

underlie an acquisition strategy that we need to conceive in order to let us develop and maintain the kind of force structure that's going to position the Air Force in the best way possible for the future environments that it has to work in.

Now, in my role as the Chief Scientist, I'm going to focus these comments primarily on the very front end of that acquisition strategy, that is to say, on the research and development strategy. How do we go about developing an R & D strategy that, in turn, supports the acquisition strategy for the future of the Air Force.

I think, if you look at the R & D that's done in the Air Force today, it's a very impressive enterprise. Our challenge is to say, how do we make the appropriate adjustments or alignments to make sure that those endeavors -- many of which won't lead to capabilities that you'll see in the field, for another ten years -- how do we go about making the right adjustments now, when we don't have the kind of feedback loop, or at least the immediate feedback, to be able to judge whether the decisions we're making are, in fact, ones that produce the outcomes that we would like? And so, really, that's what I'm going to try to focus on for the next eight or nine minutes.

There are a number of well known contributors to the broader question of what we like to say are the industrial base issues. And, I'm not going to focus on most of those. I think they've been generally well-articulated. I think the shrinking size of the U.S. R & D community is a part of that. And, I'll mention in a moment a facet of that which I think goes relatively unnoticed, and which I think may be important to the thinking that allows us to understand that piece of it.

There is much said about the technical skill sets that are eroding. And, that's undeniably true. The part of it that is generally described is the fact that, these days, we tend to build fewer systems, both in the number of copies of each system, but actually fewer numbers of systems. And, as a consequence, there are fewer opportunities for our science and engineering workforce to develop that broad skill set, or have the broadening experiences that are needed to be able to, not only develop those skills, but then also to pass them on to succeeding generations.

I think, generally speaking, we're heavy on analyzing early stage concepts and doing analyses of alternatives, which, broadly speaking, would fall under the category of what I would refer to as PowerPoint engineering. But then, when we do go and develop systems beyond that level, that's, I think, when we see that the later stage engineering skills really, in some cases, have eroded significantly.

Another part that's been discussed quite a bit is the infrastructure issue, both on the government side and on the industry side, that much of the infrastructure, especially the physical testing infrastructure, that we have used to great benefit over the past several decades, it's aging. It's very expensive to maintain. And, as a consequence, in many cases, we are all but forced to retire much of that infrastructure.

And, that puts us in a position where we either have to change the way we go about performing the role that physical testing used to play, or look at ways of modernizing that infrastructure by methods other than simply updating what we have. I think good examples, there, are the physical test facilities at, for example, the Arnold Engineering Development Center, most of which were built when that center was first started in 1951 through about 1990 or the early '90s. And, a lot of that infrastructure has had to be retired.

I think another good example is the space launch range infrastructure. I think the problems there are well known. Much of that is old equipment. And, there are questions about what is exactly the right strategy for being able to maintain the infrastructure that we need there. So, those are parts that I think are relatively well known.

I really just have four other aspects that I want to take my time here to talk about. General Kehler, this morning, used the wonderful football field analogy with the hugely-- not only more, but many different kinds of players all at once, and non-traditional players on that field.

And, I think there is something equally important going on in the R & D community that deserves attention, the idea here, of course, being that you have to understand the root causes of the problem if you're going to try to address it correctly. I think this is where a venue like this,

and indeed, the discussions that will be started out of a venue like this, can play a very important role.

If you look back about 20 years ago, there were really a remarkably small number of nations worldwide that could be rightly said to be significant players in the overall-- let's say the whole acquisition enterprise, from the R & D side all the way to the engineering development and the fielding of systems that had significant military capabilities. That is to say, there was a small number of players that were able to produce militarily significant technologies and systems.

And, that has changed quite a bit in these 20 years. If you look today, if you look at the ISI science citation index, and if you were to ask yourself-- I doubt this is a question most of you would wake up in the morning and ask yourself-- But, ask yourself, for a moment, how many technical papers do you believe are published worldwide every day? And the question is only interesting because the answer is so stunning. There are 42,000 technical papers published worldwide every day, every day.

That number was significantly smaller even ten years ago. But, there's been a much more important change. And, that is that, even ten years ago, if you wanted to enter one of those technical domains, for whatever purpose you wanted to derive from that, then the effort that was required, the time that was required for you to be able to access, even a very small set of those S&T endeavors, was a months-long process. And, even at the end of that, you would have very low confidence that you really had seen, asymptotically, everything that there was to see.

Today, you can sit at your desk and a few mouse clicks away are almost all of those 42,000 paper. And, in a matter of hours, you can literally come up to speed on a given area and see where the productive paths are, and which paths have been tried and don't work as well.

So, one of the barriers to entry in this whole militarily significant capability development process, on that very front end, has changed dramatically during that time. There are a lot more countries and players and various countries that do have access to that information, as a result, itself, of technology. But, if you look at, especially where the past 30 years, we have educated a

stunning number of foreign nationals in our undergraduate and graduate programs at our universities here in the U.S.

Contrary to popular belief, it is not true that most of those individuals have stayed here. In fact, most have gone back to their home countries. And there, they have built up their own educational systems and, indeed, engineering capabilities that, while modest, perhaps, by our standards, have created an impressive number of countries that have-- Again, I emphasize, they are not our peers, but they do have the ability to begin to produce militarily significant equipment and capabilities.

And, what's more, there's a lag effect involved in that. So, even the people that we've already educated, those that have gone back, the impact that they will have on their in-country ability to conduct serious defense-related research and development has yet to be seen. There is an inherent lag process in that. And the numbers, of course, are not decreasing. We are continuing that process. And many would argue, I think rightly so. But I think we have to understand what the impact of that is.

