OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE
BOARD

28 October 1982

MEMORANDUM FOR SECRETARY OF DEFENSE

THROUGH: Under Secretary of Defense for Research and Engineering

SUBJECT: Final Report of the DSB Task Force on Mapping, Charting and Geodesy (MC&G)

The attached final report of the Defense Science Board Task Force on Mapping, Charting and Geodesy (MC&G) was prepared under the chairmanship of Dr. Ivan E. Sutherland. The purpose of the study, requested by the Director, Defense Mapping Agency (DMA), was to identify and evaluate current and future MC&G requirements in the DoD and to assess the capability of the DMA to respond to those requirements with regard to equipment, organization and funding.

The Task Force determined that DMA has made significant progress in accommodating ever-increasing demands for technical support, especially in processing digital data for use in modern weapon systems. The most significant recommendation made by the Task Force was that DMA now be authorized to commit funds in the 6.1 and 6.2 areas for internal technology base development. Other recommendations are detailed in the report which I commend to your review.

Norman R. Augustine
Chairman

Attachment:
Report

Copy to:
Chairman, JCS

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE
BOARD

15 October 1982

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board Task Force on Mapping, Charting and Geodesy (MC&G)

This memorandum transmits the final report of the Defense Science Board Task Force on Mapping, Charting and Geodesy (MC&G), specifically on issues in those mission areas as they pertain to the Defense Mapping Agency (DMA). The Task Force met several times during the first half of 1981 and an interim report was submitted to you in June. There was no formal Task Force activity for the next nine months during which time the Dr. Richard D. DeLauer, Under Secretrary of Defense for Research and Engineering, asked Dr. Robert Hermann to convene a special group, which included some of our Task Force members, to assess current and future DMA requirements for collecting, transmitting and delivering various MC&G data. With the conclusion of that activity in January 1982, the Task Force was reconstituted to finish its assignments with the additional input. Those findings and recommendations are detailed in the Executive Summary of this report and I trust that you will urge their implementation.

The Task Force was originally chartered when Maj. Gen. Nicholson was the Director of DMA. When Major General Wells assumed that position in mid-1981, he continued full DMA support of our efforts. With that cooperation we feel that we have come to know the Agency as well as any outside group could have hoped to. We are awed by the magnitude of the tasks they are undetaking and impressed by the dedication and professionalism of the people we have met. We are pleased that our work so far seems to have made a difference to DMA and we trust that the recommendations included here will also be useful.

Ivan E. Sutherland
Chairman
MC&G Task Force

Attachment:
Report

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EXECUTIVE SUMMARY

The Defense Mapping Agency (DMA) is responsible for all Department of Defense matters concerning mapping, charting and geodesy (MC&G). The Agency publishes an impressive array of paper products including land maps, aircraft charts, nautical charts, and written information of importance to ground, air and sea navigation and targeting. In addition to this traditional business, DMA has been assigned a critical role in preparing digital data bases used to prepare guidance data for precision guided weapons and to drive digital training devices such as aircraft simulators and radar training devices. The charge to the Task Force was to identify and evaluate current and future MC&G requirements and to assess the ability of DMA to respond to those requirements with regard to equipment, organization and funding.

The Task Force notes that the Defense Mapping Agency has taken many important steps towards digital processing for preparing both its traditional paper map and chart and for preparing the new digital products that now make up about one half of its total output. While applauding these steps, the Task Force urges an increased level of investment by the agency in digital processing means. The Task Force offers the following recommendations, all for action by the Director, DMA:

- Initiate an internal 6.1 and 6.2 technology base program with a funding plan adequate to guard against the loss of technology base work now being done by the Services.

- Develop a coherent plan for an internal digital processing computer network with emphasis on:

  a. Using a lead systems design contractor to ensure a lasting and coherent design.

  b. Employing a modern digital communications network with adequate bandwidth and protocol design to last the Agency for many years.

  c. Using commercially available communications and computer equipment whenever possible with proper, but not overstated, regard for security classification requirements.

BACKGROUND

The Defense Mapping Agency (DMA) is charged with the task of developing the maps, charts, and geodetic data required for the Department of Defense. DMA publishes an impressive array of paper products including land maps, aircraft charts, nautical charts, and written information of importance to ground, air and sea navigation targeting. Some 50,000 paper line items are involved. These paper products represent the "traditional" business of the DMA and its predecessor organizations.

