ATP 3-34.80

GEOSPATIAL ENGINEERING

MARCH 2024

DISTRIBUTION RESTRICTION: Approved for public release; distribution is unlimited.

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Preface

ATP 3-34.80 provides doctrine for geospatial engineering operations at all echelons. It is an extension of FM 3-34 and is linked to joint and other Army doctrine to ensure its usefulness for operational level commanders and staffs. This manual serves as a guide for integrating geospatial engineering in support of multidomain operations at all echelons, with an added focus that describes geospatial engineering within divisions and brigades.

The principal audience for ATP 3-34.80 is geospatial engineers, engineer commanders, and staff officers, but all Army leaders, Soldiers, and Army Civilians will benefit from reading it. Trainers, combat developers, and educators throughout the Army will also use this manual. This manual will help other Army branch schools teach the integration of geospatial engineering capabilities into Army operations.

Commanders, staffs, and subordinates ensure that their decisions and actions comply with applicable United States (U.S.), international, and, in some cases, host-nation laws and regulations. Commanders at all levels ensure that their Soldiers operate in accordance with the law of armed conflict and the rules of engagement. (For further information, see FM 6-27/MCTP 11-10C.)

ATP 3-34.80 uses joint terms where applicable. Selected joint and Army terms and definitions appear in the glossary and the text. Terms for which ATP 3-34.80 is the proponent publication (the authority) are italicized in the text and marked with an asterisk (*) in the glossary. Terms and definitions for which ATP 3-34.80 is the proponent publication are boldfaced in the text. For other definitions shown in the text, the term is italicized, and the number of the proponent publication follows the definition.

ATP 3-34.80 applies to Active Army, Army National Guard/Army National Guard of the United States, and United States Army Reserve unless otherwise stated.

The proponent of ATP 3-34.80 is the United States Army Engineer School. The preparing agency is the Maneuver Support Center of Excellence (MSCoE) Fielded Force Integration Directorate, Doctrine Branch. Send comments and recommendations on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to Commander, MSCoE, ATTN: ATZT-FFD, 14000 MSCoE Loop, Suite 270, Fort Leonard Wood, MO 65473-8929; e-mail to usarmy.leonardwood.mscoe.mbx.engdoc@army.mil; or submit an electronic DA Form 2028.

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Introduction

Geospatial engineering is one of three engineering disciplines. It supports all staff sections and warfighting functions across every echelon of Army forces and plays a significant role in supporting the combat and general engineering disciplines within the Engineer Regiment. This discipline is essential and considered foundational to all four lines of engineering support (assure mobility, enhance protection, enable force projection and logistics, build partner capacity, and develop infrastructure). Geospatial engineering is an art and a science pertaining to generating, managing, analyzing, and disseminating geospatial information that is accurately referenced to a precise location on earth and used in offense, defense, stability, or Defense Support of Civil Authorities' tasks. Geospatial engineering considers terrain and geospatial data, information, and effects from all domains. These tasks provide mission-tailored data, geospatial decision aids, visualization products, and information that enable the commander and staff to visualize and understand the operational environment (OE).

Geospatial engineers aid in analyzing the physical environment, including weather effects, and in analyzing geo-located features, traits, characteristics, and activities that significantly contribute to anticipating, estimating, and warning of possible future events. Providing geospatial information that is timely, accurate, and relevant is a critical enabler throughout the operations process for developing shared situational awareness, improving the understanding of capabilities and limitations for friendly forces and the adversary, and highlighting other conditions of the OE that are required for command and control. Compared with the resolution of data and efficiency working across organizations in the early 21st century, today's geospatial engineering leverages finer temporal, spatial, and spectral resolutions from additional sensors and platforms that allow increased complex volumes of data. New methods and technologies provide the additional utility, capability, and ability to work effectively and efficiently within a broad pool of mission partners.

In addition to mastering their respective areas of expertise, staff officers and other staff members must thoroughly understand geospatial engineering to tailor geospatial information to support all warfighting functions. Advancements in technology and access to abundant data and information can quickly lead to information overload. Planners must be able to analyze the situation through the mission and operational variables, grasp the military significance of the challenges and opportunities presented, and manage information to enable situational understanding to support decision making.

This manual describes the application of geospatial engineering in support of the Army and increasingly joint forces that are conducting multidomain operations within an increasingly complex operational environment. It also acknowledges that Army doctrine remains dynamic—balancing current capabilities and situations with projected requirements for future operations. As geospatial engineering capabilities continue to improve through organizational alignments, technological advancements, and emerging best practices, leaders and planners at all echelons will be charged to leverage those improvements and adapt the processes and procedures described in this manual to meet the demands of, and provide the most effective geospatial support possible to, the commander.

ATP 3-34.80 is integrated with current or revised joint and Army doctrine, notably Army capstone doctrine for multidomain operations found in ADP 3-0, FM 3-0, and FM 3-34. This update reduces redundant content covered in other current Army publications and manuals and has been reorganized to align with FM 3-34. Other changes that have directly affected this manual include the—

- Development and fielding of the Army's Common Operating Environment (COE).
- Development of the need for geospatial/terrain data, information, and analysis on multiple security networks/domains to include but not limited to nonclassified internet protocol router, sensitive but unclassified, mission partner environment, secret releasable, secret internet protocol router, and joint worldwide intelligence communications system.
- Publication of the Army's multidomain operations concept.
- Increased quantity and quality of terrain and geospatial data, information, and products.

- Increased availability of high-resolution, three-dimensional geospatial/terrain data.
- Publication of an updated Army Geospatial Enterprise (AGE) Concept of Operations.
- Publication of TC 3-34.80 which includes a thorough representation of geospatial products, resulting in the removal of the Geospatial Products appendix.
- Acknowledgment of the CJCSI 3110.08F revised joint definition of geospatial information and services (GI&S) and geospatial intelligence (GEOINT).
- Establishment of the term "geospatial decision aids" to capture and describe tailored geospatial products that support the operational level planning processes and mission execution.

ATP 3-34.80 is organized into five chapters that describe geospatial engineering, the roles and responsibilities for integrating geospatial support at the various echelons, and the integration of geospatial engineering within the Army operations process. The following are brief descriptions of the chapters:

- **Chapter 1** provides an overview of Army geospatial engineering and explains the four main functions that geospatial engineering performs and how geospatial engineering supports all warfighting functions and staff sections.
- **Chapter 2** focuses on defining and conceptualizing the AGE and standard and shareable geospatial foundation (SSGF) data while outlining the operational use of the AGE with an emphasis on the geospatial layers of the common operational picture (COP).
- **Chapter 3** discusses the geospatial engineering capabilities ranging from national strategic to tactical level. It characterizes the national communities and agencies such as the National Geospatial-Intelligence Agency (NGA), Army Geospatial Center (AGC), Army NGA Support Team, and Army GEOINT Battalion, as well as various staff responsibilities.
- **Chapter 4** focuses on integrating geospatial engineering capabilities into the Army operations process and the military decision-making process (MDMP).
- **Chapter 5** describes the role of geospatial engineering in supporting Army operations. It also describes the critical roles that geospatial engineering units and staffs have in providing geospatial engineering within an operational environment.
- **Appendix A** provides basic conversion charts and figures for metric, slope, volumes, and associated formulas. For a complete listing of preferred metric units for general use, see Federal Standard 376B.
- **Appendix B** describes the six characteristics of terrain that geospatial engineers analyze when determining terrain effects on operations.
- **Appendix C** provides information on Army geospatial data sources with points of contact and uniform resource locator web addresses for gathering authoritative digital terrain data that supports operations and enables decision making.

Unless stated otherwise, masculine nouns or pronouns do not refer exclusively to men.

Introductory table. New and modified terms

Term	*Remarks*
geospatial decision aids	New term and definition
complex terrain	Updated term

Chapter 1

Army Geospatial Engineering Overview

Throughout history, people have fought over land. As warfare evolved, it was often the organized fighting force that effectively maneuvered and used the terrain to their advantage that ultimately won. The relationship between warfare and terrain is a permanent connection because armies operate in a defined space; regardless of operation or formation, the terrain features and climate will dominate reasoning. A deliberate consideration of this relationship requires a decisive use of terrain to alter these armies' abilities to execute movement and maneuver. From tactical to strategic planning in navigating and utilizing even the smallest terrain features and to large formations conducting cross-country mobility, the relationship between warfare and terrain characterizes and determines even the most intricate of military operations. While the weapons of war have changed, the nature of war has not. In the Army, the geospatial engineer provides the tools and analysis of the physical dimension and weather effects on the OE and other geospatial data and information (GD&I) that provide commanders situational understanding. This OE visualization is necessary to disrupt enemy forces and achieve tactical and operational objectives.

GEOSPATIAL FOUNDATIONAL CONSIDERATIONS

1-1. Geospatial engineering are those engineering capabilities and activities that contribute to a clear understanding of the physical environment by employing geographic information systems (GIS) to provide GI&S to commanders and their organizations. FM 3-34 and JP 3-34 provide additional information on engineer disciplines and their role in support of multidomain operations. Geospatial information identifies the geographic location and characteristics of natural or constructed features and boundaries on earth.

1-2. Geospatial engineering is the art and science of applying geospatial information to enable an understanding of the physical environment for military operations. The science is the ability to collect geospatial information about the physical dimension of the OE, analyze the geospatial information to identify phenomena, and exploit the geospatial knowledge gained in support of military operations. The art is the ability to utilize cartographic techniques and principles to produce mission-tailored GI&S and knowledge, geospatial decision aids, and visualization products, providing the commander and staff a situational understanding of the physical dimension and effects of the OE.

1-3. The *physical dimension* is defined as the material characteristics and capabilities, both natural and manufactured, within an operational environment (FM 1-02.1). ***Geospatial decision aids*** **are tailored geospatial products that support operational level planning processes and mission execution.** Geospatial decision aids provide commanders and their staffs with an understanding of the physical environment. The geospatial engineering discipline is also considered the foundation supporting the combat and general engineering disciplines and lines of engineer support.

GEOSPATIAL INFORMATION SYSTEMS

1-4. GIS are systems and processes for capturing, storing, analyzing, and managing geographic data and associated attributes spatially referenced to the earth. GIS computer systems are capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information. GIS is a tool that allows users to create interactive queries (user-created searches), analyze spatial information, edit data, and present the results of these operations.

1-5. GIS connects data to a map, integrating location data with all types of descriptive information. This provides a foundation for mapping and analysis used in science and almost every industry. GIS helps users understand patterns, relationships, and geographic context by using computer programming environments to aid data science. It also helps to address the three Vs of data (veracity, volume, and variety).

GEOSPATIAL INFORMATION AND SERVICES

1-6. *GI&S* is the collection, information extraction, storage, dissemination, and exploitation of geodetic, geomagnetic, imagery (both commercial and national source), gravimetric, aeronautical, topographic, hydrographic, littoral, cultural, and toponymic data that are accurately referenced to a precise location on the Earth's surface (CJCSI 3110.08F). Geospatial services include tools that enable users to access and manipulate data. Geospatial services also include instruction, training, laboratory support, and guidance for geospatial data use. The availability of commercial off-the-shelf geospatial data software applications enables a wide variety of military and civilian users to apply GI&S to various situations.

1-7. Common military applications of GI&S include support to planning, training, and operations (visualization, analytics, navigation, mission planning, mission rehearsal, modeling, simulation, and targeting). Automated geospatial applications can enhance map features (such as elevation) that may not be discernible to enable a more detailed analysis. Geospatial engineers provide GI&S, GD&I, and SSGF data for developing shared situational awareness and improving the understanding of the effects of terrain on friendly and threat courses of action (COA) and other conditions of the operational environment.

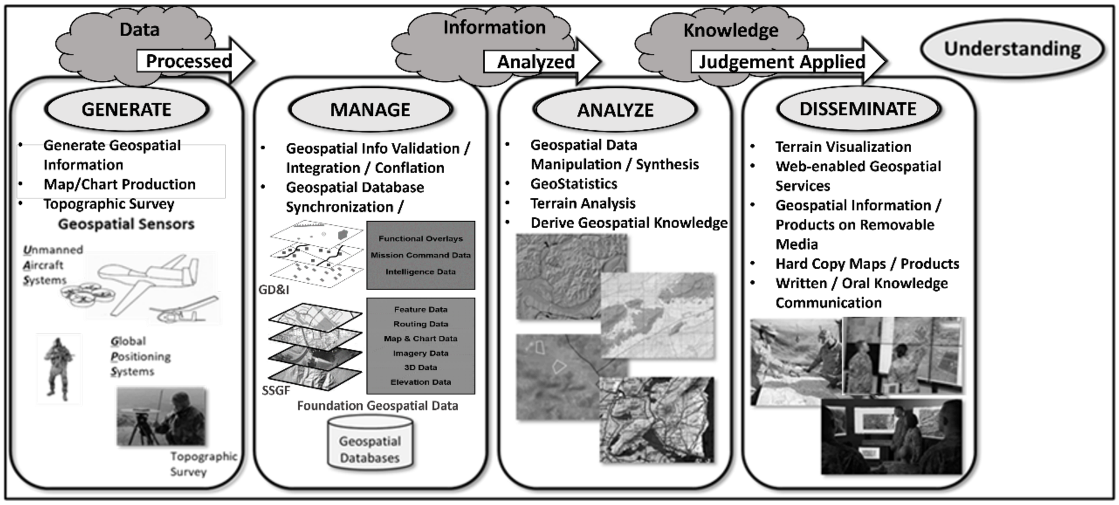
GEOSPATIAL INTELLIGENCE

1-8. *Geospatial intelligence* (GEOINT) is the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on or about the earth. Geospatial intelligence consists of imagery, imagery intelligence, and geospatial information (JP 2-0). See ATP 2-22.7, CJCSI 3110.08F, and Title 10 US Code 167 for more detailed information regarding GEOINT. See figure 1-1 for distinguishing characteristics and cross-cutting capabilities of geospatial engineering and GEOINT.

ARMY GEOSPATIAL ENGINEERING FUNCTIONS

1-9. Army geospatial engineers perform four primary functions (generate, manage, analyze, disseminate [GMAD]) related to geospatial engineering operations. See figure 1-1 for GMAD conceptual support to understanding. These four primary functions are as follows:

- **Generate.** The process of deriving geospatial information (features, traits, and/or characteristics) from data that has a spatial context, including generating requirements to capture necessary data. Geospatial data includes but is not limited to raster, vector, electro-optical imagery, terrain matrix data, Light Detection and Ranging (LiDAR) data (including bathymetric/bathymetry LiDAR data), radar data, topographic survey, reconnaissance reporting, and textual/tabular data.
- **Manage.** The collection, validation, integration, conflation, synchronization, and storage of authoritative GD&I in a standard, configurable, and interoperable format.
- **Analyze.** The use of algorithms and geospatial processing tools to identify phenomena within the physical environment or to model predictive effects of the physical environment on military operations. The geospatial knowledge derived from this process supports decision making throughout the Army Design Methodology (ADM) or MDMP.
- **Disseminate.** The distribution of geospatial data, information, and/or knowledge to provide situational awareness and a shared understanding of the physical environment and its impacts on military operations. Dissemination methods include web-enabled geospatial services, digital geospatial information on removable media, hard copy map production, and sharing geospatial knowledge through written and oral communication.



Legend:

GD&I	geospatial data and information
SSGF	Standard and Shareable Geospatial Foundation

Figure 1-1. Geospatial engineering GMAD support to understanding.

1-10. The four geospatial engineering functions are conducted as an iterative process upon receipt of newly collected geospatial data to refine and increase the understanding of impacts on military operations from the physical environment.

> ***Note***. Chapter 3 contains the roles and responsibilities for performing geospatial engineering at each echelon.

GENERATE GEOSPATIAL DATA

1-11. Geospatial data comprises a wide variety of observations and facts arranged in a particular format that are detected by a collector of any kind (human, mechanical, or electronic) and can be spatially tied to the surface of the earth. ***Geospatial data and information* (GD&I) is the geographic-referenced and tactical objects and events that support the unit mission, task, and purpose**. Geospatial data can be objects, events, or phenomena that have a location on the surface of the earth and are most utilized when discoverable and shared.

1-12. A geodetic survey is a specialized form of reconnaissance to collect data to a specific level of accuracy. Specially trained survey teams conduct geodetic surveys and establish precise locations of geographic features within a specified margin of error. They determine the spatial relationships between features to a known level of accuracy. This data set of features and locations provides the necessary information to produce accurate maps and fire and airfield control points. Geodetic survey repositories are typically retained at the civil and national agency levels.

> ***Note***. Currently, space-based survey capabilities do not provide the same accuracy and precision as geodetic surveys.

1-13. *Geospatial information* identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth, including statistical data and information derived from, among other things, remote sensing, mapping, and surveying technologies; and mapping, charting, geodetic data and related products (JP 2-0). Foundation geospatial data encompasses all available data types and information used to visualize and identify the geographic location and characteristics of natural or constructed features and boundaries on the earth. Geospatial information and foundation geospatial data provide the basic framework for visualizing the OE. This information is derived from multiple sources and adapted or transformed into common interoperable data standards. It can be presented in printed maps, charts, digital files, and publications; digital simulation and modeling databases; aerial or satellite imagery; or digitized maps and charts. Its effectiveness as an enabler is directly proportional to its currency, accuracy, relevance, and understanding by the user; however, information assurance restrictions often handicap the enabling abilities of GIS.

1-14. Geospatial engineers at each echelon are responsible for deriving geospatial information from organic information collection activities, including reconnaissance reports or remote-sensed data collection, and for capturing information in standardized geospatial formats. These formats include georeferenced imagery, elevation matrices (rasters), geospatial features (vector), military standard maps, and landcover. Elevation matrices (rasters) store elevation measurements for a given area in an evenly spaced grid. These measurements might depict bare earth digital terrain models or digital surface models that include buildings, vegetation, and other above-ground features. *Geospatial features (vectors)* are data used to represent real-world features in a GIS (FM 1-02.1). A vector feature can have a geometry point, line, or polygon (more recently called surface curves and points). Each vector feature has attribute data that describes it. See TC 3-34.80 for geospatial product examples.

