologist, wasn't it?
Fernandez: I think so. A biologist, yes.

I: It seemed to me almost to be a recruitment convention. Was it?
Fernandez: Well, we were looking, because it was very hard to the pharmaceutical companies were doing very well -- (chuckles)—during that time.

I think after—after 2001, when some of the stuff in the economy crashed, it got a lot easier for DARPA to find people, and then people were looking for interesting work. But at that time, it was all about trying to find some good people, and one of the big problems was, why should anybody come to DARPA if their background's microbiology? There were not very many other people at DARPA whose background was microbiology, so we had to build a core team. And that was what Zan, Jane, Dr. Alexander was doing a lot of.

I: When you look back at your tenure as Director there, are there certain things that make you think, "Darn. I wish I had done more on this"?
Fernandez: Uh...I'm trying to think. I wish I could have done more with the Navy than I was able to do. It turned out, though; I had a hard time getting the Navy to send good officers. They had other things for them to do. Without a good officer from the service, you couldn't do some things that you really wanted to do. And I had thought I could do that easily, because I'd had a long relationship with the Navy; I'd worked with them a lot. And it turns out I was able to get a lot more done with the Air Force, the Army, and with the Marine Corps than I was able to get done with the Navy itself. That's just the way it worked out.

I think in the area of systems, we had one program killed called Discoverer II. It was a satellite surveillance program that was going to have a network of satellites around the globe to give the warfighter near real-time updates on what's going on, compared to what they get now, which is quite often old. And we got that pretty far along, but then some things happened, and then the Congress killed the program on us. That was a disappointment, because it could have been a good program. The idea was—could you build a satellite cheaply enough that you could put a network of them up. So, you had to have special manufacturing techniques and some other things, and that was probably the biggest disappointment. We read about that in the paper when it happened, and boom, you know how it is.

I: Do you read the paper differently, now that you've been at DARPA?
Fernandez: Oh, yeah. I'll tell ya'. I was amazed at—well, we can't say "poorly," but—how incompetently the press reported whatever was going on at DARPA. And these were things I knew something about. And it wasn't that they were just being evil. They just weren't being very careful. They would run with a story on something, and you'd say, "Where did you get that information?" And it was, well, they talked to somebody, and they didn't double-check very well or something. So, I got the feeling that if this happened in areas that I knew something about, it might be happening in (chuckles) a lot of other areas at the same time. So, I got more skeptical about reading and believing some things, knowing what they did with the things we had at DARPA.

Now, I was lucky. I never got into any really big problems with the press, and that has happened at other times (chuckles) with DARPA. Other Directors have gotten into bigger problems than I did, you know.

I: Getting back to the idea of making the forces more flexible to be better prepared to approach this asymmetric enemy—did that come from the Secretary's office?

Fernandez: No. Network warfare. Networking came. There was one admiral in the Navy who was an advocate of networking. He passed away recently. I'm trying to remember what his name was. He worked for Rumsfeld. He went to work for Rumsfeld directly in the Office of Transformation, or something like that. And that was his idea—to network operations as a way to get more performance. And DARPA picked up on that because there was a lot of technology—communications technology, sensor technology—all kinds of questions of scaling and security and everything else that DARPA went to work on in that area.

So, to a certain extent, I got my major feed from the Under Secretary and now whether he got it from the Secretary or not, I don't know. I never met Cohen except socially. Never in business—never. So, Jack Gansler was the person I interfaced with, and Hans Mark, the DDR&E, and that's where some of those ideas came from.

Hans was not so keen on networking. The reason we got interested in it was we couldn't figure out another way to break this problem of escalating costs, because it was becoming clear that the technology we needed and were building was becoming unaffordable. And a lot of it was because we had to get the human out of the loop in some areas. The question was—could we automate things? Could we have networks where part of the nodes didn't have people in them, as compared to one where every node has a person with a radio or something like that? So, I guess that's really where it came from.