In addition to this traditional business, DMA has been assigned a critical new role in preparing digital products such as the data bases used as guidance data for "smart" weapons such as the air launched cruise missile and the Pershing II surface-to-surface missile. Other DMA digital products are used to drive digital training devices such as aircraft simulators, radar training devices and so forth. This high priority digital product activity has grown to about one-half of the DMA effort. DMA has also been using digital computing equipment to automate its traditional business. Thus, we observe DMA in transition from a traditional cartography and printing establishment to a primarily computer-oriented data processing activity. We believe that in another five to fifteen years by far the largest part of DMA's processing activity will be digitally based.

The Defense Mapping Agency was formed in 1972 by merger of the major MC&G activities of the three Services and some related organizations. The Army and Navy MC&G centers were then merged into a single site in Brookmont, Maryland, which has about 4,000 employees. The Air Force predecessor organization became a second major site in St. Louis, Missouri, with about 4,000 employees. A headquarters organization on the grounds of the Naval Observatory in Washington, D.C., and a number of smaller installations complete the present DMA organization. Although it is clear that the organization is unified and gains strength by the exchanges of personnel and work assignments, and by cross fertilization of equipment and processes, there is still an "Army/Navy" flavor to the Brookmont site and an "Air Force" flavor to the St. Louis site.

TECHNICAL CHALLENGE

The tasks of mapping, charting and geodesy are painstaking and exacting. The volume of data required for the process is enormous because it involves detailed knowledge of local conditions worldwide. For example, DMA maintains and updates continually a file of about 100,000 place names, another file of over 15 million gravity measurements, and enormous numbers of photographs, maps and other source documents. From this enormous collection of data its cartographers compile maps and charts for field use. The task is difficult both because of the enormous amount of data involved and because of the accuracy required in the final product; nothing is more frustrating or more dangerous in the field than an inaccurate map.

The development of modern weapons has put a new burden on the Defense Mapping Agency. Ballistic missiles of high accuracy require accurate knowledge of the locations in a common world grid coordinate system of the targets and the launch sites. Cruise missiles can be guided to targets only if provided accurate digital reference guidance data. Missions against sophisticated defensive systems can be planned only if accurate terrain data are available for the planning process. These new requirements for volume and acccuracy of data put a staggering requirement on the DMA, a requirement made the more challenging because it involves a major new thrust in sophisticated digital computing techniques.

Moreover, the sources of DMA's raw data have become more sophisticated as well. Whereas ground surveys and aerial photographs were formerly the major source of input data, today an enormous number of diverse sources must be used, including the latest reconnaissance means. Not all of these data-collecting devices meet the accuracy requirements imposed on DMA, nor does DMA have control over the order in which it receives data. Thus DMA is in the peculiar position of having to provide products for demanding customers from sources of data over which it has incomplete control.

PREVIOUS REPORTS

On 4 June 1981 this Task Force submitted a preliminary report to the Chairman of the Defense Science Board (DSB). In this report we recommended:

1. That DMA be authorized to engage in 6.1 and 6.2 R&D in order to be better coupled to advanced work in digital processing.

2. That DMA's capital investment in equipment is critical to its future and that DMA should examine carefully its methods for depreciating and replacing capital equipment.

3. That DMA has the opportunity to make a major new investment in digital image processing methods. Such an investment will eventually be necessary; the question is only now or later.

In January 1982 a group headed by Dr. Robert Hermann submitted recommendations to Dr. Richard D. DeLauer, the Under Secretary of Defense for Research and Engineering, regarding DMA and its data sources. A part of our Task Force served on the Hermann group. In terms of DMA itself, the main recommendation of the Hermann group was that DMA move quickly to make the major new investment in digital image processing methods.

As a result of our preliminary recommendations and the Hermann group report, DMA has established a project office to design, procure and install the new digital equipment required for its future. Budget requests for equipment procurement have been made but funds have not yet been authorized. In addition, DMA's enhanced budget request for FY 1984 includes funds for basic research (6.1) and exploratory development (6.2). Thus, DMA is now headed towards considerably increased use of computing equipment for all its activities. The commitment to digital processing has been made and a fairly rapid time-scale has been set.

