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DEFENSE SCIENCE BOARD

TASK FORCE

ON

DEFENSE MAPPING FOR FUTURE OPERATIONS

SEPTEMBER 1995

OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR ACQUISITION & TECHNOLOGY
WASHINGTON, D.C. 20301-3140

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DEFENSE SCIENCE
BOARD

20 SEP 1995

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION & TECHNOLOGY)

SUBJECT: Report of Defense Science Board (DSB) Task Force on Defense Mapping for Future Operations

I am pleased to forward the final report of the DSB Task Force on Defense Mapping chaired by Dean Clubb. The Task Force's objective was to develop recommendations for improving the geospatial information available to users in the Military Departments, Unified Commands, and Defense Agencies. In developing its recommendations, the Task Force pursued a process-oriented approach. This approach included a review of: the end user requirements definition process; information collection, processing, production, and dissemination; and end user application and feedback.

The Task Force's key findings and recommendations are summarized in the report's executive summary. The Task Force concluded that the Department of Defense should transition from emphasizing standard scale map and chart products to providing a readily accessible digital geospatial information source to satisfy user's mapping, charting, and weapons systems requirements.

I concur with the Task Force's conclusions, in particular its recommendation to establish an Integrated Product Team (IPT). The DSB is prepared to provide further advice, through any appropriate forum, as the Department transitions to the geospatial information concept envisioned by this Task Force.

Craig I. Fields
Chairman

DEFENSE SCIENCE BOARD

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-3140

September 15, 1995

Dr. Craig I. Fields
Chairman, Defense Science Board
The Pentagon
Washington, DC

Dear Dr. Fields:

Attached is the final report of the Defense Science Board Task Force on Defense Mapping for Future Operations. We have accommodated all changes recommended by reviewers consistent with the briefings already presented to Dr. Kaminski and Mr. Paige, ADM Owens, and Dr. Jones.

The Task Force concluded that the Department of Defense should transition from emphasis on standard scale map and chart production to providing a readily accessible source of digital information which will satisfy military geospatial, mapping, charting and weapon systems requirements. The Task Force recommends that an Integrated Product Team (IPT) be established to manage this transition. When the IPT is established, the members of the Task Force would be happy to assist in developing a transition roadmap to establish a new and exciting capability within the Department.

Regards,

G. Dean Clubb

G. Dean Clubb
Chairman

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Executive Summary

The Task Force concluded that the Department of Defense (DoD) should transition from emphasis on standard scale map and chart production to providing a readily accessible source of digital information which will satisfy military geospatial, mapping, charting and weapon systems requirements. This repository of digital geospatial information should be accessible electronically for a large variety of worldwide customers via a distributed architecture designed to make a Major contribution to battlefield information dominance and support the needs for modeling and simulation, wargaming, training, exercising, rehearsal, operations and post strike analysis. The information contained in this architecture should serve as the foundation for all DoD information management systems. Its principle attributes should be geospatially referenced and temporally tagged using Global Positioning System (GPS) time and positional standard accuracies, whenever practicable. These distributed warehouses of digital information must be linked to the Global Command and Control System (GCCS) for the Theater CINCs, their components, Joint Task Force Commanders, Corps Commanders, etc., down to the company echelon. Users must be able to build on the warehouse data to locally and dynamically tailor, profile and construct their charts, maps, displays, etc., to suit their needs without degrading interoperability.

In summary, maps and mapping are the issue of the past — the real issue is digital databases and distributed systems. This study, therefore, builds on the 1994 DSB Summer Study on Information Architecture for the Battlefield.

The current JCS Memorandum of Policy 31 (MOP 31) operational requirements process is no longer effective for defining DoD mapping needs in today's rapidly changing world situation. The process needs a major revision to make it more responsive, efficient and effective. In particular, a new requirements process should allow more direct (electronic) interaction between users and providers of geospatial information.

The current hardware architecture that limits the Defense Mapping Agency @MA) to receiving imagery from only a single source is unnecessarily restrictive and should be abrogated. The legacy Digital Production System (DPS) is a proprietary, closed and expensive to maintain system that begs to be replaced. DoD should build on the rapidly expanding commercial capability to modernize the process. Every available source of imagery and other data sources should be available to DMA to populate and maintain a global geospatial database. DMA's stated objective of using products from advanced national systems and commercial sources should be embraced and supported. Current stated product requirements exceed specified collection capabilities. However, planned electro-optic and radar remote sensors, including commercial ones, will greatly improve the collection capability for land surfaces if supplemented by an Interferometric Synthetic Aperture Radar (IFSAR) sensor.

There will be an ever increasing appetite for greater accuracy and higher resolution geospatial information and immediate access to this information from a vast spectrum of users. A distributed client/server architecture will permit local analysis of the area of interest and production of any required products. Local control will greatly ameliorate the current constriction to the flow of information caused by the practice of delaying release until all analysis is complete, even though the information may not be required by all users.

Digital information must be available electronically so that users can "pull" the changes in information to fulfill their operational and weapons systems requirements for geospatial data. Enormous expansion in both terrestrial and satellite bandwidth, continued exponential increases in microprocessor performance, and great improvements in antenna designs will enable the infrastructure to be constructed for this information network.

There are several opportunities that have become apparent:

1. The opportunity to provide a competitive advantage on the battlefield by working with digital databases and the distributed system to allow the warfighter to use those databases and take advantage of the information contained,
2. The opportunity to take advantage of the rapidly expanding commercial arena which is overtaking the government capabilities,
3. The opportunity to establish a structure within DoD that ties together everything from the sources to the user to enable meaningful trades, identify resources, and define a unified vision, and
4. The opportunity to utilize an Integrated Product Team to manage the transition to the future concept.

The Task Force determined that, in order to address the issues described above:

- A vision is needed to provide digital distributed databases of geospatial temporal information as the foundation for military information systems
- To implement this vision, DoD should:
  - Evolve a distributed heterogeneous Internet-like architecture that uses the geospatial databases as its foundation
  - Change the defense mapping mission to: Maintain the geospatial databases and protect access and integrity
  - Institute a requirements process that prioritizes users' geographic needs
  - Rapidly acquire access to virtual worldwide databases using all available commercial sources and practices
  - Equip and educate the end user to locally add value and meet his needs (e.g., smart workstations, printers, etc.)
  - Establish an Integrated Product Team to manage the whole process

1. Task Force Executive Briefing

This section contains the briefing which was presented to key DOD managers at the conclusion of the study. Key points are provided following each chart.

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Defense Science Board Task Force on Defense Mapping for Future Operations

August 1995

G. Dean Clubb, Chairman
MajGen Robert Rosenberg, Vice Chairman

> "What the Warrior Needs: a fused, real time, true representation of the battlespace — an ability to order, respond and coordinate horizontally and vertically to the degree necessary to prosecute his mission in that battlespace."
>
> Gen John Shalikashvili, CJCS — The C4I for the Warrior vision

Office of the Under Secretary of Defense
(Acquisition and Technology)

- The DSB Task Force study was initiated at the request of the director of the Defense Mapping Agency @MA), MajGen Ray Omara. The current director, MajGen Phil Nuber endorsed its execution and supported the Task Force with briefings on a variety of topics.
- The study started as a DMA study and then expanded to a higher level study of digital mapping within DoD — all the way from collection of source material to use by warfighters.
- As is implicit in the quote by Gen Shalikashvili, the digital battlefield has a requirement for adequate, responsive, timely geospatial information — and it is assumed that such information will be provided.
- Action is required to make that assumption valid and there are no fundamental reasons that those actions can't be taken.

DSB Lack of Geospatial Information Confronts the Anxiety Zone

"The want of accurate maps has been a grave disadvantage to me. I have in vain endeavored to procure them, and have been obliged to make shift with such sketches as I could trace out of my own observations and that of gentlemen around me. . . ."

Gen George Washington, 1777

- As is indicated by this quote, obtaining accurate geospatial information has been a challenge for a long time.
  - The industrial revolution solved part of the problem with the invention of the printing press.
  - Now, in the information age we have the opportunity to take it to another level.

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Task Force Members

Chairman: Mr. G. Dean Clubb, Texas Instruments, Inc.'
Vice-Chairman: MajGen (Ret) Robert Rosenberg, SAIC

Members
- Dr. Murray Felsher, Associated Technical Consultants
- Mr. Arthur Johnson, Loral Federal Systems Group*
- Gen (Ret) Robert T. Marsh, USAF, Private Consultant
- Gen (Ret) James McCarthy, USAF, US Air Force Academy
- Dr. William M. Mularie, National Media Laboratory
- Mr. Thomas Saunders, MITRE Corporation
- VADM (Ret Jerry Tuttle, ORACLE
- LTG (Ret) John W. Woodmansee, Perot Systems Corporation*

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- CDR Robert C. Hardee, USN

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- Ms. Jana Cira, ODASD (I&S)

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- Dr. Nancy Chesser, Directed Technologies, Inc.

Government Advisors
- Dr. Richard A. Berg, DMA
- Mr. Walt Boge, Topographic Engineering Center
- Mr. Eric Bradbury, Central Imagery Office
- Ms. Mary Clawson, CNO(N961CN)
- Col Steve Cummings, AF/INXF
- Mr. Frederick J. Doyle, NRO
- MajGen Brett Dula, Central Imagery Office
- CAPT Michael Hacunda, CNO(N961C)
- LTC Tom Haid, STRATCOM
- LTC Dave Maxon, Army
- Dr. Michael J. Mestrovich, DISA
- Maj. Bob Mosley, USMC, Intel Act Quantico
- MajGen Philip Nuber, DMA
- Maj Dan Saxon, USAF, AF/INXF
- Mr. Steven Schanzer, Community Management Staff
- Dr. Walter Senus, DMA
- Mr. Rick Shackleford, DIA
- Col Gil Siegert, SPACECOM
- Mr. Neil Sunderland, 497IG/INOT (AF)

* DSB Member

- This chart lists the group that participated in the Task Force.
- MajGen Robert Rosenberg, who served as vice-chairman, is a former director of DMA. He provided background and focus to those participants who began the effort with little experience in the mapping community.
- Additional expertise was provided by Gen Tom Marsh who directed the 1992-1994 DMA Study known as the Marsh Panel.
- Significant contributions were made by DSB members, retired military experts, and recognized commercial experts like Dr. Bill Mularie from the National Media Laboratory and Dr. Murray Felsher from Associated Technical Consultants.
- A broad array of government advisors from all parts of the geospatial information community contributed to the effort.

Terms of Reference

- Identify the cost-effective approach for providing needed geospatial information and products to users among the Unified Commands, Military Departments and Defense Agencies at all levels.
- Address the following:
  - Are the DoD vision, plans, and resources for geospatiai information systems adequate to address the full spectrum of potential conflicts including force readiness, training and exercises?
  - Are user needs clearly defined and prioritized? Can the system provide rapid response to address unforeseen urgent operational needs of the operating Commands?
  - Are current and planned information sources adeauate to support production requirements?
  - Are current and planned processing. production and dissemination methods responsive to the needs and compatible with the vision?
  - is technoioov development for the end users phased and resourced to take advantage of the evolving geospatial information system capability?
  - Do the best commercial processes or products contribute to meeting government needs?

- The study focused at a high level — defense mapping throughout DoD and geospatial information, not just mapping products.
- The terms of reference were intentionally broad so as to look at the complete process. (The complete Terms of Reference are provided in Appendix A.)

Task Force Approach

- **Process Focus**
  - **End User Requirements**
  - **Information Collection**
  - **Processing**
  - **Production**
  - **Dissemination**
  - **End User Application**
  - **End User Feedback**

- **Approach**

– April 6-7	**Military Services & Unified Commands Views**
– May 2-3	**DoD Mapping Process**
– June 1243	**Commercial Capabilities**
– July 6-7	**Working Session**
– August 3-4	**Finalization of Briefing**

- The Task Force approach was to focus on the process, not on the organization of participants in the process.
- The Task Force met about two days a month for five months.

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Briefings

April 6-7.1995 Military Services and Unified Command Views	
DMA Director's Perspective	MajGen Nuber
JCS Joint Warfighting Geospatial Requirements	BrigGen Hicks
DoD Vision and Geospatial Requirements	Mr. Keith Hall
USSOCOM Geospatial Requirements	Col Brazelton
USSTRATCOM Geospatial Requirements	MajGen Curtin /LTC Haid
USCENTCOM Geospatial Requirements	ColMorrisMaj. Smith
USSPACECOM Geospatii Requirements	LCDR Pettigrew
Army Geospatial Requirements	Mr. Bogel LTC Maxon
Navy/Marine Corps Geospatial Requirements	RADM Davis/ MajGen VanRiper/CAPT Hacunda
Air Force Geospatial Requirements	Col Cummings / Maj Saxon
Information Architecture for the Battlefield	MajGen (Ret) Rosenberg
May 2-3.1995 DOD Mapping Process	
CIO Overview	MajGen Brett Dula
DMA Requirements and Tasking	Mr. Guy DuBois
US Imagery System and A31	Ms. Beth Larson
Declassification Policy for Imagery-Derived	Mr. Will Hopkins
National Reconnaissance Office	Mr. Fred Doyle
National Photographic Interpretation Center	Col Charlie Latimer
GGI&S Concept	Ms. Bobbi' Lenczowski
Defense Modeling and Simulation Office	CAPT Hollenbach
Army Digitization of the Battlefield	Mr. White
TEC Overview Roles and Missions	Mr: Walter Bogs
Navy GIS-related S&T Activities	Ms. Mary Clawson
AFMC MC&G Perspective and Plan	Maj Michael Papirtis
DMA Production Backlog	Mr. Bill Hogan
Alternate Source Exploitation	Mr. Tom Holzer
Controlled Image Base Product	Mr. Merle Biggin
Remote Replication System	MajSherryFascia
Digital Production System (DPS)	Col Trey bering
Defense Information Systems Agency	Dr. Michael Mestrovich
US Geological Survey	Mr. James Plasker
Mapping & Charting at National Ocean Service	Dr. David Evans

June W-13.1995 Commercial Capabllltles	
Space Imaging, Inc.	M T'isha Viajta-Williams
Earthwatch, Inc.	Mr. Jesse Moore
MapPrinting-3M Technologies	Mr. Doug Dybvig
Earth Satellite Corporation	Mr. Charles Sheffield
Geodynamics Corporation	Mr. Robert Chiralo
MRJ, Inc.	Mr. Ed McMahon
PRC, Inc.	Dr. Paul Anderson
SAIC	Mr. Russ Richardson
TRIFID Corporation	Dr. Marshall Faintich
ERDAS	Mr. Lawrie Jordan
ERIM	Dr. Stanley Robinson
MapInfo Corporation	Mr. John Haller
DeLorme Mapping	Mr. David DeLorme
David Sarnoff Research Center	Dr. Curtis Carlson
Eastman Kodak	Mr. Charles Mondello
AT&T	Mr. Dick Lombardi
Direct Broadcast Satellite — Hughes	Mr. Mark Sabin

Facilitv Tours

- Defense Mapping Agency — St Louis
- Defense Mapping Agency — Bethesda, MD
- US Army Topographic Engineering Center
- CIA — Demonstration of Intelink

- This slide shows the many briefings that were received by the Task Force. Listening to these presentations gave the Task Force a broad and comprehensive view of defense mapping.
- The user requirements discussed at the first meeting were the least interesting — there wasn't a process. Users were operating independently and the system did not respond to their needs. The MOP 31 process was not effective in prioritizing needs.
- The DoD mapping process discussions were the most confusing — there are a lot of good ideas but there isn't a single view of what should be changed to make the system more responsive to the ultimate users.
- The commercial discussions and demonstrations were the most exciting — that community is dynamic and aggressive. The commercial groups are working to provide real time information and there are major opportunities for DoD to improve its process.
- Several members of the Task Force participated in the facility tours shown. These are modem production facilities but the process involves intensive manual feature extraction.
- There are lots of good things going on in defense mapping and good people are involved. However the process can and should be re-engineered to take advantage of databases, distributed hardware, and software technology which are now available.

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Summary

- **Our vision:**
  - **Provide digital distributed databases of geospatiai temporal information as the foundation for military information systems**
- **To implement this vision, DoD should:**
  - **Evolve a distributed heterogeneous Internet-like architecture that uses the geospatiai databases as its foundation**
  - **Change the defense mapping mission to: Maintain the geospatiai databases and protect access and integrity**
  - **Institute a requirements process that prioritizes users' geographic needs**
  - **Rapidly acquire access to virtual worldwide databases using all available commercial sources and practices**
  - **Equip and educate the end user to locally add value and meet his needs (e.g., smart workstations, printers, etc.)**
  - **Establish an IPT to manage the whole process**

- This chart provides a summary of our conclusions.

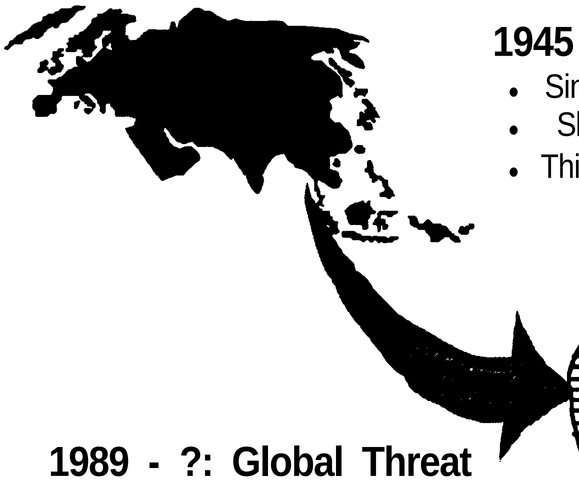
- Mapping is not the issue, the real issue is producing and distributing digital databases and systems. This area, therefore, fits in with the 1994 DSB Summer Study on Information Architecture for the Battlefield.

- There are several opportunities that have become apparent to the Task Force:
  1. The opportunity to provide a competitive advantage on the battlefield by working with digital databases and the distributed system to allow the warfighter to use those databases and take advantage of the information contained,
  2. The opportunity to take advantage of (not to try to control) the rapidly expanding commercial arena which is overtaking the government capabilities,
  3. The opportunity to establish a structure within DoD that ties together everything from the sources to the user to enable meaningful trades, identify resources, and define a unified vision, and
  4. The opportunity to utilize an Integrated Product Team to manage the transition to the future concept.

- We believe that geospatial information is a high priority for all C4I For The Warrior (C4IFTW) systems. The remainder of the presentation will describe the basis for that belief.

DSB Defense Science Board

The New World: Global Threat



1945 to 1989: Soviet Union

- Single, localized threat
- Slowly-varying
- Third world were "have-nots"

1989 - ?: Global Threat

- Distributed threats
- Rapidly changing environment
- Weapons proliferation
- Contingency operations

- Ubiquitous, military-grade imagery, mapping, GPS, . . . from commercial sources available to third-world powers.

- The world has changed over the last five years:
  - The threat is no longer localized; significant threats can appear anywhere in the world.
  - Digital battlefield demands improved levels of geospatial information accuracy.
  - Digital terrain data does not exist in those parts of the world where future threats are likely to arise.
  - GPS is changing the world of mapping and databases — GPS provides a truth file against which maps are tested.
  - Maps are not considered strategic items until the engagement begins and there are no maps.
  - Contingency operations demand a faster, more responsive approach.
  - Relatively unsophisticated countries will have access to superb imaging obtained from the commercial market.

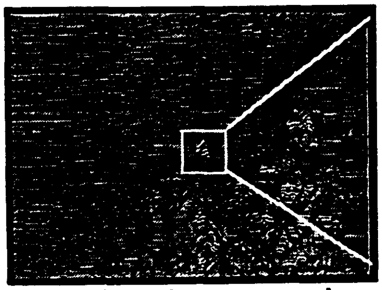
DSB **The Digital Battlefield Requires Digital Terrain and Feature Data**

- **We have a lot of paper maps - This is no longer sufficient**
- **At the minimum Digital Terrain Elevation Data (DTED) Level 2 is required**

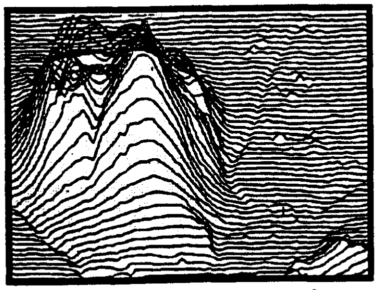
The problem is that we have little DTED Level 2 and digital feature data.

- The digital battlefield of the future demands digital terrain and feature data.
- Paper maps are required but not sufficient. There are lots of air route maps and so on, but they are not the keys to the digital battlefield.
- DTED Level 2, which corresponds to 30 meter spacing of the grid, is the minimum level of information required for the digital battlefield — many applications require Level 3 or 4.
- Digital geospatial feature data (roads, rivers, forests, etc.) with levels of detail equivalent to 150,000 scale and larger topographic line maps are also required.
- The real problem is that we have very little digital data useful to the warfighters' current needs.

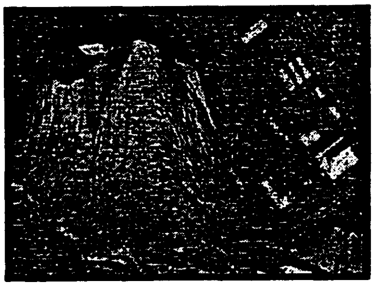
DTED Levels



Level 1 - 100 meter spacing



Level 2 - 30 meter spacing



Level 4 - 3 meter spacing

Description: matrix of digital terrain elevations that represent the Earth's land surface

Resolution (matrix spacing)

- Level 1: ~100 meter
- Level 2: ~30 meter
- Level 3: ~10 meter
- Level 4: ~ 3 meter
- Level 5: ~1 meter

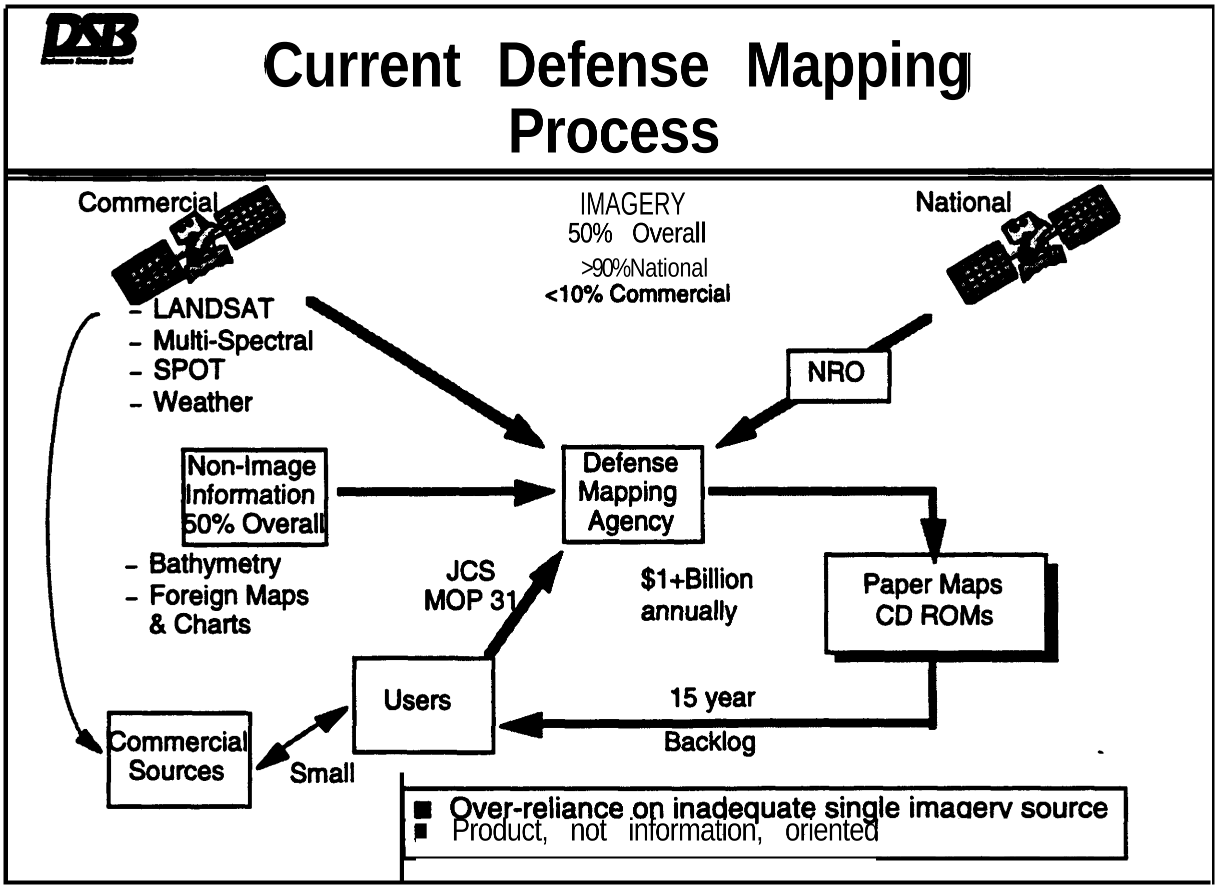
By Year 2000 Need:

- Planning level data
  - Levels 1 and 2
  - Near worldwide coverage
- Higher resolution data for operation-specific areas
  - Levels 3,4, and 5
  - Up to 300 x 300 km areas

- This chart illustrates the impact of improved resolution associated with different levels of Digital Terrain Elevation Data (DTED). Levels 1 and 2 are adequate for planning but higher resolution data is required for operations.