And then there were a couple of people in the military who were somewhat visionary. For example, Shinseki. I mean the problem he had with his tanks. He knew that he was never going to build a conventional tank that gave him what the Abrams gave him, so he had to change what you did when you talked about armored warfare. And the whole idea was—could you separate the person from the gun? If you've ever been inside a tank, it's a very tight network. There are four people inside a tank. There's a driver. There's a commander, a gunner, and a loader. And these people rehearse and practice and practice and rehearse until they really run just as a unit, just like a football team or something—incredibly good. And the question was, like I said earlier, it just weighs a lot to protect them and to do all this stuff. So, the question was —could you put the commander someplace else? Could the tank drive itself, so you don't have to have a person driving the tank; just give it a command? And perhaps you could have the gunner run the gun, but he doesn't have to be inside the tank with the gun. And, so this kind of thing was the idea, and was calling for some kind of networking we'd never done before—but without that, there was no way you could drop the weight.

I: Were there any ideas that came across your desk that made you think, "Oh, my God. That is the wackiest thing, but maybe we should look at it"?

Fernandez: Well, we used to get (chuckles) regular mail from prison inmates and other such people with ideas about perpetual motion machines and stuff like that. Those we didn't fund too many of, but there must've been 20 or 30 a year that used to come in with those kinds of ideas.

In the biodefense area, some ideas came across that were really far out, not that much chance of succeeding, but we funded them because if they worked, they really could make a difference. One was an idea for a vaccine you could give a person, but it wouldn't activate until sometime later, when you wanted it to activate. So, the idea would be that you could inoculate everybody way ahead of time—soldiers or populations, or whatever—and then only when there was a serious threat because vaccines don't last that long. When the time came that you said, "Now, I'm going to go into a particular place," you could very quickly activate that by, say, taking a pill—something that easy that didn't require a vaccination or something like that. So, ideas like that were ones that really, really got pursued, and I don't know where they've gone now (chuckles).

Track individuals and determine their intentions—that's a wild one. That was work we started but I don't know where it's gone right now. I would guess if it's gone anywhere, it would be someplace in the intelligence community.

I: When you left DARPA, what were your feelings?
Fernandez: First of all, I was a little disappointed. I had hoped when I got the job that DARPA wouldn't have to turn on the typical cycle of come Inauguration Day, you're gone. But the administration did it that way. It hadn't been done to previous DARPA Directors. It just got done this time. And the problem with that was I couldn't finish up some things with the Army that I still needed about four-to-five more months to finish. And there was a void of about five months while they found Tony, where some of the things that were going on for the future combat system fell into some disarray. Xan was Acting, but she didn't have the authority to do some things that had to be done, so there was a real problem that took place where it slowed down, I think, the Army situation somewhat.

After that, the other thing was I got out, I couldn't- I didn't want to take a job as a vice president for a company, because I didn't want that. I was trying to figure out, "Well, what do I do? "I can't work anywhere. I mean, most of everything I would work on, I'm conflicted (chuckles) for a year or two." So, I did some consulting, and then went to work at a small school in New Jersey, Stephens Tech—a little engineering school where I'd gone as an undergraduate. And that was interesting. What happened was, I just changed businesses and went into an area of education, and learned something about the business of education, which I'd never known anything about before. And I'll tell ya', it's different than anything I had ever done in my life—the education business. It's different than small companies, big companies, different than defense. It's just a totally separate business. I learned a lot there. That's what I did. I went off and did something different. I did a change. (Laughs.) DARPA was a change agent for me.

I: DARPA does that to folks, doesn't it? Well, as long as we're talking education, let's talk JASONS.
Fernandez: JASONS—January—uh, July, August, September, October, November? (Chuckles) No, the JASONS were a group of consultants who

worked for DARPA. They had worked for DARPA for quite a few years—all academics, all, I think, except one. They worked in a different way, as compared to a lot of places where you present your programs to a panel, and then they review and ask questions. The JASONS would be given problem areas every year, and they would go and get briefings from people in the technical areas related to that problem area. But they would then sit down and do some technical work of their own and, essentially, try to invent solutions to some of the problem areas.

And they've done some really interesting things. They worked for me on several areas. One of the biggest was the biodefense area, to try to help us scope out the programs, what we should invest in, and they helped an awful lot on getting us something in that area. So, to me, the JASONS were a very useful set of advisors.