FINDINGS AND RECOMMENDATIONS

As we have come to understand DMA's task and its response to the requirements laid on it, we must report a generally favorable impression. DMA has taken on a truly herculean task and started to do it with the means at hand and those readily available from current technology. For example, DMA has developed a worldwide coordinate system and used sophisticated computing means to relate all of their geographic data to it. DMA has developed a gravity model of the earth which is mathematically very sophisticated and which is supported by an enormous array of gravity and satellite measurements made worldwide. DMA is compiling a Digital Terrain Model which will describe the physical shape of the earth in considerable detail. One simply must be impressed by the sophistication and care which have gone into these and other efforts of the DMA. This is a healthy, dynamic organization, trying its best to fulfill an important and difficult mission.

DMA's future is very much tied up in the digital computing technology. DMA is using many digital computing devices in producing its traditional paper products and of course uses digital means to produce its newer digital products. Moreover, an increasing fraction of its data input sources will provide digital data. Thus, it is only a question of time before nearly all of DMA's activities will involve sophisticated computing equipment. The only question on the path to all-digital processing is how fast DMA should progress. Technical and management wisdom will be critical in the next few years as more and more of DMA's activity becomes digital. Our recommendations 2 through 5 address the major issues in developing a system of the size and complexity required for DMA's use.

By charter, DMA relies on other organizations to provide its leading edge R&D. DMA does 6.3 and 6.4 kinds of procurement of advanced equipment, but it is not supposed to do any basic research (6.1) nor exploratory development (6.2). As the DMA moves more and more into the digital computing technology where there is a very rapid pace of technological advance, it will need the best advanced thinking just to keep pace with the field. Specific authority and budget to do internal R&D would provide: (1) a thrust towards continued increase of automation; (2) a capability to utilize the rapid advance of digital technology.

RECOMMENDATION 1: Initiate a 6.1 and 6.2 technology base program with a funding plan adequate to guard against the loss of technology base work now being done in the Services.

The fiscal plan now in force should be considered as a minimum. In FY-84 DMA is planning to put 0.3% of its overall budget into

6.1 and 6.2 spending. This compares with 1.33% for the total DoD. Because DMA is necessarily a high technology operation and becoming more so, it should be a leader in these expenditures. We think that between 1 and 2 percent is a more reasonable figure. Of course, DMA will have to develop the program over time, and so a phased increase to that level is appropriate.

In building up the DMA 6.1 and 6.2 program, the DMA and the DoD should guard against the loss of the technology base work now being done by the Services. The start of internal 6.1 and 6.2 work at DMA may result in an overall decline in the technology base program in MC&G if the Services drop out of their existing activities. Some assessment of the total 6.1 and 6.2 effort in MC&G should be made to assure that the new posture of DMA is not reducing the total effort.

In sponsoring external 6.1 and 6.2 activities, DMA should put special emphasis and weight on the demonstrated competence of the people involved. A developing technology base depends on the good ideas and devoted work of the research and development people. DMA needs to establish rapport with scientific talent of the very best calibre on whose ideas and energy DMA can draw to remain vital. The contracts that DMA establishes under its 6.1 and 6.2 program will be shaping its future. We urge DMA to work with the very best people it can find.

DMA is embarking on a major equipment procurement program. The technology base program can help DMA in making the best use of that equipment if the 6.1 and 6.2 contractors have access to the new equipment or copies of it installed in their laboratories. Selected placement of prototype equipment in advanced laboratories can lead quickly to new applications of the equipment that will be directly useful to DMA. DMA should seek opportunities to place equipment of the kinds that it uses in advanced laboratories.

DMA must, over time, develop internal basic research and exploratory development efforts. This internal technology base program is required to match the outside work that it sponsors in quality and quantity. Roughly half of the technology base program should eventually be internal to DMA to ensure that DMA has people capable of selecting, working with, and using the results of the outside program. This internal program, coupled with the contacts generated by the external program, is what will generate the "capability pull" that will keep DMA's capabilities up to date for the long term future. Recruiting, equipping and managing the people involved here is a major task that DMA will have to undertake.

