Opening Address

A Military Manager Takes the Measure of Tomorrow

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LADIES AND GENTLEMEN—It is a pleasure to address this combined assembly of professionals who have given so much to mapping, charting, and geodesy. You do me a signal honor in inviting me to open your convention, giving me the opportunity to meet the outstanding people in one of the most important conventions that will take place in our nation's capital this year. I am also pleased that we could be joined in these sessions by representatives of the Pan American Institute of Geography and History. I have just returned from a visit to some of our Latin American neighbor countries, and am highly impressed with the importance of the cooperative efforts that are taking place in Central and South America. To them, "bien venido a Washington!"

Although I am new to the Defense Mapping Agency and new to most of you here, I have had a long-running professional association with experts in the MC&G community. There is certainly no doubt in my mind about the heavy dependence that national defense places on the knowledge and expertise you have in "measuring and interpreting the shape of things." You do an important work. As a matter of fact, I believe that there may even be an appointed guardian angel looking after us—"blessed are the mapmakers for they draw nations together."

Although I represent a military agency, I am keenly aware that military and civilian mapping have a great deal in common, our business in the military is preserving the peace. That is as important to us as to you. And, of course, we know that one way to preserve the peace is to be ready to protect ourselves. A wise man once said, "One sword keeps another in its scabbard." We take our work seriously, because the way to deter war is to be able to do the job if it should ever become necessary. I join you in hoping that that job will *not* become necessary.

This morning I want to take a look with you at how together we enhance our mutual capabilities to be ready, so that we can enjoy the blessings of peace—drawing nations together professionally, in technology, and in mutual understanding and progress.

Your convention theme is "Measuring and Interpreting the Shape of Things." I would like to hedge a bit on the theme and interpret the shape of things past and of things to come. I will cite four examples that come not only out of hard-and-fast experience but also right out of today's headlines. All are of direct interest to the mapmaker, because he has a great role in each of them, as he does in so many aspects of our society. I happen to have had a direct responsibility in each of these four major programs, which have special implications for our MC&G community. They are (1) developments in inertial guidance and control, (2) the intercontinental ballistic missile program, (3) the cruise missile, and (4) exploitation of breakthroughs in automatic data processing in our business.

As a military program manager in Air Force systems development and testing, I had an early exposure to the science of Earth measurement. In the mid-1950s, as a young Air Force captain, I was privileged to work with a civil arm of the MC&G community, the Coast and Geodetic Survey, flying over calibration ranges, proving out inertial navigation systems. The C&GS people had surveyed several ranges. They extended from Eglin Air Force Base, in Florida, to Mountain Home, Idaho, Ramey Air Force Base, Puerto Rico, and Hanscom Field in Massachusetts.

We made several flights along those calibration ranges, carrying on board the very first of the first-generation inertial navigation systems. We determined our position over the ground through a combination of aerial cameras, radar, visual observations, and the old Norden bombsight. On those occasions when we remembered to remove the lens cover from the camera, we found that we could establish our position within three miles, using the best inertial system of the time. But that three-mile capability was not a limitation of the inertial unit: indeed, it proved good to one mile per hour: our major problem was in establishing our aircraft position relative to the ground check points.

There could hardly have been a better lesson for me as the lone Air Force officer on many of those flights: as an airman seeking the ultimate in precision flying I came to realize that we were completely dependent on the expertise of the surveyor and the mapmaker.

To bring things full circle in this matter of measuring and interpreting the shape of things, late last year our Defense Mapping Agency completed the survey of a segment of the CIRIS network—the completely integrated reference information system—which will be used to evaluate present-day inertial units. The CIRIS stations were put in with the use of Geoceivers, employing Navy navigation satellites as signal source for the Doppler measurements. In the near future we will be able to use the Global Positioning System for this instead of the Navy satellites, with an attendant increase in accuracy.

The inertial measuring units which form the heart of these inertial navigation systems have been developed over an extended period of time, requiring a very large national investment of dollars. Our success has been unmatched by any competing technology, anywhere in the world. It has been stated that the principal advantage we have in the free world, and especially in the U.S. is in science and technology: The exploitation of that technology in the development of these highly/sophisticated inertial units is a primary case in point. DMA, or our military predecessors, and the civilian MC&G community have played a significant role in helping to develop these inertial units. As I indicated earlier, we are still very much in the inertial business, measuring the shape of things to come, so to speak. Technically, we are at a threshold right now with inertial systems. The problems of achieving further precision are not primarily in the hardware. A large part of the problem derives from anomalies in the gravity field. And so it is the gravity aspect in the error budget that is now under heavy attack by DMA. Recently, I was shown R&D systems that are truly astounding to an Air Force pilot who thought a one-mile error in inertial, hands-off cross country navigation was pretty good. The new systems put those big, clumsy black boxes we had to shame. The heart of future systems may be an engineering and production wonder called a moving-base gravity gradiometer. My own DMA is helping to guide these gradiometer developments. These should be very useful in building new gravity field models of the real earth. With high-density data we should be able to interface with fourth-generation inertial systems, gaining a truly significant performance improvement. Navigation as an art will be nothing short of fantastic as it merges with geodesy as a science. The implications for the civil community—in navigation, surveying, and oil and mineral exploration—are obvious.