I: Did they offer practical help?
Fernandez: They were good. First of all, they were totally cleared, so they had access to everything. DARPA gave them that so that they could see what was going on. And then they had some very, very good academics who knew how to solve problems. So, they would pose a problem and were able to come up with as much of a solution as you could during six weeks in the summer. But also, quite often, in doing this analysis, they were able to point out things that could be major program issues that then DARPA would use in their analysis to motivate programs.

I'll give you an example, a specific one. Back, late '60's. They did a study... There was a JPL satellite that flew called SEASAT. SEASAT was a synthetic-aperture radar satellite that was put up by NASA Jet Propulsion Laboratory back in the late '60s. It came back with some pictures of the ocean with funny streaks and features on it. People said, "What are those things caused by?" Those things are caused by underwater waves that are called "internal waves." Inside the ocean, which is stratified in depth, there are waves that propagate down inside the ocean, not just on the surface. And these waves had made changes in the roughness of the surface of the ocean that a satellite could pick up with the radar, and there they were—pictures.

Question: could that be used to find submarines? Of course, because submarines run under the water. Submarines move the water around as they run. The JASONS did a study where they took every aspect of that problem—how does a submarine make the waves; how do the waves get to the surface; if they got to the surface, how could they modulate the scattering of the surface; and what would radar that could find these things from space have to look like? They did an analysis that would've taken a contractor (chuckles) $50 million and they did it in one summer. They put together a team of people that had some of the world's best oceanographers, radar people who knew scattering, people who knew hydrodynamics—everything—and they put together an enormous start. So, that was a case way before my time which kicked off a DARPA program that went on for about eight years, to see if this would work. Very risky, almost impossible problem, but it was a case where internal wave detection—internal waves generate

Why was it important? It was important, because we counted on an asymmetry between us and the Soviets when it came to submarine warfare. We were much quieter than they were—a hundred times quieter. That was an asymmetry that we could exploit. So, the question was—if it turns out these effects are real, and their boats are about the same size as ours, and go about the same speed, and travel about the same depth—what's going to give us an edge? If this happens, we've lost our edge. And that's why it was a national-level problem that had to be looked at, because it was that simple. We counted on our quiet submarines to give us an edge over theirs.

In fact, that's how Stealth came about—right? You know, "We did this for submarines, why can't we do it for aircraft and radar?" (Chuckles) So, anyway, that was one where the JASONS helped a lot. They did some very interesting things. They were very independent guys. Sometimes they did things that were a little out of the box, but that's academics (chuckles). A lot of them became good friends.

I: Is there a role for that kind of application of scientific thinking?
Fernandez: I think so. I think that's what has to happen because as new areas of discovery- and not just in engineering- become important , areas like cognitive computing, areas microbiology become the ones that are really, really very important, then I think that what has to happen is this—this group of academics has to morph to accommodate this new knowledge. If it turned out that human performance became a major area, then people who do neural work would have to be brought in, because they understand how the body works. And so I think for this to be useful, it has to continually change as the problem areas change.

And I think one of the difficulties that might have taken place is that we were in a Cold War situation where things were changing very slowly for a long time with the Soviets. They were not broke. I mean, a whole new way of doing things started happening—and asymmetric enemies and all that. And the question now, for example, depends a lot on human performance. Close-in combat is a lot about human performance, individual performance. And, it's not crazy to suspect that people are looking for ways to either increase their performance, or degrade the other guy's human performance. So, if you're going to get information on that, and DARPA's going to work on it, it's got to have people who know about that. And it's more than just biology. It's all the other areas—psychological areas—and everything else. So, it's useful, but I think the experts have to change over time.

I: It's hard to look 25 years into the future, but if you could, how does DARPA have to change? What do they have to keep up with that kind of level of ever-increasing change?
Fernandez: Yes, I think the single most important thing DARPA's got to figure out is how to seize opportunities in technical areas that are not native to the U.S. Nobody's got a handle on how to do that right now, and I think if DARPA's going to be effective—there's going to be so much stuff that will be other places, that if

a DARPA's going to be effective, it's going to have to figure out how to exploit that, just like it figured out how to exploit good ideas of people in the U.S. Now, I don't know how to do that.