Note. Geospatial engineers use matrices to describe rasters; however, not all matrices are rasters.

MANAGE GEOSPATIAL DATA

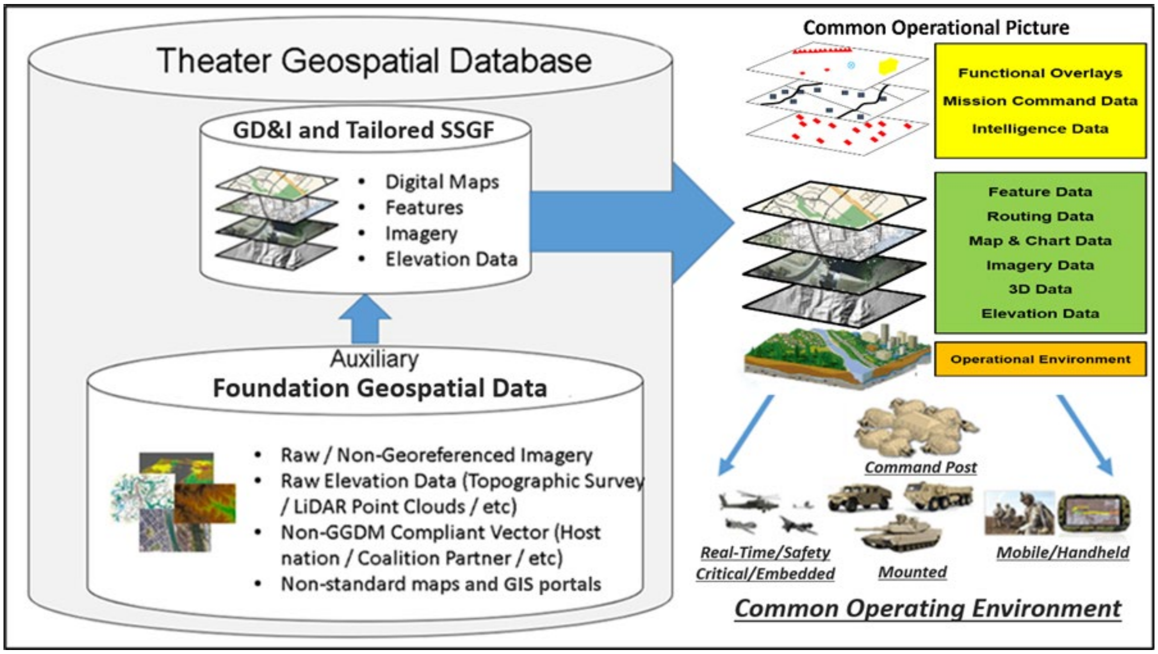
1-15. Geospatial data management includes collecting, validating, integrating, conflating, synchronizing, and storing accurate and relevant geospatial information, foundation geospatial data, and GD&I from multiple sources and in various formats in structured databases. These databases are then optimized for storing and querying. Foundation geospatial data derived from GD&I can be used to enhance the SSGF to support the COP. See figure 1-2 for a representation of this process supporting the COP. The COP displays relevant GD&I overlaid on SSGF (defined in Chapter 2) within the commander's area of interest tailored to the user's requirements and based on common data and information shared by more than one element, echelon, or command.

Theater Geospatial Database Management

1-16. Geospatial engineers at each echelon actively manage and update information in the structured databases of the Theater Geospatial Database (TGD). The TGD contains all available geospatial information, foundation geospatial data, SSGF (defined in Chapter 2), and GD&I associated with the combatant command and organization area of interest. The TGD is managed by the associated geospatial planning cell (GPC).

Theater Geospatial Database Scalability

1-17. The TGD of the organization is scalable to the area of interest and tailored to the mission of the organization. The TGD is established and managed at the onset of planning and is continuously updated and maintained during mission execution to provide users at all levels access to timely, accurate geospatial data. Geospatial engineers validate and update map editions incorporated into the COE and command and control systems to ensure that all users operate from a common map background. The *common map background* program was designed by AGC to provide the capability to assemble, host, maintain and disseminate a common geospatial data library (FM 1-02.1). The library includes AGC data and products, NGA data, and other relevant geospatial data and products. The volume of generated GD&I increases proportionately with the duration of the operation, and the data product type and scale affect download and acquisition timelines. Common map background data within the TGD is scaled specifically for a combatant command and organization area of interest. Incomplete, inaccurate, or irrelevant geospatial information residing in shared folders contributes to information overload and can be misleading. GD&I management ensures its effectiveness.



Legend:

etc	et cetera
GD&I	Geospatial Data & Information
GGDM	ground-warfighter geospatial data model
GIS	Geospatial Information Systems
LiDAR	Light Detection and Ranging
SSGF	Standard and Shareable Geospatial Foundation

Figure 1-2. Theater Geospatial Database concept

ANALYZE GEOSPATIAL DATA

1-18. Geospatial analysis uses GIS tools to analyze geospatial data and refers to extracting meaning from geospatial data to uncover and investigate spatial and temporal relationships and patterns in support of all warfighting functions. Geospatial analysis uses technology to geographically analyze data and information; these tools include GIS, global positioning systems, geo-referencing, metadata (data about data), and remote sensing. The geography of the earth is captured as spatial data and reveals characteristics when combined with temporal data, providing operational relevance that would otherwise not be considered if analyzed separately as spatial or temporal. When spatial data is combined with temporal data, time is included as another dimension of information or knowledge produced. Spatial data on the geography of the earth can be combined with other GIS, remote-sensing, or global positioning systems data to make associations between a particular parameter of interest (such as slope and soil considerations). Using data obtained at different times allows these associations to be studied, providing context such as seasonal considerations for movement and maneuver.

1-19. ***Terrain analysis* is the study of the terrain's properties and how they change over time, with us, and under varying weather conditions**. Terrain analysis is used to examine and determine the expected effects of the physical dimension of the OE on military operations. Terrain analysis starts with collecting, verifying, processing, revising, and creating source data. When conducting terrain analysis, personnel must consider the effects of climatology (current and forecasted weather conditions), natural and man-made features, and friendly and threat (enemy) unit and equipment performance capability metrics, such as vehicles and task organizations.

1-20. Terrain analysis is a highly technical and complex process that requires the expertise of geospatial engineering technicians and geospatial engineers. Terrain analysis evaluates the characteristics of natural and man-made terrain that are grouped within the following terrain factor areas and overlays:

- Hydrology (surface drainage).
- Surface configuration (slope, surface roughness).
- Surface materials (soils).
- Vegetation.
- Obstacles.
- Infrastructure (man-made features).

1-21. Terrain analysis and visualization is a combination of science and art. It is a fundamental leadership skill to understand the importance of terrain and its impact on the situation, including the effects on friendly and threat capabilities. Terrain analysis is the identification, understanding, and exploitation of terrain aspects to gain an advantage over threats and identify those terrain aspects most likely to be used by threats. It is the subjective evaluation of the physical attributes of the terrain and the performance capabilities of vehicles, equipment, and personnel that must cross over and occupy the terrain. See appendix B for additional terrain analysis information.

1-22. Geospatial engineers analyze the physical environment to help the staff understand the OE for commanders to visualize the terrain to further enable mission planning. This broad view of the OE is refined upon mission receipt by analyzing the mission variables. Geospatial engineers continually analyze the physical environment while incorporating weather effects to help focus on the characteristics of terrain effects across the warfighting functions. Knowledge derived from the analysis of geospatial information enables the ADM or MDMP. See TC 3-34.80 for examples of geospatial support products for commanders and staffs.

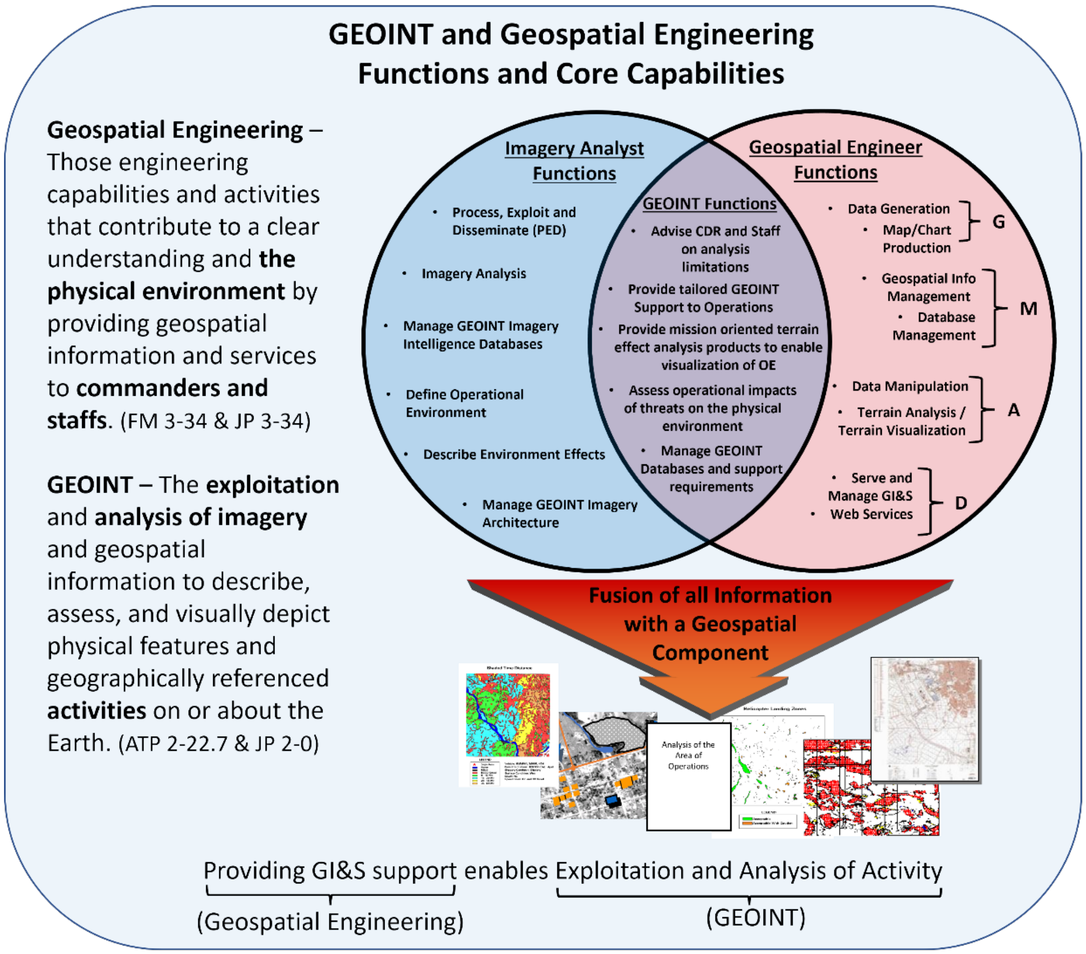
DISSEMINATE GEOSPATIAL DATA, INFORMATION, AND PRODUCTS

1-23. Geospatial data, information, and product dissemination are critical to enabling a shared understanding of the physical dimension and impacts of the OE. Dissemination is accomplished by providing standard and nonstandard hard-copy maps or geospatial analysis products, SSGF, geospatial decision aids, or geospatial applications through web-enabled services, on removable media devices, and through written or oral communication. Refer to TC 3-34.80 for examples of common products. The analysis and products provided in TC 3-34.80 are doctrinal examples and vary based on mission, utilization, operational requirements, and constraints.

GEOSPATIAL ENGINEERING AND GEOINT CORE CAPABILITIES OVERLAPPING AREAS

1-24. Geospatial engineering and imagery analyst functions overlap throughout the MDMP process. Fusing these functions provides a geospatial and GEOINT component that supports all warfighting functions across all domains and dimensions. See figure 1-3 for a representation of these overlapping functions. These functions are described in Chapter 4 throughout the MDMP process. See ATP 2-22.7, FM 2-0, and JP 2-0 for a comprehensive list of imagery analyst and GEOINT functions. The core capabilities geospatial engineering and imagery analysts provide in the overlapping areas include:

- Advise commander and staff on analysis limitations.
- Provide tailored GEOINT support to operations.
- Provide mission-oriented terrain effect analysis products to enable visualization of OE.
- Assess operational impacts of threats on the physical environment.
- Manage GEOINT databases and support requirements.



Legend:

ATP	Army technical publications
CDR	commander
FM	field manual
GEOINT	geospatial intelligence
GI&S	geospatial information and services
JP	joint publication
OE	operational environment
PED	process, exploit, and disseminate

Figure 1-3. GEOINT and geospatial engineering functions and core capabilities overlap

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Chapter 2
Army Geospatial Enterprise

The AGE is central to MDMP due to its ability to enable the visualization of a wide variety of data for the context of place and time. It is a cross-cutting capability, applying to all warfighting functions in all phases of operations across both the operating force and the generating force. As a component of the Army Enterprise Architecture and the National System for Geospatial-Intelligence (NSG), the AGE is designed to enable Army operations and unified command and control, and provide shared situational awareness between U.S. and coalition elements through standardized geospatial information collection, management, analysis, visualization, and dissemination.

AGE OPERATIONAL USE

2-1. The AGE concept includes all Army staff activities, commands, and units responsible for the acquisition, collection, management, storage, development, fielding, sustainment, training, modeling and simulation, production, exploitation, analysis, visualization, and dissemination of geospatially referenced information within the generating and operating forces. The AGE is how the Army conducts GMAD, supporting all warfighting functions with geospatial data, information, products, tools, and services.

2-2. The AGE provides a means for users within the operational force who generate foundation GD&I to submit that GD&I for inclusion/update of existing foundational and analytical GD&I repositories. See appendix C for a list of authoritative geospatial data sources.

2-3. The AGE is a net-enabled, integrated system of technologies, standards, data, and processes utilized by Army geospatial professionals to enable actionable GI&S to be tasked, posted, processed, and used as needed vertically and horizontally, from peer to peer and bi-directionally from the national to the Soldier level. As part of the Army COE strategy, the AGE provides an integrated SSGF across and between all six computing environments, from which data from all warfighting functions can be displayed within a COP. See paragraphs 4-27 through 4-32, pages 4-15 through 4-17, for descriptions of each CE. This is broken down across the area of operations as depicted in figure 2-1, page 2-2.

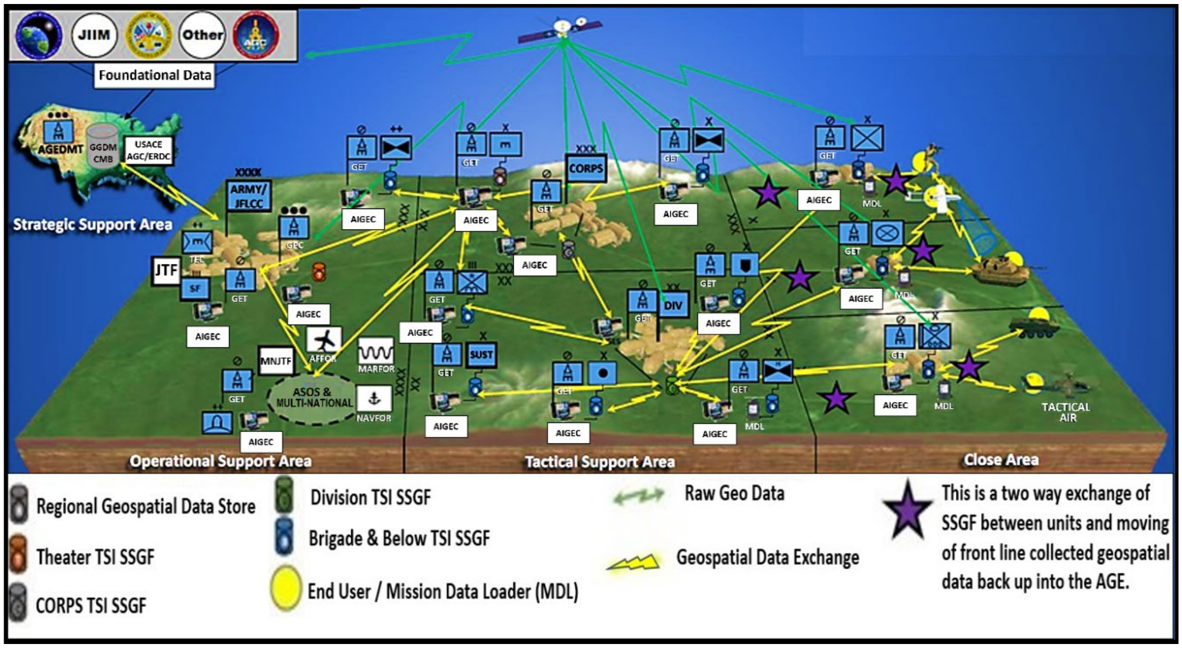
AGE ACROSS ECHELONS

2-4. The AGE provides enhanced situational awareness across all echelons and improves the commander's MDMP. The enterprise approach reduces uncertainty with versioning, resulting in common analytical outputs when interrogating data. Army units exploit network-enabled command and control systems to share GI&S promptly across the Army enterprise and with joint, interagency, intergovernmental, and multinational mission partners, improving coordination, cooperation, and collaboration.

2-5. The AGE provides a comprehensive framework for systematically exploiting and sharing GI&S to enable Army multidomain operations. Specifically, integrated technologies and processes within battle command systems allow GI&S to be efficiently collected, generated, managed, analyzed, visualized, and disseminated from peer-to-peer, echelon-to-echelon, Army-to-joint, Army-to-coalition, Army to the NSG, and operating force-to-generating force.

Note. A mission data loader can be used for disconnected systems at each echelon. See figure 2-1, page 2-2, for a conceptual end user mission data loader footprint.

2-6. Through the AGE, GI&S is collected once and used many times, thereby reducing redundancy and conserving scarce network resources, significantly reducing duplicative work and processes across the enterprise. Once produced, geospatial data sets are made available to the Soldier through the AGE and utilized many times. This increases efficiency and minimizes overhead, leading to reduced costs; improved efficiency and effectiveness and interoperability among its elements; and synchronization with the joint, interagency, intergovernmental, and multinational community (particularly with ground forces).



