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I wanted to talk today about some of the research and development efforts that we are involved in that have relevance to the things that I think are of direct interest to Kentucky. I head one of the twelve major commands ("MACOMs") of the Army. I work directly for the Chief of Staff, the senior uniformed official in the Army, but also for the Secretary of the Army; and in fact the secretary has an assistant secretary, named Secretary Dawson. I pay attention when I get introduced by Secretary Dawson, even though this secretary is Kentucky's!

The biggest single part of our business (from the standpoint of dollars) is design and construction -- overseeing the work that is done by contractors, not only in the United States, but also overseas. There's been a great deal of construction taking place in our Army over the past six years. Most taxpayers don't have a current working knowledge of a very different Army that we have in 1987. It's an Army that is married. Army veterans wouldn't recognize it if they looked at it "up close or personal." We're fifty-four percent married in the active Army, even larger than that in the reserve component. That's not a surprise. We have seven hundred eighty-one thousand active soldiers, both men and women. That represents over four thousand spouses, again both women and men. It also represents something like four hundred fifty thousand Army brats that their fathers and mothers claim on income tax every year. That's an astounding figure for those Army veterans of ten years ago, if not thirty. The construction work for the Army and the Air Force reflects that in an astounding fashion. We have been overseeing well over $4 billion worth of construction work for those two services, new construction every year, and that work is oriented in a major way on the family nature of the services.

I work directly for the water resources side for Assistant Secretary Bob Dawson, who is the senior policy official in the United States Army overseeing the Corps of Engineers work in water resources. Flood control and commercial navigation are the big hitters these days. That program runs over $3 billion a year. It is a big program, even by Washington's standards. We were given a big infusion of health last November, when the Congress passed, by overwhelming majority in both houses in the waning hours of the Ninety-Ninth Congress, and the President signed in

November, the Water Resources Development Act of 1986. We had not had a major water resources act for a decade and a half, and that law not only authorized a whole group of new projects, but even more importantly, it gave a direction in the law of water resources at the federal level that will take us well into the twenty-first century, and take the Corps of Engineers well into building the needed water projects for the next century for our grandchildren.

The research and development that goes along with those responsibilities that I briefly described does have some direct application to many of the responsibilities that many government levels share. What we're doing with research and development in my organization is looking for ways to accomplish our missions in the most efficient and most cost-effective manner. If we can't prove that, the guys that watch me do my work do not ask for more money for us to do that.

To that end, we have four laboratory centers and several other organizations that are essentially R&D in their nature. About twenty-five hundred Corps of Engineer civilians, and a handful of military at our labs, perform about fifty-five percent of our research program -- that is a little over a quarter of a billion dollars of research annually. That's an amazing number. The Corps has one of the largest labs in the United States Army. As I mentioned, the budget for this year for our labs is over a quarter of a billion dollars. Suggesting all of those missions that I covered, much of that work is done by reimbursement from the gaining organizations, sometimes our own districts, sometimes the Air force, sometimes the Navy. The Department of Energy is a big customer. The Department of Defense and other elements of it gain from our research.

We are a very decentralized organization. We push down an inordinately large amount of responsibility from our Washington headquarters. We do our work through thirty-eight district engineers. Almost all of them are colonels. I was met at the airport this morning, and was brought over here by Colonel Bob Oliver, who is our district engineer at Louisville. He's one of those folks who give our laboratory specialists contracted project work that he has money for, and he makes sure they do it right. That's fifty-five percent of what we do in-house, according to our civilian experts in the arcane fields that we work in.

However, forty-five percent of the work that we do in research and development, we contract out. We do it through contractors, and we do a large bulk of it through universities. Some of it we do through laboratories or other agencies where they have special expertise. We try to do it the most efficient way we can.

I have a senior executive service member with me, that means a career senior civilian. Dr. Bob Oswald is a career employee of the Corps of Engineers that I just hired for my office in Washington, D.C. Before he came to work with us, he worked for the Army Material Command, and he knows laboratories and that business extremely well. In fact, of the senior executive service, one way to describe what they are, those are the "civilian generals" in the Corps of Engineers. The Corps has sixty-two of them, and twenty percent of those are in the research and development business, which gives you some measure of how much importance we put into the R&D and technology transfer business for the federal government. It's a very highly applied effort. We do the most we can by taking products that are already there, techniques developed by industry, and then modifying them for either civil engineering kinds of things, or for military kinds of things, like how to make a tank do better over ground, or how to improve beach landings. We do some work for the Marine Corps, too. We use university and industry work heavily, and try not to invent new things to do these things. We are primarily in an "adapting" R&D organization. This is a problem solving process, where we systematically look at all new ideas that are out there and apply them to do more cost effectively and more

efficiently and responsively the work that we are responsible for, for the U.S. Army primarily, and our other customers.