I do feel strongly that strong links with the academic world in the U.S. is a way to get there, because the academic world in the U.S. is wired into all the foreign universities and everything else. They've made a point of going very global. The best schools in the U.S. have very strong global connections everywhere. So, if you're going to do that, somehow using that asset, the United States university assets may be a very important way to do it, because it's going to be about finding out who are the people are with the ideas and how can you get those ideas, et cetera. And, I think, the only open way we have right now to get a lot of that is through the linkages –very informal– that exist between the universities. And they're very strong. Professors do sabbaticals. They're going back and forth all the time, coming here, going there. And if I were asked, I would say DARPA should look at how could it use that to its advantage and start doing some experiments on a small scale, to see how it works. You know, pick a school here that has good connections, okay, and see how do you use this? How to fund a program to figure out what can be exploited. You know, what can be set up as separate campuses where people can come and do work that DARPA pays for; where people come here and do work because they'll get credit, or whatever—or their research will get funded, you know?

The thing I learned when I was at a school was the best way to get a professor's attention is with resources for more students. Students are the lifeblood of professors. They do all the work for them. They're their continuity in the future, so to keep students working for them, professors need resources—money. They can get grants or whatever, and that will influence professors very strongly if you can increase their student base. And I'm talking about their research students. You know, their classrooms where they go teach 150 students, that - they do. This is where they keep their sanity, because, can you imagine teaching Physics 101 for 30 years? (Chuckles.) The same class every semester every year, it can get kind of boring. It's this other part that really is what they want, because that's where they can get things done. And they need students.

So, this question of DARPA learning, becoming a vehicle to tap into this globalization of technology for the military, for national defense, I think, is critical. I don't think anybody else is going to do it. I don't think the intelligence community can do it. I think they're not set up to do it that way.

I: If it's a global threat, then why not have global thinking and global solutions?
Fernandez: Well, it's easier to say that, but how do I go (chuckles) one step further, unfortunately? What else do you do? It's a tough one, but I think the link with universities is the only thing I can come up with, which are truly linking already, and which have at their disposal a lot of the knowledge that goes into most of these technologies just about every place in the world. A lot of them went to school here, but that's okay.

I: Have thinking beyond the "old white guys come up with solutions?"
Fernandez: I think so, yes. You've got to think a little differently if DARPA's going to stay young.

DARPA may evolve from a program-office-oriented place into a place that has programs and also does venture capital. It could be that part of DARPA in the future starts to invest in companies because maybe that's the way you get the information, as compared to having the companies work for them. I don't know, but something is going to have to change, because things are just too broad and too widespread. It's not U.S.-centric any longer.

I: The industries are multicultural, diverse.
Fernandez: The universities are all over the place, you know. So, you look at the student bodies and they represent the whole world at most good schools.

So, the question is, the big change is we no longer own or control most of the knowledge in the world. It was nice in the'60s. It was all here. (Chuckles.) It really was all here, but those times have changed, and we've got to figure out what to do in this new world.

And I think for national security, a place like DARPA is going to have to be the place that leads us there, because the establishment doesn't have the freedom to think that way. I mean some of our biggest problems are in areas like energy and there's no equivalent of a DARPA that can do things like DARPA can do in the world of energy. It's absolutely amazing how different that whole world is, and, yet, it's a strategic problem we have. You know—what do we do?

I: The soldier of the future has the night goggles, the videogames and everything, but he's also got a hundred pounds of batteries on his back.
Fernandez: Or, a long cord (chuckles) back to the plug. That's (chuckles) plugged into. That's a fundamental problem—the things needed to power them.

But we'll see. That's going beyond my job description (chuckles) as a professor.

Where there really is work going on, and what I think is a major area is how can you use games—given that games are everywhere now—to provide education for young people? And I don't know the answer to that. I don't know what kind of research is going on to determine how that gets done, because when you get into the educational world, it's not something I'm very familiar with at the undergraduate level; how people determine what educates children and stuff like that.

I: We talked earlier about systems communicating with systems—biological systems with physical systems; networking at different levels with complex systems. How does that happen machine to machine?
Fernandez: Yes and the answer to that is DARPA can't work on that until there's a military need. DARPA is about defense. It's been made very clear to DARPA every time it tried to move out into other areas: "You just stay back in defense. Okay? If we want ARPA in homeland security, we'll create one" (even though it's dysfunctional). "If (chuckles) we want one in energy, we'll create one.