Legend:

AFFOR	Air Force forces
AGE	Army geospatial enterprise
ADEDMT	Army geospatial enterprise data management team
AGC	Army Geospatial Center
AIGEC	Army integrated geospatial enterprise capability
ASOS	Army support to other services
CMB	common map background
DIV	division
ERDC	Engineer Research and Development Center
GET	geospatial engineer team
GGDM	Ground-warfare geospatial data model
GPC	Geospatial planning cell
JIIM	joint, interagency, intergovernmental, and multinational
JFLCC	joint force land component commander
JTF	Joint task force
MARFOR	Marine force
MDL	mission data loader
MNJTF	multinational joint task force
NAVFOR	Navy forces
SF	special forces
SSGF	Standard and shareable geospatial foundation
SUST	sustainment
TSI	tactical server infrastructure
USACE	United States Army Corps of Engineers

Figure 2-1. Notional AGE operational concept

AGE CONCEPT

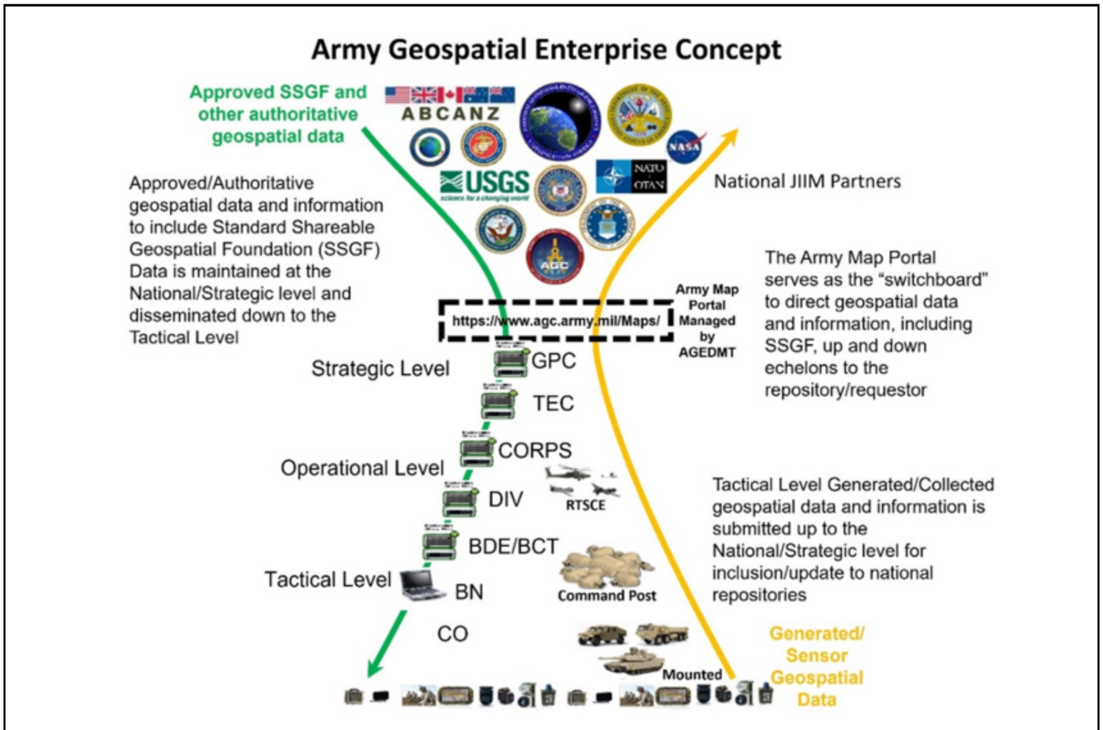
2-7. The AGE concept, depicted in figure 2-2, enables horizontal and vertical geospatial information dissemination, exchange, and synchronization between echelons. It improves continuity of operations during unit relief in place and/or transfer of authority, enhances Soldier situational awareness, improves the commander's ADM or MDMP, and ultimately improves the probability of mission success through information superiority. Army-produced operational and tactically relevant geospatial information is used to enhance and/or extend the foundation data holdings of the NGA.

ARMY GEOSPATIAL STANDARDS

2-8. Geospatial standards are the foundation of the AGE. They are developed across a broad cross-community network of voluntary and mandatory standards organizations, including the Department of Defense (DOD)/NSG and other federal agencies, allies/coalition partners, international standards organizations, and nongovernmental organizations, to include open-source communities. The Army geospatial engineer Soldier is at the center of ensuring adherence and effectuating standards across the enterprise.

2-9. The Army, primarily AGC, has partnered with the NGA to develop NSG-approved geospatial standards for the AGE. The use of these standards provides Army program managers detailed information on the implementation of the SSGF and improves system interoperability. These standards form the foundation for certifying Army systems to meet the geospatial standard of the Army and can exchange data among other certified systems. Standard compliance test tools that ensure systems conform to the standards.

2-10. The AGE framework provides the geospatial standards that support interoperability and geospatial data exchange between systems. It also supports the standardized collection, management, analysis, visualization, and dissemination of geospatial information and enables the correlation and fusion of independently collected data at different levels of fidelity and resolution into a common, interoperable geospatial data set.



Legend:

ABCANZ	American, British, Canadian, Australian, and New Zealand
AGC	Army Geospatial Center
AGEDMT	Army geospatial enterprise data management team

Figure 2-2. Army geospatial enterprise concept

Legend:	
BCT	brigade combat team
BDE	brigade
BN	battalion
CO	company
DIV	division
GPC	geospatial planning cell
JIIM	Joint, Interagency, Intergovernmental, Multinational
NASA	National Aeronautics and Space Administration
NATO/OTAN	North Atlantic Treaty Organization
RTSCE	real time/safety critical/embedded
SSGF	standard and shareable geospatial foundation
TEC	Theater Engineer Command
USGS	United States Geological Survey

Figure 2-2. Army geospatial enterprise concept (continued)

GROUND-WARFIGHTER GEOSPATIAL DATA MODEL

2-11. The ground-warfighter geospatial data model (GGDM) is a core component of the AGE. The primary focus of the GGDM is to provide standards for identifying, understanding, and managing geospatial data entities, information concepts, structural relationships, and lineage information in a shareable, accessible common environment for ground forces. The GGDM is an accepted National System for Geospatial-Intelligence Application Schema (NAS), which supports connectivity, software, data structures, naming conventions, and standard interfaces across the enterprise.

2-12. The GGDM is the container into which ground-warfighter geospatial data elements may be collected, managed, and reused. It consists of a logical data model (LDM) schema, a data dictionary, and a physical data model supporting enterprise-wide geo-services across the Army and the operations process.

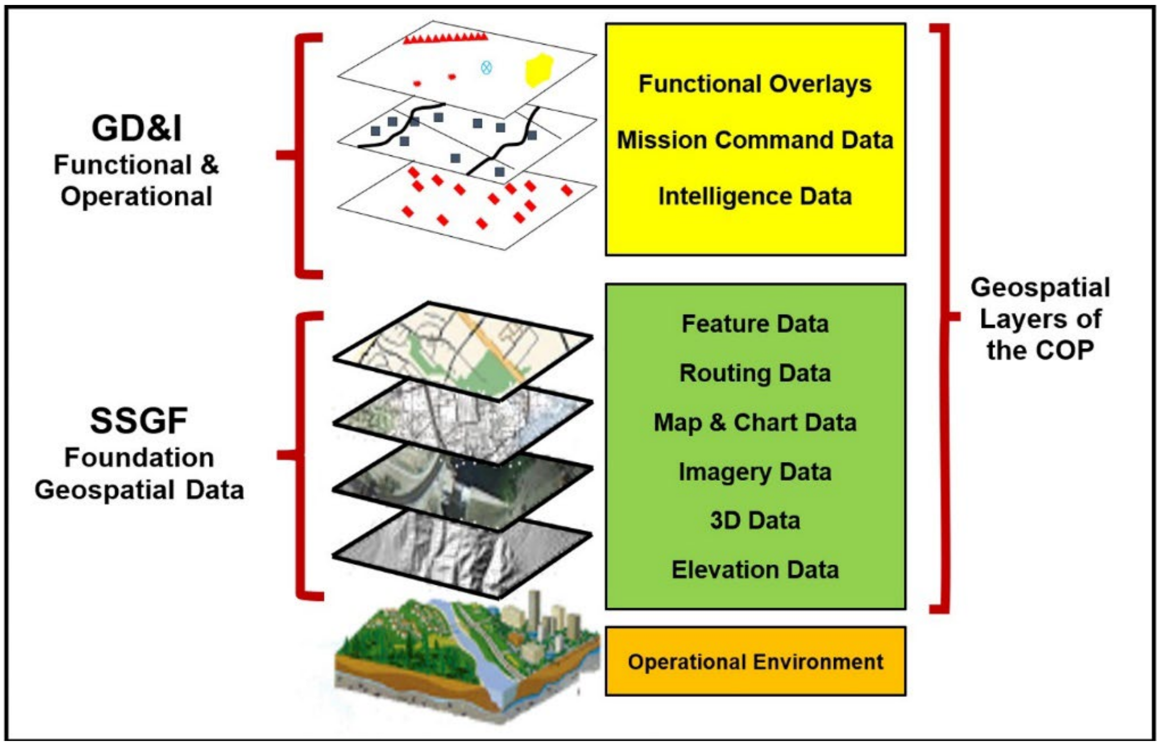
2-13. The GGDM is designed for the collection, maintenance, and dissemination of vector data (including features such as roads, rivers, buildings, fences, and bridges) and for the identifying attributes related to the features (such as function, height, type, physical condition, and operational status); and metadata that describes the accuracy, content origin, and classification level.

2-14. The GGDM provides unique ground-warfighter extensions falling outside traditional data products that can be rapidly included in the model and made available to ground-warfighter systems. It also features a tight coupling with the NSG, allowing greater interoperability and data sharing between the GGDM and NAS schema profiles.

STANDARD AND SHAREABLE GEOSPATIAL FOUNDATION

2-15. The SSGF is a standardized set of GD&I that provide a common foundation for visualizing and analyzing spatial aspects of an area of interest to enable C2, planning, and military operation execution. SSGF contains a common set of the best available geospatial data within J/G/S3 directed area of interest boundaries, providing the geospatial foundation for all COE enabling technologies. The SSGF forms the foundation on which units build their COP. As the foundation of the COP, the SSGF is relevant to all phases of operations and influences all systems, platforms, and processes that use, produce, store, manage, or disseminate geospatial data and/or information shared within and between warfighting functions. Using the SSGF supports command and control by putting current operations, planning efforts, and running estimates in the context of space and time on a common digital map shared and seen by all. The evolving specified GD&I formats that make up the SSGF continuously enhance the understanding and performance of the services and information provided. It also ensures compatibility with all COE systems for each capability set. A SSGF currently consists of four basic types of geospatial data: georeferenced imagery, elevation matrices (raster), geospatial features (vector), and military standard maps, with capabilities in three dimensions, geospatial analytics (such as on-road route planning), and vector mapping being derived as enabling technologies.

2-16. The AGE delivers the SSGF as a foundation for warfighting functions to display operational graphics on the COP in each CE, as depicted in figure 2-3. Data overlaid on the geospatial foundation includes GD&I; analysis products and decision aides; operational and planning graphics from all warfighting functions and special staff; current operations data; demographic, cultural, economic, industrial, and infrastructure data; and staff running estimate information that ties to a specific location. Because it is the basis of the COP, the SSGF is relevant to all phases of operations and includes personnel, units, systems, platforms, and processes that use, produce, store, manage, or disseminate geospatial data and/or information that can be shared within and between the six warfighting functions. Using the SSGF puts current operations, planning efforts, and running estimates in the context of space and time, which supports command and control.



Legend:

3D	three dimensional
COP	common operational picture
GD&I	geospatial data and information
SSGF	standard and shareable geospatial foundation

Figure 2-3. Geospatial data of the COP

2-17. The SSGF is managed as a series of data stores, map services, and digital media provided as a map service on which staffs can overlay other information. The COE standards required for geospatial interoperability and integration also apply to the geospatial data displayed on the COP (display symbology, data exchange formats, the format of the point location [military grid reference system, latitude, and longitude], and the precision required per CJCSI 3900.01E).

2-18. Initially, the geospatial foundation comprises baseline authoritative geospatial data from the NGA, AGC, GPCs, unified action partners, commercial sources, and other area-of-operation data. Geospatial engineering team(s) (GETs) maintain the geospatial foundation and provide it to command and control systems and platforms.

2-19. GPCs and GETs across all echelons synchronize the geospatial foundation data to support the building of the COP. The geospatial foundation data is stored at the GPC or an Army processing center, such as AGC, as a theater geospatial data store. GPCs provide the GETs of deploying units a tailored TGD containing the SSGF.

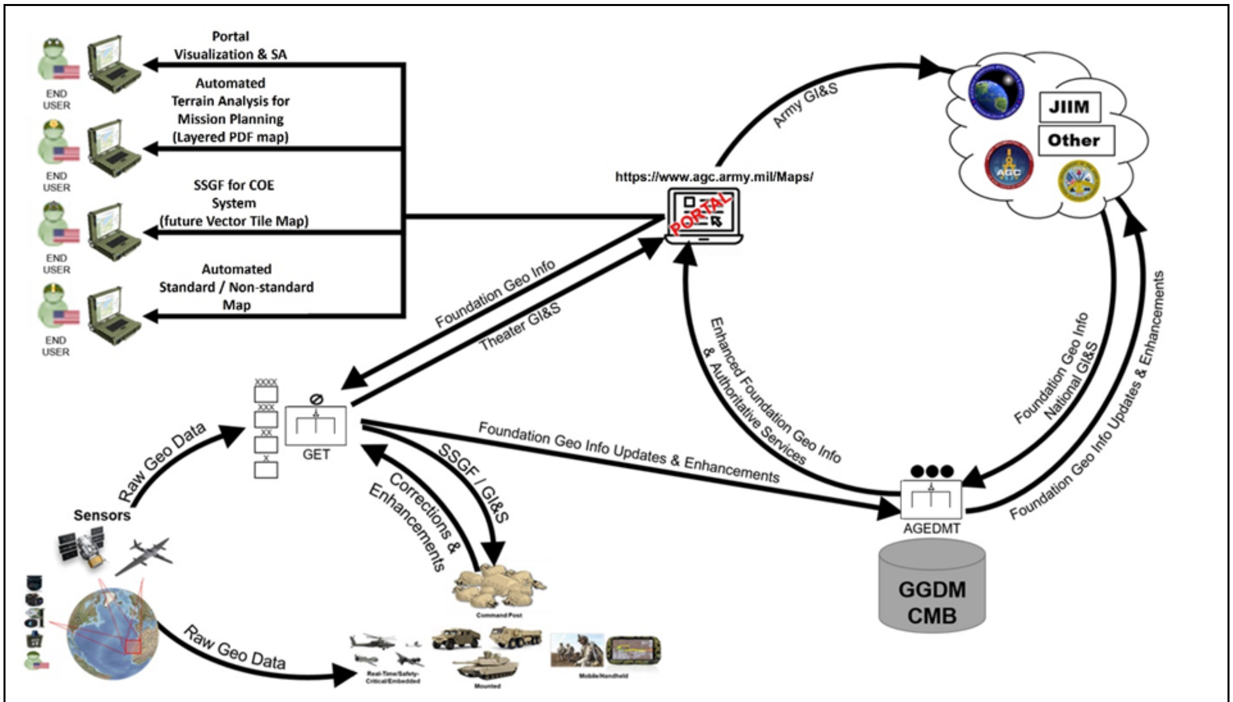
2-20. The geospatial foundation takes advantage of the following AGE infrastructure components:

- The GGDM.
- Standards for digital maps, geospatial features, imagery, and elevation data.
- Geospatial system applications and services, with emphasis on open geospatial consortium compliance.
- Two-way data flow for geospatial engineers to update, enhance, and disseminate the geospatial foundation via synchronization.

2-21. The process for handling and managing geospatial data is generally outlined as—

- Data coverage and currency. Standard NGA topographic maps and database coverage are available for only a tiny percentage of the surface of the earth. Data holdings require periodic updates to capture changes, such as urban growth and cultural and environmental geography changes.
- Initial data load and data tailoring. At the time of any given contingency operation, planners, GETs, and GPCs coordinate with the AGC and NGA for tailored authoritative content. They also request additional content to fill gaps in coverage. This becomes the GET TGD subset that includes the authoritative COP foundation data of the SSGF.
- Data exchange. GETs coordinate with unit network administrators to distribute the SSGF and updates. The SSGF is provided in the appropriate formats for systems across all CEs. GETs use the digital network and web services to offer the SSGF and updates to ingesting systems. GETs use the most efficient methods or combination of methods, available to provide the SSGF to headquarters and subordinate units. See figure 2-4 for a depiction of the SSGF data flow.
- Data collection and storage. During operations, the GET constantly enhances the coverage and quality of geospatial information in the TGD by all available means, including collection requests for high-resolution and wide-area mapping sensors. Geospatial Feature Reports (GEOFR) and Geospatial Issue Reports (GEOIR), along with other input (such as free text) from Soldiers as sensors should be used to update geospatial feature data. See appendix C for the URL links and descriptions of the GEOFR and GEOIR. The information gained from reconnaissance, surveys, sensors, and other data sets becomes authoritative for the Army once a GET vets it. The newly collected information about the OE is incorporated into the TGD. It is updated to the SSGF by the GET, where all GET geospatial data is stored and managed on the unit tactical server. Once updated, it is synchronized across echelons up to the supporting GPC TGD. Updated SSGF data is then validated by the GPC and synchronized with national holdings at NGA and AGC, where it is managed for future dissemination. See figure 1-2, page 1-5; figure 2-1, page 2-2; and figure 2-2, page 2-3, for a conceptual view highlighting echelon and data storage footprints. Reference the individual unit modification table of organizational equipment for staffing and structure to maintain and manage servers. See chapter 3 for roles and responsibilities.
- Cross security domain exchanges. SSGF data exchanges across different security networks/domains/enclaves are approved via a manual process (person in the loop) to identify and ensure that all data is appropriately reviewed for classification considerations before movement across domains.
- Unified action partners Data Releasability. The releasability of SSGF data to unified action partners is subject to international agreements for releasability and dissemination with the involved mission partners. These agreements must be considered when transferring SSGF data.