We have four major labs. The smallest of our four labs is the Cold Regions Research and Engineering Lab. We call it CRREL, and it is in Hanover, New Hampshire. It has a working daily relationship with Dartmouth, and it's up there that we work on such things as ice engineering, river ice management, remote sensing, cold regions hydrology, and construction. How do you build something in Alaska, for example? How do you manage the building of under-snow camps in Greenland? Those are the kinds of things that we do. The demand for their work is high. For example, we have completed, within less than a year, a new frost effects research facility that reproduces the differential temperature effect between ground and air, and the effects of pavement and structures that are caused by frost heaves.

The U.S. Army Construction and Engineering Research Lab is also not a very large one, about two hundred and fifty Corps of Engineers folks. But like the one at Hanover, it has a very close working relationship with a university -- the University of Illinois. Two hundred and fifty of those folks are Corps of Engineers, but we have effectively on a day-to-day basis, five hundred people. The rest of them are students, faculty, and University of Illinois employees that are working in coordination with us to bring about the kinds of things that we do, as far as tech transfer and building materials, utilities, structures, and integrating technological developments in construction. In my view, that is a very good story of efficiency in making the federal dollars spread.

The largest of our labs, and probably the most famous, is called the U.S. Army Engineer Water Experiment Center Station, or "WES." I find that people around the world know of it as "Waterways." It was indeed invented around 1930 by a Corps officer, Herbert Vogle, who headed the TVA in the 50's. He retired as a brigadier general of the Corps of Engineers. As a first lieutenant, he established the Waterway Station, and it has grown since then. It now has six separate laboratories. Just naming them gives you some idea of what they do: the Hydraulics Laboratory, the Geotechnical Laboratory, the Structures Laboratory, the Environmental Laboratory, (and you need one of those to stay alive in my business!), the Coastal Engineering Research Center, and an Informational Technology Laboratory. So, it's come a long way from just "Waterways." I have gone around the world and talked to fellow engineers, and in some cases, R&D folks, representing universities at foreign places. I've talked to scientists in Europe, in Tokyo, in Osaka, in New Delhi, in Singapore, and in Niamey, Niger. And in my conversations, I find they know "Waterways" and I find they will quickly reach for a manual or a report that pertains to their business, because the "Waterways" has been putting out those manuals and reports since 1930. It is really a center of expertise that I am inordinately proud of.

Another lab center we have at Fort Belvoir, right near Washington, D.C., is the Engineer Topographic Laboratory. Among my additional duties, I'm the Topographer of the Army, in charge of trying to get maps and remote sensing kinds of information that you need to fire a missile from point A to a place six hundred miles away, point B. All that takes topography and knowledge of where things are. That Topo Lab conducts the R&D that applies to both terrestrial and topographic sciences, and it is perhaps the most technologically advanced of all my labs. That is because we work closely with space technology and with some of the most sophisticated equipment that we have in remote sensing, both above the atmosphere and down on the ground. "ETL" (the Engineer Topo Labs) has that.

We have a couple of other activities that are in the R&D business, and they are very important to the work that we do in the Corps. Our Engineer Institute for Water Resources (we call it "IWR") is also at Fort Belvoir. The experts there look at comprehensive river base studies and regional planning. Some of the issues

Kentuckians are involved in and concerned with, are economic, social, and environmental aspects of project planning that must precede large projects. That's where our thinkers are.

We also have a very neat little place, about twenty-five scientists (mostly PhDs) in Davis, California, at a center of expertise called the Hydrologic Engineering Center. Those Corps folks know more about hydrologic engineering in the modern sense of the word than anyone else in the world. It's a neat place that does extremely important work for us and provides us information that allows us to save literally millions and millions of dollars a year.

Then finally, we have an Engineer Study Center which is part military and part civilian. Some of our best operations research type experts (both civilians and military) are there at Fort Belvoir, about fifty. We put them in a closet, give them things that are extremely important to the U.S. Army. They study and come up with recommendations that the Army's senior leadership shoot at.