The whole matter of MC&G work, of course, is satisfying a customer's needs, whether it be those of a large military operation or of a private individual. Your theme reminds me of something by Henry David Thoreau. It is from an essay titled "Life Without Principle" and reads: "As for my own business, even that kind of surveying which I could do with most satisfaction my employers do not want. They would prefer that I should do my work coarsely and not too well, ay, not well enough. When I observe that there are different ways of surveying, my employer commonly asks which will give him the most land, not which is most correct. I once invented a rule for measuring cordwood, and tried to introduce it in Boston: but the measurer there told me that the sellers did not wish to have their wood measured correctly—that he was already too accurate for them and therefore they commonly got their wood measured in Charleston before crossing the river." Mr. Thoreau could measure and interpret the shape of things better than his customers wanted. Our problem is somewhat different. Once I was the military customer: Now, as the Director of DMA, I'm trying to find out what the customer wants. Help him understand what we can do and what, for various reasons, we *can't* do, and get him the product or service as expertly as Mr. Thoreau would have liked to serve his clients.

The needs of the clients we serve—the Military Arm and the Merchant Marine—are epitomized in my own weapon system research and development experience: the Titan and

Atlas ballistic milliles, inertial systems, advanced reentry systems, and the B-1 bomber. With each of these programs, I have come *face to face* with MC&G problems and potentials. Frequently, required technology was not available when we needed it. We in the DOD program management business have had to carefully define our MC&G needs, or lend aid in developing new technology to satisfy those needs. My view of your activities, is, therefore, based on a long association and familiarity; it is a view biased by my military background. It is the "military program manager's view of MC&G" that I reflect today.

Management in the military itself has been a developing art. In World War II, Korea, and the 1950s, managers were primarily concerned with two things: technical feasibility and military effectiveness. In the 60s, Secretary Robert MacNamara introduced program management with a formal planning, programing, and budgeting system. All facets of a weapon system had to be considered in the development process. "Cost-effectiveness" trade-offs were of high consideration, with all factors of personnel, operation, and maintenance cranked into the calculations. Two decades have gone by. We now have all those earlier management concerns *plus* regard for energy problems, ecology and environment, interoperability with allied military forces, and arms control considerations.

Today's DOD program manager is challenged, then, with overall responsibility for the success—the military effectiveness—of his development effort. He must be knowledgeable of, and able to harmonize, a myriad of diverse elements. MC&G frequently play a major role, offering potentials for, or imposing limitations on, the final product. The role of MC&G is, in fact, rising rapidly in the hierarchy of factors which the program manager must consider.

The intercontinental ballistic missile and the cruise missile both had their genesis in the German Wehrmacht during World War II. The precursors of today's versions were, of course, the V1 and V2. The effectiveness of those V-weapons was dependent on psychological terror: their military utility was limited by relatively small warheads and gross system inaccuracy. The true intercontinental ballistic missile, as we know it today, was not possible until several state-of-the-art breakthroughs had combined to turn concept into capability. Key among these: first, a missile-compatible nuclear warhead; second, the transistor, for use in transistorized computers on board the missiles; and third, improved accuracy through resolution of the guidance, navigation, geodetic, and targeting problems.