2-22. As stated previously, the SSGF is the base on which units build their COP. The command-and-control systems that present the COP require the ability to layer information from various sources over one consistent geospatial foundation. This enables the fusion of mission-essential information. Units tailor this information to meet the needs of the commander. Once built, units share the COP across echelons and, when needed, with interagency and multinational partners. This facilitates the transfer of information and the unity of effort.



Legend:

AGEDMT	Army Geospatial Enterprise Data Management Team
CMB	common map background
COE	common operating environment
Geo	geospatial
GGDM	ground-warfighter geospatial data model
GI&S	geospatial information and services
Info	information
JIIM	joint, interagency, intergovernmental, and multinational
PDF	portable document format
SA	situation awareness
SSGF	Standard and Shareable Geospatial Foundation

Figure 2-4. SSGF data flow

SYSTEMS, APPLICATIONS, AND SERVICES

2-23. The AGE makes use of common suites of geospatial software that operate on standards, protocols, specifications, and common engineering principles described above to support the management of geospatial foundation and geo-enabled warfighting functions data, geospatial analysis, visualization, exploitation, and dissemination. The geospatial intelligence workstation and the evolving Army integrated geospatial enterprise capability are the primary tools used to manage the geospatial foundation and make it discoverable and accessible by geospatial engineers. Systems exploiting the AGE must also be able to tie in with applicable geospatial services within the global network enterprise construct and command and control environments.

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Chapter 3
Roles and Responsibilities

Geospatial engineering is one of three engineering disciplines, and its full potential is only realized through a concerted effort of various organizational activities and individual actions at each echelon. This chapter is a continuation of the discussion presented in FM 3-34, and it describes the key roles and responsibilities for effectively incorporating geospatial engineering in support of Army operations. See JP 3-34 for information on geospatial engineering capabilities supporting joint force operations.

NATIONAL COMMUNITIES AND AGENCIES

3-1. National communities and agencies comprise the collective components facilitating geospatial processes, capabilities, production, and dissemination. They are organized into various DOD/intelligence community elements and continue throughout all echelons of the Army. They cover the full breadth of government, commercial, and academic entities that produce, use, or contribute to one or more of the three elements (geospatial data, imagery, imagery intelligence). The communities and agencies guiding, influencing, and directing the AGE are covered throughout the following paragraphs.

NATIONAL SYSTEM FOR GEOSPATIAL INTELLIGENCE

3-2. The NGA Director serves as the DOD GEOINT Mission Manager and the intelligence community GEOINT Functional Manager. The director is responsible for tasking imagery and geospatial information collection, processing raw data, exploiting geospatial information and imagery, analyzing information and intelligence, disseminating information and GEOINT to consumers, identifying and assessing risks and capability gaps, and recommending mitigation alternatives. The NSG, which comprises the intelligence community and DOD elements, identifies the principal partners of the NSG. It also defines and describes the GEOINT enterprise, which encompasses various U.S. and foreign entities that contribute to and influence this function. The Army GEOINT office is the conduit of the Army into the NGA and the National/Allied System for Geospatial-Intelligence (NSG/ASG).

NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

3-3. NGA is a combat support agency and an intelligence community member organization. It is directly subordinate to the Secretary of Defense, the Director of National Intelligence, and the Under Secretary of Defense for Intelligence. NGA produces timely, relevant, and accurate GEOINT to the joint force. NGA is the primary source for GEOINT analysis, products, data, and services at the national level. It provides advisory tasking recommendations for Service-operated airborne and surface-based GEOINT collection platforms and sensors. NGA provides an NGA support team in direct support to a joint force commander's joint intelligence operations center and maintains NGA support teams for each of the Services, DOD agencies, and several non-DOD agencies. NGA manages satellite collection requirements and develops distribution protocols for the NSG according to the National Intelligence Priorities Framework. NGA works closely with the National Reconnaissance Office, which acquires and operates space-based surveillance and reconnaissance systems that collect geospatial information for the Intelligence Center and DOD. This collected information is used to support national security, military operations, natural disaster support, humanitarian relief operations, and near real-time imagery collection supporting geospatial requirements. The Army GEOINT Battalion and NGA support teams directly support Army geospatial organizations that are integrated into and support the overarching NSG. The Army GEOINT Battalion, subordinate to the National Ground Intelligence Center and integrated within NGA, conducts GEOINT in support of military operations and national-level requirements and enables readiness through the GEOINT Foundry training and education mission. Army NGA support teams directly support the joint force commander's intelligence operations center for each of the Services, DOD agencies, and several non-DOD agencies. See ATP 2-22.7 for additional information regarding the Army GEOINT Battalion and Army NGA support teams.

DEPARTMENT OF THE ARMY

3-4. GETs are the core personnel elements that provide commanders and planners terrain-based knowledge and visualization of the physical dimension of an OE to improve situational understanding and shared knowledge and to enhance decision making during planning, preparation, execution, and assessment. In coordination with the engineer staff officer and/or senior intelligence officer of the organization, the GET identifies and incorporates geospatial engineering requirements in support of ADM or MDMP. Coordination with the senior intelligence officer may include Department of the Army military intelligence directorates such as intelligence oversight, information management, and plans and integration.

3-5. Applications for terrain-based knowledge and visualization include—

- Promoting the timely identification of movement and maneuver restrictions, mobility corridors, choke points, and potential key terrain features to support the development of the modified combined obstacle overlay during the intelligence preparation of the battlefield (IPB) process and to assist in developing threat COA.
- Enhancing rehearsals and reconnaissance missions using terrain visualization techniques and applications (two-dimensional/three-dimensional).
- Facilitating the positioning and routing of ground and aerial surveillance assets through line of sight (LOS) analysis.
- Facilitating the positioning and establishment of fires, logistical, and support assets through site suitability analysis.

3-6. GET at all levels are responsible for performing the following primary tasks:

- Generate.
  - Identify foundation GD&I requirements to support current and future military operations.
  - Identify foundation GD&I gaps in current TGD holdings.
  - Nominate collection and/or reconnaissance tasks within information collection operations.
  - Derive GD&I from ancillary sources leveraged during information collection operations.
- Manage.
  - Collect relevant GD&I from the NGA, AGC, Army Departmental Requirements Office, GPCs, unified action partners, and commercial sources to update and/or enhance current TGD holdings.
  - Validate newly generated or collected GD&I for relevancy and accuracy.
  - Integrate and/or conflate newly generated or collected GD&I into current TGD holdings.
  - Store all relevant SSGF and operational geospatial information within the TGD of the organization.
  - Synchronize TGD updates and/or enhancements with subordinate organizations and the foundation of the AGE GD&I holdings.
- Analyze.
  - Analyze terrain characteristics to determine phenomena affecting friendly and enemy military operations.
  - Analyze weather effects within the OE to determine the expected or potential impacts on military operations.
- Disseminate.
  - Use web-enabled services and/or digital media to distribute SSGF to COE CEs.

    - Use web-enabled services, digital media, and/or hard copy production to distribute standard and nonstandard geospatial products.
    - Use written and oral communication to distribute knowledge of terrain impacts on friendly and enemy military operations.

ARMY GEOSPATIAL CENTER

3-7. The AGC—located in Alexandria, Virginia—coordinates, integrates, and synchronizes geospatial information and standards across the Army, develops and fields geospatial enterprise-enabled systems and capabilities to the Army and the DOD, and provides direct geospatial support and products to tactical formations. The Army Geospatial Information Officer is the director of the center and coordinates with staff, the Army assistant chief of staff, intelligence (G-2), and the Army Chief of Engineers to move capabilities toward the AGE.

THEATER ARMY AND ARMY SERVICE COMPONENT COMMAND

3-8. The theater army is the Army Service component command to a combatant command. Each theater Army plus U.S. Army Special Operations Command performs the following functions.

- Execute the combat commander's daily operational requirements.
- Provide administrative control of Army forces.
- Set and maintain the theater.
- Set and support operational areas.
- Exercise C2 of Army forces in the theater.
- Perform joint roles of limited scope, scale, and duration.
- Plan and coordinate for the consolidation of gains in support of joint operations.

3-9. To facilitate the above functions, the Army Service component command (ASCC) commander utilizes GPCs in coordinating and conducting the following GI&S-related tasks:

- Maintain direct and general support of standard GI&S product distribution capabilities to support U.S. ground forces, allied forces as provided for in bilateral or multilateral agreements, and other forces as directed.
- Designate an ASCC GI&S Officer responsible for—
    - Consolidating, validating, prioritizing, and documenting theater GI&S requirements for the ASCC and assigned units.
    - Synchronizing theater GI&S requirements with the combatant command GI&S Officer to account for all GI&S requirements of the Land Component Commander and ensure that the Land Component Commander's GI&S requirements are incorporated into applicable theater operation plans /contingency operation plans pursuant to CJCSI 3110.08F.
    - Submitting GI&S requirements to the combatant command GI&S Officer and Army-specific GI&S requirements with the Army GI&S Officer.
    - Developing an ASCC GI&S production plan.
- Designate a Theater Geospatial Engineer responsible for—
    - Integrating geospatial engineering throughout the ASCC operations process by warfighting functions.
    - Coordinating across ASCC staff elements and the assigned Military Intelligence Brigade-Theater (MIB-T) to ensure that geospatial engineering requirements are accounted for and documented.
    - Ensuring the development and upkeep of a TGD to manage and maintain the terrain feature data components of SSGF and other components as required. The TGD will be maintained in conformance to standards mandated in the DOD Information Technology Standards Registry and implemented based on guidance promulgated by the Army Geospatial Information Officer to maximize interoperability with Army, joint, and unified action partners.

  - Maintaining close liaison with the intelligence staff and engineer reconnaissance teams assigned to the ASCC to enhance information collection efforts to provide, coordinate, and integrate engineer technical expertise, engineer-related information requirements, and specialized engineer assets.
  - Disseminating the feature data component of SSGF to all theater-assigned and time phased force deployment data units, as necessary, to support joint task force or combined joint forces land component command responsibilities to joint land operations according to JP 3-31.
  - Providing SSGF data supporting the COP for all ASCC command and control systems within their area of responsibility (AOR).
  - Providing reachback support to assigned units to ensure that geospatial information is shared horizontally and vertically among units to ensure a common SSGF for command-and-control systems.
- Coordinate with the combatant command commander to revise, update, and maintain sufficient stocks of standard maps, controlled image base charts, and other aeronautical and maritime navigation aids to support pre-positioned war reserve requirements and sustained crisis operation requirements according to theater operation plans/contingency operation plans, as specified in DODI 3110.06.
- Serve as an NSG partner.

3-10. The GPC, engineer detachment is the theater geospatial engineering asset designed specifically to GMAD the TGD to support operations within a combatant command AOR. They provide the SSGF to the ASCC and, additionally, the GPC provides analysis of the physical dimension of the OE to assist the theater Army commander and staff in fulfilling its designated functions.

3-11. The GPC coordinates with NGA, host and allied nation topographic support activities, higher headquarters, and ASCC battle staffs and major subordinate commands to generate and analyze terrain data; prepare terrain-based decision support graphics, image maps, and terrain visualization products (two dimensional/three dimensional); and enhance and/or update the TGD. It coordinates with unified action partners, host-nation geospatial support activities, and higher headquarters to create and maintain an enterprise geospatial database environment. GPCs can deploy a forward element with and in support of an ASCC contingency command post (CCP) or equivalent forward element. The ASCC holds command and control, Uniform Code of Military Justice, and other administrative authority of the GPC. Although the GPC is a separate detachment, it functions as a staff section subordinate to the ASCC engineer. The GPC consists of an operations section, a geospatial enterprise section, and a plans and analysis section.

3-12. The GPC collects, validates, integrates, and/or conflates the geospatial data and/or information gathered by GET operating within the area of operations (AO) of the combatant command into the TGD, SSGF, and the AGE of the theater. GPCs disseminate or synchronize updates and/or enhancements to the TGD with units, including multinational mission partners operating in the AO of a combatant command. The GPC coordinates with GET across all echelons to ensure that a synchronized GD&I collection effort is incorporated into the TGD to provide a common user database.

3-13. The GPC hosts an NGA coproduction team that provides theater-generated data to the NGA for inclusion in the national geospatial data holdings. These coproduction efforts utilize the most recent sources available to fill gaps in GIS databases, enabling unified content and accuracy.

3-14. The theater Army headquarters relies on a task-organized engineer brigade GET and/or GPC CCP team to provide geospatial engineering support. GPCs are the only units in the Army force structure with a unique, dedicated foundation geospatial information generation capability. The engineer brigade GET and the GPC require full access to the integrated enterprise network, integrated tactical network, and tactical secret internet protocol router network and ensure the ability to push to the joint worldwide intelligence communication system to update and disseminate geospatial data, information, and products.

CORPS AND BELOW

3-15. Geospatial engineers assigned to the corps headquarters must be prepared to support at both the tactical and operational levels of warfare. The corps may become a joint and/or multinational headquarters for operations when organized, staffed, trained, and equipped as a tactical formation. The corps serves as the Army forces when operating as the senior Army headquarters under a joint task force. The corps can serve as the coalition force land component commander when suitably augmented with joint and multinational personnel. Geospatial engineering provides analysis of the physical dimension of the OE to assist the corps commander and staff in fulfilling its roles when acting as the—

- Senior Army tactical formation in large-scale combat, commanding two to five Army divisions and supporting brigades and commands.
- Army forces (with augmentation) within a joint force for campaigns and major operations when a field army is absent.
- Joint task force headquarters (with significant augmentation) for crisis response and limited contingency operations.
- Coalition force land component commander (with significant augmentation) commanding Army, Marine Corps, and multinational divisions with supporting brigades and commands when a field army is absent.

3-16. The GET in the corps partners with geospatial intelligence imagery analysts within the G-2 to form the GEOINT cell. The GEOINT cell operates within the G-2 analysis and control element, which provides GEOINT support for all planning phases across all warfighting functions. The GEOINT cell fuses intelligence and geospatial information into a common picture for the commander, staff, and subordinate units. Geospatial engineer Soldiers within the GEOINT cell perform content and knowledge management of the TGD of the unit. Geospatial engineer Soldiers provide geospatial engineering support to the commander; the assistant chief of staff, operations; other staff sections; and subordinate units as directed.

DIVISION

3-17. Geospatial engineers are assigned to the division headquarters, the principal tactical formation in the Army during multidomain operations. Each GET disseminates and synchronizes GI&S and SSGF efforts to enable a COP across subordinate forces of the organization. This includes two and five brigade combat teams, a mix of functional and multifunctional brigades, and a variety of smaller enabler units.

3-18. The GET of the division partners with geospatial intelligence imagery analysts within the G-2 to form the GEOINT cell. The GEOINT cell operates within the G-2 analysis and control element, which provides GEOINT support for all phases of intelligence operations within the G-2. The GEOINT cell fuses intelligence and geospatial information into a common picture for the commander, staff, and subordinate units. Geospatial engineer Soldiers within the GEOINT cell perform content and knowledge management of the TGD of the unit. Geospatial engineer Soldiers provide geospatial information and services to the commander; the assistant chief of staff, operations; other staff sections; and subordinate units as directed.

BRIGADE COMBAT TEAM

3-19. Geospatial engineers assigned to the brigade combat team headquarters, the primary combined arms close-combat maneuver force of the Army, and principal ground maneuver units of the division or joint task force provide visualization and understanding of the impacts of the physical dimension, enabling the brigade combat team to maneuver against, close with, and destroy the enemy. The GET supports the staff by providing terrain analysis and products and maintaining the brigade geospatial database and receives operational updates from the staff, enabling geospatial updates to the brigade AO within the TGD. The team captures and validates field-collected information from within the brigade for inclusion in the geospatial database and manages the geospatial intelligence imagery analysts to form the geospatial intelligence cell. The geospatial intelligence cell is task-organized within the S-2 and supports the battalion or brigade operations staff officer, other staff sections, and subordinate units. Geospatial engineers provide GI&S, as directed, to fuse warfighting functions support of the COP for the commander and continued utilization across all warfighting functions.

MULTIFUNCTIONAL AND FUNCTIONAL BRIGADE

3-20. Geospatial engineers assigned to the task-organized multifunctional and functional brigades provide GI&S support to organizations based on their unique geospatial needs (aviation, fires, maneuver enhancement brigades, security forces assistance brigades, and multidomain task forces). They support the unique needs of these brigades (such as navigation safety and targeting) with tailored geospatial content. The brigade GET performs all tasks identified in paragraph 3-6.

THEATER ENGINEER COMMAND AND ENGINEER BRIGADE

3-21. The theater engineer command (TEC) or engineer brigade commanders serve as the senior engineer for their perspective AO, whether theater, corps, or division. Geospatial engineers assigned to the TEC or engineer brigade headquarters serve as the in-theater interface for the theater-aligned GPC. These GET serve as the epicenter for collecting, managing, and validating theater geospatial data collected within that theater and providing it to the GPC for incorporation into the TGD, SSGF, and national holdings. The TEC and engineer brigade GET disseminate the TGD and SSGF to all organizations conducting reception, staging, onward movement, and integration and operating within a defined theater, and synchronize any updates as they are received.

3-22. The TEC is designed to have C2 of assigned or attached engineer brigades, other engineer units, and contracted construction engineers within the supported theater AOR. This C2 capability provides the TEC and engineer brigade GETs the breadth to perform the tasks identified in paragraph 3-29 to enable the execution of complex engineer missions (such as gap crossings, deliberate defenses, and city-wide reconstruction). The TEC focuses on operational-level engineer support across all three engineer disciplines.