The safest means of transportation, water navigation transport, doesn't go everywhere. However, the safest means of transportation of the big five, especially for major bulk shipments, is indeed water because it tends to be away from population centers, and it is usually under pretty good control.

Annually we do approximately $20 million worth of what I can call highway research, which includes pavements, road drainage, and so forth. We get into highway related research, not just because of highways, but because we do air fields, and we do motor pools. Motor pools sound sort of dull and dreary, but I've talked about the soldiers. Our soldiers do not volunteer for the U.S. Army and stay in. We give them the most modern equipment that we're getting now through the recent defense budgets, but often we don't give them a place to take care of it ... meaning a motor pool. There are so many places still in the world where we haven't done it all yet. Our soldiers are expected to climb under the truck or tank in the mud, and we are putting a lot of money to try to give them a place that they can be proud of. About twenty million dollars a year, about seven percent of our overall research budget, is highway research relating to all kinds of pavements.

My "gee whiz" figure for the day, five hundred and sixty million square yards of pavement, is what we have at Army installations alone. The research areas include such things as pavement design, pavement materials, construction, road concrete pavements. We've been deep into that, both in the business of building dams with "RCC" (Roller Compact Concrete) but also particularly over the last two or three years trying to improve the technology so we can make cheaper motor pools and roads in RCC.

Expedient construction is important to us. Most taxpayers are more impressed and get more out of expedient construction things than we do. The Army and the Marines have to move over beaches, and you can't bog down in the sand. When you talk about expedient construction, that also should bring to mind that period of time when you have the temporary arrangements while you're building the permanent fix, whether it be a road or a bridge or whatever, and expedient construction means you might have a lot to offer to folks in the permanent non-expedient highway business.

One aspect of pavement design R&D involves developing techniques and procedures for predicting the weakening of roads due to frost and thaw. Kentucky probably is more interested than Florida and less interested than Wisconsin, but we are conducting laboratory studies to assess the potential for using soil index properties to measure the susceptibility of soil weakening under the freeze/thaw cycle. About half the United States is directly affected by that, both U.S. industry and U.S. government agencies: state, local, federal, it makes no difference. We're there; these are federal dollars largely; and we share it. We're also assessing the influence of geotextiles, and restricting moisture migration in frost susceptible soils. Another

typical research effort that we are conducting in the use of new frost design procedures is to reconstruct a runway in Wisconsin. We did part of the runway by the reconstruction technique, and weren't sure it is going to work, and the other half we didn't. We used the regular techniques to maintain it, and now we put measures on it, so over the next several years we'll find out which one is the better way to go.

I already referred to Roller Compacted Concrete ("RCC") pavements. There's a good deal we are doing there. The first RCC dam in the United States was finished about four years ago by us at a place called Willow Creek, Oregon. Since then, there have been about six or seven, either underway or completed. Two or three were built for the Bureau of Reclamation, and there are at least two that state agencies have taken up to build. So, we are plowing some new ground in that area. We've learned a lot, and we're doing it a lot better today around the world than we did five years ago. It was a successful dam effort.

I also mentioned that we were working on the concrete pavement side with RCC that is facing, even in the Army, some acceptance problems. It just doesn't look as pretty as the pavements that our customers are used to seeing. However, we don't know all the things about them either. Are they more susceptible to frost or are there going to be more maintenance problems down the road? As we learn those things, we again are prepared to share them with industry and the government of the United States.

Concrete technology is another area we're looking into. A buzz word that we invented for ourselves a few years ago was "REMR": Repair, Evaluation, Maintenance, and Rehabilitation of Concrete and Steel Structures. This is the business of the aging infrastructure of the United States, and we have shared that with many people. The primary thrust that we're doing frankly refers to locks and dams and things like that. However, the knowledge we're developing in "REMR", such as how to maintain the concrete, is applicable all across the industry, and we share that technology as we develop it with the Transportation Research Board and others from around the world. We're also studying things that have a general interest to industry, such as cracking phenomena in concrete, so we understand it better.

The Corps and the Air Force care about maintaining runways under attack. To know how to fix runways in a hurry is crucial. Otherwise, the Air Force planes would have taken off, but they can't land. Our transport planes bringing in our reinforcing troops and materials can't get in, so we are just as interested in that as the United States Air Force. So, to us rapid repair materials is a very big heavy hitter item for the Army and Air Force.