DSB Digital Terrain Elevation Data Level 2 (DTED2) available from DMA

- The data shown here is very sobering.
- DTED level 2 data is extremely limited - it is only available for a few locations in Europe and the Middle East, and near selected bases in the US.
- DTED Level 2 only marginally meets the stated warfighter needs and there is no equivalent level of digital feature data available.
- Populated digital geospatial reference databases are now essential to modem military planning, exercising, rehearsing and operations — and precious little data.



- This chart depicts the current mapping process with DMA at the center. There are two major pieces of the process:
  1. Information collection and transfer to DMA, and
  2. DMA serving the customers' needs.

- Within collection there are two sources of information — imagery provides about 50% of the information and other types of data (bathymetry, foreign maps and charts) provide the remaining 50%. Within imagery, approximately 90% of the information is obtained from national sources and 10% is obtained from commercial imagery sources. However, as happened during Desert Storm, during a crisis the national assets may not be available for mapping because intelligence needs have higher priority. The mapping community is extremely dependent on national assets, and on single spectrum EO sources in particular.

- Within the portion of the process devoted to serving the users, the primary product is paper maps with an ever-increasing quantity of digital data on CD-ROMs. Over one billion dollars is spent annually by DoD to address this portion of the process.

- The requirements process is driven by JCS Memorandum of Policy 3 1 (MOP 3 1). That process doesn't work — there is currently a 15 year backlog based on the requirements specified under MOP 3 1. As a result, the users are going to commercial sources to obtain what they need. Part of the problem is that the requirements process is unconstrained and product-oriented.

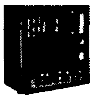
Findings

- The DoD system isn't responsive to 2lst Century needs
  - Users / developers / implementers not closely linked
  - User geographic coverage requirements process is ineffective
  - Weapon system requirements have not always been included
  - Security issues limit dissemination of DMA imagery products derived from NRO sources
  - Long production pipeline causes excessive backlog. Feature extraction is a major contributor.
  - Minimal product standardization
  - DoD is making major investments in modernizing military information systems without a common interoperable geospatial foundation
  - There is not a single DoD coherent vision of the future — in fact there are many separate visions

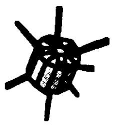
These problems can be corrected within current budget projections

- The bottom line is that the existing process is not going to be responsive to the needs of the 21 st Century. This chart lists the reasons that the Task Force reached this conclusion.
- The participants in the process are not closely linked and the requirements process isn't working well. The releasability **of** data collected using the national assets is an issue. Timeliness is a critical concern.
- DoD is making major investments in modernizing military information systems, including C2, trainers, simulators, and wargaming, without a common interoperable geospatial foundation.
- There is no single DoD vision to drive the entire process.
- These problems can be corrected — and we believe they can be corrected within budget by trading off production of lower priority current taskiig and other less-than-critical functions. However, the process must be changed.

The 21st Century: Commercial Leadership



- Commercial sources — The primary supplier of geospatial-related data, services arid products by the year 2000.



  - The global information infrastructure investment exceeds $1Trillion/yr. High leverage for supporting future geospatial architectures.
  - Commercially-available imaaerv of l-meter (panchromatic) and 4 meter (multispectral) resolution will be ubiquitous.

  - Commerciallv-available digital terrain data derived from aircraft and orbiting SAR, IFSAR and imagery platforms will be the major source for the global geospatial databases.
  - Commercial global broadband communications developers are implementing robust, secure, high capacity terrestrial and satellite networks which will exceed DoD capabilities.

  - Commercial markets are driving geospatial standards

DoD - Take advantage of commercial world - others will!

- The question becomes: what is available to make the system responsive to the needs of the 21st century? Commercial technology is being developed at an incredible rate so we looked to see what the commercial world could offer.

- The commercial arena is a hot bed of activity. A great deal of money is being invested and accuracies are improving significantly. The world-wide market for one meter imagery is expanding (e.g., the cellular phone companies are using imagery to choose the location for cellular antennas).

- Accuracies are approaching DoD level and the imagery is multi-mode (EO, SAR, IFSAR) and multi-spectral. The database to tie that imagery to a reference system is critical if the data are to be used for targeting.

- Databases and networks are being developed.

- The tremendous investment in the commercial marketplace is driving commercial 1 geospatial standards and DoD should be involved.

- There are both offensive and defensive reasons that DoD must become involved. Offensively the need is obvious. Defensively, potential adversaries will take advantage of these opportunities. The US cannot afford to not be linked with the commercial world.

Planned Remote Sensing Satellites

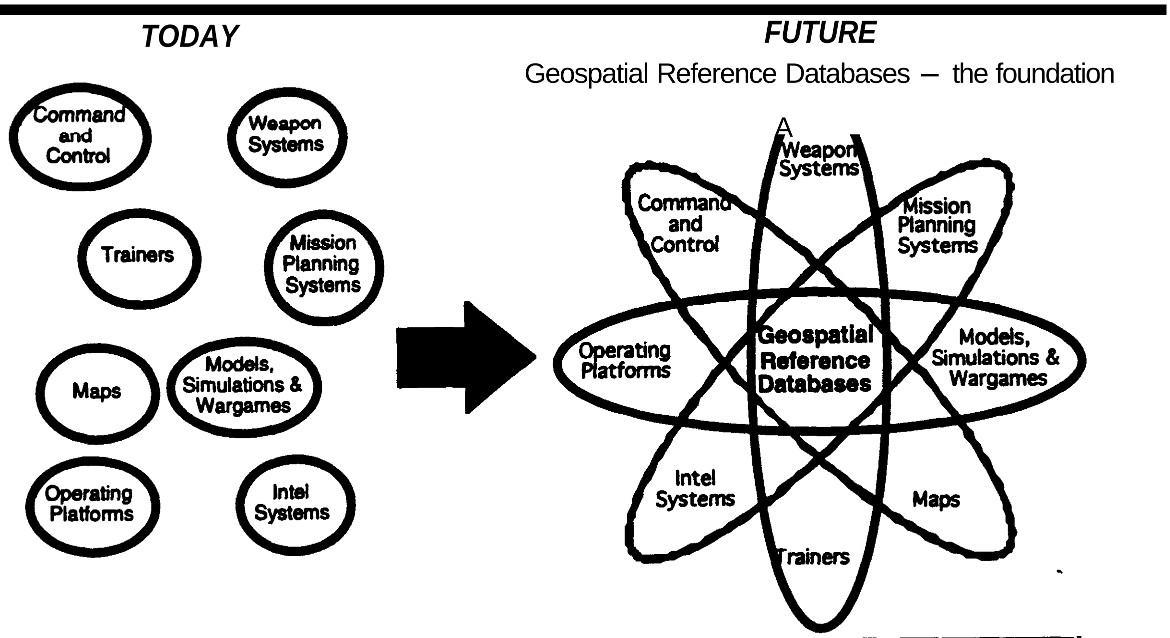
(Partial List)

Satellite	Owners/Operators	Launch	Description*
Helios 1	France	Launched	(< 1 m)
CBERS	Brazil/China	1995	Panchromatic/Multi-spectral (20/20 m)
RADARSAT	CSA/RI/MM (Canada)	1995	SAR (8,30,100 m)
Resurs-O2	Hydromet (Russia)	1995	Multi-Spectral (27 m)
Resurs-02	ISRO (India)	1995	Panchromatic/Multi-spectral (10/20 m)
CBERS	Brazil/China	1996	Panchromatic/Multi-spectral (20/20 m)
ADEOS	Japan	1996	Panchromatic/Multi-spectral (8/16 m)
Almaz-2	Russia	1996	Radar (5 m)
Lewis	TRW/NASA (US)	1996	Panchromatic/Hyper-spectral(5/30 m)
Clark	CTA/NASA (US)	1996	Panchromatic/Multi-spectral (3/15 m)
Early Bird	Earthwatch (US)	1996	Panchromatic/Multi-spectral (3/15 m)
Quick Bird	**Earthwatch (US)**	**1997**	**Panchromatic/Multi-spectral (1/4 m)**
CRSS	**Space Imaging, Inc.**	**1997**	**Panchromatic/Multi-spectral (1/4 m)**
MECB SSR-2	**INPE (Brazil)**	**1997**	**Land Sensing**
Eyeglass	**OSC (US)**	**1997**	**Land Sensing**
Orbview	Orbimage (US)	1997	Panchromatic (1 m)
SPOT-4	CNES (France)	1997	Panchromatic/Multi-spectral (10/20 m)
Envisat	ESA	1998	Radar (30 m)
Landsat-7	US	1998	Panchromatic/Multi-spectral (15/30 m)
EOS AM-1	Japan/US	1998	Multi-spectral (15 m)
KOMSAT	Korea	1998	Panchromatic (10 m)
IRS-1d	ISRO (India)	1999	Panchromatic/Multi-spectral (10/20 m)
SPOT-5A	CNES (France)	1999	Panchromatic/Multi-spectral(5/10 m)
SPOT-5B	CNES (France)	2004	Panchromatic/Multi-spectral (5/0 m)
EOS AM-2/ Landsat-8	US	2004	Panchromatic/Multi-spectral (10/30 m)

* length listed is resolution

- This slide is a real eye-opener.
- Many commercial satellites are in place already and this chart lists some of the planned launches. The pace of launch is accelerating with 6 or more launches planned each year for the next few years.
- Note that the French launched a Helios satellite (the first line on the chart) during the course of our deliberations. As is indicated that satellite will provide 1 m resolution.
- Also note the three launches in the box in the middle of the chart. These US satellites will provide high resolution multi-spectral imagery commercially. The commercial world foresees business opportunities in this area and they are investing significant funds to establish the capability to provide high resolution imagery. We saw little planning within DoD to use this capability effectively.

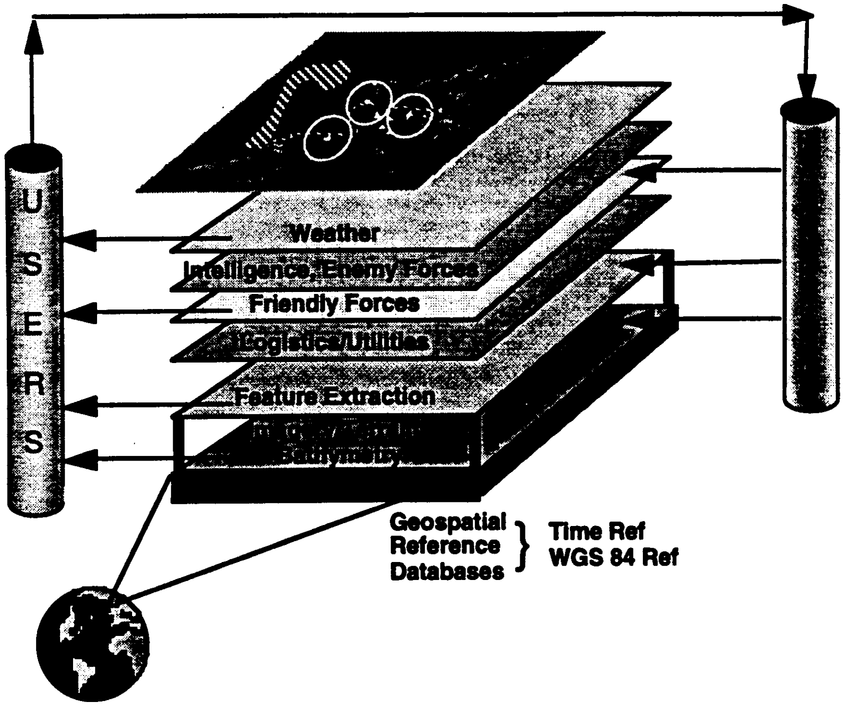
DSB The Growth of Information Systems is Changing the Geospatial Information Requirement



lime is of the essence — money is being spent daily — make it count

- Our concept of mapping has changed significantly over the course of the study. Improved map production is not as important as developing geospatial reference databases.
- There is major value in everyone using the same geospatial database.
- Many users need access to a database in order to do their jobs. That database should be common to allow the many activities shown on the chart to be carried out effkiently.
- Money is being spent in these areas every day so time is of the essence. A common approach will maximize the return on investment.
- What is really needed is a common geospatial reference foundation.

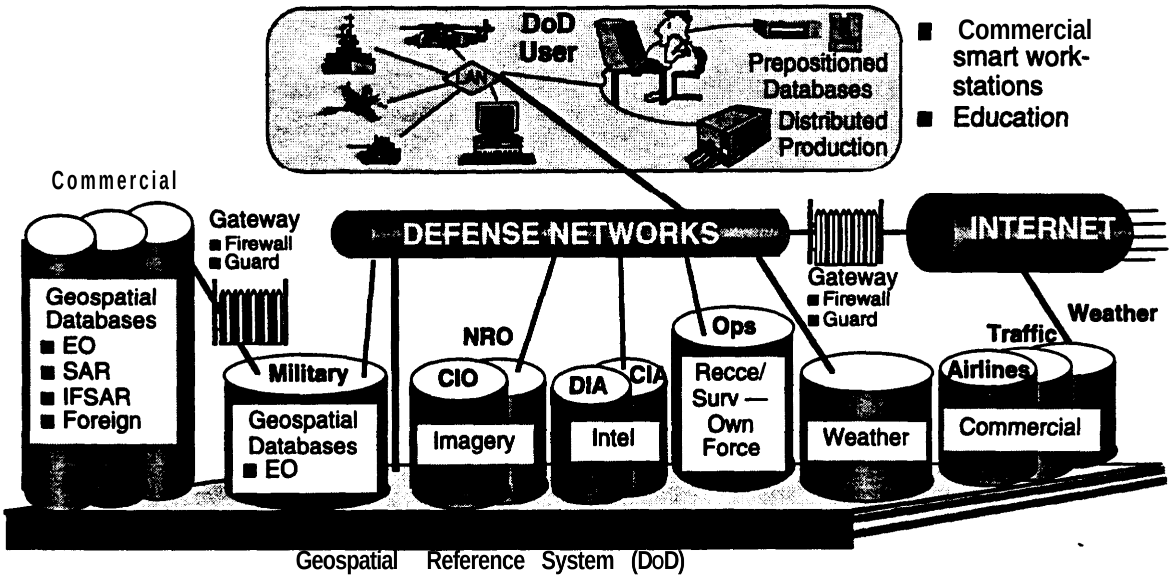
Our Vision: A Time-Tagged Geospatial Foundation



- The view of the future is to create common reference databases — a foundation that you can build on. The databases will bring together various images in a common reference system to create a system which is greater than the sum of its parts.
- This foundation will permit the user to customize his product and obtain what he needs to complete his tasks and to achieve an advantage over his adversary.
- Note on the right that the vision provides a feedback mechanism to reflect real-time changes to the data — enabling up-to-date information in urban conflicts etc.

DSB

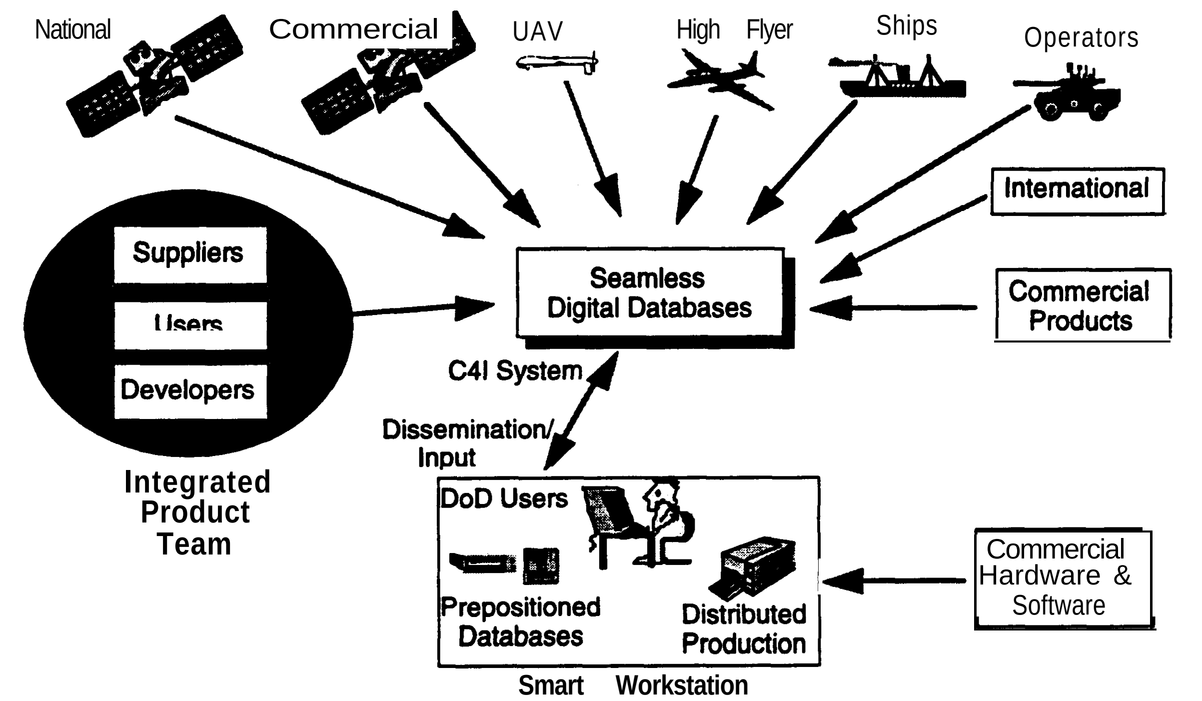
Vision — Operational Implementation



Distributed databases, referenced geospatially, empower the user

- This chart describes the pieces that transform the vision to operational implementation.
- This effort would build upon the Information Architecture for the Battlefield described in the 1994 Summer Study co-chaired by Craig Fields and Gen James McCarthy (Ret).
- The vision is based on a distributed, high transaction rate, very large object-oriented database. While this is not currently a mature technology it is certainly envisioned as the future approach in many commercial areas and another opportunity for DoD to ride the commercial curve.
- The underlying philosophy assumes that the user would have smart workstations with prepositioned databases and exception data updates.
- The user would also have access to local production capability for the customized products he develops. There is no reason to print maps in the US and ship pallets of maps to the warfighter.
- Notice that the geospatial reference system provides a foundation to stack databases in a common reference. The databases are distributed in an Internet-like arrangement and security is maintained by gateways.
- We envision distributed databases from which the user could obtain information to "overlay" on a map developed using prepositioned data and updates from the geospatial databases. Commercial geospatial information would be accessed through a DoD link to ensure that the information is "pedigreed." This restriction is imposed to maintain security and avoid contaminating the database through intentional or unintentional insertion of false information. Raw imagery, intelligence data, and weather data would be available from the appropriate agencies. Operational units would provide reconnaissance and surveillance data from the field, as well as own force information. Commercial databases could be accessed through a secure gateway to obtain airline schedules and routes, local traffic information, travel guides, and local weather to augment DoD information.

Future Defense Mapping Process That Meets Our Vision
What is DoD's Vision?



- This chart depicts the vision of the Task Force.
- We believe DoD should take advantage of all of the available data sources as shown across the top of this slide. The databases should be populated as quickly as possible to deal with potential contingencies.
- The C41 system links with the users should be established using the "catcher's mitt" described in last summer's study. Local production capability should also be put in place.
- In all of this we should take advantage of commercial products, hardware, and software.
- An Integrated Product Team (IPT) should be established to manage the entire effort as we transition from today's implementation to the future.
- Whether this vision is exactly correct or not, it is important that DoD adopt a common vision and move forward to implement the vision.
- DoD must migrate to high resolution, rapidly accessible, releasable, interoperable databases for multiple and integrated uses:
  - training
  - wargaming
  - mission planning
  - operations

DSB

Our Recommendations

- The remainder of the briefing provides specific recommendations.

Establish & Implement a Coherent DoD Geospatial Information Vision via an Integrated Product Team*

Integrated Product Team

- Commercial
- OSD
- Army
- Navy
- Air Force
- Marine Corps
- DMA
- DIA
- DISA
- JCS

Responsibility and Authority →

Put In Place

- GIS architecture/ standards
- Layered databases
- Realistic geographic coverage priority process
- Accelerated access to sources (Metric set & tracked)
- Smart workstations

** as Extension of DSB C4I Vision*

- The Task Force believes that DoD should adopt a vision and begin to put the components in place.

- An IPT with responsibility and authority should be established to implement the vision. The IPT must have authority and responsibility to implement the system. It is important to involve the commercial suppliers in the IPT.

- The IPT should be allowed to trade off requirements, priorities, implementation schemes, and funding levels. For example, the IPT should consider terminating scheduled production of a variety of less-than-critical map products in order to fund putting in place a distributed digital system.

Requirements Process

- CJCS institute a realistic geographic coverage prioritization process driven by the warfighter

- Establish a metric to measure the progress toward enabling the digital battlefield

- The warfighters must reengineer the requirements process because MOP 31 is ineffective.
  - The new process should eliminate emphasis on "traditional" DMA products and focus on information needs. The user should indicate that he needs the information to operate a contingency force in a specific area — not that he needs 150 topographic maps of the area.
  - The process should emphasize contingency responsiveness and expansion of the geospatial database.
  - The process should also address weapon system, C2, simulation, and wargaming needs.

- Metrics should be established to include geospatial information as part of Force Readiness Measurements.

- Database availability and feasibility should be tied to acquisition of weapon system, C2, simulation, and wargaming systems.

DSB

Data Collection and Standards

Now

- National Assets
- Limited Commercial Sources
- Other

Change the Mind Set

Future

- Cultivate and incentivize global industry sources and standards
- Expand the use of all sources
- Gain access to existing and future databases
- Ensure drones / UAV / aircraft compatibility

Set a Metric
e.g. Imagery (% National Assets / % Commercial Sources)
90/10 → 20/80
5 yrs

- The mind set concerning imagery collection must be changed to take full advantage of all sources and processing tools in order to load the databases. We are currently extremely dependent upon a single EO source. We should work with and incentivize commercial sources to look upon DoD as a paying customer with reasonable procurement methods.