STAFF RESPONSIBILITIES

3-23. Geospatial engineering capabilities are task-organized based on the mission, political, military, economic, social, information, infrastructure, physical environment, and time factors. The engineer staff officer is responsible for understanding the full array of engineering capabilities (combat, general, and geospatial engineering) available to the force and for synchronizing them to best meet the needs of the maneuver commander. The engineer staff officer or plans officer and the geospatial engineer are responsible for establishing the SSGF for visualization and production of analytical products for staff planning per joint staff, operations; the assistant chief of staff, operations; or operations staff officer guidance or the standard operating procedure. The section of assignment and grouping of engineer staff varies among echelons and unit types. The organization of the assigned staff to meet the unique requirements of the headquarters and situation is ultimately determined by the theater Army, corps, or division commander. Army staff responsibilities are described in ADP 6-0.

ENGINEER STAFF OFFICER

3-24. The 12A engineer staff officer (usually the senior engineer officer) is responsible for coordinating engineer assets and operations for the command. Regardless of the distribution of the engineer staff or its section of assignment, the engineer staff officer ensures the synchronization of the overall engineer effort, including geospatial engineering.

3-25. The engineer staff officer is responsible for integrating geospatial engineering throughout the operations process. On behalf of the chief of staff, this officer directs the GET on geospatial requirements to support mission and planning operations. The engineer staff officer performs the following tasks to support the GET:

- Advises the commander on how best to employ geospatial engineering capabilities in support of operations.
- Develops and coordinates geospatial engineering requirements.
- Reviews all geospatial engineering-related annexes and appendixes of OPLANs and/or operation orders (OPORDs).

- Provides command and control functionality of all geospatial engineering requirements and efforts within their designated AO.
- Coordinates with the senior intelligence officer for prioritization of geospatial engineering efforts.

GEOSPATIAL PLANNING CELL, ENGINEER DETACHMENT

3-26. GPC provides geospatial support to deployed units that require augmentation. Geospatial engineering capabilities include analysis, collection, generation, management, finishing, and printing. GPCs generate, manage, and disseminate geospatial data, information, and products supporting ASCC headquarters and combatant commands. GPCs are responsible for managing the TGD, which contains detailed information about geographic features within the ASCC AOR. The below paragraphs detail the key billets integral to GPC operations. These billets are generally described as unit commanders with discretionary authority to modify beyond the modification table of organizational equipment designations to meet mission and operational requirements. See appendix C for GPC locators and associated uniform resource locators.

Operations Officer

3-27. The operations officer serves as the officer in charge (OIC) of the GPC. The GPC OIC coordinates through the ASCC Deputy Chief of Staff, Engineer and G-2, military intelligence brigade–theater, Army and national agencies, engineer staff officers, and G-2s at echelons above brigade to plan and synchronize geospatial engineering augmentation in support of Army requirements. In doing so, the GPC OIC performs the following tasks:

- Serves as the GI&S Officer for the ASCC if appointed by the ASCC commander.
- Serves as the program manager and proponent for the theater geospatial enterprise (programs, policy, and governance).
- Oversees enterprise contracts for materiel and services and coordinates the validation and prioritization of GI&S requirements.
- Coordinates closely with the NGA to establish budget programs, revise data standards, and verify production assurance.
- Coordinates with the supporting and supported foreign disclosure officers to provide disclosure guidance for geospatial products to maintain the enterprise.
- Coordinates with subordinate and regionally aligned forces to identify geospatial data and/or information requirements.
- Coordinates with the engineer brigade, the ASCC Deputy Chief of Staff Engineer, and all principal staff to ensure—
  - Continued geospatial production and analysis activities to support ASCC missions and planning operations.
  - Two-way synchronization and updates for the TGD.
  - Synchronized data and/or information generation efforts in support of the TGD. Deployment and reach-back support of GPC resources supporting contingency operations of the ASCC.
- Coordinates with subordinate and regionally aligned forces to ensure that—
  - Relevant and accurate foundation and operational geospatial data, information, products, and services are provided to those units conducting plans and/or operations supporting theater operations.
  - Organic GET maintain the necessary database management, analysis, and print capabilities to meet requirements.
  - Procedures are established for effectively transferring field-collected data and/or information between GET and the GPC.

Geospatial Enterprise Manager

3-28. The Geospatial Enterprise Manager, the senior geospatial engineering technician assigned to a GPC, is responsible for generating, storing, and disseminating foundation geospatial data and GD&I comprising the SSGF for the ASCC AO. The Geospatial Enterprise Manager performs the following tasks:

- Coordinates with the ASCC GI&S Officer to determine prioritization of foundation geospatial data and/or information production operations.
- Manages the day-to-day generation, storage, and dissemination of foundation geospatial data and/or information, to include—
  - Controlled and/or rectified imagery datasets.
  - Digital elevation models.
  - Standardized geospatial feature datasets using GGDM.
  - Topographic maps.
- Coordinates the two-way exchange of updates and enhancements to the TGD with subordinate and regionally aligned forces.

Plans and Analysis Officer in Charge

3-29. The Plans and Analysis OIC, the junior geospatial engineering technician assigned to a GPC, is responsible for analyzing and disseminating geospatial information and knowledge in support of the missions and planning operations of the ASCC. The Plans and Analysis OIC performs the following tasks:

- Coordinates with the GPC Operations Officer, ASCC Deputy Chief of Staff Engineer, and ASCC staff to determine terrain analysis and visualization requirements for missions and planning operations.
- Manages the day-to-day analysis and dissemination of geospatial information and knowledge, to include:
  - ADM or MDMP support products.
  - Two-dimensional/three-dimensional visualization products and/or web-based applications.
- Manages geospatial engineering operations in support of the ASCC CCP.

GEOSPATIAL ENGINEERING ACROSS ALL ECHELONS

3-30. Geospatial engineering is considered the foundation that supports combat and general engineering disciplines across all lines of engineer support. As a result, terrain is central to the three engineering disciplines. Combat and general engineering focuses on affecting the terrain, while geospatial engineering is focused on improving the understanding of terrain. The below paragraphs detail the fundamental responsibilities of geospatial engineers and technicians.

Geospatial Engineering Technician

3-31. The 125D geospatial engineering technicians are the terrain analysis and GI&S experts of the Army. As an integrator, the technicians participate in each step of the ADM or MDMP to ensure an understanding of the mission and the commander's intent. They ensure a proactive geospatial engineering effort to provide the correct information at the right time to facilitate decision making. Geospatial engineering technicians invest much of their time coordinating with planners and staff sections to ensure the fulfillment of geospatial information requirements across the warfighting functions. At tactical echelons with geospatial engineers and geospatial intelligence imagery analysts, the geospatial engineer technician serves as the leader of the geospatial intelligence cell and manages geospatial intelligence production. The technician is responsible for–

- Managing the generation, storage, analysis, and dissemination of geospatial information, knowledge, and products during geospatial engineering operations.
- Integrating GI&S and/or geospatial products in support of the ADM or MDMP.
- Integrating Army geospatial engineering system(s) of record into organizational information technology architectures to support command and control.

- Advising commanders and planners on the effects of terrain and weather on military operations.
- Advising commanders on the integration of geospatial engineering operations.
- Informing Army leaders on geospatial engineering operations gaps in doctrine, organization, training, material, leadership, personnel, facility, or policy (DOTMLPF-P).
- Integrating emerging technology that supports data processing and data visualization.

Geospatial Engineer

3-32. The 12Y geospatial engineer, in combination with other engineers and other staff members, provides mission-tailored data, geospatial decision aids, and visualization products that define the physical environment characteristics and impacts of the OE for commanders and planners. They also provide the commander a common view of the terrain through terrain visualization, which enables the commander to understand and describe intent. Geospatial engineers use terrain analysis and visualization capabilities to integrate people, processes, and tools by using multiple information sources and collaborative analysis to build a shared knowledge of the physical environment supporting the unit mission. These tools and processes increasingly include artificial intelligence and machine learning (ML). Due to the complexity and breadth of skills needed to fulfill the requirements for geospatial engineering, geospatial engineers must focus individual efforts on defined roles and responsibilities. These roles and responsibilities include the following:

- Geospatial Engineering Analyst:
  - Analyzes the characteristics of the terrain and how it changes over time with use and under varying weather conditions to determine the expected effects of the physical dimension of the operational environment on military operations using manual and/or object-oriented processes to synthesize geospatial information into knowledge.
- Geospatial Services Specialist:
  - Disseminates the Standard Shareable Geospatial Foundation (SSGF) to the common operating environment (COE) via the tactical server infrastructure geospatial database, geospatial knowledge, and/or geospatial applications through web-enabled services or removable media devices.
- Geospatial Production Specialist:
  - Generates or updates National System for Geospatial-Intelligence (NSG) standardized map products using cartographic principles.
  - Specializes in the art of cartography: develops standard-scale topographic maps heavily used for planning and navigation across all Army formations.
- Geospatial Database Specialist:
  - Manages, collects, integrates, conflates, synchronizes, and stores accurate and relevant geospatial data and information in the Theater Geospatial Database (TGD).
  - Extracts foundation geospatial information from multiple sources and in various formats and integrates them into approved geospatial data models for analysis and documentation.
- Geospatial Engineer Sergeant:
  - Implements quality control measures to validate the completeness, accuracy, and integrity of geospatial operations across all four primary functions of GMAD.
  - Manages metadata and processes to ensure the proper use of SSGF, geospatial information and/or products being read, created, collected, reported, updated, ingested, or deleted.
  - Ensures that geospatial information and/or data is protected and security procedures are enforced.
- Geospatial Database Manager (division/corps/GPC/engineer brigade):
  - Administers and implements enterprise GI&S database solutions, to include managing and enforcing database accounts, roles, and permissions.
  - Manages enterprise GI&S using REST services.
  - Integrates enterprise solutions to support command and control operations.

- The GDM:
  - Collects data from lower and adjacent forces, ensures data quality, updates the theater geospatial database, and redistributes the data across all formations within the theater of operations and higher to AGC and/or NGA.
- Geospatial Engineering Mission Manager (GET noncommissioned officer in charge):
  - Participates in the planning and current operations cycles to ensure timely GI&S and/or terrain analysis product delivery.
  - Delegates responsibilities, communicates with staff, consults technically with leaders, allocates resources and budgets, and tracks logistics of Geospatial Engineering projects.
- Geospatial Engineering Senior Operations Sergeant (engineer brigade/GPC):
  - Assists in geospatial planning and control activities.
  - Assists in determining requirements and providing technical supervision of geospatial engineering programs.
  - Assists in command supervision and coordination of map production or reproduction.
  - Provides staff supervision and principal noncommissioned officer direction to units performing geospatial engineering missions.

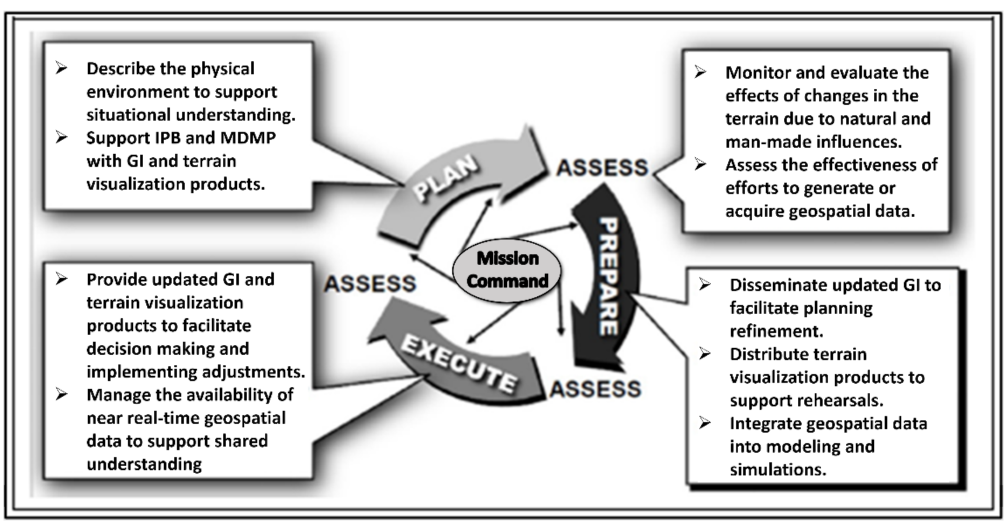
Chapter 4

Geospatial Engineering Support Integration

The successful integration of geospatial engineering support is founded on providing the right geospatial information to the right person at the right time. Successful integration requires a thorough understanding of the depth of geospatial engineering resources available, inherent capabilities, and the ability to recognize and expose opportunities during military operations to exploit and maximize those capabilities. Geospatial engineering efforts require a thorough understanding of the systems available, the differing types of information involved, and the methods used to exploit these factors into relevant information and geospatial decision aids. Effective use of geospatial engineering enables integration and support for staff sections, warfighting functions, COE, and the operations process.

GEOSPATIAL ENGINEERING FOR PLANNING AND OPERATIONS

4-1. As described in ADP 5-0, the operations process consists of the major command and control activities performed during operations (planning, preparing, executing, and continuously assessing the operation) and is driven by commanders. The cyclic activities of the operations process may be sequential or simultaneous and are usually not discrete; they overlap and recur as circumstances demand (see figure 4-1). Throughout the process, the four major functions of GMAD are continuously performed to describe the physical environment and the operational significance of the terrain to facilitate the further analysis of the OE, support situational understanding, and enable decision making to support all command and control activities. The engineer staff officer is the primary staff integrator for the geospatial engineer tasks and works with the geospatial engineering technician and the primary staff sections in advising the commander to realize the full potential of geospatial engineering.



Legend:

GI	geospatial information
IPB	intelligence preparation of the battlefield
MDMP	military decision-making process

Figure 4-1. Geospatial engineering applied throughout the operations process

4-2. After collecting requisite geospatial data, planning begins with analyzing and assessing conditions in the OE. Continuing the ongoing analysis of political, military, economic, social, information, infrastructure, physical environment, and time factors, staffs analyze the current situation using mission variables while preparing running estimates. Commanders and staffs use the MDMP, described in ADP 5-0, to develop the detailed information needed during execution. The MDMP also synchronizes several processes (IPB, targeting, risk management) discussed later in this chapter. Tailored geospatial engineering analysis and products are integrated throughout the MDMP. Geospatial engineers tailor analysis and products to address the following:

- Mission-specific criteria and/or limitations are the characteristics and impacts of the physical environment of a defined OE.
- Enemy force capabilities, disposition, or restrictions.
- Friendly force capabilities, disposition, or restrictions.
- Civil considerations.
- Information considerations.

Geospatial Engineering Integration Into MDMP

4-3. MDMP helps leaders apply thoroughness, clarity, sound judgment, logic, and professional knowledge to understand situations, develop problem-solving options, and reach decisions. Geospatial engineering analysis and products help the commander and staff to understand, visualize, and describe the physical dimension and its impacts on the operation. Additionally, geospatial engineers enable the facilitation of collaboration on a COP.

Step 1: Receipt of Mission

4-4. Upon initiation of MDMP, based on the receipt or anticipation of a mission, the GET analyzes current foundational geospatial data, GD&I, and TGD holdings to determine the availability of geospatial data and/or information for the defined AO. The team immediately begins disseminating SSGF and available geospatial knowledge products to the staff to support planning. If gaps in the TGD holdings exist, the team develops a running estimate that defines the gaps, identifies potential information collection assets to fill the gaps, and estimates the time until all gaps are filled. Initial visualization products are developed to assist the commander and staff with understanding the physical dimension of the OE. Table 4-1 shows how the key inputs affect and generate geospatial engineering operations for key outputs.

Table 4-1. Geospatial engineering operations upon receipt of mission

MDMP Step	*Key Inputs*	*Geospatial Engineering Operations*	*Key Outputs*
Step 1: Receipt of mission	Higher headquarters' plan (or order) or a new mission anticipated by the commander	• Determine initial geospatial information requirements based on the— ▪ AO. ▪ Mission. • Disseminate available geospatial information and knowledge products for staff planning. • Ensure that organic command and control systems have access to SSGF. • Ensure that staff sections have access to geospatial knowledge repositories. • Assess the availability of existing geospatial data and/or information. • Identify gaps in SSGF holdings.	• Commander's initial guidance • Initial allocation of time • Warning order

Table 4-1. Geospatial engineering operations upon receipt of mission (continued)

MDMP Step	***Key Inputs***	***Geospatial Engineering Operations***	***Key Outputs***
		▪ Identify organic assets' ability to collect against geospatial data gaps. ▪ Identify high headquarters', national, and coalition collection capabilities to collect against geospatial data gaps.	
Legend: AO area of operations MDMP military decision-making process SSGF Standard and Shareable Geospatial Foundation			

Step 2: Mission Analysis

4-5. During mission analysis, commanders and staffs gather, analyze, and synthesize information to orient themselves on the current conditions of the OE. Part of this analysis is the initial IPB, which identifies critical gaps in the commander's knowledge of an OE. Geospatial engineering operations assist during IPB by providing knowledge on the effects of the physical dimension on both friendly and enemy operations by warfighting functions. Staff members conduct IPB throughout the remaining MDMP steps to update and refine the assessment as new information is received. Table 4-2 shows how the key inputs affect and generate geospatial engineering operations for key outputs.

Table 4-2. Geospatial engineering operations during mission analysis

MDMP Step	***Key Inputs***	***Geospatial Engineering Operations***	***Key Outputs***
Step 2: Mission Analysis	• Commander's initial guidance • Higher headquarters' plan or order • Higher headquarters' knowledge and intelligence products • Knowledge products from other organizations • Running estimates • Army design methodology products (if applicable)	• Generate geospatial information from available geospatial data sources to fill SSGF gaps. • Manage the integration and synchronization of available geospatial data and/or information into the organization's SSGF and TGD holdings. • Analyze geospatial information to determine impacts of the physical domain on military operations by identifying (OAKOC/SWEAT-MSO)– ▪ Observations/fields of fire—terrain that permits a force to see the friendly, enemy, and neutral personnel and systems or that a weapon or group of weapons may cover effectively ▪ Avenues of approach—Corridors through unrestricted terrain that provide enough space to support mobility; used to identify avenues of approach	• Updated IPB and running estimates • Problem statement • Mission statement • Initial commander's intent • Initial CCIRs and EEFIs • Initial planning guidance • Assumptions • Evaluation criteria for COAs

Table 4-2. Geospatial engineering operations during mission analysis (continued)

MDMP Step	Key Inputs	Geospatial Engineering Operations	Key Outputs
		▪ Key terrain—identifiable characteristic whose seizure or retention affords a marked advantage to either combatant ▪ Obstacles—natural or man-made features that impede mobility ▪ Cover/Concealment—natural or man-made features that protect from the effects of fires or from observation/surveillance ▪ Infrastructure—sewage, water, electricity, academics, trash, medical, public safety, transportation, communications • Disseminate available geospatial information and knowledge products for staff planning. • Ensure that organic command and control systems have access to SSGF. • Ensure that staff sections have access to geospatial knowledge repositories. • Share geospatial knowledge through written and oral communication.	