You stay in defense."

So that DARPA has to usually find a reason that it can use. Now, what we've done at DARPA, , which we did, is we said the training of military kids is one where games may provide a way to do that, so we slanted it that way. Okay? Using computers and technology to train young people—okay—how to do some of these complicated jobs. How you translate that down to younger people is not clear, because we deal with a population in the military that we get them at 18, and that's when they start.

I'll give you one example, though, of an area that's become a very big question, and DARPA is getting involved in it with the Marine Corps right now. Tony has a program going on in this area. Dr. Tether has a program in this area. The Marine Corps want to push decision making down to the squad level. Currently, when you're a Marine and you're an enlisted person, you're taught to be proficient in certain areas. You're taught to shoot a gun very well. You have to be able to shoot a gun otherwise you don't become a Marine. You have to have physical capabilities, strength, and run and hand-to-hand combat. You have to be able to read a map so you know how to get from A to B, but you're not taught to make decisions. You're not taught to deal with uncertainty. What you're taught is to carry out orders.

What they're coming to find now is that a lot of things and some of the things they've learned in Iraq close-in combat, you could really do a lot better if you could push that decision making down to the squad-leader level. But squad leaders are not taught to make decisions. Squad leaders are taught to act. So, the question of how do you do this without having all these enlisted Marines spending their whole careers in classrooms becomes one of—what can technology do to enhance training? And we're talking computers and information technology, obviously, and advanced computer interfaces and everything to advance training and teach decision-making skills—something all officers are taught in the military. The officers are taught about making decisions. That's a core part of officer training, but it's not an enlisted person's job. So, yet, it looks like some of this asymmetric warfare, if it's going to be fought close-in at squad levels, will require that you not call back and get permission to fire; that you make the decision to call for fire.

I mean, right now, if a sergeant in a squad sees a target, he calls back to the company, who calls back to the (chuckles) battalion, who calls back to the regiment to get the release to fire on that target. Okay? Special Operations people are different. They can call for a fire, but those are Special Ops guys. I'm talking the normal ones

So, the question is—what do you have to teach people how to do to be able to do this? You have to teach them communication skills. Most of the young people we have in the military are not taught the communication skills to talk, say, to an air traffic controller. And if he's going to call a plane for a strike, he's going to have to talk to an air traffic controller—if it's going to be done directly. So, this whole question of how you educate young Marines and soldiers to drive decision making down to lower levels is starting to boil as a big area, and it looks like it's a major tech area, because I don't think you can do it with just training. You'll spend so many hours training if you just do it the old way, that the guys won't have a chance to (chuckles) fight. So, the question becomes what kind of tools can you provide them, so that they can be doing off-hour simulations, games where they're learning decision skills, and basically learning to deal with uncertainty? That's becoming a very big area. It's called "distributed operations," I think, is the name it's being given in the Marine Corps.

I: Is it logic and reasoning? Thinking?

Fernandez: All these things. Dealing with uncertainty. It's fundamentally when you're an enlisted person; you are taught to carry out three prescribed things that you're supposed to know how to do: run up that ten yards, fall on the ground, and shoot the guy. Well, you've been taught to do that. Dig a hole. You've been taught how to dig a hole—you know, a hole—a foxhole. But, for everything else, normally what you do is you call an upper level or echelon to be told what to do.

Well, it looks like you may want to drive that decision capacity down lower to be much more effective, primarily because these asymmetric threats are so fleeting. By the time you get the decision, the picture has changed. And what they're learning is that the soldier on the ground has much better intelligence, quite often, than what they have at the command, but the soldier on the ground doesn't have the authority or the training to act on it. So, that's something they have to be trained to do.

The question of education, I think, is going to revolutionize it—technology will revolutionize it. Can you imagine? In the future—and I'm talking 50 years out, okay—with all the memory and all the databases, whatever—I can imagine that classrooms won't be classrooms in the sense of "classrooms.". If you wanted to take a course in physics, and say it's mechanics, you could probably have Newton there, because you'll have this machine, his works on a machine and you'll have interfaces where he could be talking to you and answering your questions. So, you could talk to him about why does a ball roll down a hill, and he'd say, "Look, this is why." And you'd be talking to a machine—okay? Education will become a situation where you can customize your rate and speed of learning. And this big, giant database will be providing you with access to the very people who invented the science, not the people who go and learn it and then transcribe it for you. Why do you have to have the middleman? The teacher was just somebody who provided that middle function. The person did understand Einstein, and then he transcribed Einstein to you. Why can't you talk directly to Einstein? Why can't you have the machine tell you what Einstein would've said from whatever he wrote and what they know about it? It could be just fantastic], as long as we don't kill ourselves off first (chuckles).