- To measure our progress toward the utilization of commercial imaging, we should set a goal of moving, for example, over the next five years from the current status of 90% of imagery coming from National assets with 10% from commercial, to 20% from National assets and 80% commercial.

DSB

Analysis and Production

- Build on imagery, not topographic stick figures -
  -Use incremental vs. full data analysis
- Utilize commercial sources and methods for feature extraction
- Take advantage of multi-mode / multi-spectral data
- Resolve the imagery security issue

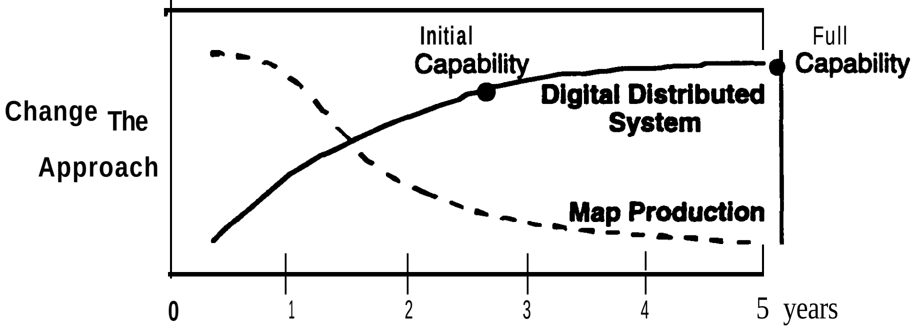
- In the current need for rapid response, there isn't time to wait for production of traditional topographic maps. We should build on imagery to produce the best we can, as fast as we can. The information should be provided to the user as it becomes available and incrementally densified with feature data, not held back until the traditional data set is complete.

- We should purchase tools from the commercial suppliers and take full advantage of the multi-spectral data to aid in feature extraction. Feature extraction should be automated to the extent possible to meet timeliness requirements. However, we must also utilize commercial feature extraction databases to assist in map generation.

- The security issue must be resolved. The users need unclassified resampled imagery products to distribute to uncleared troops in the field and to share with coalition partners. It makes no sense to buy commercially what we already have available from national sources.

DSB Dissemination, User Tools and Remote Replication

- Plan phased end to centralized map printing
- Services need to provide smart workstations, education, and replication capabilities to support distributed production
- Link defense mapping to C4I for the Warrior
- Provide user the capability to update the databases



- DoD should establish a transition plan to move toward the distributed system of the future and phase out the traditional printed map approach. This should all be tied to the C4I For The Warrior process that is already going forward.
- We should exploit the commercial market for smart workstations, printers, services, and products.
- We must educate and train the troops so that they know how to properly read, manipulate, and update the databases in a controlled manner.
- As map production is phased out, funds will become available to establish the new digital database system.

DSB

Summary

- **Our vision:**
  - **Provide digital distributed databases of geospatial temporal information as the foundation for military information systems**
- **To implement this vision, DoD should:**
  - **Evolve a distributed heterogeneous Internet-like architecture that uses the geospatial databases as its foundation**
  - **Change the defense mapping mission to: Maintain the geospatial databases and protect access and integrity**
  - **Institute a requirements process that prioritizes users' geographic needs**
  - **Rapidly acquire access to virtual worldwide databases using all available commercial sources and practices**
  - **Equip and educate the end user to locally add value and meet his needs (e.g., smart workstations, printers, etc.)**
  - **Establish an IPT to manage the whole process**

- In summary, the Task Force believes that DoD should:
  - Shift from a paper map mentality to a digital distributed system
  - Exploit the commercial market place for imagery, hardware and software tools, and services
  - Authorize the IPT to make it happen

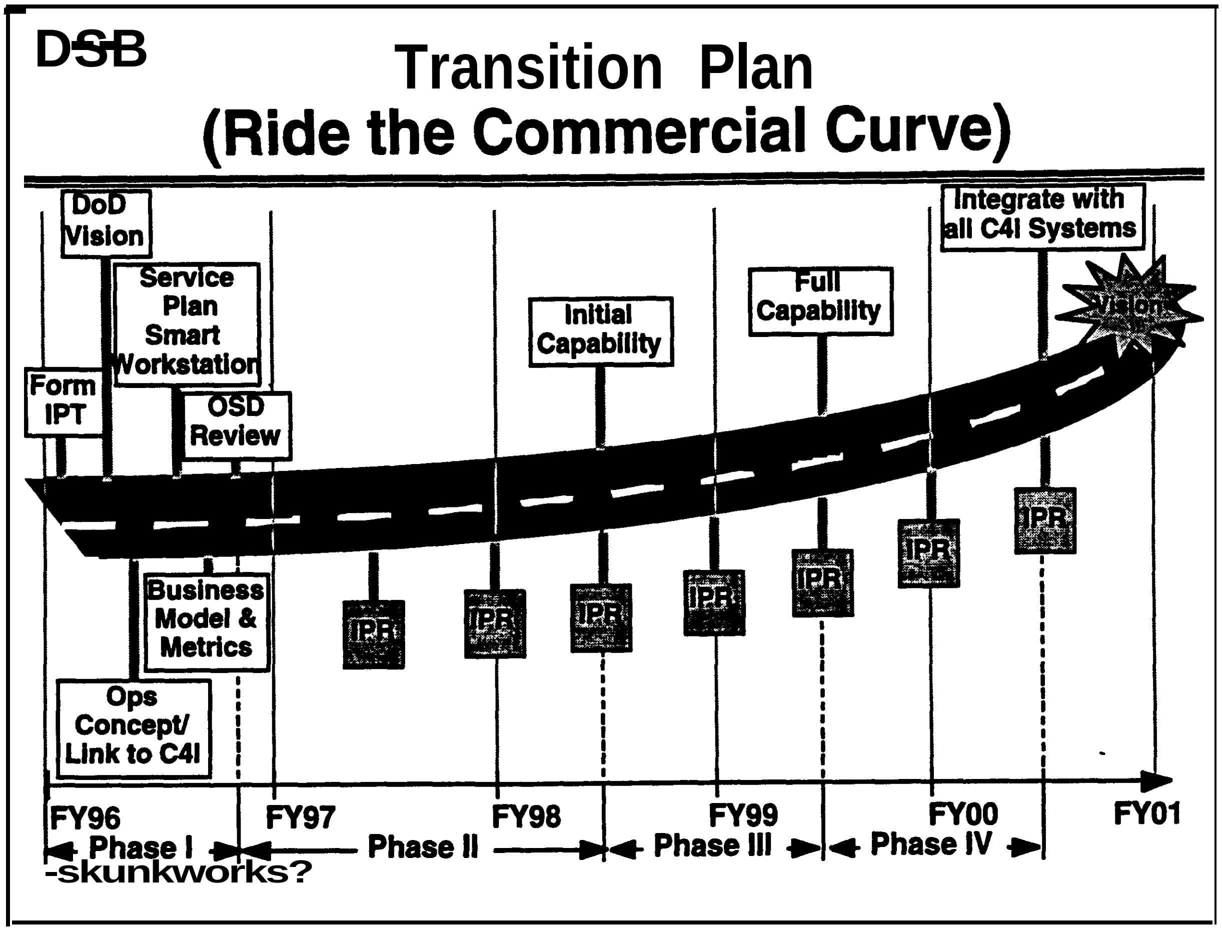
Recommended Actions

SECDEF:

- **Establish and implement a geospatial information vision**
- **Put in place an Integrated Product Team led by CJCS**
- **Change the DMA mission**
  - **-from maps and charts**
  - **-to maintain access to and protect the geospatial databases**
- **Direct the CJCS to re-engineer the requirements process**
- **Direct the Services to provide infrastructure to use the system (smart workstations and distributed production capabilities)**

- This chart summarizes the specific actions needed to implement the Task Force recommendations.

- These actions would position DoD to take advantage of several opportunities:
  1. The opportunity to provide a competitive advantage on the battlefield by working with digital databases and the distributed system to allow the warfighter to use those databases and take advantage of the information contained,
  2. The opportunity to take advantage of (not to try to control) the rapidly expanding commercial arena which is overtaking the government capabilities,
  3. The opportunity to establish a structure within DoD that ties together everything from the sources to the user to enable meaningful trades, identify resources, and define a unified vision, and
  4. The opportunity to utilize an Integrated Product Team to manage the transition to the future concept.



- This chart provides a roadmap for transition based on riding the commercial curve.
- Establishing the details of this roadmap would be the responsibility of the IPT. However, the members of the Task Force would be happy to assist in the preparation of phase definition and statements of work.
- We believe that this can be accomplished with initial capability in mid FY98 if we get started quickly with the IPT.
- There is no doubt that many roadblocks will be encountered and statements of "This is impossible." will be made. One method to overturn this mind set would be to establish a skunkworks of a dozen or so innovative people working in parallel to prove what can be done.

2. Task Force Overview

2.1 Background

The Department of Defense (DoD) and the national security community in general have undergone significant changes over the last decade. The demise of the Soviet threat and the end of the Cold War have forced the DOD to reevaluate its missions, requirements and processes in all areas of national security support. Further, the declining budget demands that the Department search for commercial sources wherever cost-effective solutions are available. In advanced electronics and information technology, commercial industry now leads the Department in important areas. The Defense Mapping Agency (DMA) is implementing a concept for a customer-accessible data base of global geospatial information which will contain the information generally found on maps and related materials. These changes present opportunities for DoD, as well as potential risks from the diffusion of commercial technology to adversaries.

The Defense Science Board was requested to establish a Task Force to identify the cost-effective approach for providing needed geospatial information and products to users among the Unified Commands, Military Departments and Defense Agencies at all levels. Within the scope of this Task Force effort, the following was to be addressed:

1. Are the DoD vision, plans, and resources for Defense mapping systems adequate to address the full spectrum of potential conflicts including force readiness, training and exercises?
2. Are user needs clearly defined and prioritized? Can the system provide rapid response to address unforeseen urgent operational needs of the operating Commands?
3. Are current and planned information sources adequate to support production requirements?
4. Are current and planned processing, production and dissemination methods responsive to the needs and compatible with the vision?
5. Is technology development for the end users phased and resourced to take advantage of the evolving defense mapping capability?
6. Do the best commercial processes or products contribute to meeting government needs?

The Assistant Secretary of Defense (C31) was the sponsor for the Task Force. The Terms of Reference and Membership List for the Task Force are provided as Appendices A and B respectively.

For these discussions geospatial information is defined as:

- Geographically referenced data or data used to position objects or activities referenced to the earth with accuracy appropriate to the application (Mapping Science Committee)
- Information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth (Executive Order 12906 - National Spatial Data Infrastructure)

Geospatial information includes traditional printed maps; geographically annotated orthophotos; gridded elevation data; raster maps, charts, and images; vector information with attributed points lines and areas, and textual data.

The Task Force focus responded to the changing status described in Figure 2-1.

<u>what's Changing</u>?

- Information Technology Revolution yielding new opportunities for distributed access to vast and growing "on line" digital databases of geospatial information with:
  - increasing use of digital information for systems
  - increasing opportunities for customized, multi-spectral products
  - increasing ability to procure products (screen and paper) in remote (local) areas
  - increasing commercial capability
- Geopolitical Revolution — a shift in national security from the focus on nuclear deterrence/Soviet Union to a more complex set of challenges of major regional contingencies and operations other than war (shift from strategic to tactical)
- Shift in Source Material from predominantly national technical means to increasing availability of commercial data
- Proponent Shift

The warfighting systems/processes have crossed the "digital Rubicon." The current system of supplying those digits is inadequate.

<u>What's Needed?</u> A process that exploits the technical revolution to meet exponentially increasing digital needs of the entire force in a cost effective solution incorporating best commercial processes.

Figure 2-l Current Status

2.2 Constraints and Caveats

The primary focus of the effort was on the process of digital mapping and not organization issues.

23 Definition of Functional Areas Encompassing Geospatial Information Systems

The defense mapping process can be envisioned as shown in Figure 2-2. The users define requirements to enable effective planning and operations, to support modeling, simulation and wargaming efforts, and to support development of new weapon systems and platforms. The mapping community collects the appropriate information and performs the required data extraction and analysis. It then produces and disseminates the products. The users then use these product in various ways and provide feedback to the mapping community as to the adequacy and utility of the products.

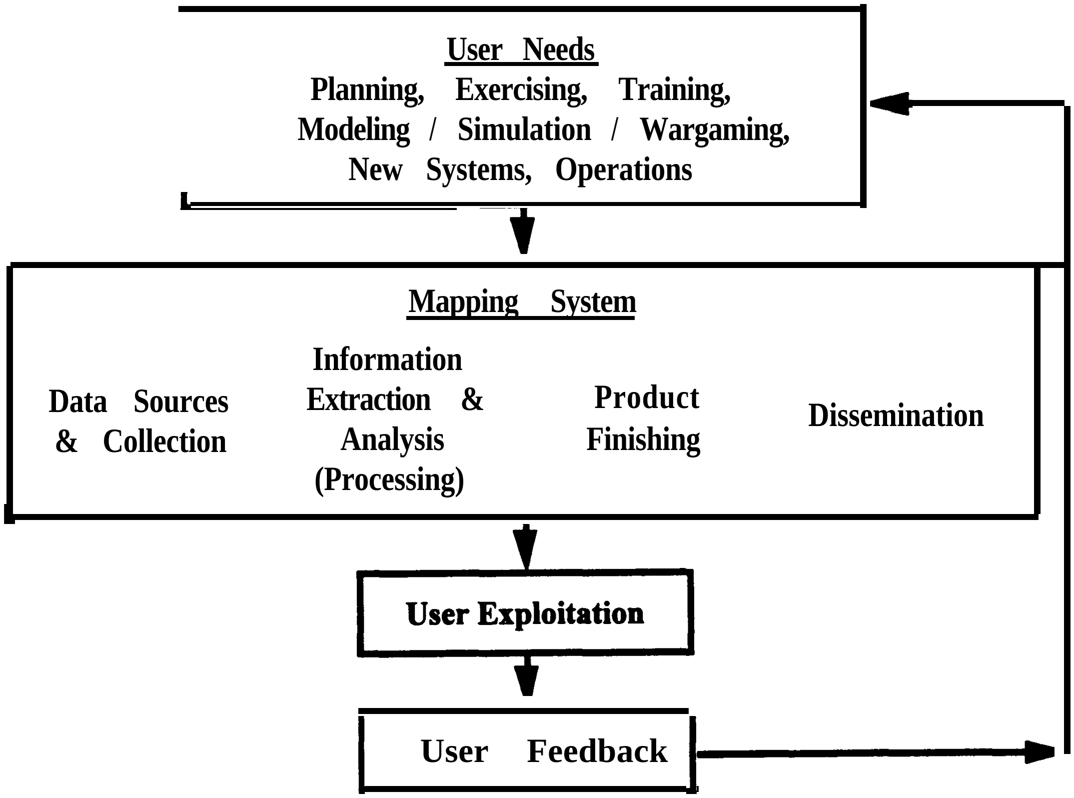


Figure 2-2 Defense Mapping Process

2.4 Input to the Study

In the process of conducting the study, the Task Force received many useful briefings, reports, and comments from government and industry which served as useful inputs to Task Force deliberations. These inputs are summari 'zed in Appendices E through G (Current and Planned Government Capabilities and Resources) and H (View from Industry).

Critical to the process of responding to the Terms of Reference was the need to understand the users' perspective. In their presentations to the Task Force, therefore, the users, producers and industry were asked to address the questions listed in Figure 2-3. This process led to the identification of a series of issues to focus the Task Force discussions. These issues are summarized in Figure 2-4.

Questions for CINCs

1. What are the Command's views on the current and future requirements for geospatial information and on how well these requirements are being met?
2. How have the Command's requirements changed in recent years, in light of the significant changes in national security requirements?
3. How are the Command's requirements for geospatial information defined and incorporated within the Command's overall planning processes?
4. How are shortfalls dealt with at the Command?
5. What Command capabilities exist to produce and distribute geospatial information products? What capabilities are needed?
6. What is the Command's vision for geospatial information for the 21st century?

Questions for Military Departments/Agencies

1. How are user requirements for geospatial information defined?
2. What arc the current and future requirements for geospatial information?
3. How well are these geospatial information requirements being met?
4. How are geospatial information requirements incorporated within Service/Agency planning, programming and budgeting processes?
5. How do geospatial information requirements and programs interface with weapon system development efforts and other C41 initiatives (e.g., C4I for the Warrior)?
6. What Departmental capabilities exist to produce and distribute geospatial information products? What are needed?
7. What is the vision for geospatial information requirements for the 21 st century?

Figure 2-3 Questions for Briefers

- Providing support to regional conflicts.
  - Many recent contingencies have been to locations where the local infrastructure is very limited. Further, military commanders may be required to deploy much faster than the times associated with Cold War missions of the past.
  - A particular area of concern is providing maps and charts in urban areas.
- Distributing geospatial information capabilities to theaters vs. centralizing such capabilities.
  - Consider the cost-effectiveness of distributed approaches to providing mapping information to users in comparison with a centralized approach.
  - Providing information to the CINCs is not the same as providing it to lower level warfighting commanders within the Unified Commands.
- Providing support to mission planning for new weapon systems.
  - Many individual weapon systems are deployed without adequate interface with the geospatial information system community. Program Managers are not typically rated by such life cycle issues. Rather, they are rated by nearer term criteria: cost, performance and schedule.
  - There are instances where unique mission planning capabilities have been developed in parallel with broader efforts of the geospatial information community. Such independent efforts are not affordable.
- How DMA priorities are set.
  - DMA gets its priorities from the Joint Chiefs; however, there are times when normal priorities interfere with other DMA demands.
- Capabilities of users to specify their mapping needs and to provide feedback on satisfaction.
  - Unified Commanders and their staffs do not have the engineering resources to be "smart customers."
- Balancing the mapping effort of production of charts and maps with construction of a database with information that can be accessible to users in the field.
- Mechanisms for dissemination of products and available data.
  - Resources for dissemination are currently very limited. In a constrained budget, DoD needs innovative ideas on how to get the mapping information to users. The rich commercial information network may be useful in this endeavor.
- Need for "on call" collection, processing, production and dissemination services and databases from industry.
  - Given the diversity of missions and needs, DoD will need mechanisms for tapping commercial resources.
  - Perhaps this community needs to develop a "commercial reserve" capability
- Mechanisms for exploitation of emerging commercial capabilities.
- Technologies for merging disparate sources and types of data supporting maps and charts.
- Synchronization between plans of the geospatial information community and the needs and capabilities of military end users.
- Infrastructure costs of the geospatial information community are high.

Figure 2-4 Issues Identified

3. Task Force Evaluation

3.1 A Vision for the Future

The Department of Defense should have readily available, on demand, for a large variety of world-wide customers, imagery, mapping and charting information. DoD should establish a repository for both analog and digital information from every appropriate source, including commercial, but with an ever increasing emphasis on digital information. Authorized customers should have the ability to access this information, preferably on-line, and prescribe their desired information domain, i.e., administratively, geographically and temporally, and to specify required resolution, granularity, terrain features, etc. Customers should have available digital information for planning and event execution. They should be able to locally manipulate this imagery/ mapping/ charting information, vary the dimensions, tailor the information, do mensurations, provide over-lays, seamlessly project on large screen displays and directly integrate into mission planning and weapons systems. The customers should be able to select any scale, with measurements computed automatically, as they telescope in, or out, on the desired geographical area. DoD should shift its emphasis from standard scale-based map and chart production to the creation and maintenance of databases tethered/referenced to the Global Positioning Systems (GPS) time and positional accuracy and tied to the World Geodetic Reference System (WGS-84). Information in the digital database should be tagged with the time at which the data was considered valid, and a reference to the information pedigree. This information should be available over communications arteries of the highest bandwidth that the user's priority will permit for distribution and local map/chart production. These databases should serve as the reference system to register various layers of information available to the user. Figure 3-l depicts that vision.

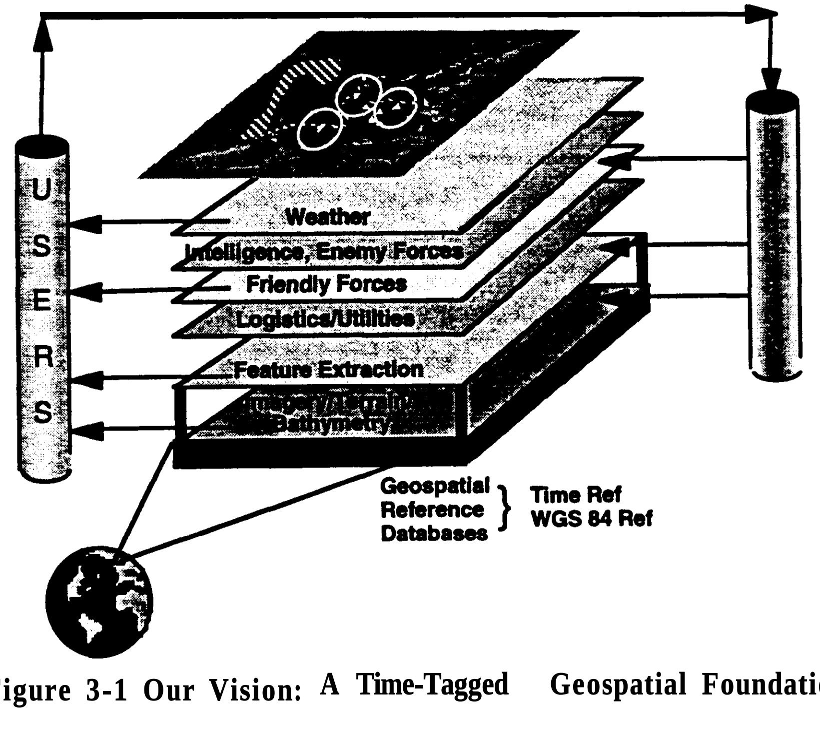


Figure 3-1 Our Vision: A Time-Tagged Geospatial Foundation

3.2 Architecture — Implementing the Vision

Most senior representatives of DMA and the user agencies share a notional vision of the Global Geospatial Mapping Information & Services (GGMI&S) concept; i.e., a worldwide digital data base serving diverse users through the requisite communications channels to satisfy all their imagery, charting and mapping information needs. However, it appears that the current state of maturity of planning and designing is still fragmented. Specifically, the community is still pursuing autonomous concepts from the intelligence and DoD perspectives. No coherent DoD strategy exists to transition from today's "hard copy production" environment to the geospatial information system envisioned. Few, if any, resources have been planned - even identified - to support the transition to the new GGMI&S system.

In the transition phase from centralized to distributed provider there will be confusion, in that some old concepts and language are being carried over in spite of the fact that they are not appropriate in a server/client environment, for example:

The Languages of Two Worlds

Current Centralized Model	GGMI&S Server Environment
• standards	• Compatibility (e.g. ATM) and Standards
• Requirements	• Needs (time sensitive)
• Request (Ordering)	• Browse, Query
• Delivery	• Download
• End User	• User
• TimeFrame (Months, Years)	• TimeFrame (Minutes, Hours)

In an environment where all data had geospatial information tags, a common picture of the information could be constructed. Since some of the data that would be related has dynamic properties, it is important to augment geospatial information with temporal data. However, since some geospatial information is temporal too (the presence or absence of a bridge for example - either pre-construction or post bomb damage assessment time frames), time tags seem to make sense for geospatial data. Similarly, the pedigree of information is important to geospatial data and would carry over as a benefit for the C4I for the Warrior concept and for management information systems.

The Task Force recommends that DoD design a data and physical architecture that embodies these essential characteristics:

- 💧♏♋❍●♏⬥⬥
- Open operating environment
- Multilevel security/trusted systems
- User pull
- Client/server
- Distributed
- Scaleable
- Object-oriented

3.3 Users and Requirements

Many recent contingencies have been to locations where the local Siastructure is very limited. Further, military commanders may be required to deploy much faster than the times associated with Cold War missions of the past. A particular area of concern is providing maps and charts in urban areas. Providing information to the CINCs is not the same as providing it to lower level warfighting units and warriors within the Unified Commands.