RECOMMENDATION 2: Develop a modern and powerful communication network with emphasis on long equipment lifetime.

Digital computing systems of the complexity envisioned for DMA consist of "boxes" made by many manufacturers each of which serves some purpose in the overall system. These boxes will communicate with each other over some kind of a digital communication network. As the system grows, new boxes will be attached to the network to serve new purposes. For example, some of the boxes will serve as a huge data repository, others will serve as input and output stations. As new kinds of analysis are required, new analysis stations will be added. As more information is accumulated, new and better data storage boxes will be added. As new kinds of source data begin to be important, new input stations will be added to the network. As older pieces of equipment become obsolete, they will be replaced by newer generations of equipment with similar but improved function.

The lifetime of the system, as opposed to the lifetime of any one part of it, will be controlled by the utility of the communication network that interconnects the boxes. New boxes can be added to such a communication network by building a suitable network interface for each such box added. To change the network form, however, is a major undertaking that requires replacing at least a part of every box. It is vital, therefore, that the communication network design be very carefully done, so that a network with a very long lifetime will be obtained. This lifetime will be limited both by equipment reliability, but more importantly by equipment obsolesence. It is essential that a modern and powerful communication network be built because it will have to last for several decades.

RECOMMENDATION 3: Design an adequate digital communications protocol drawing on knowledge from existing networks.

The communications protocol used on the network is, in effect, the language spoken over the network by the boxes that use it. Requests put into the network by parts of the system will be undertaken by various boxes on the network, but as the system evolves, which boxes undertake to fill which requests may change. For example, a request for a particular data element will be filled by whatever is the current data storage device. An identical request made a year or two later may be filled by a different device.

The communications protocol or language used on the network may even outlast the equipment in the network. As the communications network becomes obsolete, the same kinds of messages as were previously used may be transmitted over new communications equipment just as the same message formats can be used over satellite communication links as were used on land lines or on microwave circuits.

A change to the language of communication between devices will require a major change to all of the devices in the system. Such a change will not be possible after the system is in operation. It is vital, therefore, that the communication protocol or language be very carefully designed with adequate expansion capability for the future.

There are two ways to make communication languages. The simple, but inadequate way, is to enumerate all of the message types that are possible over the network. This approach is inadequate because it is impossible to anticipate all of the kinds of communication for which the network will be used. The better way is to establish a syntax for messages which leaves room for new meanings in message headers provided they conform to some simple basic rules. The simplicity of the rules can reflect the freedom that future designers will have in adapting the communication protocol to new uses. The protocol should address communications by function and not by specific box number or name to provide for the adaption of boxes. We urge the DMA to get the best possible help in making the critical decisions on protocol that will establish the limits of system growth.

The art of building networks is not new. The ARPAnet, the COINS network, and several commercial packet-switched networks, such as Ethernet and TELEnet, provide a base of technology on which DMA can and should draw. DMA people should understand these existing networks and the differences between them. In short, DMA should take full advantage of the existing and emerging technology of computer communication networks.

RECOMMENDATION 4: Use commercially available communications and computer equipment whenever possible with proper, but not overstated, regard for security classification requirments.

Commercial computer companies produce a remarkable array of products very economically. To the extent that these products can be used to meet DMA's requirements, using them will reduce the cost of the system that DMA has to install. The need for cost reduction is most dramatic in terminals for the analyst. Because many such terminals will be required, it is important that low cost equipment be used.

For viewing images at teminals there are now a number of standard products using the 1,000-line commercial television standards. To use any other kind of viewing equipment would increase the cost substantially. DMA should consider very carefully the possibility of using analyst stations built around 1,000-line commercial television equipment.

Although much of the data in the DMA system will be highly classified from a national security standpoint, we see little advantage in classifying the overall system requirements. For example, although one might wish to protect the specific resolution of particular imaging systems, one could deal with digital images of say 512x512, 1024x1024 ...1,000,000x1,000,000 pixels each, without any need to classify the resolutions available. Similarly, although one might want to classify the total amount of data available in the system, one should be able to deal with memory system procurements in an unclassified way.