This need for improved accuracy brought DMA's predecessors into the picture. Enhanced guidance and control demanded an in-depth knowledge of the gravity field which would perturb the missile in flight. It also meant that we had to have accurate geodetic positioning of launch points and targets relative to one another. The development of the geocentric relationship between launch and target points was probably the major task facing the MC&G community in those early days. Initially, then, we relied on huge warheads, accepted large positional error with the early Atlas and Titan I missiles, and aimed at *area* targets: later, with the Titan II and early Minuteman missiles, we reduced our aiming errors, largely through refinements in measuring the Earth's gravity field, as well as through continued improvements in target positioning. In the early 60s, we could aim at specific complexes, rather than large areas. Refinements go on: we do new correlations of launch and target points. . . we model the fine structure of the Earth's gravity field. Each of these reduces the error budget. As missileers say, the ultimate goal is to aim, not at a building, but at a selected window on a given floor of that building. . . to put the warhead in a predetermined room, without damaging the windowsill. We hope, of course, that we will never have to employ these weapons. But if that *should* become necessary, we want these systems to be effective: we want to come out on top. Precision targeting allows us to strike military targets while minimizing collateral damage to civilian facilities and noncombatants. DMA's MC&G support to ICBMS will continue with the new generation of the land-based ballistic missile—the MX—and with the sea-launched Trident missile. The MX mobile basing concepts, employing either trenches or shelters, will require astronomic, geodetic, and gravity data inputs. These are all required to initialize inertial measuring units. DMA will support the MX program in defining the means of acquiring these data, in surveys for the developmental program, and by providing data for the operational missiles. We are considering use of a variant of the vehicle-mounted inertial positioning system—or as you know it, the Auto-Surveyor—for part of this work. Evaluation of the MX inertial guidance system will require calibration of the high-speed sled track at White Sands Missile Range. DMA is acquiring equipment capable of measuring that 17-kilometre track to an accuracy of 1 millimetre.

The cruise missile will be in the armed forces of the 80s and beyond. The cruise missile is not a ballistic missle but an air-breathing machine somewhat like the old V-1, but with several significant differences! We improved on the German's crude V-1 in our work with the tactical Matador and the strategic Snark. We learned a lot in those days, and some of it was having to be humble about our own limitations. For none of these systems were overly successful, primarily because of warhead size limitations and inadequacies of the navigation and guidance systems. The cruise missile, however, is ushering in a new era of warfare, which provides a significant addition to our arsenal. It will come in several delivery versions: an air-launched version, called "ALCM"; the ground-launced "GLCM," a sea or submarine-launched "SLCM." The cruise missile will be hard to detect because of its low radar profile. It will have a remarkably efficient, small but mighty power plant. It can be used with either conventional warheads or nuclear payloads. It will be comparatively cheap to build and maintain and will have a combined guidance and control system resulting in extreme accuracy on target, if we ever have to use it.

Just as the ICBM was impractical until certain MC&G problems were resolved, so the cruise missile remained *concept* rather than reality until the MC&G limitations were removed. The concept involves a unique navigation and guidance technique, known as TERCOM, or terrain contour matching. TERCOM employs correlation techniques, matching a stored ground reference scene with a sensed scene developed during flight. Periodic comparison of the sensed and reference scene provides error signals for correction of the missile flight path. My agency is responsible for generating the TERCOM matrices that will be stored on operational cruise missiles. These are produced from DMA's digital terrain elevation data base. These matrices made the cruise missile concept viable: the accuracy with which DMA completes this task directly translates into reduced miss distance: more precise TERCOM matrices result in more accurate missiles.

Thus far, I have discussed the role DMA—and MC&G—have played in the evolution of three major militarily significant efforts. One can come away with the impression that MC&G is a panacea, that DMA has all the answers. Let me assure you such is not the case. I am reminded of the story of the king and his wise men told by Dr. Edward Teller years ago.

A King called his wise men together and said, "I have heard that the Earth is round, not flat. What is the truth?"

The chief wise man spoke and said, "O King, your question is profound indeed, and you, O King, are most fortunate that of all the wise men on Earth those gathered here before you today are the only ones who know the answer to your question. Know, O King, that the Earth is not flat but the round back of a turtle."

The King pondered this a moment and then asked, "And on what does the turtle rest?"

The head wise man again replied, "O King, only a few of the wisest men have that esoteric knowledge, and it is most fortunate that those few are here today. Know, O King, that the turtle swims in a basin of water."

"And what," enquired the King, "Does the basin rest upon?"

The chief wise man bowed before the King and said, "O King, of all the wisest of the wise men on earth, only one knows the answer to that question. It is most fortunate that he is before your now. Know, O King, that the basin in which the turtle swims rests on the back of the great white elephant."

At that the King pressed on: "And on what does the great white elephant stand?"

The wisest of the wise men bowed down even lower, and said, "O King,—that—not even *I* know!" Like the wise man, DMA is wise enough to know when we have run out of answers. As a matter of fact, we operate in relative degrees of ignorance. As the great American humorist Josh Billings once said, "The trouble with most folks isn't so much ignorance, as knowing so many things that ain't so."