Many individual weapon systems have been developed without adequate interface with the geospatial information system community. Program Managers are not typically rated by such life cycle issues. Rather, they are rated by nearer term criteria: cost, performance and schedule. There are instances where unique mission planning capabilities have been developed in parallel with broader efforts of the geospatial information community. In today's budget environment, independent efforts are not affordable.

The Task Force heard the DMA describe a "H-year" backlog in defense mapping requirements. The Task Force is concerned that the prioritization approach depicted by this DMA briefing might lead to attempts to map everything everywhere, rather than on achieving the needed mapping information when needed, as it is needed. The DMA has a menu of many different products, some more relevant to the Cold War than today's missions and environment. The users of DMA products do not have a feel for the relationship between "value-added" of a particular DMA product and its cost.

The requirements process does not include affordability. The Army's geospatial requirement to support Force XXI consists of digital elevation data down to l-meter resolution, and highly dense feature data anywhere in the world. A system should be developed that encompasses the ability to respond immediately with planning level data at the advent of a crisis and then focuses assets on production of high resolution digital data of the identified crisis area in a timeframe that meets deployment and employment schedules of the identified forces. The ability to react rapidly with imagery, map extraction, printing and distribution requires less of an investment and less operating cost. This cycle time approach will reduce inventory dramatically.

3.4 Data Collection and Standards

The over-dependency on a single source must be among the most serious deficiencies to be changed rapidly. The emerging architectures must incorporate upcoming US commercial imagery systems. DoD must not act as just a user. Rather, DoD must identify the unique military value added capabilities desired to assure that in time of crisis, surge and other needs, that the systems will support DoD needs, as well as work with industry to incentivize incorporation in their systems. Additionally, all National intelligence and DoD imagery systems, whether space based or airborne, should include the capability to provide "mapping capable" imagery as a costed option for DoD decision makers to consider in the acquisition decision process.. The recent go-ahead for DAR0 Tier II+ without a metric capability should be changed to consider mapping capability.

Two-dimensional images, such as LANDSAT, that have been geo-registered have no three dimensionality and cannot be used for determining elevations or heights. Unfortunately, these are often called maps, but in fact they are limited in their use until and unless they are combined with digital terrain data. In the case of high-fidelity modeling and simulation requirements, the third dimension is fundamental to mission and rehearsal, as defined, for example, by the US Army Force XXI concept. In a global geospatial information environment, every element of terrain, and every identification of a feature, must be registered to a three-dimensional geoposition. These requirements, however satisfied, will place demanding needs for high-resolution stereoscopic imagery source materials.

3.5 Data Extraction, Analysis and Product Finishing

Users want up-to-date paper maps for fighting units. Digitized products which can be manipulated at a computer terminal are useful for sites which have such terminals, but there remain soldiers who conduct their missions without such equipment. Further, paper (the right paper) has a beneficial property all its own, so for the foreseeable future there is likely to remain a need for paper map production — but the production should occur at user locations using modem commercial technology.

When the requirement is for very large scale information, actual imagery is a good supplement to map products. However, large scale image products tend not to be very accurate in an absolute positioning sense. There is a need to link imagery/photography to precise coordinates.

As DoD moves towards an integrated information environment, the distinction between traditional mapping (geospatial) information and intelligence information about places and things is rapidly disappearing. For example, the digital information about the location of a road network will contain much more information than is currently available to the user by interpreting symbology on traditional paper maps and charts. Where the user of a paper map might only be able to determine location and whether a road is a single lane hard surface road, the data in the digital geospatial database will allow computer access to the width of the road, the specific surface material, the condition of the road, the connectivity to other roads and bridges, and can be rapidly updated to show where damaged sections are evident from military activity. Information that traditionally resided in intelligence databases should be directly linked to geospatial databases. In order to meet the rapid response requirements of the 2lst century, DoD needs to acquire new sensor and feature extraction capabilities.

Today's environment where military forces are required to enter coalition operations throughout the world is testing the defense classification system. It is crucial that mapping products and services be accessible to coalition partners. Classification constraints also hinder US-only operations. The classification of imagery support data severely constrains the utility of some needed products. Many forces need photomaps and other mapping products and they typically need them to be unclassified.

3.6 Dissemination, User Tools and Remote Replication

The availability of good and timely global geospatial information is not sufficient. The Services and Commands should develop and deploy systems for dissemination and use of such information by operational forces. It is important that an end-to-end system exist to collect and process mapping information, produce needed products, disseminate such products to operational users, exploit such products efficiently and provide feedback to the system developers on the value of the service.

Little is being done in some end-users' environments to provide for the "catcher's mitt" portion of the geospatial vision; this seems particularly true below the Joint Task Force (JTF) level. Again there is a parallel to the intelligence community; OSD agencies are busy planning for and funding dissemination and exploitation architectures so that Unified Commands and JTF levels can receive and "pull" the information they need in time of crisis. The Services are not keeping pace in planning for the "bandwidth explosion" and the information availability explosion that is just over the horizon. Forces below the JTF level should start laying in the infrastructure they'll need to handle and access a wide variety of digital information — and lots of it.

Figure 3-2 represents how the multiple repositories, not only of mapping information, but also other information can be managed via the Defense Information Infrastructure @II).

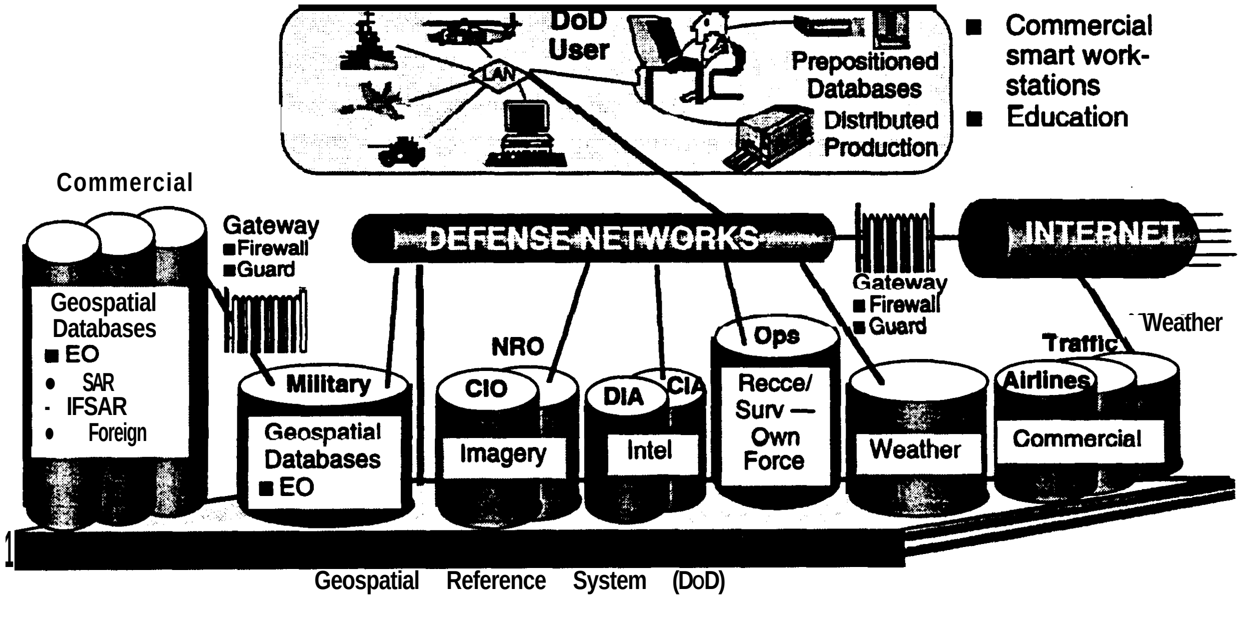


Figure 3-2 Implementing the Vision

It is important to note that bandwidth limitations exist regardless of the media chosen for communications among distributed forces. Assuming users are accessing data over "Internet" class communications media, one can estimate data transfer rates on the order of 25-30 kilobytes per second. At this rate, one CD-ROM worth of data (500-600 megabytes) will take 5.5 hours to transfer. A significant number of users will need more than one CD-ROM's worth of data. The bandwidth limitations over communications media can be somewhat alleviated by the prepositioning of some of the information

The physical implementation might be a combination of prepositioned CD-ROM products which have mostly time-insensitive data, and use of the DII as a means for updating the resident (locally stored) information. This is most likely true for each of the "servers" depicted in the diagram. Moreover, the servers themselves may be distributed. In this manner, multiple contributors (sources), value added participants, and users, may interchange information on a more robust and dynamic network than would be supportable by a single, centralized database. Pointers to the diverse servers may be included in the original prepositioned information, and updates or augmented pointing to sources can be managed over the network.

3.7 Business Plan

The commercial marketplace is offering tremendous opportunities to enhance defense mapping capabilities. Multiple sources for imagery source material are becoming available nationally and internationally. Systems to exploit that source material are currently available, allowing users to customize data to fit needs and desires. Therefore, the government should stay clear of inventing or developing systems which are available to&y commercially. However, the defense mapping community within DoD is not structured properly to maximize the use of available commercial applications and technologies to enhance or replace defense mapping functionality.

Resources for dissemination are currently very limited. In a constrained budget, DoD needs innovative ideas on how to get the mapping information to users. The rich commercial information network will be useful in this endeavor.

DoD's role needs to change from centralized producer of MC&G data to:

- maintainer of "national" databases fed by commercial producers, DoD (unique data that the commercial world can't provide), other co-producers (federal or international), and by users who have added value,
- certifier of products and processes for DoD use, and
- establisher of standards based on current best commercial products and practices.

DoD should only produce what others cannot do more efficiently and cost effectively — outsource the rest.

4. Major Findings

4.1 Change the Defense Mapping Mission

In order to address the problems identified in Figure 4- 1, DoD needs to change the overall mission for defense mapping. The focus should shift from maps and charts to the data and its availability to users in digital form. Specifically, the defense mapping community should be tasked to:

- Provide a geospatial foundation for the Defense Information Infrastructure DII)
- Protect integrity of the data
- Rapidly populate the geospatial database
  - Establish standards and processes for other agencies to participate, e.g.,
    - HUMINT / Field observation
    - Joint STARS
    - Tier II+
  - Expand sources for populating worldwide database including commercial imagery sources and products
  - Allow the customer to establish priorities for filling database voids
- Empower the user for end-product exploitation
  - Educate users on possibilities
  - Train users on techniques
  - Obtain feedback on user interface

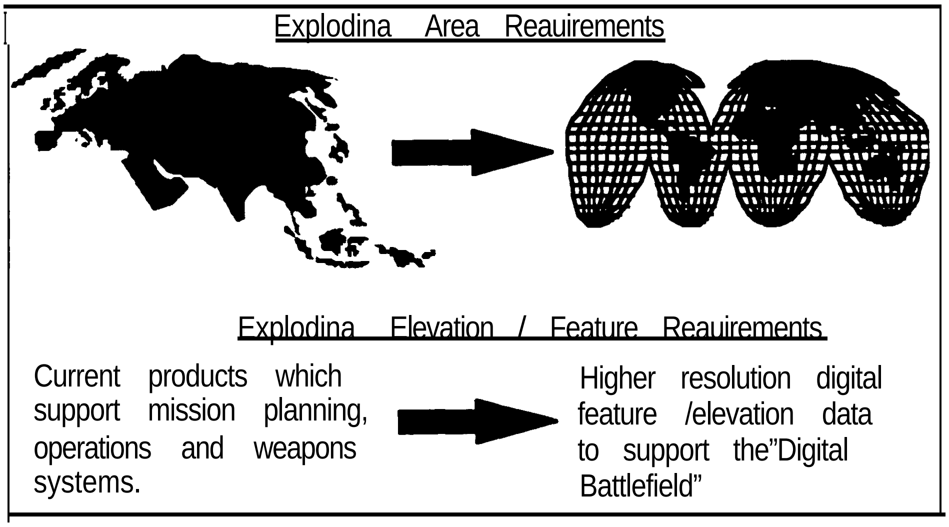


Figure 4-1 Changing Requirements for Defense Mapping

4.2 Implement the Vision

CJCS should build a concept of operations that ceases emphasis on traditional scale-based products and emphasizes contingency responsiveness and geospatial database expansion.

DoD should incentivize commercial businesses to provide sources and exploitation tools to include a focus on commercially-based standards, certification of inputs, software tools and exploitation of evolving commercial products and services.

DoD should then establish an Integrated Product Team (IPT) to define a defense mapping process to:

- Enable DoD and other government sources to contribute to the geospatial database
- Empower the user to help define the system, including training to make him an informed customer
- Adjust the DoD resource plan to support the vision

43 Business Plan

The Task Force found no current business plan for defense mapping.

It appears that DoD is spending well over $1 B annually on mapping, but the Office of the Secretary of Defense had great difficulty in collecting accurate data on the DoD-wide effort (see Appendix G). OSD identified $0.98B in FY96, principally the efforts of the Defense Mapping Agency. The investments being made by the Services and the operational commands is less understood. These organizations have not collected costs for mapping. Rather, their contributions are part of the broader investments being made in C41. The hardware and software being developed and deployed for dissemination of mapping information and for remote use and replication are extensive, but not focused on mapping.

Further, the Task Force finds that defense mapping requirements are not linked to costs. Users do not now directly pay for map products or for access to the database and have not viewed such resources as finite.

The Integrated Product Team should develop strategies for implementing an economic analysis linkage between requirements and data production and distribution.

4.4 Requirements Process

The JCS MOP 3 1 process for prioritizing needs is highly ineffective. Needs for mapping information and products are now defined in terms of standard products vs. true information needs. As a result, there is a significant imbalance between demand and supply. As is depicted in Figure 4-2, a closer link between the users and developers must be forged.

Another important issue is that the acquisition process for major weapons and information systems does not uniformly address geospatial information needs early enough. Although policies and guidance are clear and adequate, compliance with such OSD acquisition policy is lacking. The CJCS should institute a realistic prioritization process driven by the warfighter:

- Shift from detailed maps to “controlled image base” readiness products
- Develop contingency rapid response capability which includes the ability to automatically, or at least very rapidly, extract data from all available imagery
- Include new weapons and information system needs as part of process

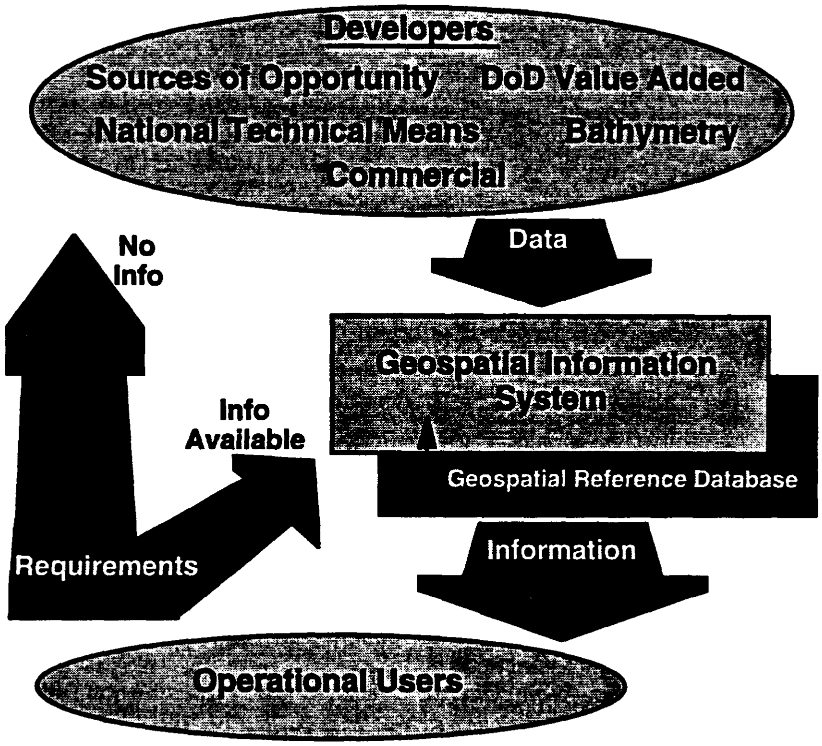


Figure 4-2 Closer Link Between Users and Developers

4.5 Data Collection and Standards

The Task Force finds a number of important inadequacies in the source data, in terms of coverage and quality against current requirements. The DMA production system architecture is limited to using only a single source of imagery. Further, the imagery sources suffer weather and priority impacts. Current and planned space systems do not address shallow water requirements and the standards for using various sources are inadequate. Current standards do not assure interoperability and standards for future imagery information sources are embryonic.

Future sources supplemented by an IFSAR sensor appear adequate for future needs for land forces but DoD is not programmed to use them. EO, radar, commercial, and foreign systems will address coverage, weather and priority impacts; unclassified sources will reduce classification problems. Navy collection of shallow water information using airborne laser and autonomous underwater vehicles will provide increasing amounts of data in the future.

OSD should direct the IPT to design a process that facilitates the use of all sources, including satisfaction of ocean coverage requirements. DoD should set in place commercially-based standards for all government and commercial users - processes for participation.

4.6 Data Extraction, Analysis and Product Finishing

There is an increasing need for high resolution, rapidly accessible, releasable databases for multiple and integrated uses. Current DOD-wide production shortfalls include long lead times, and limited rapid-response capability and jointness / interoperability / standards.

Annotated imagery products and more accurate GPS may provide the warrior with a better ability to accurately locate himself on the battlefield. They can also provide the capability to operate in areas with no map coverage until the necessary geospatial data can be provided.

SECDEF should issue a Policy Statement and DEPSECDEF should issue a corresponding Program Decision Memorandum (PDM) to change DOD'S production role from a vertically integrated product producer to the developer and maintainer of DoD's geospatial information database. DoD should lead in the building of a distributed (client-server; user-producer) architecture with a single "authority" for control of content, protocol and access. Further, DoD should acquire the capability to very rapidly extract data from a variety of sources once crisis areas have been developed. DoD should also develop an unclassified controlled image base.

4.7 Dissemination, User Tools and Remote Replication

Planning for dissemination and end user tools appears inadequate to the Task Force. DoD remains oriented to map printing and physical dissemination rather than transition to the digital world. The DMA GGMI&S vision shows promise, but is insufficiently defined and understood by the real users. The Services still assume most DMA standard products will continue, and, as a result, their planning for digital dissemination and remote replication is inadequate. However, the Task Force saw some planned C4I systems for using DMA digital data that provide excellent user products (e.g., Army's Digital Topographic Support System, Navy's Tactical Aircraft Mission Planning System, Air Force Mission Support System). But, these systems do not cover all of the Service's needs; rather, these systems service a small cross-section of the users.

DoD should:

- Plan phased end to most mapping and charting printing by DMA
- Direct the Services to provide the tools and replication capabilities to support a distributed presentation and production system
- Link defense mapping to GCCS and Joint C4IFTW systems effectively
- In the near-term, develop the capability for real-time electronic updating of deployed CD-ROM or tape format static data
- Exploit commercially available systems and develop other technology enablers to support the remote users

4.8 Summary

The Task Force sees significant room for improvement in the defense mapping process. Our vision for defense mapping is to provide users a digital distributed database of temporal geospatial information as the foundation for all military information systems. To implement this vision, the Task Force recommends that DoD:

- Evolve a distributed heterogeneous <u>Internet-like architecture</u> that uses the geospatial databases as its foundation
- Change the defense <u>mapping mission</u> to: Maintain the geospatial databases and protect access and integrity
- Institute a <u>requirements process</u> that prioritizes users' geographic needs

- Rapidly acquire access to virtual worldwide databases using all available commercial sources and practices
- Equip and educate the end user to locally add value and meet his needs (e.g., smart workstations, printers, etc.)
- Establish an IPT to manage the whole process

5. Summary of Action Items

SECDEF should issue a Policy Statement to change DoD's production role **from a** vertically integrated product producer to a manager of the geospatial database, and then direct ASD(C31), DMA, and Services to:

- Plan phased end to most mapping and charting printing by DMA
- Provide the tools and replication capabilities to support distributed presentation and production system
- Link defense mapping to GCCS and Joint C4IFTW systems effectively
- In the near-term, develop the capability for real-time electronic updating of deployed CD-ROM or tape format static data
- Exploit commercially available systems and develop other technology enablers to support the remote users

CJCS should build a concept of operations that:

- Ceases emphasis on traditional scale-based products
- Emphasizes contingency responsiveness and geospatial database expansion

CJCS should also institute a realistic prioritization process driven by the warfighter:

- Shift from detailed maps to "controlled image base" readiness products
- Develop contingency rapid response capability which includes the ability to automatically, or at least very rapidly, extract data from all available imagery
- Include new weapons and information system needs as part of process

OSD should establish an Integrated Product Team to define a defense mapping process to:

- Enable DoD and other government sources to contribute to the geospatial database
- Empower the user to help define the system, including training to make him an informed customer
- Adjust the DoD resource plan to support the vision
- Design a process that uses all sources
  - Set in place standards for all government and commercial users
  - Facilitate commercial sources – processes for participation
  - Include ocean coverage requirements

OSD should issue a Program Decision Memorandum (PDM) to change DoD's production role from a vertically integrated product producer to a manager of the geospatial database

OSD should also develop a controlled image base for releasable information and build a distributed (client-server; user-producer) architecture with a DoD "authority" for control of content, protocol and access.

DoD should incentivize commercial businesses to provide sources and exploitation tools, including a focus on standards, certification of inputs, software tools and exploitation of evolving commercial products and services.

Appendices

A. Terms of Reference

B. Membership and Government Advisors

C. Briefings Provided to Task Force

D. Previous Related Studies

E. Current Government Imagery and Mapping, Charting & Geodesy Capabilities

F. Government Planned/Proposed Geospatial Information Capabilities

G. DoD Resource Summary

H. A View from Industry

I. Acronyms & Glossary

A. Terms of Reference

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-3010

ACQUISITION AND TECHNOLOGY

MAR 2 3 1995

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference — Defense Science Board Task Force on Defense Mapping for Future Operations

YOU are requested to establish a Defense Science Board Task Force on Defense Mapping for Future Operations. The Defense Department and the national security community in general have undergone significant changes over the last decade. The demise of the Soviet threat and the end of the Cold War have forced the DoD to reevaluate its missions, requirements and processes in all areas of national security support. Further, the declining budget demands that the Department search for commercial sources wherever cost-effective solutions are available. In advanced electronics and information technology, commercial industry now leads the Department in important areas. The Defense Mapping Agency (DMA) is implementing a concept for a customer-accessible data base of Global Geospatial Information (GGI) which will contain the information generally found on maps and related materials and will conform to standards. These changes present opportunities for DoD, as well as potential risks from the diffision of commercial technology to adversaries.

The mission of this Task Force is to identify the cost-effective approach for providing needed geospatial information and products to users among the Unified Commands, Military Departments and Defense Agencies at all levels. Within the scope of the study the following should be addressed:

1. Are the DoD vision, plans, and resources for Defense mapping systems adequate to address the full spectrum of potential conflicts including force readiness, training and exercises?
2. Are user needs clearly defined and prioritized? Can the system provide a rapid response to address unforeseen urgent operational needs of the operating commands?
3. Are current and planned information sources adequate to support production requirements?
4. Are current and planned processing, production and dissemination methods responsive to the needs and compatible with the vision?
5. Is technology development and equipment acquisition for the end users phased and resourced to take advantage of the evolving defense mapping capability?
6. Do the best commercial processes or products contribute to meeting government needs?