And, of course, the diffusion of systems that result from those endeavors on the worldwide arms markets, I think, have an impact far beyond even those countries. So, that's a very different football field than what we dealt with, as I said, even 20 years. And, I think we need to understand what the impact of that is and how it will impact our acquisition strategy.

I think our job-- I put it forward as a rhetorical question here—is, I would contend, to accept that at least the representation of the U.S. in the worldwide science and technology environment is going to decrease. That is, I think, unavoidable, in terms of sheer representation-- dollar terms, the number of players, and so forth.

I think our job is to make sure that our capabilities relative to the rest of the world do not follow that same curve. That is to say, if we choose to focus on the right technologies, the ones that map correctly into the likely future environments that the Air Force will be working in, then I think it is anything but a given that we have to follow the same curve as will our sheer representation

worldwide. So, I think that's a set of important decisions that have to be made. And, we have to understand the strategic perspective that underlies those decisions.

There is another piece of the industrial base aspect that I think is largely underappreciated and is worth putting forward for your consideration. We often talk about a shrinking R&D community. And I would contend that, as much as anything else, there is a fundamental shift in the way R&D is conducted, at least here in the U.S., but arguably, to a lesser extent, but a growing extent, in Europe and Japan as well.

Again, if you look back 20 or 30 years, most large engineering companies had substantial in-house R&D organizations. And, those organizations conducted everything from basic research to applied research, advance development, and even interfaced with the engineering activities to develop real systems. Examples are, that come to mind, of course, include AT&T Bell Labs, perhaps the most famous, but the Xerox Palo Alto Research Center, TRW -- it's a very long list of companies that had these substantial organizations.

And, indeed, they viewed those organizations as providing much of the seed from which their own future business products and services would come from. And then, we went through a shift, where there was a change in the country, where we focused on business efficiency to a far, far greater degree than we had before. And, that was a nationwide trend.

And, as a consequence, the fixed costs of supporting those R&D organizations became viewed as unbearable. And most of those large companies, either largely or completely divested themselves of those internal organizations. Now, that coincided, roughly, with the end of the Cold War. But, I would contend, it was not caused by the end of the Cold War, and, in fact, it's important to understand that it was not caused by that.

It is, first and foremost, a result of the increasing shift of focus on business efficiency. But, at the same time, there was a growth in our capital markets. Again, here in the U.S., I'm talking principally. Also, a societal shift to focusing on technology-oriented or technology-derived

consumer products, things like PCs and cell phones and such, disproportionately in the electronics sector, but in other areas as well.

And, that led to a growth of entrepreneurial companies here in the U.S., often funded through the SBIR, Small Business Innovative Research Program, a program that had been in place since 1982, but was significantly expanded in 2000. It's an interesting set of numbers that I'll just very, very briefly go through.

Today there is about \$2 billion dollars annually that gets put into small companies through SBIR. And, the point I'm trying to make, here, is that much of the activity, the science and technology on the industrial side, that used to occur within our large engineering companies, now is occurring in these small entrepreneurial companies.

Over half of that \$2 billion dollars a year in SBIR funds goes to companies with less than 25 employees. So, these are very, very small organizations, typically built around one or two technologies, trying to develop those by mortgaging their house and their children's future and whatnot. And, if that technology succeeds, then they'll be bought by a company, if indeed that technology is in a market area that is deemed valuable enough.

Well, if you look at that \$2 billion dollars in SBIR funds-- and I would contend here, for your consideration, that this is really where much of the S&T and early stage R&D is done, that our nation relies on for its military capabilities. It turns out over half, \$1.2 billion a year, is associated with DoD services and agencies. And, if you look at the split among those, the Air Force is the single largest contributor to the DoD/SBIR endeavors.

I think that suggests that we ought to ask ourselves, given the role that these SBIR funds and the companies that they support play in the whole acquisition chain, on the front end of it at least, I think it's worth asking, given that the Air Force is the largest single player in that domain, do we need to restructure that program in a way that it can better meet the R & D needs that support this acquisition strategy that is, really, the subject of this topic?

I think I'll, very quickly, just wrap up on two other issues. One is the STEM issue, which gets a lot of attention, rightly so. I mean, the Air Force held its first STEM conference in August, this past August. And, there were some very important high-level decisions made there about how we were going to attack that problem, as a way of keeping the skill sets active that the Air Force needs, to be able to support an effective acquisition process.

Now, I'm all for increasing both the number and the quality of U.S. science, technology, engineering and mathematics graduates. And, indeed, other nations recognize the value of their STEM graduates to improving their standard of living. But, I think we have to understand that problem correctly. The numbers don't bear out what is often said, which is that there are declining numbers of degrees being awarded in STEM fields. That is not the case. The numbers actually show that our STEM degrees are going up.

And, I remember hearing about an impending shortage of scientists and engineers 35 years ago when I was an undergraduate student. And, we're still talking about it today. So, I think we can work through the sheer numbers part of the problem. I think the challenge, there, is for us-- and there are ways we can do it-- to put in place working level initiatives.

And, you see some of those being done around the research labs, for example, in Dayton. Near Edwards Air Force Base, in that vicinity, there are some very, very good and very successful initiatives being done at the grassroots level, to ensure that we draw people into the Air Force labs and be able to provide the skill levels that we need there. So, I think STEM is an important piece of that. But, we have to understand it correctly.

Very last point in my last 30 or negative-30 seconds, is to point out that we're in likely times of flat, or perhaps declining, absolute budgets. And, in times like that, we need to have a very clear understanding that we cannot invest in everything. At some level, of course, all science and technology is valuable. That's a true statement. But, that's a useless statement. We have to, instead, figure out which technology investments the Air Force needs to focus on, either because they are, themselves, so valuable in that future environment that it's going to be operating in, or because they won't be picked up elsewhere in the industry.