Keeping highways open while making needed repairs can be done using these rapid repair materials. Polymer concretes, fiber reinforced concretes, epoxy injection of concrete, and many other areas like these, qualify as rapid repair methods. Sand grid confinement is another rapid repair material/method. I've been trying to find a way to describe what I mean by sand grid confinement. The gizmo is about 18 inches thick, it's long and fairly wide, but it's very easily transportable. You can transport many of them in the bed of a truck. I describe it by saying if you take one of those cartons that has room for twelve wine bottles or liquor bottles in it, and you take out the grid that keeps the bottles apart, of course, it will fold flat, and that is what it looks like. But if you spread it out, and then fill it with sand, and put that down, you can drive over it, if you put it down right. What it does is keep that uniformly grated sand in place. It keeps the sand from moving, and it really is a substitute for finely grated sand that doesn't move around, doesn't rut, and it doesn't bog your trucks down under a situation that we have to face in a combat zone. We're doing this with special kinds of material now. We've found the most economical material and the design that lasts the best. There are many places in which these sand grid approaches provide transport with poor soils for a limited period of time. Perhaps in

the future, sand grid confinement may have application to a number of our transportation needs across the U.S. There are other applications of that grid that also apply to transportation needs. We found that we can use them for protection, embankment stabilization, erosion control, drainage ditches, footings for bridge peers, crash barriers. We get protection for the crew when it's placed around an artillery piece.

I've several times mentioned finding ways to extend serviceable life of pavements in coal regions. Suffice it to say that we are putting a lot of effort in this, and if there are some special needs that Kentuckians have, I'd appreciate it if you'd put them in writing for us. We're glad to share what we have. One other thing that the research folks are very much acquainted with is an application that we came up with called "PAVER". It is a computerized management pavement system which identifies the most economical time periods for road maintenance. PAVER provides storage for data, defines the network, rates the condition, prioritizes projects, schedules inspections, determines present and future network conditions, determines maintenance, conducts economic analysis and produces the budget. Therefore, the entire road maintenance schedule can be presented to the Secretary, and hopefully after you've convinced him and the legislature, you can then take it the bank. We have been using that successfully at both Army and Air Force institutions. The APWA has accepted it, and it is now something that is circulating around the United States. It is one of our success stories in sharing things that we've learned as we try to manage the taxpayers' money in a better way.

We're doing a good deal of research in the water resources area. One large transportation related area that the Corps supports work within is the waterways. It is something that I think taxpayers should know about. Kentucky and the other states around her have a great deal of dependence that might not be known very well because water transportation is taken for granted by many and is not known by too many others. People don't see much of it unless they travel from Covington over to Cincinnati, or watch WKRP in Cincinnati, and get a snapshot of the waterways. We've been working on the Ohio/Mississippi system since the early eighteen hundreds. We now have in this country twenty-five thousand miles of inland waterways serving 87% of the one hundred and fifty largest cities in the U.S. There are very few cities that are not directly served by either our ports or our waterways or both. We also maintain and operate two hundred and fifty locks and dams in that system, and maintain about fifty major ports and four hundred smaller harbors around the inland waterways.

In the 1930's and the 1950's, and even in the last few years, there's been a lot of discussion in Congress about modernizing, for example, the Ohio River system. The nation decided to modernize the Ohio system in the 1930's. It was an engineer President named Hoover who predicted that within ten years there would be congested traffic on the Ohio river. The people were poo-pooing him at the time. Within ten years, the river had responded something like two or three times what he had predicted in 1930 or 1931, when he made that speech. We've had predictions like that since. Not too many miles from here (about two hundred and fifteen, as the crow flies) is the northern end of the Tennessee-Tombigbee Waterway. We built that for $1.7 billion. It's a shortcut to the Mississippi from the Ohio and Tennessee systems, and some of my most spirited conversations over the past eight years, since I've been in Washington, D.C., have been with congressmen and senators from other parts of the country who don't understand why we're pouring $1.7 billion dollars into a waterway. Senator Pat Moynihan once called that the "clone of the Mississippi." "Why do you need two of them when you've already got one that doesn't have one lock on it?" he asked. That shortcut argument we finally brought to closure after a memorable trip down to the Tenn-Tom with the senator, in which Moynihan said,

"You know, General, I promise not to say in public that the Tennessee-Tombigbee Waterway is a clone of the Mississippi anymore. I understand what you're doing, and you've made your point. However, I still think we ought to get more money in public works in the Northeastern part of United States." However, for one piece of the Tenn-Tom story, even though it was a controversial project, we finished it two years early. It was supposed to be finished a few months ago, but we finished it over two years ago. We caught the industry and the local communities not ready for it. The docks weren't prepared, and the loading paraphernalia wasn't prepared. We also caught the towing industry and the barge industry in a terrible slump brought about both by some of the coal and grain problems in other portions of this area and the Midwest. So, we found the towing industry in a slump that I believe is temporary.