The Assistant Secretary of Defense (C31) has agreed to sponsor the Task Force and provide funding and other support as may be necessary. Mr. G. Dean Clubb will serve as Chairman and MajGen Robert A. Rosenberg, USAF(Ret) will serve as Vice Chairman. Ms. Jana Cira of the Office of the Assistant Secretary of Defense (C31) will serve as Executive Secretary and CDR Robert C. Hardee, USN will be Defense Science Board Secretariat representative. I request that you provide a final report to the Department by October 1995. It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Paul G. Kaminski

B. Membership and Government Advisors

Members

Mr. G. Dean Clubb, Texas Instruments, Inc.* — Chairman
MajGen (Ret) Robert Rosenberg, SAIC — Vice-Chairman
Dr. Murray Felsher, Associated Technical Consultants
Mr. Arthur Johnson, Loral Federal Systems Group*
Gen (Ret) Robert T. Marsh, USAF, Private Consultant
Gen (Ret) James McCarthy, USAF, US Air Force Academy
Dr. William M. Mularie, National Media Laboratory
Mr. Thomas Saunders, MITRE Corporation
VADM (Ret) Jerry Tuttle, ORACLE
LTG (Ret) John W. Woodmansee, Perot Systems Corporation*

* DSB Member

Executive Secretary

Ms. Jana Cira, ODASD(I&S)

DSB Secretariat Representative

CDR Robert Hardee, USN

Government Advisors

Dr. Richard Berg, Defense Mapping Agency
Mr. Walt Boge, Topographic Engineering Center
Mr. Eric Bradbury, Central Imagery Office
Ms. Mary Clawson, CNO(N96 1 CN)
Co1 Steve Cummings, AF/INXF
Mr. Frederick J. Doyle, National Reconnaissance Office
MajGen Brett Dula, Central Imagery Office
CAPT Michael Hacunda, CNO(N961C)
LTC Tom Haid, STRATCOM
LTC Dave Maxon, Army
Dr. Michael J. Mestrovich, Defense Information Systems Agency
Maj Bob Mosley, USMC, Intel Act Quantico
MajGen Philip Nuber, Defense Mapping Agency
Maj Dan Saxon, USAF, AF/INXF
Mr. Steven Schanzer, Community Management Staff
Dr. Walter Senus, Defense Mapping Agency
Mr. Rick Shackleford, Defense Intelligence Agency
Co1 Gil Siegert, SPACECOM
Mr. Neil Sunderland, 497IG/INOT (AF)

Task Force Support

Mr. Bradford Smith, Strategic Analysis, Inc.
Dr. Nancy Chesser, Directed Technologies, Inc.

C. Briefings Provided to Task Force

April 6-7,1995 Military Services and Unified Command Views

DMA Director's Perspective	MajGen Nuber
JCS Joint Warfighting Geospatial Requirements	BrigGen Hicks
DoD Vision and Geospatial Requirements	Mr. Hall, DASD(I&S)
USSOCOM Geospatial Requirements	Co1 Brazelton
USSTRATCOM Geospatial Requirements	MajGen Curtin / LTC Haid
USCENTCOM Geospatial Requirements	Co1 Morris / Maj Smith
USSPACECOM Geospatial Requirements	CAPT Benson / LCDR Pettigrew
Army Geospatial Requirements	Mr. Boge / LTC Maxon
Navy/Marine Corps Geospatial Requirements	RADM Davis/ MajGen VanRiper/ CAPT Hacunda
Air Force Geospatial Requirements	Co1 Cummings / Maj Saxon
Information Architecture for the Battlefield (1994 DSB Summer Study)	MajGen (Ret) Rosenberg

May 2-3,1995 (DoD Mapping Capabilities)

CIO Overview	MajGen Brett Dula
DMA Requirements and Tasking	Mr. Guy DuBois
US Imagery System Architecture Migration Plan	Ms. Beth Larson
USIS 2000 - Imagery Standards	Ms. Beth Larson
Accelerated Architecture Acquisition Initiative (A31)	Ms. Beth Larson
Declassification Policy Status for Imagery Derived Products & Low Resolution Imagery	Mr. Will Hopkins
National Reconnaissance Office	Mr. Fred Doyle
National Photographic Interpretation Center	Co1 Charlie Latimer
GGI&S Concept	Ms. Bobbi Lenczowski
Defense Modeling and Simulation Office	CAPT Hollenbach
Army Digitization of the Battlefield	Mr. White
TEC Overview Roles and Missions	Mr. Walter Boge
Navy GIS-related S&T Activities	Ms. Mary Clawson
AFMC MC&G Perspective and Plan	Maj Michael Papirtis
DMA Production Backlog	Mr. Bill Hogan
Alternate Source Exploitation	Mr. Tom Holzer
Controlled Image Base Product	Mr. Merle Biggin
Remote Replication System	Maj Sherry Fascia
Digital Production System (DPS)	Co1 Trey Obering
Defense Information Systems Agency	Dr. Michael Mestrovich
US Geological Survey	Mr. James Plasker
Mapping and Charting at National Ocean Service	Dr. David Evans

June 12-13,1995 (Commercial Capabilities)

Space Imaging, Inc.	Ms. Tish Viajta-Williams
Earthwatch, Inc.	Mr. Jesse Moore
Map Printing Technologies — 3M	Mr. Doug Dybvig
Earth Satellite Corporation	Mr. Charles Sheffield
Geodynamics Corporation	Mr. Robert ChiraIo
MRJ, Inc.	Mr. Ed McMahon
PRC, Inc.	Dr. Paul Anderson
SAIC	Mr. Russ Richardson
TRIFID corporation	Dr. Marshall Faintich
ERDAS	Mr. Lawrie Jordan
ERIM	Dr. Stanley Robinson
MapInfo Corporation	Mr. John Haller
DeLorme Mapping	Mr. David DeLorme
David Sarnoff Research Center	Dr. Curtis Carlson
Eastman Kodak	Mr. Charles Mondello
AT&T	Mr. Dick Lombardi
Direct Broadcast Satellite Service — Hughes	Mr. Mark Sabin

Facility Tours

Defense Mapping Agency - St. Louis
Defense Mapping Agency - Bethesda, MD
US Army Topographic Engineering Center (TEC)
CIA - Demonstration of Intelink

D. Previous Related Studies

D.1. Digital Production System Maintenance Management — July 1993

Review Panel Report on Digital Production System Maintenance Management
Robert T. Marsh, Chairman — July 1993
Prepared for: Defense Mapping Agency

Executive Summary

To&y, the Defense Mapping Agency's Digital Production System (DPS) must respond to a changing geopolitical climate that requires newly defined Mapping, Charting & Geodesy (MC&G) products on short notice. Since the original DPS design was conceived, the traditional method of generating standard MC&G products for a stable user community has vanished. The DPS may satisfy its original requirements, but the changing customer needs requires a continuing emphasis on maintaining system viability.

This study responds to a request from the Director, DMA, for a panel of selected, recognized experts in the field of system maintenance to conduct an objective review of the DPS hardware/ software maintenance program and to provide a summary report with tidings, conclusions, and recommendations. This Review Panel examined the technical and management approach for DPS maintenance being conducted by DMA with both government and contractor users, with particular emphasis on discrepancy report (DR)identification and handling, segment capabilities and interaction, contractor support, and system full-scale production capability. It was concluded that a DPS strategic plan was needed to control the direction of future DPS maintenance. Major decisions on DPS maintenance must be addressed in a system-wide strategic plan that incorporates the following recommendations:

- Establish a separate, permanent development and test facility (DTF) that is a faithful replication of the DPS.
- Develop ways to rigorously test the MC&G database for size-related problems using the DPS development and test facility.
- Define DPS software development standards and metrics based on state-of-the-art processes and implement these across all DPS redevelopment and enhancement efforts.
- Further refine the granularity of DRs to permit the sub-prioritization of level-c DRs, especially to assess the importance of level-C DRs between segments.
- Reassess plans to replace contractor resources with government personnel for DPS software maintenance and consider using only enough in-house maintenance personnel to be a "smart customer."
- Initiate planning and preparation for the earliest practical open competition for a *single* DPS maintenance contractor.
- Implement a Customer Service Center for DPS users.
- Structure the FY94 maintenance budget as a best-estimate level of effort, and revise the outyear budgets, if necessary, after collection of further data ("actuals").

D.2. **Information Architecture for the Battlefield — Summer** 1994

1994 DSB Summer Study on Information Architecture for the Battlefield
Craig Fields and Gen James McCarthy (Ret), Co-Chairmen

Executive Summary

This Defense Science Board Summer Study Task Force was charged to make recommendations for implementing an information architecture that would enhance combat operations by providing commanders and forces at all levels with required information displayed for assimilation. The Task Force was instructed to focus on information support to the theater or Joint Task Force Commander in preparation for and during combat operations.

The global security environment provided the background for understanding the information needs of warfighting commanders in scenarios likely to occur in the coming decade. Based upon this environment, the Task Force assessed four aspects of information architecture for the battlefield:

- the use of information in warfare;
- the use of information warfare, both offensive and defensive;
- the business practices of the Department of Defense (DoD) in acquiring and using battlefield information systems; and
- the underlying technology required to develop and implement these systems.

The fmdings and recommendations of the Task Force are summarized as follows:

Key Findings:

- The warfighter must be an informed customer, with an integral role in the determination of the operational output (specification of requirements), acquisition, and implementation of information systems;
- Warfighters require flexible information systems that can be readily and rapidly adapted and/or altered to accomplish different missions;
- DoD information systems are highly vulnerable to information warfare, but so are those of potential adversaries; and,
- The DoD can greatly leverage limited DoD resources by exploiting available commercial practices and technology plus "buying into" commercial practices.

Key Recommendations:

Recognize Information in Warfare as a critical element of warfighting success by:

- establishing a Battlefield Information Task Force to define the warfighter information systems needs and future vision;
- combining and expanding DoD capabilities for exercises, games, simulations and models;
- giving the Commander in Chiefs (CINCs) better staff support by strengthening the CINCs' technical expertise and establishing an Information Warfare Officer; and

- augmenting the Enterprise Integration Council structure to coordinate the integration of functional requirements with technical architectural frameworks for warfighter information systems.

- Gear up for Information Warfare, both offensive and defensive, by:
  - conducting an overall net assessment to determine the impact of information warfare on the DoD;
  - investing more in information warfare defense;
  - providing Red Teams to evaluate information warfare readiness and vulnerabilities;
  - creating a joint DoD strategy cell for offensive and defensive information warfare; and
  - providing strong DoD inputs to the formulation of a coordinated national policy on information warfare.
- Leverage the commercial world by:
  - using commercial direct broadcast systems;
  - buying and/or leasing communications bandwidth and other information services from the commercial market;
  - providing a "civil reserve" commercial information service capability;
  - adopting commercial practices in hardware and software acquisition; and
  - exploiting commercial research and development (R&D).

In summary, the Task Force believes that the timing is right for a major push to improve the effectiveness of information systems to support the Warfighters. There is a need for cultural change throughout DoD regarding the way information systems are developed and employed. In fact, such changes must be a part of a larger "re-engineering" of DoD'S warfighting approach. This Task Force underscores the importance of such a cultural change to achieving information dominance on the battlefield.

In addition, the Task Force sees significant vulnerabilities in today's information systems. The Department has not come to grips with the leverage of Information Warfare as a tool for use by the Warfighter. Unfortunately, the business practices of the Department are hindering DoD'S ability to exploit the best systems and technologies available in the commercial sector. Finally, it is not clear that DoD is investing its science and technology resources in the best way. The recommendations of this Task Force are intended to address these issues, for implementation of such recommendations will substantially improve CINC effectiveness and readiness. However, if real change is to occur, DoD leadership must aggressively pursue implementation of these recommendations.

E. Current Government Imagery and Mapping, Charting & Geodesy Capabilities

E.l. Overview

The National Military Strategy (NMS) requires geospatial information to achieve fundamental objectives. Geospatial information is critical to the support of nuclear deterrence, Major Regional Contingencies (MRCs), and lesser regional contingencies such as humanitarian operations, noncombatant evacuation operations, peacekeeping operations, and any other deployment of US forces supporting the components of the NMS.

Geospatial information products support ClNC requirements associated with targeting, navigation, mission planning, and command and control of assigned forces; the training, organization, and force development missions of the Services; as well as the modeling, simulation and battlespace visualization requirements of the CINCs, Services and DoD agencies. Geospatial information support is required for both the most sophisticated weapon systems and the infantry squad leader.

The very nature of the NMS and the missions assigned to the CINCs requires the US to obtain, or have the ability to quickly obtain, geospatial information on a global basis. Unified, joint, combined, and coalition operations require a common foundation of geospatial information data, applications, and data exchange capabilities which are interoperable. Additionally, the inherently different missions of the Services require that a wide variety of products, from paper maps to digital data bases, be available to support military operations.

This Appendix describes the current capabilities to provide geospatial information, first tracing ‘the “primary” process involving DMA and then describing the role of other organizations. Appendix F describes the improved geospatial information capabilities planned or proposed by the Services and government agencies. Appendix G summarizes the DoD resources allocated in FY96 for geospatial efforts. All of the information in Appendices E, F, and G was provided by the government advisors to the Task Force.

E.2. Users and Requirements

DMA provides a variety of world-wide military mapping, charting and geodesy (MC&G) products for US and allied forces. In response to a very diverse customer base, DMA coordinates, integrates and manages the program to satisfy many DoD and other federal agency MC&G requirements. DMA annually produces thousands of highly precise and accurate military maps, charts and geodetic products and services, comprising some 230+ product lines and services. DMA also executes statutory responsibility for provision of world-wide safety to navigation products and services.

Typical military needs include:

- USSTRATCOM requires precise coordinates for targeting and navigation, TERCOM map sets for cruise missile navigation, digital terrain elevation data for mission planning and aircraft navigation, aeronautical charts with intelligence data overprints for SIOP bomberhanker missions, gravity data for missile launch and trajectory, and relocatable target analysis data.
- The bulk of the current requirements to support land combat forces consists of hard copy Topographic Line Maps and Tactical Terrain Analysis Databases. The Army is transitioning to the use of digital products and is increasingly using raster based map background products for command and control and mission planning systems. Elevation data is used for mission planning and basic battlefield visualization. The emerging modeling and simulation community requires much more detailed and robust digital data than is currently available in most areas of the world. Army systems currently being fielded have been designed to use Tactical Terrain Data (or its predecessor Interim Terrain Data) which is not generally available. An additional requirement exists for controlled imagery to serve as a stable geometric Framework for overlaying geospatial data produced by field units.
- Naval forces need world-wide coverage in a Digital Nautical Chart format to support navigation systems and command and control systems, operable by the end of 1997. The Navy also requires broad area coverage of terrain and controlled imagery to support mission planning and digital point positioning data bases for accurate targeting.
- Air forces require broad area coverage for mission planning, terrain and vertical obstruction information for aircraft safety, flight data for use in the cockpit, gravity data for low altitude flight and the ability to generate very precise point positioning data for large numbers of accurate tactical target positions.
- The Marine Corps has traditionally required a wide array of MC&G support due to the integrated Marine Air Ground Task Force (MAGTF) concept of organization, doctrine, and missions. Land, air, and sea missions focused in the littorals require a new and better way of packaging nautical, surf/beach, and hinterland geospatial data into a deconflicted, integrated and seamless database to support "Operational Maneuver from the Sea."
- The users also require unclassified imagery products, which are to be fulfilled by DMA's Controlled Image Base (CIB).
- Special Operations Forces require very detailed information in small operating areas.

E.2.1. Support to the Warfighter

The responsibility for identifying which products are needed, and where, is shared by the force provider, normally a Service, and the force employer, normally the Unified Command. The force provider identifies which types of MC&G products are used when the force or system performs designed functions, and indicates the relative significance of each type of product to the performance of the function. The force employer determines the areas where the products are needed based upon where the force plans to operate. Priorities are determined by considering the importance of the force to the plan and the significance of the product to the force or system.

DMA Customer Support Teams work through the planning process with the CINCs and Services to identify their MC&G planning, operational and sustainment requirements on a mission and weapon system basis. The Unified Command, as well as supporting Commands, prioritize these requirements in accordance with guidance from the JCS as outlined in the Memorandum of Policy 3 1 (MOP 3 1). Federal agencies also follow the guidance of the NMS and MOP 3 1. The MOP 3 1 process results in a database of requirements for all missions currently planned by the Unified Commands, Services and Federal Agencies supporting DoD missions. The integrated database of priorities is submitted to the JCS for review and approval, resulting in resource and production priority guidance to DMA. Each mission requirement is normally reviewed on a biennial basis.

There are currently 38 unique operational plans for which MC&G support is required. The almost 500,000 plan requirements collectively identify 150,000 unique maps, charts, and cells of digital data. The MOP 3 1 process includes an annual worldwide assessment of the potential for DoD involvement in events affecting US national interests. Because of the lengthy process of acquiring and building map products, the system results in a "just-in-case" production paradigm.

In the post-Cold War environment, production requirements have become time-urgent across a diverse mix of locations and products. DMA's customers are demanding increasingly more sophisticated products, information, and services to support intelligence activities, decision making, combat planning and operations, navigation, and on-board weapons system guidance. DMA coordinates with service programs for the application of DMA products to 383 current and developmental systems, including command and control, mission planning and rehearsal, advanced navigation, modeling and simulation, and onboard guidance. Weapon Systems have become increasingly dependent on geospatial data to achieve their missions (see Figure E-l).

Based on requirements and intervening national security missions, DMA has an unending backlog which significantly exceeds its annual production capability. Figure E-2 displays the breakdown of coverage required and available for core mapping products. Figure E-6 through Figure E-5 display the worldwide availability of selected mapping products. The digital battlefield requires Digital Terrain Elevation Data @TED) Level 2 or better (Levels 3,4, or 5 - see Figure E-7) plus Digital Feature Analysis Data @FAD). Topographic Line Maps are used by land combat forces. Geographically the deficiencies are most apparent in Latin America, Africa, and the area from India to S. China. Currency, or lack thereof, is a large contributing factor limiting the "adequacy" of products. In various situations, currency may or may not be critical.

Service	Systems	Missions
Joint	Generic Area Limitation Environment (GALE), SOFPARS, JDAM, JSTARS, GCCS	Advanced Navigation, Mission Planning & Rehearsal, Terrain Analysis, Modeling & Simulation, Weapons Delivery, C31
Army	ASAS, FAISS, MSE, Guardrail, ABCS, AMPS, CA'IT, Corps Battle Simulation, Brigade/Battalion Battle Simulation, Combat Simulation System (JANUS), SIMNET, DTSS, MSIP, CTIS, ATACS, ATACMS, Commanche, AFAS-C, MLRS	
Navy/ USMC	Tomahawk, Trident, Navigation Sensor System Interface (NAVSSI), Seawolf, V-22, TAMPS, TCO, IAS, ATACC, AAAV	
Air Force	B-2, B-lB, F-15, F-15E, F-16, F-l 17, F-22, Contingency Theater Automated Planning System (CTAPS), Combat Intelligence System, AFMSS Trainers	

Figure El Examples of Systems Needing Geospatial Information

Product	Percentage of Total World Area		
	Required*	Available*	Adequate*
Digital Terrain Elevation Data (DTED)	100%	66%	41%
Tactical Pilotage Chart (TPC)	96%	79%	26%
Joint Operations Graphic (JOG)	87%	67%	8%
Digital Feature Analysis Data (DFAD)	71%	17%	11%
Point Positioning Data Base (PPDB)	31%	18%	18%
Topographic Line Maps (TLM)	29%	13%	5%

* Required - The sum total of world land areas for which there are stated and validated requirements for production.

Available - Percentage of world area for which product coverage is available. Note that some individual products may not meet currency and/or accuracy specifications, and may, therefore, be less than desirable or even unusable for a specific purpose.

Adequate - Percentage of world land area for which product coverage is available and meets both currency and accuracy specifications.