Legend:

CCIR	commander's critical information requirements
COA	courses of action
EEFI	essential elements of friendly information
IPB	intelligence preparation of the battlefield
MDMP	military decision-making process
OAKOC	obstacles, avenues of approach, key terrain, observations/fields of fire, cover/concealment
SSGF	Standard and Shareable Geospatial Foundation
SWEAT-MSO	sewage, water, electricity, academics, trash, medical, safety, and other considerations
TGD	Theater Geospatial Database

4-6. Commanders and staffs use operational and mission variables to help build situational understanding. They analyze and describe an OE in terms of political, military, economic, social, information, infrastructure, physical environment, and time. Upon receipt of a mission, commanders filter information categorized by the operational variables into relevant information concerning the mission. They use mission variables and operational variables to refine their understanding of the situation and to visualize, describe, and direct operations. The mission variables are mission, enemy, terrain and weather, troops and support available, time available, and civil considerations, each of which have informational considerations and informational considerations (METT-TC [I]).

Operational Variables

4-7. Operational variables are fundamental to developing a comprehensive understanding of the OE.

- **Political**. This variable describes the distribution of responsibility and power at all levels of governance, including formally constituted authorities, and informal or covert political powers. Geospatial engineering support considerations include political and/or administrative boundaries, political and/or administrative capital/seats, and border control points.
- **Military**. This variable includes the military and paramilitary capabilities of all relevant actors (enemy, friendly, and neutral) in a given OE. Geospatial engineering support considerations include military installation location(s).
- **Economic**. This variable encompasses individual and group behaviors related to producing, distributing, and consuming resources. Geospatial engineering support considerations include major import/export facilities or features (such as seaports, natural gas/oil pipelines, agricultural regions).
- **Social**. This variable includes the cultural, religious, and ethnic makeup within an OE and the beliefs, values, customs, and behaviors of society members. Geospatial engineering support considerations include ethnic boundaries, population density, and demographic information.
- **Information**. This variable describes the nature, scope, characteristics, and effects of individuals, organizations, and systems that collect, process, disseminate, or act on information. Geospatial engineering support considerations include the location of major telecommunication or media infrastructure and/or networks.
- **Infrastructure**. This variable comprises the basic facilities, services, and installations needed for the functioning of a community or society. The memory aid to describe this assessment is SWEAT-MSO (sewage, water, electricity, academics, trash, medical, safety, and other considerations). See ATP 3-34.81 for more information. Geospatial engineering support considerations include transportation architecture, power generation/distribution/transmission facilities and/or networks, and the categorization of urban zones (government, industrial, residential, academic).
- **Physical environment**. This variable includes the geography, man-made structures, climate, and weather in the AO. Geospatial engineering considerations include the terrain factor areas and overlays (hydrology [surface drainage], surface configuration [slope, surface roughness], surface materials [soils], vegetation, obstacles, infrastructure [man-made features]), weather effects on those features, and how those features will impact military operations.
- **Time**. This variable describes the timing and duration of activities, events, or conditions within an OE, and how the timing and duration are perceived by various actors in the OE. Geospatial engineering support considerations include crop types and harvesting times.

Mission Variables

4-8. Mission variables are fundamental in developing a COA for a given operation. Mission variables describe characteristics of the AO, focusing on how they might affect a mission.

- **Mission**. Leaders analyze the warning order or OPORD of the higher headquarters to determine how their unit contributes to the mission of the higher headquarters. Geospatial engineering support considerations include visualization and understanding of the physical dimension of the OE and how they will impact the mission.
- **Enemy**. For small-unit operations, leaders need to know about the composition, disposition, strengths, recent activities, ability to reinforce, and possible COA of the enemy. Leaders determine how available information about the enemy applies to their operation. They also determine what they do not know but should know about the enemy. They identify these intelligence gaps to their higher headquarters to obtain the necessary information or take action. Geospatial engineering support considerations include visualization and understanding of the physical dimension of the OE and how it will impact enemy operations to direct/focus information collection operations.

- **Terrain and weather**. Leaders analyze the five military aspects of terrain expressed in the memory aid of OAKOC:
  - **Observation/fields of fire**. *Observation* is the condition of weather and terrain that permits a force to see the friendly, enemy, and neutral personnel and systems, and key aspects of the environment (FM 1-02.1). Observation is the ability to see (or be seen by) the adversary visually or through surveillance devices. *Field of fire* is the area that a weapon or group of weapons may cover effectively from a given position (FM 3-90). Observation and fields of fire apply to both enemy and friendly weapons. Leaders consider direct-fire weapons and the ability of observers to mass and adjust indirect fire.
  - **Avenue of approach**. *Avenue of approach* is a path used by an attacking force leading to its objective or to key terrain (FM 1-02.1). Avenues of approach include overland, air, and underground routes. Underground avenues are particularly important in urban operations.
  - **Key terrain**. *Key terrain* is an identifiable characteristic whose seizure or retention affords a marked advantage to either combatant (FM 1-02.1). *Decisive terrain*, when present, is key terrain whose seizure and retention is mandatory for successful mission accomplishment (FM 3-90). Terrain adjacent to the AO may be key if its control is necessary to accomplish the mission. Geospatial engineers recommend key terrain based on the commander's guidance, intent, operational considerations, and terrain analysis.
  - **Obstacles**. *Obstacles* are any natural or man-made obstruction designed or employed to disrupt, fix, turn, or block the movement of an opposing force, and to impose additional losses in personnel, time, and equipment on the opposing force (JP 3-15). Obstacles can exist naturally, man-made, or be a combination of both. Obstacles include military reinforcing obstacles, such as minefields.
  - **Cover/concealment**. Cover is protection from the effects of fires, while concealment is protection from observation or surveillance. Terrain that offers cover and concealment limits fields of fire. Leaders consider friendly and enemy perspectives. Although remembered as separate elements, leaders consider the military aspects of terrain together.
- **Troops and support available**. Perhaps the most important aspect of mission analysis is determining the combat potential of one's force. Leaders know the status of their Soldiers' morale, their experience and training, and the strengths and weaknesses of subordinate leaders. They realistically determine all available resources. This includes troops attached to, or in direct support of, the unit. The assessment includes knowing the strength and status of their equipment. It also includes understanding the full array of assets supporting the unit. For example, leaders know how much indirect fire will become available, and when it is available, they will know the type. They consider any new limitations based on the level of training or recent fighting. Geospatial engineering support considerations include visualization and understanding of the friendly force and equipment locations within the OE.
- **Civil considerations**. Civil considerations are the influence of man-made infrastructure; civilian institutions; and activities of the civilian leaders, populations, and organizations within an AO on military operations. Military operations are rarely conducted in uninhabited areas. Most of the time, units are surrounded by noncombatants. These noncombatants include residents within the AO, local officials, and governmental and nongovernmental organizations. Leaders identify civil considerations that affect their mission based on information from higher headquarters and their knowledge and judgment. Commanders may analyze civil considerations by using the six factors known by the memory aid: areas, structures, capabilities, organizations, people, and events.
- **Informational considerations**. Informational considerations are those aspects of the human, information, and physical dimensions that affect how humans and automated systems derive meaning from, use, act upon, and are impacted by information.

Steps 3-6: COA Development/Analysis/Comparison/Approval

4-9. A COA is a broad potential solution to an identified problem. The COA steps generate options, identify difficulties or coordination problems and probable consequences of planned actions for each considered COA, compare COA independently and against evaluation criteria set by the commander and staff, and present the recommended COA to the commander for a decision. Throughout these steps, geospatial engineering operations refine any analysis already conducted to support the evaluation of each COA considered. Table 4-3 shows how the key inputs affect and generate geospatial engineering operations for key outputs.

Table 4-3. Geospatial engineering operations throughout the COA steps

<table>
<tr><th>MDMP Step</th><th>Key Inputs</th><th>Geospatial Engineering Operations</th><th>Key Outputs</th></tr>
<tr><td>Step 3: COA development</td><td>• Mission statement
• Commander’s planning guidance
• Approved CCIRs and EEFIs
• Updated IPB products and running estimates
• Evaluation criteria for COAs</td><td rowspan="2">• Generate geospatial information from available geospatial data sources to fill SSGF gaps.
• Manage the integration and synchronization of available geospatial data and/or information into the organization’s SSGF and TGD holdings.
• Update and/or refine geospatial information analysis (OAKOC/SWEAT-MSO) based on the—
▪ Mission statement.
▪ Initial commander’s intent, planning guidance, CCIRs, and EEFIs.
▪ Evaluation criteria for COA.</td><td>• COA statements and sketches
• Revised planning guidance
• Updated running estimates and IPB
• Updated assumptions</td></tr>
<tr><td>Step 4: COA analysis</td><td>• Updated running estimates
• Revised planning guidance
• COA statements and sketches
• Updated assumptions</td><td>• Refined COAs
• Potential decision points
• War-game results
• Initial assessment measures
• Updated running estimates
• Updated assumptions</td></tr>
<tr><td>Step 5: COA comparison</td><td>• Updated running estimates
• Refined COAs
• Evaluation criteria
• War-game analysis
• Updated assumptions</td><td rowspan="2">• Disseminate available geospatial information and knowledge products for staff planning.
• Ensure that organic command and control systems have access to SSGF.
• Ensure that staff sections have access to geospatial knowledge repositories.
• Share geospatial knowledge through written and oral communication.</td><td>• Staff-recommended COA
• Cost and benefits between COAs
• COA selection rationale
• Updated running estimates
• Updated assumptions
• Updated IPB</td></tr>
<tr><td>Step 6: COA approval</td><td>• Updated running estimates
• Evaluated COA
• Recommended COA
• Updated assumptions</td><td>• Commander-approved COA with any modifications
• Final commander’s intent, CCIRs, and EEFIs
• Updated assumptions
• Warning order</td></tr>
</table>

Table 4-3. Geospatial engineering operations throughout the COA steps (continued)

Legend:	
CCIR	commander's critical information requirements
COA	courses of action
EEFI	essential elements of friendly information
IPB	intelligence preparation of the battlefield
SSGF	standard and shareable geospatial foundation
MDMP	military decision-making process
OAKOC	obstacles, avenues of approach, key terrain, observation/fields of fire, cover/concealment
SSGF	Standard and Shareable Geospatial Foundation
SWEAT-MSO	sewage, water, electricity, academics, trash, medical, safety, and other considerations
TGD	Theater Geospatial Database

Step 7: Orders Production, Dissemination, and Transition

4-10. The staff prepares the order or plan by turning the selected COA into a concise concept of operations and the required supporting information. The staff writes the OPORD or OPLAN using the operation order format of the Army. The GET is responsible for ensuring that geospatial knowledge about the effects of the physical dimension, guidance on accessing and acquiring GI&S, and guidance on the procedures for gathering geospatial data and/or information during information collection operations are articulated in the OPORD or OPLAN. Table 4-4 shows how the key inputs affect and generate geospatial engineering operations for key outputs.

Table 4-4. Geospatial engineering operations during orders production and dissemination

MDMP Step	*Key Inputs*	*Geospatial Engineering Operations*	*Key Outputs*
Step 7: Order production, dissemination, and transition	• Commander-approved COA and any modifications • Refined commander's intent, CCIRs, and EEFIs • Final commander's planning guidance • Updated IPB and running estimates	• Refine geospatial information requirements based on the commander's intent, CCIRs, and EEFIs. • Assess the availability of existing geospatial data and/or information. • Identify gaps in SSGF holdings. • Identify organic assets' ability to collect against geospatial data gaps. • Identify higher headquarters', national, and coalition collection capabilities to collect against geospatial data gaps. • Generate geospatial information from available geospatial data sources to fill SSGF gaps. • Manage the integration and synchronization of available geospatial data and/or information into the organization's SSGF and TGD holdings. • Disseminate available geospatial information and knowledge products for staff planning. • Ensure that organic command and control systems have access to SSGF.	• Approved operation plan or order • Subordinate understanding of the plan or order

Table 4-4. Geospatial engineering operations during orders production and dissemination (continued)

MDMP Step	*Key Inputs*	*Geospatial Engineering Operations*	*Key Outputs*
		• Ensure that staff sections have access to geospatial knowledge repositories. • Share geospatial knowledge through written and oral communication.	
Notes: OPORD References paragraph—Mapsheets associated with AO; Annex B–Appendix 1–Tab A—Description of physical domain; Annex B–Appendix 5—Description of GI&S support to GEOINT; Annex G–Appendix 4—Description of Geospatial Engineering operations; Annex L—Define geospatial data requirements; Annex L–Appendix 1—Define process for transport of geospatial data from asset to Geospatial Engineering Team.			
Legend: AO area of operations CCIR commander's critical information requirements COA courses of action EEFI essential elements of friendly information GEOINT geospatial intelligence GI&S geospatial information and services MDMP military decision-making process OPORD operation order SSGF Standard and Shareable Geospatial Foundation TGD Theater Geospatial Database			

GEOSPATIAL SUPPORT TO THE FOUR LINES OF ENGINEER SUPPORT

4-11. Engineer missions seek to provide freedom of action for supported forces. This is accomplished by utilizing the engineering disciplines specific capabilities, grouped by purpose into the five lines of engineering support (assure mobility, enhance protection, enable force projection and logistics, build partner capacity, and develop infrastructure). See table 4-5 for specific geospatial engineering support. See FM 3-34 for more information on the sub-task(s) of each line of engineering support.

Table 4-5. Geospatial engineering support for engineering efforts

Engineering Efforts	*Geospatial Engineering Support*
Combined Arms Breaching	• Identify the position of the obstacle and its placement. • Plot and visualize weapons range/employment fans. • Conduct cross-country mobility analysis studies. • Analyze cover and concealment, and identify dead space to determine the last-known covered/concealed positions. • Analyze the weather effects on battlefield obscuration. • Conduct route analysis. • Analyze the LZ and DZ.
Gap crossing	• Hydrological assessment • Crossing sites analysis • Route analysis (near and far side) • Staging, holding, and call forward area analysis • Soils analysis • Initial bridge analysis • Slope analysis • Cover and concealment analysis

Table 4-5. Geospatial engineering support for engineering efforts (continued)

Engineering Efforts	*Geospatial Engineering Support*
Defense Support of Civil Authorities	• Support to security planning • Infrastructure assessment • Route/LOC analysis • Logistical support area placement analysis
Construction Site Analysis and Selection	• Base camp site selection and layout • Identification of barrow sites/material locations • Route/LOC analysis • Site security planning
Engagement Area Development	• Maneuver corridors/avenues of approach • Identification of obstacle integration/placement sites • Plotting and visualizing the emplacement of weapons and weapons range/employment fans for both direct and indirect fires • Slope analysis • Line of sight analysis
Area and Route Clearance	• Route analysis • Line of sight analysis • Soils analysis • Cover and Concealment analysis • Slope analysis • Conduct cross country mobility analysis studies • LZ and drop zone DZ analysis
Legend: CCM cross country mobility DZ drop zone LOC lines of communication LZ landing zone	

GEOSPATIAL SUPPORT TO WARFIGHTING FUNCTIONS

4-12. Geospatial engineering is primarily aligned with the C2 warfighting functions. Still, it also serves as a direct liaison with the intelligence warfighting functions and as a secondary functional relationship to the remaining warfighting functions (see figure 4-2). Command and control requires tactically and technically competent commanders, staffs, and subordinates operating in an environment of mutual trust and shared understanding. A critical challenge for commanders, staffs, and unified action partners is creating a shared understanding of an OE. Through disseminating the SSGF and tailored terrain knowledge, geospatial engineering provides the foundation for building the shared understanding of the physical dimension of an OE for the commander and all warfighting functions. Geospatial engineering support to command and control is conceptualized and visualized by creating various products that support the broad requirements of each warfighting function. See figure 4-3 for a graphical depiction of how geospatial engineering supports each warfighting function.