My crystal ball isn't better than anybody else's, but I think that coal is going to rebound. I'm almost as sure in my own mind that so is grain. In any event, the traffic on the Tenn-Tom started slow. Traffic was slow on the Ohio after President Hoover's speech in 1931 about the Ohio. President Hoover's speech reflected a later navigation project on the Arkansas. We finished that one about seventeen or eighteen years ago, and it had virtually no traffic for the first two or three years. By the eighth year, however, it had reached its twentieth year ultimate projection of traffic. The thing that surprised us, and it was already on the Tennessee-Tombigbee, the traffic wasn't the kind we predicted it would be. It takes industry, and it takes the preplay of this economy of ours, this very vital economy, to decide what the waterway will offer.

The other side of the world doesn't have that kind of freedom. Time will find reasons for this economic transportation I am certain, and I would like to handle the Tenn-Tom question. I don't have to handle it today, but I would prefer to handle it in eight or ten years when we see that one come up.

But the other story of the Tenn-Tom that I'm inordinately proud of is that the decision to start the Tenn-Tom came from Congress, along with the NEPA Act. The environmental act that came pouring upon us in about 1970, poured down on all of us in the engineering and development business. It really gave us a rough row to hoe. The Corps was fighting to stay alive, and we weren't sure how to adapt to this. Often our hands were tied, and we were in court all of the time; regulations kept coming up. The reason we weren't stopped with that $1.7 billion project was that around $170 million of it was adjusted to the original non-environmental plan so that it would fit that part of the environment in that portion of the United States. That was a good story. We hired a board of environmental consultants, and we listened to them, and we dealt with them, and we were able to take that to the bank, so to speak, and finish that project. It is a good story. I wish I could say that about some of the other big projects that we're working on.

One other area that I refer to, it's not a huge actor on Bob Oliver's Louisville District stretch of the Ohio River, but is extremely important to us as a nation. It has to do most directly with the fifty major ports that we're responsible for keeping open from the standpoint of annual dredging. You have to take deposits off that have been collecting there from places that sometime provide very bad materials, and you've got to put it somewhere. It's sort of like toxic dumps. Everything has got to go somewhere and that includes our dredge material, which sometimes is not clean. More often than not, it is, but we have to prove that it's clean before we put it somewhere. We had been putting literally millions of dollars into our dredging efforts, so we know what we have and we can explain to folks that dredging material can have good effects, too. We're going to use the good effects of the dredge materials to maintain those harbors that we have. With the new laws, we are going ahead and improving our harbors so that we have a better competitive world. That has been money for the taxpayers that has been very well spent. We are seldom stopped in court on our port-dredging facilities, and that is a good story that I'm happy to report.

It's a direct result of the research and development done at the waterway station between our "waterways" and environmental laboratories.

Our surveying and satellite applications indeed include areas that are of interest to many taxpayers: surveying, mapping, and remote sensing. In fact, we cut our teeth on remote sensing right up the road in Cincinnati. We were able to arm our Louisville District, about eight or ten years ago, with remote sensing capabilities. This effort broke the code on what remote sensing can do for an engineer as you're planning, and then have to explain your planning to the rest of the world.

I attempted to describe the flavor of the Corps research and development program, and I wanted to depict the capabilities that we have. I hope some feeling for the stewardship we've been providing to those portions of taxpayers' federal dollars, both in the water business and in the military business for which we are responsible, has come through. Most of the rest of the research and development in the U.S. Army, as is true in the other services, is centralized in one major R&D and acquisition command. My predecessors for many years and I have been attempting to make the same point: that it is important for the engineer who has to do the work on the ground to also be able to keep his or her hands on the research and development that supports that engineer. We have been successful in keeping those labs in the Corps of Engineers. Over the last several weeks the Army has been debating whether to give me another lab. This lab happens to be one in terrestrial and environmental matters. I shudder a little about that, because I've been reading the headlines, and I'm afraid it might put my organization in the business of becoming the expert or the bad guy in acid rain. I don't have that now and I don't want that one. But if they want me to take it, I'll use the Corps of Engineers motto ... "Essayons", or "We'll give it our best shot!"