Figure E-2 **DMA Core Product Coverage (as of October 1994)**

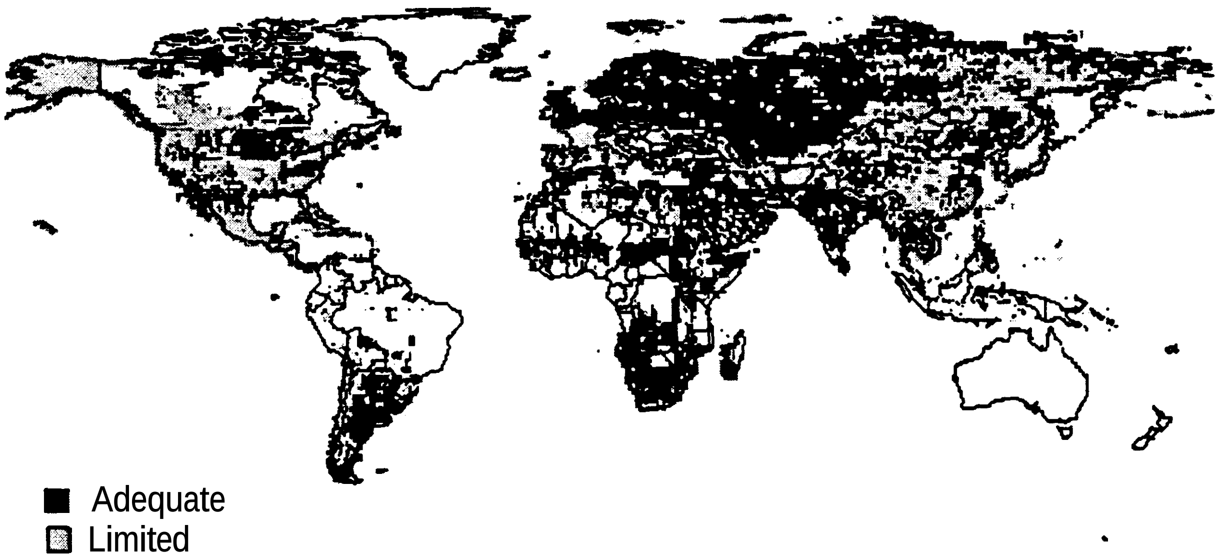


Figure E-3 Digital Terrain Elevation Data Level 1 (DTEDl) Available from DMA

Figure E-4 Digital Terrain Elevation Data Level 2 (DTED2) Available from DMA

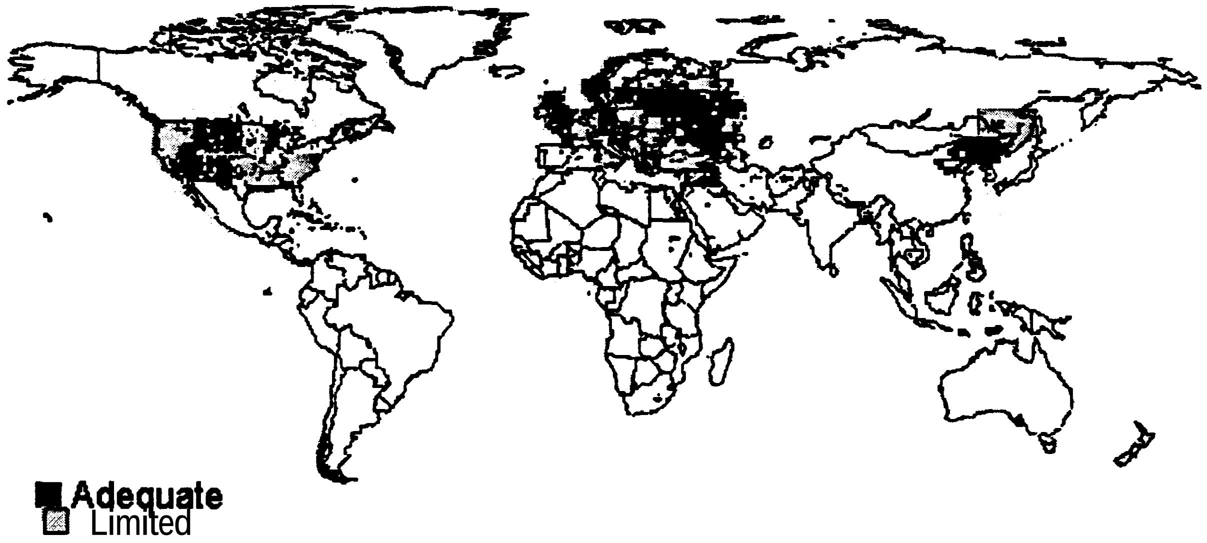


Figure E-5 Digital Feature Analysis Data Level 1 (DFADl) Available from DMA

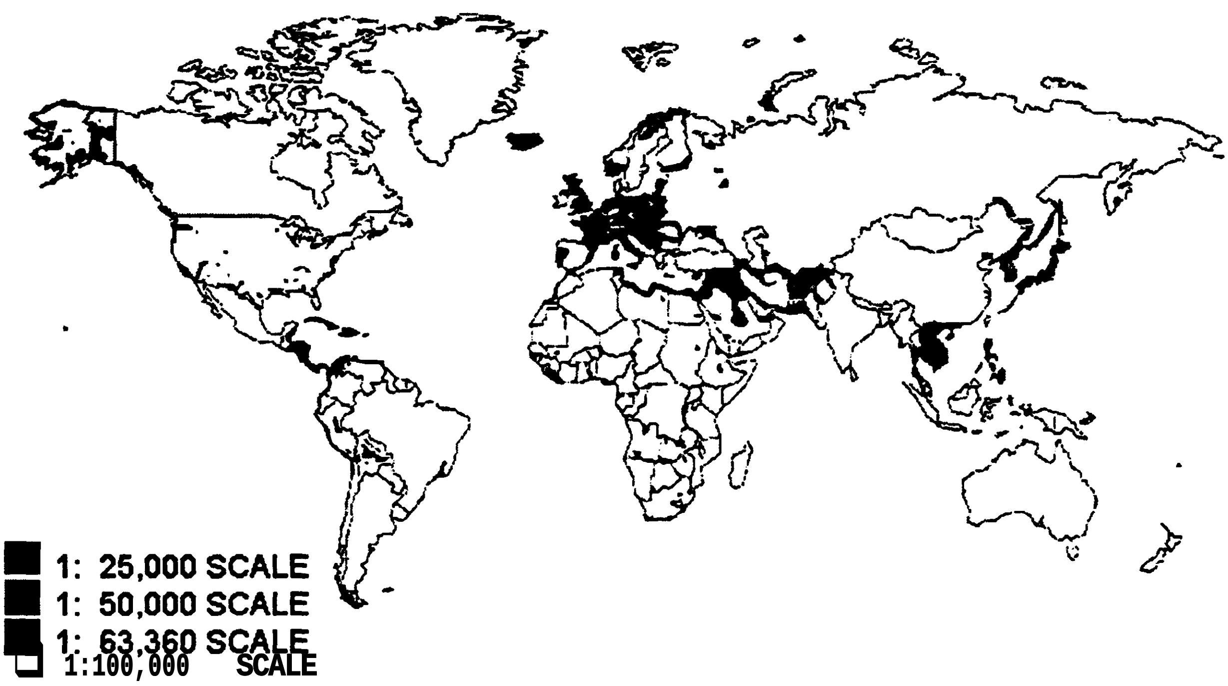
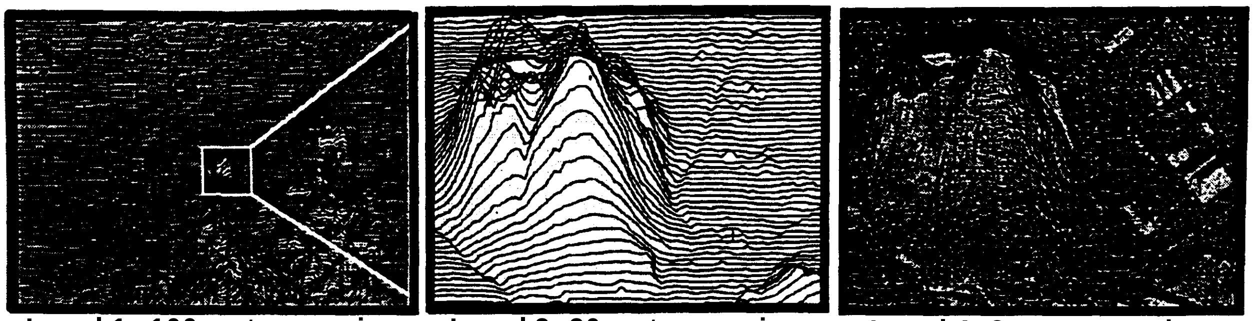


Figure E-6 Topographic Line Maps Available from DMA



Level 1 - 100 meter spacing   Level 2 - 30 meter spacing   Level 4 - 3 meter spacing

Description: **matrix of digital terrain elevations that represent the Earth's land surface**

Resolution (matrix spacing
- Level 1: ~100 meter
- Level 2: ~30 meter
- Level 3: ~IO meter
- Level 4: ~ 3 meter
- Level 5: ~ 1 meter

By Year 2000 Need:
- **Planning level data**
  - Levels 1 and 2
  - Near worldwide coverage
- **Higher resolution data for operation-specific areas**
  - Levels 3,4, and 5
  - Up to 300 x 300 km areas

Figure E7 DTED Levels

E.2.2. Support for System Development

DMA provides geospatial information and services to the military services responsible for development, test, evaluation, and deployment of new systems or their modification or upgrade. Efforts are made by DMA to ensure that a system will utilize standard DMA products, and only under circumstances where mission needs cannot be met with standard products does DMA undertake creation of a new one. When this occurs, initial product prototypes and product specifications are fast developed to support concept demonstration. Next, if system demonstration leads to approval to proceed with engineering and manufacturing development, product specifications are finalized and preparations are made to establish a DMA production capability.

Historically DMA has had considerable difficulties in identifying geospatial data requirements in a timely manner in support of system development. For a variety of reasons, some developers overlook the geospatial information needs or contract for generation of proprietary or unique geospatial information. When the Services identified requirements early in the development cycle, DMA has normally met operational deployment schedules. DoD needs to address the geospatial information support requirements in the context of the life cycle in developing new weapon systems and modifying existing systems. Resource requirements and production schedules for geospatial information support must be a part of the system development milestone review process.

E3. Data Collection and Standards

E.3.1. Imagery

The Central Imagery Office (CIO) was established in 1992 to provide central direction and leadership for imagery efforts relating to national security and to improve support for military operations. Imagery includes all products of reconnaissance that provide a likeness of natural or manmade features or related objectives or activities. In addition to policy, requirements, and planning functions, including establishing collection priorities, CIO is also responsible for establishing imagery architectures for collection, exploitation and dissemination, and for establishing standards for interoperability.

Imagery obtained from National Technical Means (NTM) sources is used for three purposes:

1. for extracting geospatial mapping information
2. for intelligence, and
3. for targeting and weaponeering.

Currently classified EO imagery, augmented by some unclassified Multi-Spectral Imagery, makes up 50% of the material needed by DMA for mapping.

DMA nominally uses medium resolution, broad area, stereo imagery that is not more than three years old, whereas the National Photographic Interpretation Center (NPIC) uses high-resolution, small area, monoscopic imagery with required coverage as frequently as daily. Other marked differences also exist. Cartographers navigate extremely large areas of real estate-over which all MC&G features meeting specifications are extracted from the imagery. Intelligence analysts may scan large areas, but they are more selective and extract even more detailed information over a much smaller area. Cartographers may spend several weeks extracting geospatial features and attributes from a single stereo image pair. For many intelligence problems, image analysts exploit much smaller image areas within a period of hours or days. Detailed intelligence assessments may require intensive analysis of a single image. DMA needs collection and delivery of large quantities of rigorously defined, accurate, cloud-free imagery. Figure E-8 displays the roles of the various organizations within the imagery community.

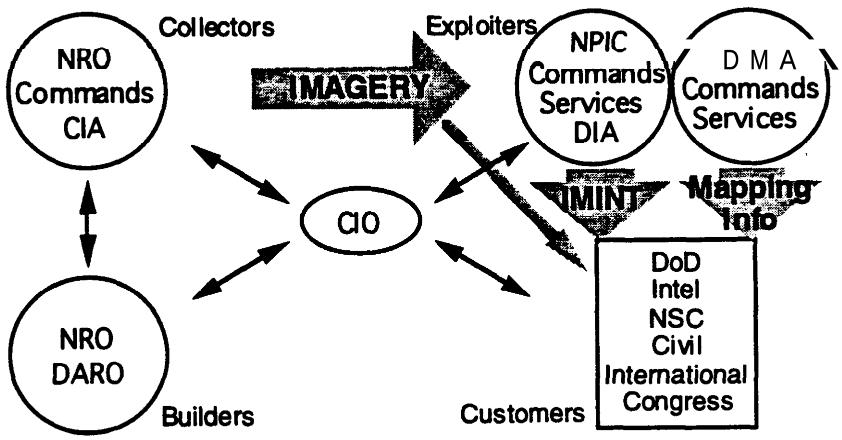


Figure E-8 Imagery Community Relationships

Operationally CIO, working with the community to consolidates imagery requirements, sets priorities, and tasks national imagery assets through the Community Support Center (CSC). Requirements and policy for the Joint Military Intelligence Program (JMIP) and Tactical Intelligence and Related Activities (TIARA) efforts are received from ASD(C3I) and CJCS. Requirements and policy for the National Foreign Intelligence Program (NFIP) efforts are received from the Director of Central Intelligence. Intelligence missions are arranged in Tiers as defined in Presidential Decision Directive PDD-35 (Tiers 0 through 2 constitute the US intelligence design goal.):

- Tier 0 - Crisis Coverage Required
- Tier 1 - Countries that are enemies/potential enemies
- Tier 1A - Topics of highest priority
- Tier 2 - Other countries of high priority
- Tier 3 - Low priority countries commanding some effort
- Tier 4 - Low priority countries not covered

The tasking process is described in Figure E-9.

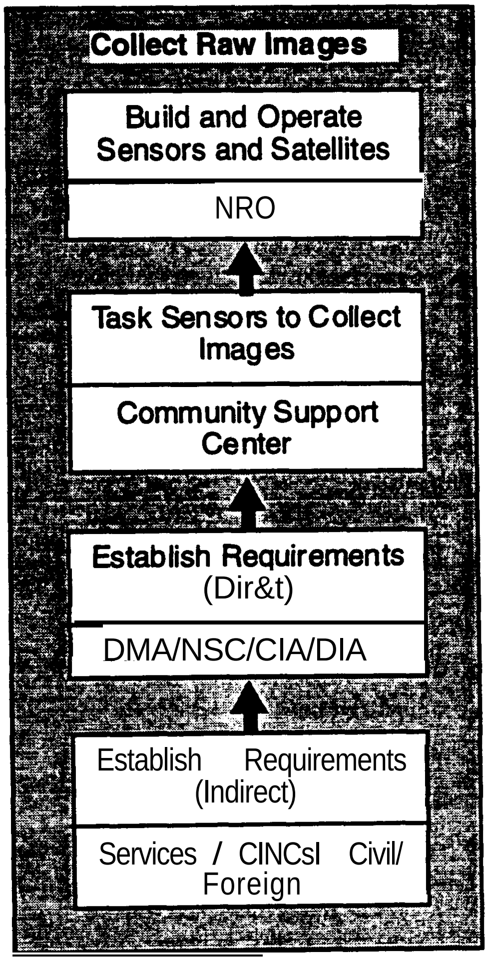


Figure E-9 Source Tasking

During Desert Shield/Desert Storm, imagery collection for mapping was cut off in favor of imagery collection for intelligence analysis. As the war progressed, the leadership of the CJTF recognized the need for current mapping imagery and supported the change of priority to the CIO and others in the national structure. This "lesson learned" has been utilized again in crises such as the former Yugoslavia and Korea. A concern is that this effective mode of operation is not a documented process for performance in future operations. A doctrine supporting collection of mapping imagery prior to a crisis is critical to the realization that battlefield decision-making demands precise geospatial information.

The National Reconnaissance Office (NRO) is responsible for building and operating satellite-based sensors. The Defense Airborne Reconnaissance Office (DARO) has oversight for program, assets, and budget related to airborne intelligence collection. DAR0 assets include the U-2; Tier II, Tier II+, and Tier III- UAVs; TAC UAV and F/A-l8 collectors; and all deployable imagery ground stations (including satellite receive ground stations for national imagery).

DMA's Digital Production System (DPS) is tightly coupled to a single imagery source. DMA is developing a front-end processing environment which would convert alternate source data to the standard format accepted by DPS. This Alternate Source Exploitation (ASE) program has projected costs of $60M over four years (FY95-FY98) to allow inputs from commercial sources as well as other DoD sensors.

The Services have identified a need for unclassified broad area imagery data. DMA's Controlled Image Base (CIB) begins to address that need if it can be populated worldwide, have sufficient resolution to establish control points referenced to WGS-84, and be accompanied by adequate Digital Terrain Elevation Data @TED).

E.3.2. Other Sources of Information

To augment DMA survey data collection, terrain, geodetic and beach surveys are provided by the Marine Corps and Army Topographic Units. Hydrographic data (depths of water, nature of bottom, and tides and currents in a given area) are collected by the Navy, National Ocean Service (NOS), and foreign governments for DMA. Extensive geodetic and gravity source data is acquired by DMA under commercial and academic agreements.

The Navy maintains a fleet of eight multipurpose ships to collect hydrographic and bathymetric data worldwide. Along with an international hydrographic cooperation program, the Navy can minimally meet the CINC requirements in high priority areas. Advanced technology such as airborne laser bathymetry and autonomous underwater vehicles are essential to improve future collection capabilities.

Intelligence and other data is collected by forces in the area, tactical sensors, and other sources.

DMA has international exchange agreements with over a hundred foreign nations, many of which involve the exchange of mapping, charting, hydrographic, gravity and geophysical sources. Through its own active program, DMA also acquires several thousand maps and charts per month, catalogs them, and holds an extensive collection of maps and charts. Smaller collections of maps and charts exist at other DoD and federal agencies.

E.4. Data Extraction, Analysis, and Product Finishing

In a global geospatial information environment, every element of terrain, and every identification of a feature, must be registered to a three-dimensional geoposition. These requirements, however satisfied, will place demanding needs for high-resolution stereoscopic imagery source materials.

As DoD moves towards an integrated information environment, the distinction between traditional mapping (geospatial) information and intelligence information about places and things is rapidly disappearing. For example, the digital information about the location of a road network will contain much more information than is currently available to the user by interpreting symbology on traditional paper maps and charts. Where the user of a paper map might only be able to determine location and whether a road is a single lane hard surface road, the data in the digital geospatial database will allow computer access to the width of the road, the specific surface material, the condition of the road, the connectivity to other roads and bridges, and can be rapidly updated to show where damaged sections are evident from military activity. Information that traditionally resided in intelligence databases should be directly linked to geospatial databases.

DMA has recently introduced an all-digital production system with computer-exploitable data bases. This is the DoD's MC&G production system capable of metric exploitation of national source information.

E.4.1. Digital Production System

DMA's Digital Production System (DPS) forms the backbone of DoD's defense mapping production (see Figure E-10). It was congressionally mandated to build maps from classified, metric EO sources and extract digital MC&G data (surface elevation, natural terrain and man-made features, and point targets) that can be used to create digital or hardcopy products. With several hundred computers, (including mainframes, minicomputers, and workstations) and more than 7.5 million lines of custom code, the DPS contains three production segments, two management/ services segments, two support segments, and other "mini-segments." The mini-segments adapt DPS imagery and cartographic workstations to support counter-narcotics and crisis production operations outside the DPS environment.

DPS development began in 1983 and achieved initial operational capability in 1989 to meet Cold War requirements for an established product mix with long lead times. This stable DPS requirements environment changed dramatically with the end of the Cold War in 1989.

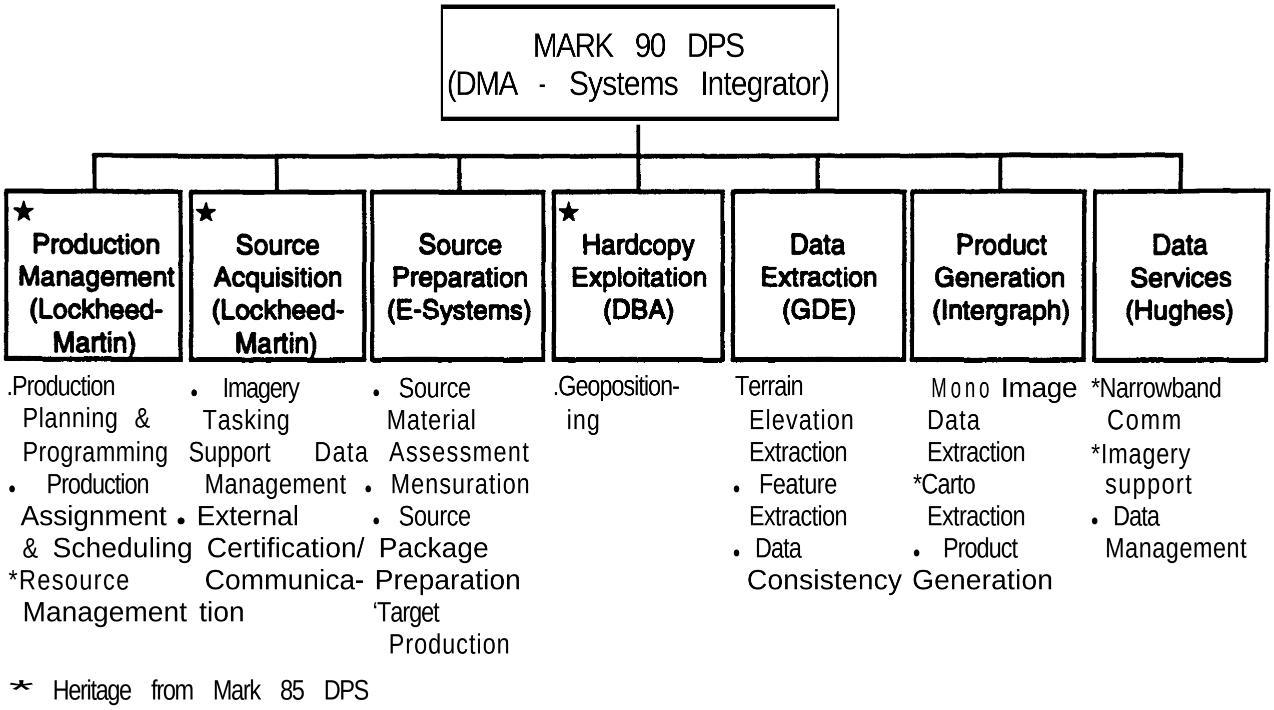


Figure El0 Digital Production System

Unlike other elements of combat power, geospatial information and services is completely area specific. Ammunition stocks for Iraq can be used in Korea; maps cannot. In this post-Cold War era, where the US national interests, including military forces, are often deployed to unexpected places with little advance warning, timely availability of geospatial information and services is essential but limited. DMA's ability to supply the full range of products and information necessary to meet customers requirements, to include those of combat forces, is driven by three factors:

1. the availability of source material for the area of interest,
2. the ability to re-allocate production resources quickly, and
3. continued investment in the production system and work force to prevent obsolescence.

Availability of Source Material. DMA is dependent on timely and accurate source information to produce products and geospatial information. While the demand for DMA products continues to increase in terms of accuracy and currency, the availability of source data that can be processed remains limited. Currently, the DPS is reliant on a single sensor and a unique input format for source material. DMA plans to modify its current DPS processes with an integrated architecture that will accommodate new sensors and source materials.

Production Flexibility. DMA's current system, designed in the early to mid 198Os, was not built with flexibility as a primary consideration. A flexible system is needed to ensure that DMA aligns production with shifting customer requirements and priorities. Response to crises will also require expedited feature extraction using automated processes where possible.

Investment. In the late 1990s, the DPS will be at the end of it's life cycle and will be subject to replacement in order to

- avoid disruption of products and services to customers (because of system degradation),
- curtail rising maintenance costs, and
- allow for the insertion of more efficient and less expensive commercially available software/ hardware.

DMA's migration modernization strategy proposes to transition the custom equipment and code to commercially available hardware and software. The target architecture is intended to leverage off current and emerging market technology, and to comply with DoD Common Operating Environment guidance described in the Technical Architecture Framework for Information Management (TAFIM). Continued investment in training and maintaining a highly competent professional work force is also required to meet DoD'S geospatial data needs.

E.4.2. The DPS Modification Program

DMA has developed a three-part strategy to modify the DPS to meet the changing requirements of its customers - the warfighters:

- Readiness Modifications focus on near term changes to improve both productivity and operational responsiveness of the production system.
- Exploitation Enhancements which include changes to utilize new sources, new interfaces with partner systems, and new products and services.
- Modernization Migration - the evolution of the DPS infrastructure to an open systems architecture.

Current DMA development, investment, and operations programs allow only for critical near-term DPS readiness modifications and enhancements to DMA's production system to maintain readiness and flexibility. Figure E-l 1 summarizes the approved funding profile.

	FY96	FY97	FY98	FY99	**FY00**	**FY01**	**Total**
RDT&E	67.3	69.7	32.7	34.5	34.6	35.1	273.8
Investment Equipment*	24.2	21.0	22.1	25.1	24.8	25.7	142.9
Other O&M	93.3	92.9	92.0	94.9	94.7	94.7	562.5
TOTAL	184.8	183.6	146.7	154.5	154.1	155.4	979.2

* Investment Equipment is part of the Operations & Maintenance (O&M) Expenditure

Figure E-11 Approved Funding for DPS Modification ($M)

The Defense Resources Board recently approved a POM enhancement and directed full funding for the DPS sensor interface enhancements and migration programs. These funds will allow DMA to sustain and improve the responsiveness of its production capability by exploiting the technology expected in the year 2000 and beyond. Total cost FY 1997 to FY 200 1 is $485.2 M as shown in Figure E-12, with $369.3M provided from within current approved DMA funding.

	FY97	FY98	FY99	FY00	FY01	Total
RDT&E	34.1	42.2	62.0	99.2	81.2	318.7
Investment Equipment*	6.8	3.6	27.9	39.9	40.2	118.4
Other O&M	0.0	0.0	8.4	16.5	23.2	48.1
TOTAL Required	40.9	45.8	98.3	155.6	144.6	485.2
Available Base Program $	30.0	30.7	55.0	109.1	144.6	369.3
Approved POM enhancement	10.9	15.1	43.3	46.5	0.0	115.9

* Investment Equipment is part of the Operations & Maintenance (O&M) Expenditure

Figure El2 DPS Sensor Interface/Migration Program Funding ($M)

E.4.3. Other Extraction, Analysis and Product Finishing Options

DMA currently contracts to augment its production. In addition, DMA has pursued international partnerships for cooperative production and standardization. As a result, the international government community has increasingly adopted DMA's MC&G standards, facilitating interoperability for joint military, peacekeeping, and nation-building activities. Co-production agreements with over a hundred foreign governments have resulted in about 25% of DMA's current inventory of maps and charts being foreign-produced. This represents a savings in excess of $100 million annually.

There are many commercial sources, military agencies and field units of the Army and Marine Corps that have the capability to produce data for small areas or to densify data in larger areas. This capability can be used to enhance population of the DMA database.

Other production capabilities for original compilation exist. Most notable are those of the US Geological Survey, whose mission is to map the United States, and the National Ocean Service, with responsibility to chart the coastal waterways of the US and its territories.

Where the commercial marketplace excels is in the area of product finishing. Numerous companies provide software packages capable of sophisticated integration of cartographic information.