And language—why the heck does language continue to be such a barrier? Think of it. Okay? We have to get people who are translators. Why can't you have the Star Trek thing—okay—where there's a recorder that's smart enough to start learning and parsing things, and developing language skills, so that there isn't this language barrier we have now? That will come along, I think, and it will change everything. It will just change everything about education, about interactions, about communications.

But the problem's going to be the little battery (laughs) to operate all these devices. So, we've got to have a new source of power, too.

I: Real-time translator?
Fernandez: Why not?

I: How does DARPA recruit? Are they competing with Pfizer or Microsoft?
Fernandez: That's the hardest job the Director and the Office Directors have. One of the major jobs of Office Directors at DARPA is to provide reach into new people to come work at DARPA, because they multiply up what the Director can do. They have particular areas they're interested in, and so in those areas they're perhaps better connected than the Director. They just provide more access to more people to interview.

That said the hardest thing is recruiting good, young people to come to DARPA. We get a lot of retreads; people want to come back. Sure, it was a great time while they were there, but that's not really what you're looking for. You want, really, new people. And the hardest thing is to find the people who at that point in their life want to make a change in their career and convince them that DARPA can be the vehicle for them changing, whatever their career is. So, it could be a person in a university. Maybe they're a full professor, but maybe they want to see if they're going to go do something else. Or, maybe they're not a full professor and they're not getting slated for tenure. They're looking for a change. And DARPA can give them something whereby if they can invent an area, a problem, they get incredible exposure, because they're spending large amounts of money. That means people will talk to them. And they'll get known, and maybe that makes a change, and they go off on a different career path. That's the only selling point I found that really makes sense.

Now, the problem with that is out of all the people you talk to, you've got to be able to isolate the ones who want to make a change. A lot of people don't want to make a change in their career, and DARPA's not a good place for them because they're going to work real hard, be on a plane seven days a week. Why do you do that unless you want to do something where your life's going to change as a result of it?

So, that's been the hardest part—recruiting.

I: How difficult was it to find IT people during the "dot com boom?"
Fernandez: Oh, my God. In the late'90s, we couldn't get people to come to work at DARPA because they had so much money to do anything they wanted to do. They want to run a program—the company would give them money to run a program. There was money being thrown at everything in the information-technology world, so we were having a hard time. In my opinion, we ended up having to bring in too many academics, so that the balance shifted towards academics in the IT part. And you want some academics, but you want some people who've got industrial experience, too. We couldn't get them to pay attention.

I would go to talk to Cisco, and even though DARPA was instrumental in getting Cisco going years back, Cisco couldn't spare their good people. "Sorry." (Chuckles.) "Got more important things to do." So, that's just what you have to put up with. Then the crash came a few years later, and then there was a lot more people available (laughs) you know, like everything else.

So, that's the only answer I've got. I don't know how DARPA would be allowed to get involved in the educational world except indirectly through the military part of education. One of the things I did notice is that you had to be very careful if some other agency or department saw you were moving into their turf. With all the freedom you had at DARPA, and new review, and then plans, I mean things could just go ballistic.

I: Hasn't there always been a high level of rationalization coming out of DARPA, too, in certain areas.

Fernandez: Oh, sure. (Chuckles.) "DARPA invented this." "Yeah. Oh, we sure did." "Another victory for DARPA." (Chuckles.)

But DARPA's been lucky enough, you know, a lot of this stuff is luck. I mean, after a lot of years of working—and I spent my whole life in R&D with small companies and large companies before I went to DARPA, and then after that in the educational world for a few years—luck always trumps planning. No question. Bad luck—things can happen you have no control over that can trump the best plans. Or, by serendipity—something happens. So, the thing happens—are you alert enough and active enough to exploit what happens, or does it just go right by you? Do you just sit and do nothing about it? That's, I think, where you can do something about it. You see something that starts to break, and then you move, whether it's a technical area, or a relationship, or whatever.