This brings me to my fourth program: one thing that *is* so is that DMA is engaged in transition, and the heart of that transition is the exploitation of our DMA digital data base. For some uses it is not only possible but operationally preferable to convert from analog methods to the digital regime in building graphic presentations. Although we are not saying that we will ever totally do away with printed maps and charts, we are finding digital data base applications that meet certain needs of the user in unique and vital ways. Automatic data processing methodology also has a place in compilation and printing as well as other production phases. This holds the prospect of reduced inventories, more current products, and greater variety and content in our products. It also raises a key point: The military program manager more and more must be educated to the revolution I have just described. He must be able to understand what we are doing, and how we are doing it. He must perceive the flexibility and potential of these techniques. This is no easy task. Indeed, the DOD is in its infancy in the exploitation of digital techniques. Although we have many outstanding technical personnel laboring diligently in this area, we have merely scratched the surface in applying this technology for the benefit of the military field commander.

These comments on technology apply, of course, to civil uses as well, for the potential for new applications is virtually unlimited. The three-dimensional experimental map which the Engineer Topographic Laboratories and DMA have distributed at this conference is a good case in point. Although it is an experimental product, I believe it forecasts the shape of things to come. We have, today, the capability of generating this map, with selected cultural details and symbology, using a minicomputer and graphic display unit from stored digital data files. This requires only a few seconds. The slowest part of the process lies in printing the hard copy. With a graphic display scope used to augment hard copy, a military planner can effectively—and in near real time—accomplish flight mission planning, terrain analysis, or estimation of terrain masking effects. We may at last get to the point where we are answering the old complaint of the infantryman and the Marine leatherneck who ask, "Why do all battles have to be fought uphill and at the corners of four maps?" With digitized products there won't *be* any corners. Digitized techniques also allow us to consider such things as variable-scale maps and charts, expanding the scale at will in regions of interest. With portable, stored data bases, it may be feasible to do this in the field at some point in the future, lessening the need to transport large quantities of paper maps. I stress here that we do not see digital techniques *replacing*, but *augmenting*, the conventional hard copy maps. And when we think about portable data bases and digital techniques, the concept of developing inflight capability comes immediately to mind. We have used standard paper maps inflight for over 70 years; over the past four decades, radar has provided synthetic images or ground maps of an aircraft's flight path: Now the prospect is for augmenting these with a near-real time, inflight display of the terrain profile ahead of the aircraft, using DMA's digital data base for generating the video display.

The system manager must know about these possibilities: he must be able to take advantage of our automated cartographic, digital compilation and production potentials. He must plan to incorporate these into the technologies of future systems.

The transition to digital techniques and the production of our digital terrain elevation data base have opened new vistas for DMA. My earlier discussion centered on the key role of MC&G in weapon systems over the last few decades: I am equally optimistic about the prospects for application of the digital MC&G data to systems of the future. Indeed, I see an unknown, but seemingly unlimited, potential. The great virtue of the digital data base is in its flexibility for diverse applications. Augmenting these changes, we foresee a revolution in conventional navigation and positioning as a result of the Global Positioning System and gravity gradiometer-aided inertial units. By 1985, the completed GPS will provide a suitably equipped user with the means to determine his position anywhere over the surface of the Earth to less than 10 metres in three dimensions. He will simultaneously be able to find velocity to an accuracy of 3 cm/sec, and time to about 20 nanoseconds, all from the GPS.

In conclusion, let me flag two problems which concern DMA and, on a broader scale, this entire community: first, the need to predict accurately the key milestones and paths of technological developments to ensure timely and efficient planning. We must minimize false starts in adapting new technologies, and maximize benefits from application of our limited resources. It is vital that we continue to insure transfer of technology between the civil and military MC&G communities. Second, DMA sees a great need to educate the next generation of program managers to make them aware of the potentials and pitfalls of emerging technology, especially the potential for application of the digital data base. Only through the education of system managers and planners can we be assured that state-of-the-art MC&G capabilities will be intregrated in future system developments.

Forecasting our future and educating our program managers will require your active participation. The entire MC&G community, more than any other military-civilian discipline, has enjoyed a two-way flow of technolgoy. We have all benefited from an open interchange with much of our research and development; that interchange between DMA, industry, university, and other government groups must continue. We need the assistance of the ACSM/ASP members, you experts in the field, to stay abreast of the state of the art and to keep program managers current. This is a working relationship in a professional field that has much to do with coming great improvements in MC&G activities. It has to do with your jobs and your professions and your businesses. I am excited about the prospects. We *can and must* do it together. For in using our combined capabilities in mapping, charting, and geodesy we will not only help *insure* the peace but advance the kind of peace that we all want to enjoy.

Mrs. Mac cuts ribbon to open 1978 ACSM-ASP Exhibit.

Pres. Cartwright and Herb Trager discuss the Carl Zeiss Exhibit.