E.5. Dissemination

On an annual basis, DMA disseminates numerous types of paper, digital and informational products throughout the world to the warfighters and civilian customers. This operation is supported by an infrastructure that consists of a distribution depot, worldwide combat support elements and a local telecommunication network with newly established gateways to other global DoD networks. The communication network, which represents the initial geospatial information gateway, is linked to the Joint Worldwide Intelligence Communications System (JWICS) network and associated systems (the Intelink System and the Joint Defense Intelligence Support System - JDISS); the military unclassified but sensitive Non-Secure Internet Protocol Router Network (NIPRNET) linked to the Public Internet; and soon to be realized (Sept 95) the Secret Internet Protocol Router Network (SIPRNET).

DMA provides product support to a base of 16,000 customer of which 10,000 receive some products through subscription programs. DMA annually responds to approximately 85,000 requests for products with a total dissemination of 30 million copies. The products are paper or digital in the form of magnetic tape, CD-ROM and video laser disk. Within the past year DMA has initiated the dissemination of precise target information, digital TERCOM maps, Geographic Names file, and information about DMA and DMA products, over established DoD communication networks.

E.6. User Tools and Remote Replication

The vast majority of geospatial or MC&G products are currently used in paper form. The paper map or chart is the primary tool used for land, air or sea navigation. Additionally, except at the highest command and control levels, the paper map or chart is the primary tool used for mission planning, battlespace visualization, and command and control.

Due to the power and proliferation of the microprocessor, certain MC&G functions at the higher levels have been automated (i.e., weapon system navigation, mission planning, etc.). Automation has resulted in an increasing need for geospatial products to be produced in a digital format (for example, within the United States Strategic Command Headquarters, over 80% of the MC&G products used are in digital form).

Digital geospatial products require computer-based application tools, often developed uniquely by the CINCs, Services and DoD agencies:

- Digital maps require software to permit map display and manipulation on a variety of computer architectures. The Air Force’s Common Mapping Program, Navy’s Chart II, National Security Agency’s OILSTOCK and the commercially available ESRI’s ARCINFO/ARCVIEW and Delorme’s XMAP are all examples of display software.
- Elevation data in digital format is used for weapon system navigation (B-2 terrain avoidance, cruise missile INS updates, etc.) and in mission planning systems (USSTRATCOM’s Route Planning and Evaluation System). This data is also often merged with digital maps or imagery to provide visualization for mission rehearsal and simulations.
- Geographic Information Systems, such as Defense Intelligence Agency’s Generic Area Limitation Environment (GALE) and Environmental Systems Research Institute’s ARC/INFO offer intelligence capabilities through their ability to assemble, store and manipulate geographically referenced data.

- The Joint Mapping Tool Kit, as mutually agreed by the Services and DMA, is now part of the Global Command and Control System (GCCS) baseline and will be upgraded as future versions of GCCS are deployed.

DMA relies on lithographic printing technology and the maintenance of large quantities of products to support several years of expected product demand.

DMA is implementing a three-stage development effort to transition into a just-in-time printing process and to improve customer responsiveness while reducing operational costs. The first stage is to stimulate the development of interest through research and development and cooperative funding. As a second effort, the Agency is installing a kind of "fax-a-map" crisis capability between itself and commands or DoD elements having large-size Cannon bubble-jet copiers. The intent is to support crisis planning requirements by transmission and generation in the field of identical color copies of DMA base-plant copies within several hours. The third of DMA's efforts is focused on installing a remote replication system (RRS) to provide low-volume, multicolor, large-format printing on water-resistant paper. The RRS can either scan and reproduce an existing chart, or print from digital data.

E.7. User Feedback

DMA's very large inventory of products is scrutinized by thousands of users every day, many of whom are familiar with the real estate portrayed symbolically or digitally on those products. As an important source of information for correcting/updating products, DMA solicits user feedback of information to be used to improve product quality. Today, information most commonly received from users consists of hydrographic sounding data, vertical obstruction data, and various other hazards to safety data suitable for publication in Notice to Mariners and Notice to Airmen. Soliciting geospatial information input, as well as measures of performance, will be the primary focus of DMA's newly established customer support teams, even though there is no current DoD doctrine which requires feedback of this information to DMA.

E.8. Other Organizations

The Defense Modeling and Simulation Office (DMSO) reports to DDR&E. DMSO is responsible for establishing interoperability and standards for DoD Modeling and Simulation (M&S) efforts. The M&S community is a user of geospatial information. Digital terrain and atmospheric models are the foundation of many simulation tools. DMA is the DoD Executive Agent for terrain data. Other needs for geospatial information include mission space visualization, and computer generated force movement analysis tools.

The Army's Topographic Engineering Center (TEC) is part of the Army Corps of Engineers. TEC is the lead laboratory for all technology base in-house R&D in topography. TEC and DMA work together on a number of development projects. In these instances TEC receives funding from DMA. TEC exploits DMA data where it is available and gathers data where none exists. TEC also provides a critical role in gathering and filtering Army requirements for geospatial information, and in advocating the Army's new systems' capabilities and needs for geospatial information and services.

The Navy maintains a fleet of eight multi-purpose ships to collect hydrographic and bathymetric data worldwide. The Navy also has an extensive international hydrographic cooperation program to augment collection capability.

The National Photographic Interpretation Center (NPIC) provides imagery analysis for the intelligence community and DoD. One key difference between NPIC and DMA exploitation of imagery is that the end products for NPIC are usually quick-look reports and reports on specific issues while DMA products are long-term reference maps, charts and other products.

The National Ocean Service (NOS) is part of the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce. NOS provides aeronautical and nautical charts and related information for safe navigation of marine and air commerce in the US and its territories. DMA produces similar charts and information in foreign areas for DoD users and marine navigators generally. NOS also provides limited backup printing capability for crisis situations, essentially a one-press capability. NOS provides public distribution of DMA aeronautical and hydrographic charts and publications. Additionally the National Geophysical Data Center under NOAA supports digital geophysical data collection and dissemination.

The US Geological Survey (USGS) is primarily active in domestic mapping for Digital Elevation Maps (DEMs), standard-scale-based Quad sheets and Digital Orthophoto Quadrangle products. DMA has contracted with USGS for the production of DTED. USGS has responsibility for domestic land surfaces while DMA is responsible for mapping foreign land areas. DMA purchases USGS maps at retail cost and provides them to DoD users. USGS also provides a very limited, one-press printing support capability for DoD in crisis situations or for disaster relief. USGS provides public distribution of unclassified DMA products and imagery.

F. Government Planned/Proposed Geospatial Information Capabilities

F.1. Vision and Architecture

In the past, geography and cartography joined forces to provide paper-constrained geospatial information in the form of maps and charts. The lithographic product is no longer the exclusive source for reliably positioning things or activities relative to the earth. As sources for geographic data have expanded, synergistic uses have also grown. Adaptive computer technology has accommodated powerful analytic applications which consume vast digital stores of geographic, cartographic, socio-economic, geophysical and political data, to enable reliable decision-enhancing tools. To help meet the growing need for data, DMA has embarked upon an initiative called Global Geospatial Mapping Information and Services (GGMI&S). This effort further encourages interoperability through commitment to community standards for the data model and encapsulation, as prototyped through the Digital Chart of the World.

The GGMI&S concept (Figure F-l) proposed by DMA calls for a worldwide Global Geospatial Mapping Information (GGMI) digital database serving diverse users through the appropriate Defense Information Systems Agency (DISA) Defense Information Infrastructure (DII) communications channels to satisfy all their geocoded imagery, charting and mapping information needs. It is the goal of GGMI&S to provide information that is:

- worldwide
- precise, accurate, and current
- spatially and temporally co-referenced information about the earth
- arranged in a coherent structure
- supportive of measurement, mapping, visualization, modeling, terrain analysis, and spatial reasoning applications.

Compatible with sophisticated geographic information system technologies, the GGMI&S initiative envisions "desktop" import and export of standard geospatial data sets and interactive and reliable data manipulation, update, and value adding. Gateway connections into multi-level secure networks will promote rapid access to and distribution of needed data.

DMA has outlined a vision in which digital data and information are provided to users, and the actual production of mapping products is left in the hands of the operators where they can tailor the product to the specific needs of the operation. This vision requires new joint doctrine and DoD policy. Achieving this vision must be accomplished in an evolutionary way, so that both the producers of the data and the users are ready for the change. In the GGMI&S environment the user controls the process--- what he wants, when he wants it. He is able to browse the DMA-generated databases and DMA-identified commercial databases and download appropriate data sets, perhaps to supplement a CD-ROM local data source. In the DMA concept, the customer has instantaneous visual and physical access to a wide variety of choices and can quickly "customize" the product both in kind and quantity. The GGMI data warehouse will provide the foundation for this service.

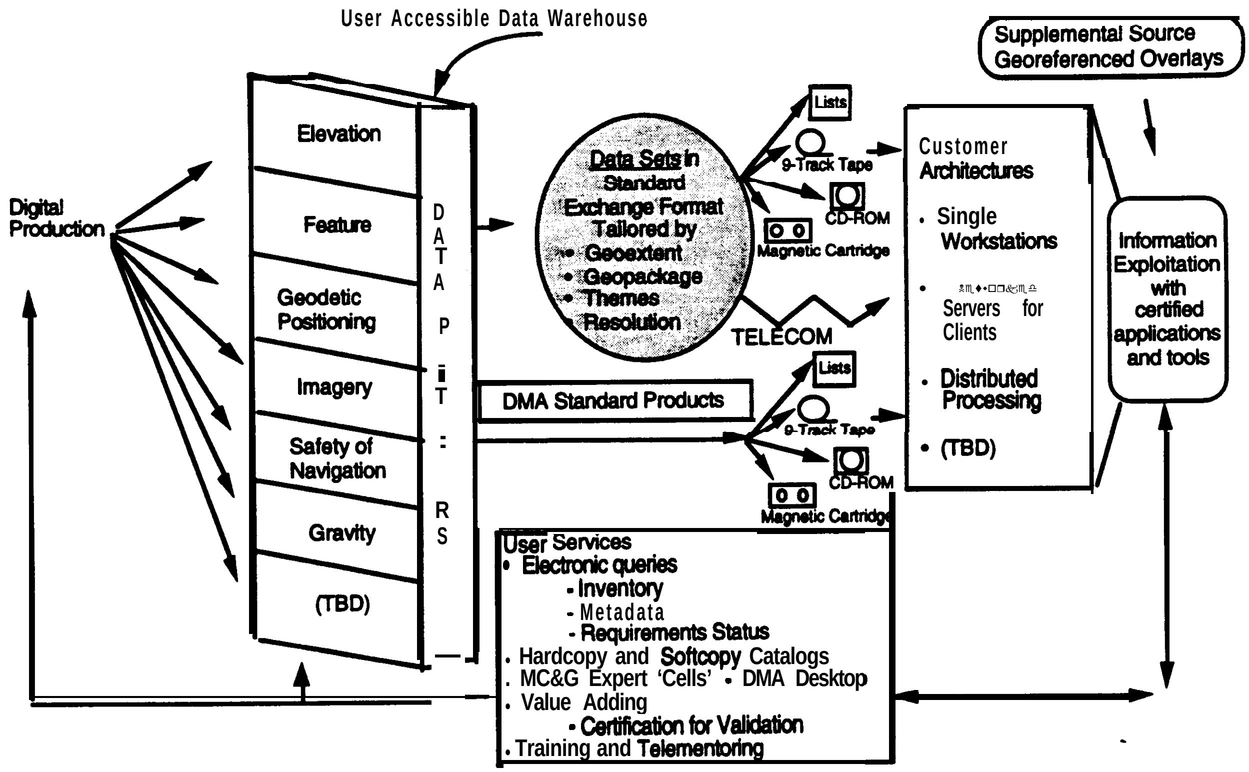


Figure F-l Notional Concept for GGMI&S (Evolving)

To achieve this vision, DMA will:

- Eliminate inconsistent multiple representations of features.
- Smooth without gross abruptness from one resolution of spatial data to another.
- Accommodate time-varying characteristics of some spatial features.
- Embed each object with all its topological relationships so that decluttering and generalization is robust.
- Invest each element of the geospatial domain with as much integrity as is appropriate, balancing consumer demands with production realities.
- Deliver geospatial information which moves smoothly from the topographic view of the shoreline to the hydrographic view of that shoreline.
- "Package" DMA expertise for the spatial information users.
- Provide gateways between DMA's digital holdings and its customers, by using the various networks available to the defense community.
- Develop a system to accept digital data into the databases from a variety of commercial and customer sources.
- Assume the role of geospatial clearinghouse for DoD in the Defense Information Infrastructure, paralleling the comparable role USGS's National Mapping Division has assumed in the National Spatial Data Infrastructure which is part of the National Information Infrastructure.

Global geospatial information describes the next generation of mapping, charting, and geodesy support. The GGMI&S initiative is fundamentally a data management and information delivery endeavor. The GGMI&S architecture can be implemented with proven and emerging technology. However, the work to develop the necessary standards required for the reference model of the notional architecture demands aggressive leadership from DMA and collaborative effort with industry, academia and other government agencies.

In concert with DMA's GGMI&S vision for dissemination, archiving and exploitation, CIO worked with DMA in developing their Accelerated Architecture Acquisition Initiative (A31). A31 includes a distributed network of libraries that can store both original imagery and value-added products such as maps, annotated imagery, graphics, and multi-media products. The common focus on concepts for digital dissemination, exploitation and production aligns GGMI&S with A31. A formally established, single, integrated, jointly designed information architecture, operational concept, and doctrine is required; continuation of the separate, loosely coupled intelligence and DoD activities is not desirable.

At present, both A31 and GGMI&S are partially funded. A31 is funded for procurement of operational system assets while GGMI&S is funded for study, design and prototype activities. DMA's funding also includes acquiring operational capabilities for DMA but does not include any modifications required by the user. The deficiency is that the appropriate "customer" funding streams have not been separately identified. Both activities have taken the initiative to formulate plans for the future based on the various pieces of national "policy" that are emerging in this arena. For example, both activities recognize the growth of a communications infrastructure, the need for standardization and interoperability, the need to use commercial off-the-shelf (COTS) solutions wherever possible, and principles of "good business practice" the DoD is supporting.

F.2. Users and Requirements

DMA's strategic plan for digital data production embeds global objectives. Continuous support is mandated at all times for safety of navigation. The Digital Chart of the World and its source, the Operational Navigation Charts, provide both digital and lithographic coverage. In FY98, DMA will also have completed the vector-formatted Digital Nautical Chart program, derived from its sources - the paper coastal, approach, and harbor maritime products. Other vector data sets will also correspond to existing and planned paper products. Currently, DMA is completing conversion of its lithographic holdings to a raster format and has begun distribution. A new product of orthorectified, geocoded imagery will provide DMA's initial immediate response to crises and will provide global readiness.

Only a few years ago, the modeling and simulation community was almost entirely a defense enterprise. But as commercial interests have seen the potential for combining geographic information system technology with imaging and graphics technologies, modeling has migrated from weapons trainers to profitable arcades. The simulation contractors in turn now use virtual reality, with associated data management capability, with real-time operations on very high resolution, descriptive geospatial information, and with analytical derivation of inferences or deductions. These approaches dominate planning and mission rehearsals but also have far broader application. Artificial intelligence and decision-support systems ingest and rapidly fuse several intelligence sources. They use flexible planning tools, wargaming, simulation and multimedia technology.

In the era of reduced budgets, the military is "training as it will fight," but without actual physical presence. Datasets of geographically remote locations with high degrees of authenticity for reliable exercises are demanded. Because high resolution compilation is production-intensive and costly, the database may not be fully populated when an actual crisis flares. Part of the GGMI&S strategy is to recognize that dispersed sites, at the command level and below, will have equipment and authority to populate, manage and distribute specific features or attributes within virtual and re-definable local databases.

Typical military needs in the near future include:

- The Army's geospatial requirement to support Force XXI consists of digital elevation data down to l-meter resolution, and highly dense feature data in limited areas. This data is needed for small areas within hours of a JCS-confirmed crisis, expanding over time to encompass an area of 300 km x 300 km within 12 days of notification. This data supports a variety of planned and envisioned systems from individual soldier level to Corps level and above. The ability to support battlefield visualization as well as simulations for mission rehearsal at all levels with an identical data set is a firm requirement. The requirement for all data to be unclassified is essential.
- Analytical systems for command and control, mission planning and rehearsal, modeling and simulation, wargaming, and advanced weapon systems will drive demands for GGMI&S. Standards to facilitate access to and exchange of geospatial data, and to ensure interoperability among users will be extremely important. Geospatial data must consist of fusible information sets, in standard formats which may be released to other governmental and non-governmental agencies and to joint or coalition forces. Future requirements must be based on what a CINC needs in order to be operational, not where the CINC operates.

F.3. Data Collection and Standards

The over-dependency on a single source must be among the most serious deficiencies to be corrected in the near term. The emerging architectures must incorporate upcoming US commercial imagery systems. Additionally, all National intelligence and DoD imagery systems, whether space based or airborne, should include the capability to provide "mapping capable" imagery as a costed option for DoD decision makers to consider in the acquisition decision process. DMA will continue to use international programs to accelerate global geospatial data collection and database population to augment their production and satisfy priority requirements.

F.4. Data Extraction, Analysis, and Product Finishing

The challenge for geospatial information suppliers like DMA is to provide user accessibility to accurate data, which users can leverage into trusted information for various needs. As the geospatial information infrastructure expands with more demanding users who have increasingly powerful analytical tools, their concern about available data sets is broadening. All DMA data sets carry auxiliary information describing absolute and relative accuracies. Because so many data sets are now being extended to new uses, different "measures of trust" are being defined for each application. That levies against the producer an obligation to provide even more data about the data: source, currency, lineage, completeness and like elements. DMA uses the Federal Geographic Data Committee's metadata standard for its data delivery.

Although documenting data sets with metadata allays concern about the level of risk attendant to use, it does not reduce the need to improve the information. Accuracies needed by DMA's future customer require nearly an order of magnitude improvement over the present to match the higher granularity of data. Although the earliest production of the higher resolution vector formatted products, like the Digital Nautical Chart DNC) and Vector Smart Map (VMap), will be from existing cartographic sources, DMA will rapidly migrate production to metric imagery sources to ensure the greatest accuracy.

The spatial accuracy and precision promised by GGMI&S with its spatially co-referenced data sets, rely upon exploiting geodesy. All current DMA digital products are referenced to a common datum: the World Geodetic System 84 (WGS 84). Refinement of the WGS 84 geoid would augment support to inertial navigation and enable the definition of a single World Height vertical reference. Modernizing procedures for collecting photo-identifiable first order surveys would expedite an extensible, global control network for phototriangulation.

The more accurately data is produced, the more likely data sets, even collected at different times or for different uses, will fuse. Geocoded raster and vector data will align for visualization and will support consistent analytical evaluation, especially if the metadata accompanying those data sets is comprehensive.

As the DoD supplier of GGMI&S, DMA bears enterprise responsibility for the definition of geospatial models and elements. Adherence to a suite of standards, whether developed or adopted, will allow the structural coherency needed in the fully interoperable environments. A general data model, applicable horizontally and vertically among all users, of varying-resolution geospatial features, must be collaboratively completed. DMA, as authorized by DISA as the geospatial data lead, has been engaged with other agencies and organizations to provide standard data definition for terms used across the defense community.

The GGMI&S production strategy calls for user-accessible data in operational databases. These databases can be accessed directly or used by DMA or others to "finish" traditional products. Products would be available at various stages in the production flow as shown below:

Response	Tvpical Information
First Order	Raster Data, Bathymetry, Image Orthophotos, Safety of Navigation Products
Attributed but not "Productized"	Elevation Data, Lines of Communication, Feature Layers Vector Data
Digital Product	Vector Map Products, Digital Nautical Charts, DTED
Standard Paper Product	Harbor Approach Charts, Topo Line Maps, Joint Ops Graphics, Air Target Charts, Hardcopy Maps

F.5. Dissemination

Under GGMI&S, dissemination would utilize a geospatial data warehouse. Subsets of the warehouse foundation data would be disseminated via physical media to distributed data sites. Updates would be exchanged via the DII and commercial telecommunications in near real-time. Remote replication would provide hardcopy at the user locations.

DMA will use standard media, including the standard conventions for directories and indices, to forward deploy its data sets. Magnetic tape, CD ROMs, or newer industry-standardized media solutions will be used consistent with customers' terminal capabilities. When communication networks are used, DMA will prepare its digital data compliant with necessary transmission protocols.

The Defense Information Systems Agency (DISA) is working toward a Defense Information Infrastructure (DII) that is a seamless web of communications, networks, computers, software, databases, applications and other capabilities that meets the information processing and transport needs of DoD users. The DII includes

- the physical facilities to transmit, store, process and display information,
- the applications, engineering and data practices to build and maintain the software needed,
- the network standards and protocols to facilitate interoperability and security, and
- the people and assets to design, manage, and operate the DII.

Initial capabilities will be tested in the Joint Warrior Interoperability Demonstration (JWID '95).

F.6. User Tools and Remote Replication

GGMI&S must work with existing and planned architectures and include industry to leverage their capabilities. Developing community involvement is another key to GGMI&S definition, development, and implementation.

DMA will distribute stable foundation data upon which the consumer can build reliable inferences. DMA's digital data will be accompanied by importers and display tools. To assure that the marketplace encodes MC&G algorithms satisfactorily, DMA will warrant tools to be catalogued in the Defense Software Repository System. These tools will also be found in the Global Command and Control System (GCCS) Joint Mapping Tool Kit (JMTK) as it evolves to its maturity. Those, and other GGMI&S warranted tools, may also be used by collaborative producers for reliable value-adding in the deployed environment.

F.7. User Feedback

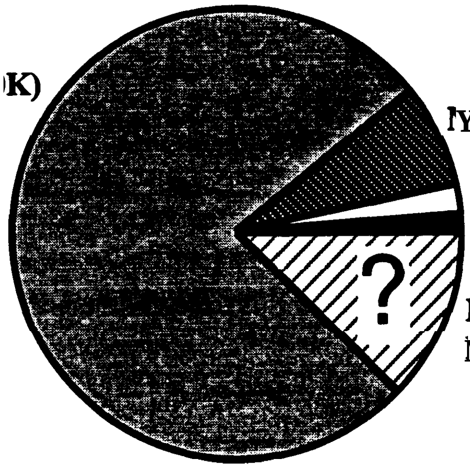
As DMA moves into the GGMI&S era over the next decade, customers will be offered the means to add value to DMA data (update/correct/add/delete), and return that value-added product to DMA for storage and subsequent retrieval for use by other customers with similar data needs. While challenges in data standardization, accuracy, and completeness remain to be met and solved, this scenario holds great promise for augmenting GGMI&S data holdings, fostering data standardization, and bringing DMA and its customers closer together on these and other matters.

DMA is establishing Customer Support Teams (CSTs) for each customer, which deploy with the customer as necessary. Each team becomes familiar with customer needs and provides a single point of contact for all services. CSTs are empowered to interact with customers on behalf of DMA. Each team assists the customer in developing strategies for satisfying the need for GGMI&S required for planning and executing mission operations. CSTs also, manage the execution of the programs necessary to satisfy their customers' needs. A customer support team will consist of several DMA employees, some of whom reside with the customers, and others who are located at DMA, available to the customer on a "virtual presence" basis through communication networks. CSTs will include technical and production experts responsible and accountable for the identification, generation and dissemination of global geospatial information, services and products.

G. DoD Resource Summary

The Task Force is concerned that it was able to obtain little information on how DoD is spending its resources in support of defense mapping operations. Figure G-I summari 'zes the funding information that was available. Of particular note is that untold millions are being invested every day to field and upgrade weapon systems and C2, training, wargaming, and intelligence systems without a common interoperable spatial reference system.