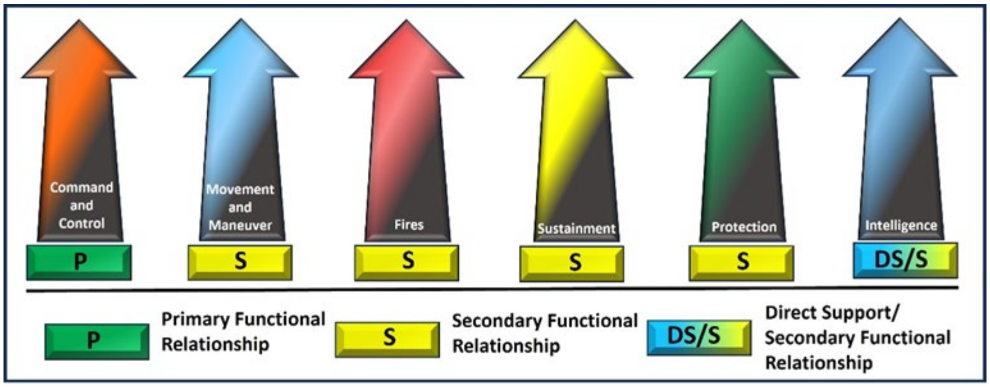


Figure 4-2. Geospatial engineering functional relationship across warfighting functions

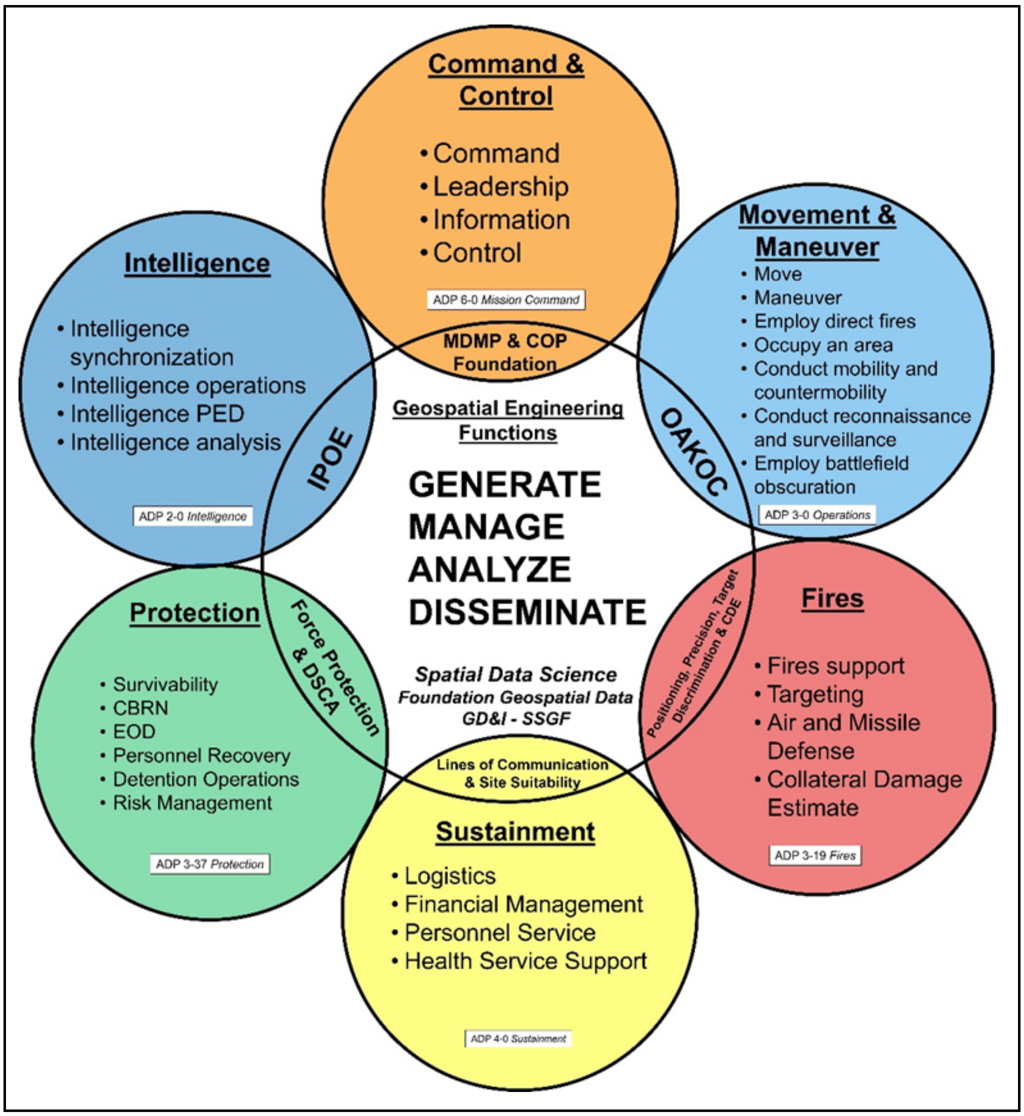


Figure 4-3. Geospatial engineering support to warfighting functions

Legend:	
ADP	Army Doctrine Publication
CBRN	chemical, biological, radiological, and nuclear
CDE	Collateral Damage Assessment
COP	common operational picture
DSCA	Defense Support of Civil Authorities
EOD	explosive ordnance disposal
GD&I	geospatial data and information
IPB	intelligence preparation of the battlefield
MDMP	military decision-making process
OAKOC	observations/fields of fire, avenues of approach, key terrain, obstacles, cover/concealment
PED	processing, exploitations, and dissemination
SSGF	standard and shareable geospatial foundation

Figure 4-3. Geospatial Engineering support to warfighting functions (continued)

COMMAND AND CONTROL

4-13. The *command and control warfighting function* is the related tasks and a system that enable commanders to synchronize and converge all dynamics of combat power (ADP 3-0). The primary purpose of C2 warfighting functions is to assist commanders in integrating the other warfighting functions (movement and maneuver, intelligence, fires, sustainment, protection) effectively at each echelon, applying combat power to achieve objectives and accomplish missions. Employing geospatial engineering data and assets is vital to the commander's ability to conceptualize the OE across time and space.

4-14. Geospatial engineering supports commanders by providing timely and relevant geospatial data and/or information, geospatial knowledge on the impacts of the physical dimension on operations, and assistance in preparing plans and orders. They coordinate with geospatial engineers and staffs of higher echelon, lower echelon, supporting, supported, and adjacent units to synchronize and ensure a common SSGF to facilitate the COP. Geospatial engineering considerations to support C2 include, but are not limited to,

- Contributing to situational understanding.
- Establishing the SSGF for the COP.
- Analyzing and identifying terrain suitability (including LOS) for positioning command posts and communication systems.

MOVEMENT AND MANEUVER

4-15. The *movement and maneuver warfighting function* are the related tasks and systems that move and employ forces to achieve a position of relative advantage over the enemy and other threats (ADP 3-0). Direct fire and close combat are inherent in maneuver. The movement and maneuver warfighting functions include tasks associated with force projection. Movement is necessary to position and disperse the force as a whole or in part when maneuvering. Maneuver directly gains or exploits positions of relative advantage. Commanders use maneuver for massing effects to achieve surprise, shock, and momentum.

4-16. Geospatial engineering provides a tailored understanding of the impacts of the physical dimension on friendly and enemy military operations. This assists commanders and staffs in identifying terrain that seizing and/or retaining provides advantages to friendly force maneuver; determining restrictions to movement or maneuver based on terrain factors; and leveraging terrain aspects to find, fix, and destroy enemy forces. Geospatial engineering considerations to support movement and maneuver include, but are not limited to,

- Analyzing and identifying terrain restrictions on movement and maneuver.
  - Analyzing existing transportation networks for route suitability.
  - Predicting off-road mobility.
  - Analyzing site suitability for landing zones and drop zones.
- Analyzing and identifying mobility corridors.
- Analyzing and identifying potential key terrain features.
- Analyzing and identifying terrain effects on observation to identify potential observation posts, ambush points, or sniper locations.

- Analyzing and identifying terrain effects on direct fires to identify potential support-by-fire positions or engagement areas.
- Analyzing and identifying terrain features that would obscure or mask from detection.
- Analyzing and identifying terrain features that would protect from in-direct fires.

INTELLIGENCE

4-17. The *intelligence warfighting function* is the related tasks and systems that facilitate understanding the enemy, terrain, weather, civil considerations, and other significant aspects of the operational environment (ADP 3-0). Other significant aspects of an OE include threats, adversaries, and operational variables that vary with the nature of operations. The intelligence warfighting functions synchronize information collection with the primary tactical tasks of reconnaissance, surveillance, security, and intelligence operations. Commanders drive intelligence, and intelligence drives maneuver. Intelligence involves analyzing information from all sources and conducting operations to collect information. The Army executes intelligence, surveillance, and reconnaissance through the operations and intelligence processes, emphasizing intelligence analysis and information collection.

4-18. Geospatial engineering provides a tailored understanding of the impacts of the physical dimension on enemy military operations. This assists the intelligence warfighting functions with assessing and predicting enemy operations based on the impacts of the physical dimension. The intelligence warfighting function is supported in concert with other warfighting functions to ensure that enemy threats and capabilities are characterized spatially and temporally and that geospatial engineering support closely aligns with movement and maneuver. Geospatial engineering considerations to support intelligence include, but are not limited to,

- Analyzing and identifying terrain aspects in support of the IPB process.
- Analyzing and identifying terrain aspects to assist in information collection operations.
- Analyzing and identifying terrain aspects in support of targeting operations.

FIRES

4-19. The *fires warfighting function* is the related tasks and systems that create and converge effects in all domains against the adversary or enemy to enable operations across the range of military operations (ADP 3-0). These tasks and systems create lethal and nonlethal effects delivered from both Army and joint forces and other unified action partners. The fires warfighting functions do not wholly encompass, nor are they wholly encompassed by, any particular branch or function. Many of the capabilities that contribute to fires also contribute to other warfighting functions, often simultaneously. For example, an aviation unit may simultaneously execute missions contributing to the movement and maneuver, fires, intelligence, sustainment, protection, and C2 warfighting functions. Space and cyberspace capabilities can allow commanders to destroy or disrupt enemy networks, manipulate enemy information and decision making, and contribute to other information advantages. The accurate target location is not only required for precision-guided munitions but also for every fire mission.

4-20. Geospatial engineering provides a shared understanding and visualization of maneuver control measures, fire support coordination measures, and airspace coordinating measures as they relate to the physical dimension. This assists the fires warfighting functions with synchronizing and deconflicting their activities, including creating effects. Accurately visualizing fire support and airspace coordinating measures is critical in preventing fratricide and civilian casualties. Geospatial engineering considerations to support fires include, but are not limited to,

- Contributing to situational understanding to maximize terrain management. Terrain considerations vitally facilitate targeting operations, ensuring that field artillery capabilities to shift and mass fires rapidly.
- Analyzing and identifying terrain suitability for positioning logistics sites and position areas for artillery—primary and alternate from dispersed locations and can displace rapidly to new position areas.

- Enabling accurate target location using electronic navigational aids with map analysis verification.
- Understanding the critical importance of accurately portraying and visualizing complex terrain. ***Complex terrain* is a geographical area consisting of one or more of the following: an urban center larger than a village, or two or more types of restrictive terrain or environmental conditions occupying the same geographic location**.

SUSTAINMENT

4-21. The *sustainment warfighting function* is the related tasks and systems that provide support and services to ensure freedom of action, extend operational reach, and prolong endurance (ADP 4-0). Sustainment employs capabilities from all domains and enables operations through each domain. Sustainment determines the limits of depth and endurance during operations. Sustainment depends on joint and strategic integration and should be meticulously coordinated across echelons to ensure continuity of operations and that resources reach the point of employment.

4-22. Geospatial engineering provides a shared understanding and visualization of the OE to facilitate the provision of logistics, personnel services, and health service support necessary to maintain operations. This includes critical capability in support of mortuary affairs when conducting search and recovery operations and planning and identifying interment sites (see ATP 4-46/MCRP 3-40G.3/NTTP 4-06/AFTTP 3-2.51). This assists the sustainment warfighting functions with coordination, integration, and synchronization of resources from the theater strategic to the tactical level.

4-23. LSCO in urban terrain is especially complex and resource-intensive; thorough knowledge of the terrain mitigates complications and risks in urban OE. Geospatial engineering considerations to support sustainment include, but are not limited to,

- Analyzing and identifying lines of communication (ground, aerial, and littoral) in support of force projection (mobilization, deployment, employment, sustainment, and redeployment).
- Analyzing and identifying terrain suitability for intermediate staging and forward operating base emplacement.
- Analyzing and emphasizing restrictive terrain to assist planners with aerial and ground delivery considerations.
- Analyzing and identifying natural resources and infrastructure for sustainment operations.

PROTECTION

4-24. The *protection warfighting function* is the related tasks, systems, and methods that prevent or mitigate detection, threat effects, and hazards to preserve combat power, and enable freedom of action (ADP 3-0). Protection encompasses everything that makes Army forces hard to detect and destroy. Protection requires commanders and staffs to understand threats and hazards throughout the OE, prioritize their requirements, and commit capabilities and resources according to their priorities. Commanders balance their protection efforts with the need for tempo and resourcing the main effort. They often assume risk in operations or areas that may be vulnerable but are likely low enemy priorities for targeting or attack. Commanders account for threats from space, cyberspace, and outside their assigned AO while developing protection measures. Protection results from many factors, including operations security, dispersion, deception, survivability measures, and how an operation is conducted. Planning, preparing, executing, and assessing protection is a continuous and enduring activity. Defending networks, data, and systems; implementing operations security; and conducting security operations contribute to information advantage by protecting friendly information. Prioritization of protection capabilities is situationally dependent and resource-informed. Chemical, biological, radiological, and nuclear (CBRN) coordination and collaboration is integral to protection. CBRN and geospatial engineering interface at the physical environment, including weather effects relevant to both. Staffs use geospatial information to plan for CBRN threats and hazards, and geospatial data is critical to CBRN warning and reporting applications. Geospatial data can provide timely and accurate information on environmental hazards, such as toxic industrial materials, in an operational area. This is important to maintain an accurate COP for CBRN operations.

4-25. Geospatial engineers enable deliberate exploitation of terrain considerations, greatly contributing to the commander's ability to extend throughout the OE. Geospatial engineers provide spatiotemporal data to visualize and emphasize the importance of planning and expanding protection priorities, including protecting mission partners, civilian populations, equipment, resources, infrastructure, and cultural landmarks using authoritative georeferenced and attributed data. Spatiotemporal data assist commanders with terrain preparation and management, such as identifying key physical terrain features vital in seizing, retaining, and exploiting the initiative to shape the OE. Geospatial engineering provides a shared understanding and visualization of threats and hazards in the OE as they relate to the physical dimension. This assists the protection warfighting functions with evaluating available protection capabilities and applying the dynamics of combat power to deter or mitigate these threats or hazards from negatively impacting friendly operations. Geospatial engineering considerations to support protection include, but are not limited to,

- Analyzing and identifying terrain that supports protection measures and complements the position of forces during planning.
- Analyzing and identifying terrain that supports survivability by providing cover and/or concealment.
- Analyzing and identifying terrain impacts on chemical, biological, radiological, and nuclear operations.
- Analyzing and identifying terrain impacts on personnel recovery.
- Analyzing and identifying physical dimension impacts on populace and resources control operations.
- Analyzing and identifying physical dimension impacts on local and/or area security.
- Analyzing and identifying physical dimension aspects of cyberspace security.
- Analyzing and identifying physical dimension aspects of electromagnetic protection. (See table 4-6, page 4-16, for a list of product considerations.)

COMMON OPERATING ENVIRONMENT INTEGRATION

4-26. The common operating environment (COE) is an approved set of computing technologies and standards that enable secure and interoperable applications to be rapidly developed and executed across various CEs. Among the 16 cross-cutting capabilities directed in the COE is the SSGF. The SSGF provides a common base for visualizing the OE to all CE under the COE. The geospatial engineer is responsible for assembling, managing, and disseminating the SSGF for the CEs to consume; the geospatial engineer capabilities to perform these functions in a tactical operation are integrated and hosted in the Command Post Computing Environment (CPCE).

COMMAND POST COMPUTING ENVIRONMENT

4-27. The CPCE is a significant component of the COE of the Army. The geospatial engineer functional capabilities are integrated into CPCE at brigade and higher. The CPCE delivers interoperable command post capabilities from ASCC to battalion command posts. The geospatial engineer provided and managed cross-cutting capability SSGF is central in the CPCE in the services provided to COE. The CPCE capabilities operate on unit-purchased end-user device hardware, which conforms to a set of computer hardware standards, and the Assistant Secretary of the Army (acquisition, logistics, and technology) provided tactical services infrastructure servers. The tactical services infrastructure servers host infrastructure services, applications, and data storage, including the SSGF.

Table 4-6. Warfighting functions geospatial data, information, and product considerations

Warfighting Functions	*Geospatial Information and Product Considerations*
Movement and Maneuver	• Identify mobility corridors and determine avenues of approach. • Predict on- and off-road mobility. • Analyze cover and concealment. • Template zones of entry (helicopter landing zones and drop zones). • Provide LOS observation overlays for determining patrol routes, observation posts, and potential ambush or sniper locations. • Locate points of penetration and support-by-fire positions in support of attacks and breaching operations. • Identify and analyze potential engagement areas and obstacle locations based on LOS observation and fields of fire. • Provide updated SSGF.
Intelligence	• Provide terrain analysis products in support of IPB. • Enable intelligence, surveillance, and reconnaissance synchronization. • Provide support to targeting (emphasis on high-payoff target information). • Provide products supporting movement and maneuver as required.
Fires	• Facilitate the targeting process. • Template observer and firing points based on visibility and suitability using LOS, slope, and elevation considerations. • Analyze mobility to facilitate repositioning of artillery systems. • Provide survey control points for subordinate agencies employing mounted and handheld CE platforms.
Sustainment	• Display transportation network (road/rail/air/sea) information for establishing LOCs and main supply routes. • Determine terrain suitability for positioning sustainment capabilities and establishing base camps based on hydrological analysis and assessment of other environmental conditions, such as hazards associated with industrial areas and underground utility lines.
Command and Control	• Contribute to situational understanding and information superiority. • Establish the geospatial foundation data for the COP. • Determine terrain suitability (including LOS) for positioning command and control nodes and communication systems.
Protection	• Identify potential areas for antiaircraft and aerial threat avenues of approach through terrain analysis emphasizing elevation and LOS analysis. • Provide visibility analysis for implementing protection measures. • Provide cover and concealment analysis for assembly areas and forward resupply nodes. • Provide observation and fields of fire analysis for implementing counter direct and indirect fire and terrain denial measures. • Identify the availability and location of force protection materials.
Legend:	
COP	common operational picture
IPB	intelligence preparation of the battlefield
LOC	line of communications
LOS	line of sight
SSGF	Standard and Shareable Geospatial Foundation

MOUNTED COMPUTING ENVIRONMENT

4-28. The mounted computing environment (MCE) is designed as an on-the-move, networked command and control system. MCE enables units to share near real-time friendly and enemy situational awareness information portrayed and overlaid on common geospatial data using SSGF. MCE does not host geospatial engineer capabilities; it is a primary consumer of SSGF and geospatial engineer products supporting battlefield awareness mobility, and routing. MCE uses the same SSGF as CPCE to easily integrate communications and facilitate interoperability between vehicles and command posts for terrain visualization commonality.