We believe that a system framework can be made that uses mainly commercial equipment. Such a framework could provide the digital environment into which some selected special devices would be placed. Procurement of the special devices might be classified as required by their particular capabilities. We are not recommending that DMA use only commercial equipment; but the relative costs of commercial equipment and the need for very many terminals suggest that most of the system could be built from commercial technology.

RECOMMENDATION 5: Select a lead systems design contractor in designing and establishing new digital systems.

In designing and establishing this digital system, DMA will need the help of many contractors. But we feel that a particular relationship with a systems design contractor could be very helpful. Such a systems design contractor should be independent of any of the equipment manufacturing companies that will be involved in the system. Such a systems design contractor should have experience with large systems and with image processing tasks. The obvious candidates for such a role are the many not-for-profit systems houses.

APPENDIX A

MEMBERSHIP LIST

DSB Task Force on Mapping, Charting and Geodeay

Chairman

Dr. Ivan E. Sutherland
Sutherland, Sproull and Associates, Inc.

Members

STAT

Mr. Guy H. Dobbs
President
Xerox Electro-Optical Systems

General Russell E. Dougherty, USAF (Ret.)
Executive Director
Air Force Association

Dr. Ivan A. Getting
Consultant

Dr. Percy A. Pierre
Consultant

Dr. Lem Wong
Aerospace Corporation

Executive Secretaries

Lt. Col. Jerome A. Atkins, USAF
Military Assitant, Defense Science Board

Lt. Col. Carol A. Yarnall, USAF
Military Assistant, Defense Science Board

APPENDIX B

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

RESEARCH AND
ENGINEERING

7 JAN 1981

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: DSB Task Force on Mapping, Charting and Geodesy

You are requested to convene a Defense Science Board Task Force to review the DoD's posture in the functional areas of mapping, charting and geodesy (MC&G). The Defense Mapping Agency (DMA) is responsible for all DoD matters concerning MC&G.

The advent of preprogrammed weapon systems has brought about a significant change in DoD's need for MC&G. For example, the guidance of cruise missiles and other future weapons systems will require large amounts of precise global digital terrain information. As the quantity and quality of data required for such systems increases, it is conceivable that the production, processing and distribution of MC&G data could become a pacing item in some system development cycles.

The Task Force should identify and evaluate current and future mapping, charting and geodesy requirements, and assess the ability of the MC&G community to respond to these requirements. Topics of particular concern include generation, derivation or collection of MC&G data from available source material; transformation of that data into a form suitable for production of MC&G products; storage of and access to data; transmission of data to user or other production facilities; and interpretation of data. In addressing these issues the Task Force should specifically answer the following questions:

1. What MC&G data are required for existing and projected weapons systems? In what form should these data be stored, transmitted, delivered, and used?

2. What means are now used by DMA or are projected for use for collecting, transmitting, delivering, and accessing various MC&G data?

3. Are the means now in use and now projected adequate to meet the present and projected needs of the nation? Are the MC&G data tasks now a pacing item in weapons system development? Are MC&G data tasks likely to become pacing items in future systems?

4. Are the current organizational structures and technical, managerial, contracting, processing and communication capabilities of the Defense Mapping Agency adequate to meet the current and future needs of the nation? What changes, if any, are needed?

5. Is the Department of Defense, through the Defense Mapping Agency, making the best use of commercial resources and know-how in MC&G? What improvements, if any, are possible?

6. Is the Defense Mapping Agency equipped and structured to maintain its ability to meet the national need in the face of rapid technical developments which can be expected? How does new information flow into DMA? What research efforts, advisory efforts, and education efforts could be undertaken to maintain execllence in the DoD's MC&G effort?

The subject Task Force should be convened as soon as possible and provide a final report to me no later than 1 June 1981.

Several experts in the theory of photogrammetry, cartography, topology, weapon guidance requirements, and computer/communications should be selected for the Task Force. If possible, at least one map production representative from the private sector should also be a member.

The Director, Defense Mapping Agency, Major General W. L. Nicholson, III, will be the cognizant Deputy for the Task Force. The Chairman will be Dr. Ivan E. Sutherland. Lieutenant Colonel Carol A. Yarnall, USAF, Military Assistant to the Defense Science Board, will be the Executive Secretary.