I mean, the thing with the Army in future combat was nothing more than this general said, "I want to make a change." And I got our guys together. I said, you know, "This guy's asking for something that's impossible." And the outcome of that was really interesting. General Shinseki knew he had a problem. He said, "I'm going to turn to technology and networking," et cetera. "See if you can solve it."

So, we put together some programs where certain things had to happen, and work, and all of that. It was high—very high risk—and everybody knew it. So DARPA said, "We'll up-front the cost. Because if this dies in three years, you shouldn't have put your money into it. That's what we were created to do." And the Army says, "We'll go up the back end so that the things that are starting to look good, we'll pull on those and get them into the Army."

And what General Shinseki did, which was incredible, was there's a thing called the Army Science Board. They're a high-level review panel that meets every summer to review Army programs—like the Defense Science Board, but they do it for the Army. He made a point, for the two years I was there during this thing, of showing up personally at their out-brief. Now, the Chief of Staff of the Army never shows up for these things, because they're not operational, or whatever. He made a point of showing up. Of course, since he showed up, every other three- or four-star general showed up, so all of a sudden the Army Science Board had an audience they could give their out-briefs to. That was an order of magnitude more impressive and influential than they'd had before. And General Shinseki did this just because he said, "I pick technology to be the important thing. Now I'm going to show all the people who work for me that technology is important by showing up, which means they have to show up"—because that's the way things work in the Pentagon (chuckles). But it was impressive. I mean, things got done, and got exposure that would've never been seen before.

I: Like what?
Fernandez: There was one part of the program that was a surveillance helicopter that could have very high endurance — 25-hour endurance—and fly up as high as 25,000 feet, and things like this. And that all of a sudden got a push because people saw it who said, "Oh, I could use this for search and rescue." Well, all of a sudden, this wasn't just a DARPA program; it was something that might have all kinds of things. So, there's one example of a program that got a strong push. And then Boeing bought the small company, and I don't think anything's worked ever since they bought the (chuckles) small company. I guess the price is not high enough. (Laughs.)

I: What about bad luck? You mentioned sometimes bad luck happens.
Fernandez: I'm trying to think. I think the one area where we had bad luck was in some cyber security things, which, it turns out, were being run by people who didn't understand that the hardest problem– and there are a lot of problems— with making security for networks is that every piece of software you write, or every piece of hardware you put on the network to guarantee security, becomes an overhead move. It's not doing the major job the network is designed to do; it's an overhead function that's taking care of protecting the network, but it's not the primary function of the network, which is to move information around, and things like this. And the difficulty is a lot of ideas that look good when the network's got ten nodes just explode in the amount of bandwidth that they use up, and they don't scale, so the whole thing crashes of its own weight when you try to scale it up.

And we had a couple of times where some ideas that looked really good just never got anywhere. The people who were doing it hadn't paid enough attention to the scaling, which to us is the single biggest problem in computer security—how much overhead do you pay? And you see it quite often. When it crops up, all of a sudden the latency goes up, and it takes you longer to get back and forth. And humans only tolerate a certain amount of that, and after a while they want no more and they stop using it. You've seen this when you put some of these Norton anti-virus programs on your machine. They slow the heck out of a machine. That's overhead. That's exactly what they're doing. And there were things like that that went on that we couldn't tolerate in the military, because you can't have latency for a system that's going to direct a weapon. No! (Chuckles) You know—things like that. Most of the things, I mean outside of the programs, we killed, which were, those were calculated things, you know. Um—that's about it.

I: Did you ever have to kill your darlings- a pet project?
Fernandez: No, you didn't have to worry about that, because if you can count on so many, you didn't have to do it. It would just (chuckles) die when it didn't get transitioned. It went on the cutting room floor. The way your things got killed at DARPA was not that you had to kill them. You didn't have the energy or the way to transition them. Then they would go nowhere. I mean, by definition, unless something moves out of DARPA into someplace else, it's going to end up on the floor. So, you don't have to kill it. Just everything that you don't move out ends up (chuckles) on the floor.

I: That's great. I think we've got it.