There are many different agencies and organizations involved in mapping with what appear to be overlapping functions, spanning defense agencies, the Military Departments, the operational commands and other government agencies.



DMA	856,080 K$
Navy Oceanographer	84,569
Army TEC	22,145
ARPA	5,600
NPIC	2,597
4rmy operations	2,124
DIA	1,846
NSA	1,068
USMC	741
US Space Command and components	508
Air Force	175
TOTAL Identified	977,453 K$
Embedded in other military systems (C2, Training, Simulation, Wargaming, & Information Systems)	unknown

Figure G-1 FY96 Geospatial Funding

H. A View from Industry

El. The Common Commercial / DoD Need: Establishment of a Geospatial Database

The geospatial reference base is critical to the roles and missions of DoD, from command and control to the traditional mapping function, as shown in Figure H-l. Each class of the DoD user requires several types of data ranging from digital elevation and feature data to 3-D visualization data to map data. This database should contain both static (map) data and dynamic, temporally relevant (operational) data. Management of the data base must ensure that there are standards for insertion of data into the database and for sorting and retrieving the data.

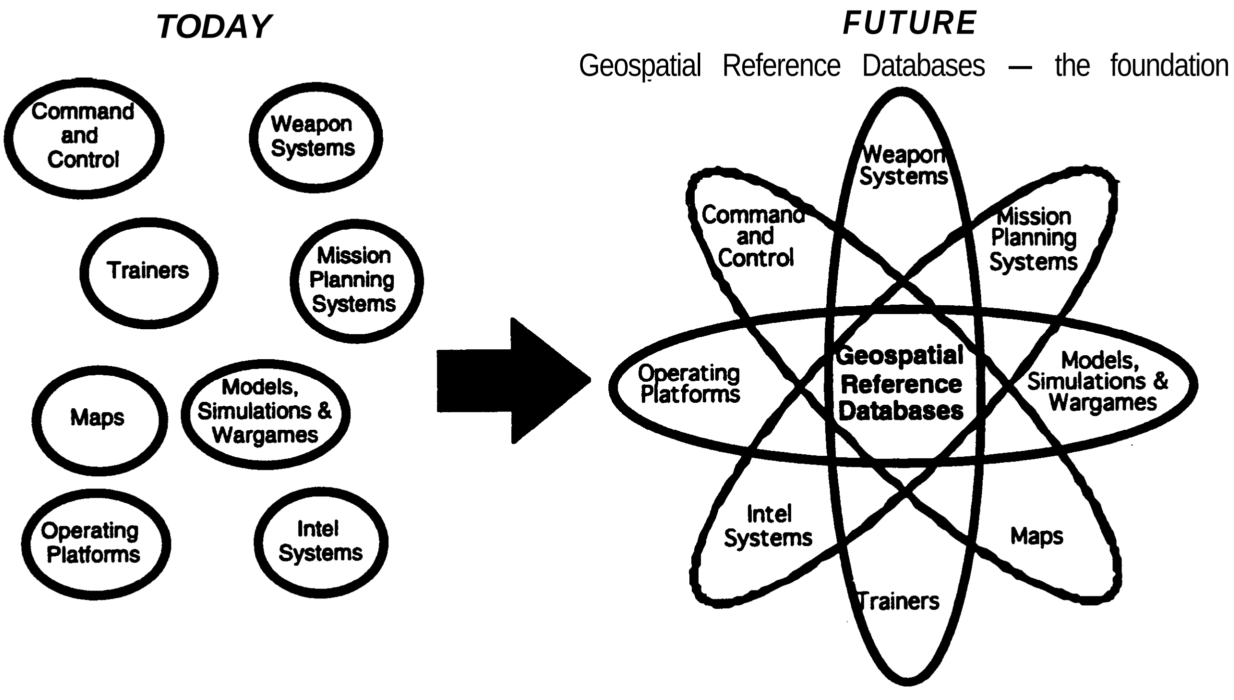


Figure H-l Multiple Users of Geospatial Information

An "atomic orbit" diagram similar to that on the right side of Figure H-l could be drawn for the commercial markets, where some of the orbital lobes would include "Remote Surveying", "Land Use Patterns", "Soil Composition", "Real Estate", "Environmental Change" etc.

In this appendix we examine some of the activities and resources being developed by the commercial markets which can be leveraged by the DoD.

H.2. Commercial Industry Activity

The rapid convergence of several commercially-driven forces is making the problem faced by the DoD in generating and utilizing a global geospatial database, and specifically the MC&G challenge, tractable in the near term. These forces include:

- the emergence of a commercial imagery industry,
- the emergence of a dynamic commercial industry based upon GPS, with increasing demands for higher geolocation accuracy, and the tools of our information revolution,
- the emergence of data repositories of georeferenced information in the civil sector,
- the acceptance of the non-DoD user community of satellite imagery as a standard base map upon which supplemental digital data can be superimposed, and
- the availability of high speed digital computers, workstations, high density storage, database management tools and the global push for high bandwidth telecommunications channels — where the channel bandwidths are now "faster" than the computer CPU and 110 speeds, and all of this increased performance is available at geometrically decreasing cost.

In the context of this revolution, briefings were received from representatives of commercial industry engaged in the entire "food chain" of MC&G from new imagery platforms, content generation, communications and user support. These briefings included :

Imagery Platforms	Space Imaging, Inc. Earthwatch, Inc. Earth Satellite Corp.
Communications / Storage / Dissemination	AT&T **Eastman Kodak** David Sarnoff Labs
Content Generation -Data Extraction & Analysis - Printing - • • •	Geodynamics Corp. MRJ, Inc. PRC, Inc. SAIC TRIFID Corp. ERDAS ERIM MapInfo Corp. DeLorme Mapping

We note that the proprietary image processing/image analysis software being developed by commercial vendors is of such applicability to DoD user requirements as to be considered by DoD for incorporation into its own programmatic activities.

H.3. Imagery Sources

Over the next few years numerous imagery sources, owned by countries, international consortia, and individual companies, will become available. It is estimated that by the year 2000, thirty countries will have indigenous capabilities in imaging satellites. The tacit assumption of the briefers was that a large portion of even the foreign national imagery products would be available for commercial use (as is their current experience). As is illustrated in Figure H-2, these platforms cover a variety of spectral regions, spatial resolutions, and spectral resolutions.

As shown, high resolution data will become available from US commercial space-based sensors (Earthwatch will launch its EarlyBird 3-meter satellite in 1996, Space Imaging, Inc. and Earthwatch will each launch a l-meter satellite in 1997). These commercial sources will be able to provide imagery to support 1:24,000 mapping products with ground control points.

The companies involved in these imagery platforms project sufficient commercial market demand to warrant these investments; they do not rely on government support. To date, distribution of images to other nations is not restricted, although image processing must be accomplished within the US.

There is also significant activity in data collection from airbreathing platforms, such as current activity in Interferometric Synthetic Aperture Radar (IFSAR). IFSAR uses interferometric radar techniques aboard an airborne platform to collect and record phase history data and then ground process it into Digital Terrain Elevation Model (DTEM) data. IFSAR has a swath width of 10 km and will collect data at a rate of lOO+ sq km per minute. Quoted accuracies are three meters spatial and three meters vertical.

The availability of stereoscopic and multispectral imagery, including Synthetic Aperture Radar (SAR) and IFSAR data and the improved (low cost) geolocation capability provided by GPS and differential GPS, are key in the commercial thrust to the rapid generation of traditional mapping products using an imagery base.

Without question these domestic and foreign platforms will provide a vast image library base — one whose contents will be available to DoD. It is incumbent upon DoD to be aware of this imagery, and to prepare plans to use this imagery as supplemental sources.

Satellite	Owners/Operators	Launch Date	Description*
Landsat-	NOAA (US)	**1982**	Land Sensing
Landsat-	NOAA (US)	1984	Land Sensing
Resurs-0	Hydromet (Russia)	1985	Land Sensing
SPOT-l	CNES (France)	1986	Land Sensing
IRS-la	ISRO (India)	**1988**	Land Sensing
SPOT-2	CNES (France)	1990	Land Sensing
MOS-lb	NASDA (Japan)	1990	Land/Ocean Color
IRS-lb	ISRO (India)	1991	Land Sensing
SPOT-3	CNES (France)	1993	Land Sensing
IRS-P2	ISRO (India)	1994	Land/Ocean Sensing
Helios I	France	1995	Panchromatic (< 1 m)
CBERS	Brazil/China	1995	Panchromatic/Multi-spectral (20/20 m)
RADARSAT	CSA/RI/MM (Canada)	1995	SAR **(8,30,100** m)
Resurs-02	Hydromet (Russia)	1995	Multi-Spectral (27 m)
IRS-lc	ISRO (India)	1995	Panchromatic/Multi-spectral (1 0/20 m)
CBERS	Brazil/China	1996	Panchromatic/Multi-spectral‘(20/20 m)
ADEOS	Japan	1996	Panchromatic/Multi-spectral (8/l 6 m)
Almaz-2	Russia	1996	Radar (5m)
Lewis	TRW/NASA (US)	1996	Panchromatic/Hyper-spectral(5/30 m)
Clark	CTA/NASA (US)	1996	Panchromatic/Multi-spectral (3/l 5 m)
Early Bird	Earthwatch (US)	1996	Panchromatic/Multi-spectral (3/l 5 m)
Quick Bird	Earthwatch (US)	1997	Panchromatic/Multi-spectral (114 m)
CRSS	Space Imaging, Inc.	**1997**	Panchromatic/Multi-spectral (l/4 m)
MECB SSR-2	INPE (Brazil)	**1997**	Land Sensing
Eyeglass	osc (US)	**1997**	Land Sensing
Orbview	Orbimage (US)	**1997**	Panchromatic (1 m)
SPOT-4	CNES (France)	**1997**	Panchromatic/Multi-spectral (1 0/20 m)
Envisat	ESA	1998	**Radar (30** m)
Landsat-7	u s	1998	Panchromatic/Multi-spectral (15/30 m)
EOS AM-l	Japan/US	1998	Multi-spectral (15 m)
KOMSAT	Korea	1998	Panchromatic (10 m)
IRS-ld	ISRO (India)	1999	Panchromatic/Multi-spectral (1 0/20 m)
SPOT-5A	CNES (France)	1999	Panchromatic/Multi-spectral (5/l 0 m)
SPOT-5B	CNES (France)	**2004**	Panchromatic/Multi-spectral (5/0 m)
EOS AM-21	US	**2004**	Panchromatic/Multi-spectral (1 O/30 m)
Landsat-8			

* length listed is spatial resolution

Figure H-2 Current and Planned Remote Sensing Satellites (Partial List)

H.4. Content Generation (Data Extraction, Analysis, and Printing)

In the "content generation" briefings (including ground processing) several key commercial initiatives were discussed and demonstrated, which will help realize in the near term the goal of distributing the processing and production capability to the end user. They include:

• Automated Data Extraction. The bottleneck in converting imagery into conventional maps, or the image-based map products demonstrated by several commercial briefers, is the identification of image features (buildings, roads, . . •). Looking at the explosion in future demands, it appears that several approaches must be pursued:

- assist the image analyst in the loop by continued investment in automated feature extraction,
- further utilize multi- and hyper-spectral sensors to assist in feature identification, and
- support cooperative agreements with commercial and other government agencies for current efforts to manually collect feature data

As was pointed out by a government advisor to the Task Force, not all feature data can or should be extracted "through a stereo microscope." One commercial map developer described enlisting foreign partners to manually populate the global feature base, e.g., he is contracting an Asian partner to provide feature data much like our census activity. None of these approaches in isolation will remove the exponentiallygrowing feature extraction bottleneck. Collectively, by using the heterogeneous feature databases growing worldwide, the problem becomes tractable.

• Production (Printing. Advances such as direct digital data-to-printing plate will simplify and speed the production process for mass production of maps. However, the most significant developments for MC&G hardcopy needs lie in the commercial desktop publishing developments, i.e., low cost, moderate resolution (300-600 dpi), high productivity (100 pages per hour), large format color printers robust enough to operate in a tactical environment.

• Standards. The comment was made, "Standards are good, everyone should have one." The commercial geospatial information and services community, because of its infancy, is in the dawn of standards activity — a slow convergence, the presence of cartels driving proprietary, de-facto standards and the first groups trying to provide a degree of standards coalescence. The government can influence but not lead this process. Most commercial developers in these briefings have developed software interfaces to utilize data sets in disparate formats.

H.5. Communications and Dissemination: Getting the bits to the end user

• Terrestrial Communications: By the year 2000, every urban center on the globe with a population greater than 100,000 people will be linked by high bandwidth optical fiber, which with optical amplifiers and wavelength multiplexing schemes will have single channel capacities of 10s of gigabits/sec. These channels will provide robust (through the massive parallelism of these networks), ubiquitous access and security of transmission using even simple public key encryption techniques.

• Satellite Communications: Investment in commercial satellite communications platforms such as the Hughes Direct Broadcast Satellite (DBS) is also exploding. DBS has been exercised by the Navy (Project Athena) to provide broadband dissemination of data to theater areas. The JWID '95 demonstration effort will evaluate the utility of DBS in distributing weather, battle damage videos, order of battle, situational awareness, intelligence information, geospatial information, and imagery.

• Non-Electronic Dissemination: Compact disks (CDs) are becoming the transport medium of choice for large files. The prices are dropping for both stamped CDs for transmitting static data and writeable CDs which can be modified. Read/write speeds are increasing and capacity of the disks is increasing. CDs are approaching 50% market share for dissemination of large geospatial information files.

H.6. Tools for the End User

The goal of the commercial developers of geospatial information software tools is to allow non-MC&G-trained users to rapidly extract information from heterogeneous databases, process it, and produce the information product needed in his local environment, i.e., "plug and play." Much progress has been made by commercial developers toward this goal. One demonstration, the ERDAS Global Navigator, showed the power (with software simplicity) of dynamically linking multi-spectral, multi-source imagery and geographical data to rapidly produce map products.

H.7. Feedback from the Commercial Briefers

The DSB task force also provided a "soapbox" for the commercial briefers to comment on other aspects of the MC&G problem or commercial / government issues. Among the comments or concerns were the following:

Mr. Robert J. Porter of the Earth Satellite Corporation raised 5 key issues in designing a DoD-unique systems architecture:

1) Are there single-point failures in the operation? (e.g., single source)
2) Does the system operate in fail-soft mode? (alternate "imperfect" sources)
3) Are there mechanisms to identify commercial capabilities that can be used?
4) Are there vehicles in place to use commercial capabilities in a surge mode?
5) Is the current government/industry structure the correct one? Does defense mapping need a JASON-like Advisory Board with people from outside the community?

Dr. Curt Carlson of the David Sarnoff Labs stated that, in the exponential growth of the commercial / consumer information market, the government was threatened with becoming "exponentially obsolete." The implied threat to our national security is that if the DoD does not find ways of taking full advantage of the commercial information capabilities (riding the commercial curve), our enemies will do so. Dr. Carlson called for the DoD to exploit the US commercial leadership in information technologies by establishing new organizations, developing new skills for its personnel, and establishing new operational doctrines and tactics — based upon what is now possible with the tools emerging from the commercial marketplace. These tools include: communications (CATV, terrestrial, digital direct broadcast systems, wireless), multi-media server development, 2-way interactivity, and emerging information security technologies.

H.8. Technology Opportunities

Figure H-3 lists technologies currently being developed which offers some increased capability potentially of use to the defense mapping community.

Information Sources

- Interferometric Synthetic Aperture Radar (IFSAR)

Data Extraction and Analysis

- Automated Data Extraction

Production

- Lithographic Printing: Direct-to-plate and no-process plate techniques, waterless printing, and electronic printing (direct to press)
- Desktop Printing: Improved inkjet techniques, electrophotography

Dissemination

- Fiber Optics
- Compact Disk
- Interactive Systems
- Direct Broadcast Satellite (DBS)

User tools

- Geospatial information software tools

Figure H-3 Technology Opportunities

I. Acronyms & Glossary

A31	Accelerated Architecture Acquisition Initiative (CIO)
AAAV	Advanced Amphibious Assault Vehicle
ABCS	Army Battle Command System
AF/IN	Air Force Deputy Chief of Staff Intelligence
AFMC	Air Force Material Command
AFMSS	Air Force Mission Support System
ARPA	Advanced Research Projects Agency
ASAS	All Source Analysis System
ASD (C31)	Assistant Secretary of Defense (C31)
ATM	Asynchronous Transfer Mode
Bathymetry	Science of determining and interpreting ocean depths and ocean-floor topography
c2	Command and Control
c3	Command, Control, and Communications
C31	Command, Control, Communications, and Intelligence
C4I	Command, Control, Communications, Computers, and Intelligence
C4IFTW	C41 For The Warrior
CD	Compact Disk
CD ROM	Compact Disk Read Only Memory
CENTCOM	US Central Command
CIA	Central Intelligence Agency
CIB	Controlled Image Base
CINC	Commander in Chief
CIO	Central Imagery Office
CIS	Combat Intelligence System
CJCS	Chairman, Joint Chiefs of Staff
CJTF	Commander, Joint Task Force
CNO	Chief of Naval Operations
CNO(NO96)	Office of Oceanographer of the Navy
Composite Data	See definitions of data types at the end of this appendix
COTS	Commercial Off The Shelf
CST	Customer Support Team DMA)
CTAPS	Contingency Theater Automated Planning System (Air Force)
DAR0	Defense Airborne Reconnaissance Office
Datum (geodetic)	See Geodetic Datum
DBS	Direct Broadcast Satellite
DDR&E	Director, Defense Research and Engineering
DEM	Digital Elevation Map (USGS)
DEPSECDEF	Deputy Secretary of Defense
DFAD	Digital Feature Analysis Data

DIA	Defense Intelligence Agency
DII	Defense Information Infrastructure
DISA	Defense Information Systems Agency
DMA	Defense Mapping Agency
DMSO	Defense Modeling and Simulation Office
DNC	Digital Nautical Chart
DoD	Department of Defense
dpi	dots per inch
DPS	Digital Production System DMA system)
DR	Discrepancy Report
DSB	Defense Science Board
DTED	Digital Terrain Elevation Data
DTEDl	DTED Level 1 - (100 meter resolution)
DTED2	DTED Level 2 - (30 meter resolution)
DTED3	DTED Level 3 - (10 meter resolution)
DTED4	DTED Level 4 - (3 meter resolution)
DTEDS	DTED Level 5 - (1 meter resolution)
EO	Electra-Optics
Force XXI	Army Plan for Next Century
GALE	Generic Area Limitation Environment DIA system)
GCCS	Global Command and Control System
Geodetic Datum	A reference coordinate system defined by five parameters: two of which define a reference ellipsoid and the remaining three of which (latitude, longitude, and geoid height) specify the datum origin. DMA standardizes its geographic information and services to the WGS-84 datum. GPS is referenced to WGS-84 but some receivers accommodate transformation into other selected datums.
GGI&S	Global Geospatial Information & Services
GGMl	Global Geospatial Mapping Information
GGMI&S	Global Geospatial Mapping Information & Services
GIS	Geospatial Information System
GPS	Global Positioning System
HUMINT	Human Intelligence
Hydrographic Chart	Nautical chart showing depths of water, nature of bottom, contours of bottom and coastline, and tides and currents in a given area
IFSAR	Interferometric Synthetic Aperture Radar
IMINT	Imagery Intelligence
INS	Inertial Navigation System
Intelink	A set of networks for disseminating/sharing intelligence information (uses JWICS and SIPRNET)
IPT	Integrated Product Team

JCS	Joint Chiefs of Staff
JDISS	Joint Defense Intelligence Support System
JMIP	Joint Military Intelligence Program (see also NFIP and TIARA)
JMTK	Joint Mapping Tool Kit
JOG-A	Joint Operations Graphic - Air (1:250,000 scale)
JTF	Joint Task Force
JWICS	Joint Worldwide Intelligence Communications System - a TS/SCI network
JWID	Joint Warrior Interoperability Demonstration
LAN	Local Area Network
LANDSAT	Satellite for Land Imaging
M&S	Modeling and Simulation
MAGTF	Marine Air-Ground Task Force
MC&G	Mapping, Charting & Geodesy
MOP	Memorandum of Policy
MRC	Major Regional Conflict
MSE	Mobile Subscriber Equipment
NAVSSI	Navigation Sensor System Interface
NFIP	National Foreign Intelligence Program (see also JMIP and TIARA)
NIPRNET	Non-Secure Internet Protocol Routed Network (see SIPRNET)
NMS	National Military Strategy
NOAA	National Oceanic and Atmospheric Administration, Dept of Commerce
NOS	National Ocean Service, part of NOAA
NPIC	National Photographic Interpretation Center
NRO	National Reconnaissance Office
NSA	National Security Agency
NSC	National Security Council
NTM	National Technical Means
O&M	Operations and Maintenance
OP	Operations
0SD;	Office of the Secretary of Defense
PDD	Presidential Decision Directive
PDM	Program Decision Memorandum
Raster Data	See definitions of data types at the end of this appendix
RDT&E	Research, Development, Test, and Evaluation
Recce	Reconnaissance
RRS	Remote Replication System
S&T	Science and Technology
SAR	Synthetic Aperture Radar
SC1	Sensitive Compartmented Information
SECDEF	Secretary of Defense

SIOP	Single Integrated Operational Plan
SIPRNET	Secret Internet Protocol Routed Network (GCCS users will be on SIPRNET)
SPACECOM	Space Command
SPOT	Systeme Probatoire d'Observation de la Terre - Imaging Satellite owned by SPOT-IMAGE (French)
STRATCOM	Strategic Command
TAFIM	Technical Architecture Framework for Information Management
TAMPS	Tactical Advanced Mission Planning System
TBD	To Be Determined
TEC	Topographic Engineering Center (Army)
TERCOM	Terrain Contour Matching
Text Data	See definitions of data types at the end of this appendix
TIARA	Tactical Intelligence and Related Activities (see also JMIP and NFIP)
TLM	Topographic Line Maps
Topographic Map	Map which presents vertical position of features in measurable form as well as their horizontal positions
TPC	Tactical Pilotage Chart (1500,000 scale)
TS	Top Secret
UAV	Unmanned Air Vehicle
USA	us Army
USAF	US Air Force
USCENTCOM	US Central Command
USD (A&T)	Undersecretary of Defense (Acquisition and Technology)
USGS	US Geological Survey
USIS	US Imagery System
USMC	US Marine Corps
USN	US Navy
USSOCOM	US Special Operations Command
USSPACECOM	US Space Command
USSTRATCOM	US Strategic Command
Vector Data	See definitions of data types at the end of this appendix
VMap	Vector Smart Map
WGS	World Geodetic System (WGS 84 is baseline geoid)

Data Types

Raster Data	A representation of MC&G data characterized by a matrix of evenly spaced rows and columns of data points. These data points (called "pixels" in image and scanned map data) typically represents some value at that point, while the position within the columns and rows determines the geographic position. Raster data structures are typically used to record scanned maps and charts (MC&G graphic data), image data, or gridded data.
Text Data	Textual descriptions of data in paragraphs or lists
Vector Data	Data which represents each cartographic feature by an entity description (feature code) and a spatial extent (geographic position). Geographic position may be two-dimensional (horizontal position only) or three-dimensional (including elevation). Features are categorized as point, line, or area features. The position of a point feature is described by a single coordinate pair (or triplet for three dimensional data). The spatial extent of a line feature is described by a string of coordinates of points lying along the line, while the extent of an area feature is described by treating its boundary as a line feature. Vector data may be stored in a sequential, a chain node, or a topological data structure.
Composite Data	Geographic object composed of a raster product format (RPF) frame with vector product format (VPF) features located within the boundaries and text product format (TPF) paragraphs whose indexes fall within the boundaries.