MOBILE/HANDHELD COMPUTING ENVIRONMENT

4-29. A mobile handheld computing environment is the command-and-control system that enables digital communications for dismounted leaders down to the team level. Similarly to MCE, it does not host geospatial engineer capabilities; it is a primary consumer of SSGF and geospatial engineer products supporting battlefield awareness, navigation, and routing. The mobile handheld computing environment collaborates extensively with MCE to implement common messaging formats and geospatial mapping standards using SSGF, ensuring that mounted and dismounted Soldiers see the same COP for exchanging critical information.

ENTERPRISE COMPUTING ENVIRONMENT

4-30. The enterprise computing environment delivers cloud-based computing infrastructure with shared networks, servers, and storage devices. This infrastructure allows the enterprise computing environment to host geospatial engineer capabilities, enabling the full AGE within the enterprise computing environment, thus delivering SSGF, raw geospatial data sources, and full geospatial engineer functionality in various environments. It further reduces the need for on-site equipment and allows units to function as a more unified force when conducting dispersed operations. The commander has the discretion to determine necessary on-site equipment and database requirements weighed against geospatial engineer Soldier recommendations, risk considerations, and bandwidth capability.

REAL-TIME/SAFETY CRITICAL/EMBEDDED COMPUTING ENVIRONMENT

4-31. Unlike the other CEs, the real time/safety critical/embedded computing environment is not focused on hardware or software development, but rather the framework of standards that foundationally integrate the other platforms. As with MCE and the mobile handheld computing environment, it does not host geospatial engineer capabilities; it is a primary consumer of SSGF and geospatial engineer products supporting battlefield awareness, navigation safety, and routing. The real time/safety critical/embedded computing environment focuses on common sets of devices, displays, and various platforms, all of which portray and overlay information on common geospatial data using SSGF.

SENSOR COMPUTING ENVIRONMENT

4-32. The sensor computing environment focuses on improving the interaction of sensors with Soldiers, platforms, and command post systems across all warfighting functions. As with the MCE, mobile handheld computing environment, and real-time/safety critical/embedded computing environment, it does not host geospatial engineer capabilities; it is a primary consumer of SSGF and geospatial engineer products supporting battlefield awareness, navigation safety, and geospatial positioning. As sensors continue to proliferate as a valuable information source across the operational environment, their delivery results in a common interoperability layer portrayed and overlayed as common geospatial data using SSGF.

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Chapter 5

Support to Army Operations

A critical aspect of applying combat power and successfully conducting operations rests on the collective ability of commanders and staffs to visualize the OE. FM 3-0 states, "Although there are new capabilities in space and cyberspace, Army forces use them just as they employ any other capability—to accomplish missions on land." Knowledge of the terrain is never more critical than during combat operations. All operations are multidomain operations regardless of joint force capabilities contributions at each Army echelon (see FM 3-0). This environment offers various sources of geospatial engineering, GI&S, and GIS capabilities. The characterization of effective geospatial engineering lies in understanding these available capabilities and effectively leveraging them while working effectively with other staff sections, organizations, and unified action partners. This becomes critical as coordination across functional areas focuses on supporting various mission types. This coordination includes the ability to fully define requirements, discover and obtain the necessary geospatial data, and incorporate this data for use within the COE and COP, all while simultaneously utilizing, sharing, and maintaining this data.

MULTIDOMAIN OPERATIONS

5-1. Multidomain operations are the combined arms employment of joint and Army capabilities to create and exploit relative advantages that achieve objectives, defeat enemy forces, and consolidate gains on behalf of joint force commanders. All operations are multidomain operations, regardless of joint force capabilities contributed at each Army echelon. This is because Army forces employ organic capabilities in multiple domains and continuously benefit from Army capabilities they do not control, including global positioning systems and various types of networks. Multidomain operations demand a mindset that focuses on how Army forces view their OE and threats. Army forces must accurately see themselves, see the enemy or adversary, and understand their OE before identifying or exploiting positions of relative advantage.

5-2. Commanders visualize OEs in terms of the factors that are relevant to decision making. However, OEs produce enough information to overload C2 systems and impede decision making. Commanders simplify information collection, analysis, and decision making by focusing on how they see themselves, see the enemy, and understand the OE. These three categories of factors are interrelated, and leaders must understand how each relates to the others in the current context. Leaders see themselves by understanding their combat power relative to the threat and how the OE creates advantages for both friendly and threat forces. Leaders see the threat by understanding its relative combat power advantages within the context of the OE. Leaders understand the OE by assessing how conditions in one domain and its dimensions impact the others.

UNDERSTANDING THE OPERATIONAL ENVIRONMENT

5-3. Leaders view the OE regarding domains, dimensions, and operational and mission variables relevant to their decisions. In the context of decision making, understanding is the knowledge that has been synthesized and had judgment applied to comprehend the situation's inner relationships, enable decision making, and drive action. Understanding is judgment applied to knowledge in the context of a particular situation. Understanding is also knowing enough about the situation to change it through action. Judgment is based on experience, expertise, and intuition. Ideally, true understanding should be the basis for decisions. However, judgment is critical because uncertainty and time preclude achieving perfect understanding before deciding and acting.

5-4. Geospatial engineering operations provide understanding and knowledge of the impacts of the physical dimension on military operations. Geospatial engineers at all echelons process and analyze GD&I associated with the physical dimension to facilitate answering the commander's critical information requirements and priority intelligence requirements, enhancing the understanding of the OE.

COMMON OPERATIONAL PICTURE

5-5. A COP is key to achieving and maintaining shared situational understanding in all domains and making effective decisions faster than the threat. The *common operational picture* is a display of relevant information within a commander's area of interest tailored to the user's requirements and based on common data and information shared by more than one command (ADP 6-0). Although the COP is ideally a single display, it may include more than one display and information in other forms, such as graphic representations or written reports.

5-6. The COP facilitates collaborative planning and helps commanders at all echelons achieve shared situational understanding. Shared situational understanding allows commanders to visualize the effects of their decisions on other elements of the force and the overall operation. Mission command allows subordinates to use the COP with the commander's intent to guide their exercise of disciplined initiative.

5-7. Command posts draw on a common set of relevant information within a shared database to create a digital COP. Units always maintain an analog COP if the digital COP is not possible. Command posts maintain shared situational understanding by drawing on a common set of relevant information within a shared database to create a digital COP. During large-scale combat operations, communications are likely to be degraded or denied. Units should always maintain an analog COP, including hard-copy maps and overlays if the digital COP is not possible.

5-8. The difficulty of maintaining a COP in a multinational environment varies based on language differences, a lack of data sharing, the technical compatibility of systems, and restrictions based on classification and other national caveats. Often, unified action partners will not have the technical capability or compatible systems to create and share a digital COP. Commanders must recognize and plan for this possibility by using alternate methods: employing liaison officers, dispatching runners, and utilizing other direct forms of communication.

5-9. Geospatial engineering operations provide the foundation for establishing the commander's COP through maintaining and disseminating the SSGF in digital and hard-copy formats. The AGE facilitates the dissemination and synchronization of foundation GD&I across echelons (vertical and horizontal), DOD services, supporting organizations, and partnered nations, enabling a shared situational understanding.

LAND DOMAIN

5-10. *Land domain* is the area of the earth's surface ending at the high-water mark and overlapping with the maritime domain in the landward segment of the littorals (JP 3-31). The variations in climate, terrain, velocity, and complexity of people interacting and the diversity of populations have a far greater impact on operations in the land domain than in any other domain. The most distinguishing characteristic of the land domain is the human dimension. Humans transit the air, maritime, and space domains but ultimately live, make political decisions, and seek conflict resolution on land.

MARITIME DOMAIN

5-11. *Maritime domain* is the oceans, seas, bays, estuaries, islands, coastal areas, and the airspace above these, including the littorals (JP 3-32). It overlaps with the land domain in the seaward segment of the littoral. Maritime capability may be considered a global, regional, territorial, coastal, and self-defense forces. Only a few navies are capable of sustained employment far from the shores of their country. However, regardless of whether their navies are capable of global power projection, most maritime nations also maintain air forces capable of conducting operations over the adjacent maritime domain. This air capability, combined with land-based long-range fires, greatly impacts operations in the maritime domain.

AIR DOMAIN

5-12. *Air domain* is the atmosphere, beginning at the earth's surface, extending to the altitude where its effects upon operations become negligible (JP 3-30). The speed, range, and payload of aircraft, rockets, missiles, and hypersonic glide vehicles operating in the air domain directly and significantly impact operations on land. Likewise, advancing ground-based air and missile defense, electromagnetic warfare, directed energy, and cyberspace capabilities increasingly contest freedom of maneuver in the air domain.

SPACE DOMAIN

5-13. *Space domain* is the area surrounding earth at altitudes of greater than or equal to 100 kilometers above mean sea level (JP 3-14). At this altitude, atmospheric effects on airborne objects become negligible. The space domain is the U.S. Space Command AOR. This is a developing area for geospatial, and the NSG is evaluating current geospatial standards to see if they are still applicable to the space domain.

CYBERSPACE DOMAIN

5-14. For Army forces, the cyberspace domain is the networks and information technology infrastructures, resident data, the internet, telecommunication networks, computer systems, processors, and the portions of the electromagnetic spectrum that facilitate or inhibit any of these cyberspace components. Cyberspace is an extensive and complex global network of wired and wireless links connecting nodes that permeate every domain. Cyberspace networks cross geographic and political boundaries, connecting individuals, organizations, and systems worldwide. Cyberspace is socially enabling, allowing interactivity among individuals, groups, organizations, and nation-states. Friendly, enemy, adversary, host-nation networks, communications systems, computers, cellular phone systems, social media, and technical infrastructures are all part of cyberspace.

OPERATIONS DURING COMPETITION BELOW ARMED CONFLICT

5-15. Competition below armed conflict is a state of tension that exists when most of the national interests of the adversary are incompatible with U.S. interests and that adversary is willing to actively pursue them short of open armed conflict. Operations during competition are intended to deter malign adversary action, set conditions for armed conflict on favorable terms when deterrence fails, and shape the OE with allies and partners to support U.S. strategic interests. Army forces contribute to conventional deterrence during competition by preparing for armed conflict, including large-scale combat operations. This includes assisting allies and partners to improve their military capabilities and capacity.

THEATER ARMY AND ARMY SERVICE COMPONENT COMMAND

5-16. During competition below armed conflict, the Geospatial Enterprise section of the GPC collects and/or generates foundation geospatial information to fill gaps or enhance the TGD for the assigned theater while synchronizing with strategic geospatial organizations within the AGE. The Geospatial Enterprise section provides the SSGF for the ASCC headquarters COP. The Geospatial Enterprise section develops, trains, and integrates tactics, techniques, and procedures for disseminating and synchronizing TGD updates and/or enhancements with the assigned theater engineering organization (TEC or theater engineer brigade). The Plans and Analysis section provides commanders and planners an understanding and knowledge of the physical dimension of the theater in support of planning efforts to achieve strategic objectives.

THEATER ARMY ASSIGNED FORCES

5-17. During competition below armed conflict, GET below the theater echelon are developing, training, and integrating geospatial engineering tactics, techniques, and procedures that enhance the commander’s understanding and knowledge of the physical dimension of the OE; this includes the synchronization of TGD updates and/or enhancements derived during information collection operations with the higher headquarters organization.

5-18. GET assigned to theater engineering organization(s) TEC or theater engineer brigade develop, train, and integrate tactics, techniques, and procedures for disseminating TGD updates and/or enhancements to GET supporting tactical organizations operating in a defined theater and for synchronizing TGD updates and/or enhancements derived from within a defined theater with the associated theater GPC.

OPERATIONS DURING CRISIS

5-19. A *crisis* is an incident or situation involving a threat to the United States, its citizens, military forces, or vital interests that develops rapidly and creates a condition of such diplomatic, economic, or military importance that commitment of military forces and resources is contemplated to achieve national objectives (JP 3-0). A crisis may be the result of adversary actions or indicators of imminent action or may be the result of natural or man-made disasters. Crisis response operations are characterized by high degrees of volatility and uncertainty. A crisis may erupt with no warning or be well anticipated. Its duration is unpredictable; it may end swiftly with a return to competition or an escalation to armed conflict.

THEATER ARMY AND ARMY SERVICE COMPONENT COMMAND

5-20. During crisis operations, the Geospatial Enterprise section of the GPC disseminates the TGD to organizations conducting reception, staging, onward movement, and integration operations. The Geospatial Enterprise section provides the SSGF for the ASCC headquarters COP. The Plans and Analysis section provides commanders and planners an understanding and knowledge of the physical dimension of the theater in support of planning efforts for achieving strategic objectives and preparing to deploy GET to support the ASCC CCP(s).

THEATER ARMY ASSIGNED FORCES

5-21. During crisis operations, GET below the theater echelon requests and integrates the TGD into their organic geospatial information storage solution. The teams are disseminating the TGD to subordinate GET and the storage solutions for organic COE systems. The teams analyze the physical dimension of their assigned OE using the operational and mission variable construct. The teams provide a shared understanding of the effects of the physical dimension on military operations by warfighting functions with commanders and planners.

OPERATIONS DURING ARMED CONFLICT

5-22. Armed conflict encompasses the conditions of a strategic relationship in which opponents use lethal force to achieve objectives and impose their will on the other. The employment of lethal force is the defining characteristic of armed conflict and is the primary function of the Army. The immediate effect of lethality is in the physical dimension—reducing the capability and capacity of the enemy to fight. During armed conflict, operations can reflect irregular and conventional warfare combinations. Irregular warfare can include counterinsurgency and unconventional warfare. Leaders apply the doctrine of large-scale combat operations during limited contingencies that require conventional warfare approaches.

5-23. Large-scale combat operations occur within the context of armed conflict. They are extensive joint combat operations in terms of scope and size of forces committed, conducted as campaigns aimed at achieving operational and theater strategic objectives through the application of force. Large-scale combat on land occurs within the framework of a larger joint campaign, usually with an Army headquarters forming the base of a joint force headquarters. These operations typically entail high tempo, high resource consumption, and high casualty rates. Large-scale combat introduces complexity, lethality, ambiguity, and speed to military activities uncommon in other operations.

THEATER ARMY AND ARMY SERVICE COMPONENT COMMAND

5-24. During armed conflict, the Geospatial Enterprise section of the GPC disseminates TGD updates from national strategic organizations to the assigned theater engineering organization. The Geospatial Enterprise section synchronizes TGD updates or enhancements derived during tactical operations with theater strategic organizations. The Geospatial Enterprise section provides the SSGF for the ASCC headquarters COP. The CCP GET(s) provides commanders and planners with the knowledge and understanding of the physical dimension of the theater in support of planning efforts to achieve strategic objectives and provide the SSGF for the COP of the CCP.

THEATER ARMY ASSIGNED FORCES

5-25. During armed conflict, GET below the theater echelon facilitate the commander's understanding and knowledge of the physical dimension of the OE by providing tailored analysis and products. The GET synchronizes TGD updates and/or enhancements derived during information collection operations with the higher headquarters of the organization.

5-26. GET assigned to theater engineering organization(s) (TEC or theater engineer brigade) to disseminate TGD updates and/or enhancements to GET supporting tactical organizations operating in a defined theater. GET synchronize TGD updates and/or enhancements derived from within a defined theater with the associated theater GPC.

SUPPORT OF ARMY OPERATIONS IN MARITIME-DOMINATED ENVIRONMENTS

5-27. A maritime-dominated OE adds requirements for coordination and synchronization by Army echelons that do not exist in the land-dominated OE where most of the force trains. Army and joint force planning requires understanding the dynamic nature of the threats and constraints to land forces in these regions. Army movement and maneuver between land masses almost depend entirely on joint capabilities. Control of critical land masses is essential to the sustainment and protection of joint operations in a maritime-dominated OE.

5-28. Maritime land masses include a variety of environmental conditions. Islands throughout Southeast Asia are predominantly jungle and savanna regions. Islands throughout the Baltic, Arctic, and sub-Arctic regions may experience prolonged periods of extreme cold weather. Mountainous terrain can be found on jungle, Arctic, and desert islands. Each island can contain unique environmental planning considerations that affect how Army forces are resourced and employed. In a predominantly maritime environment, all land that can be occupied to attain a physical position of relative advantage by friendly or enemy forces is key terrain.

5-29. Maritime environments include littoral regions divided into two segments: seaward and landward. Seaward segments include the area from the open ocean to the shore, which must be controlled to support operations ashore. Landward segments are those areas inland from the shore that can be supported and defended directly from the sea. Maritime littoral regions are divided into four categories:

- Enclosed and semienclosed seas—bodies of water surrounded by a landmass and connected to an ocean of another enclosed sea by a connecting body of water, such as a straight.
- Islands—single land masses surrounded by a body of water.
- Archipelagoes—groups of islands.
- Open seas—unenclosed bodies of water, typically outside territorial boundaries.
- Marginal seas—portions of open seas or oceans that bound land masses such as peninsulas, islands, and archipelagos.

5-30. The maritime environment includes the Arctic region. The Arctic encompasses part of the areas of responsibility of three different combatant commands, eight countries, and all time zones. The Arctic presents a harsh and demanding maritime, land, and air environment for military operations. Extreme temperatures, long periods of darkness and extended daylight, high latitudes, seasonally changing terrain, and rapidly changing weather patterns define Arctic conditions, impacting the operational and mission variables. The variability of the physical terrain and weather exposes military forces and capabilities to increased levels of risk.

5-31. Ground mobility is typically most favorable during the winter months. Summer poses significant challenges for most vehicles moving off-road, while the most challenging period is the spring thaw, when ground movement becomes impossible across considerable swaths of territory. Air and sea mobility are critical enablers for military operations regardless of season. Thawing permafrost affects infrastructure across the region. Lacking the climate-moderating effect of the warm Gulf Stream, the North American Arctic hosts a much harsher environment than the European Arctic. The warming of the Arctic has led to longer windows of reduced ice conditions over a larger area. Long-term trends point to a more consistently navigable Arctic, potentially affecting the mobility of Army forces during armed conflict. Operations in the Arctic region get more complicated when roadways, seaports, and airfields become unusable depending on seasons.

THEATER ARMY AND SERVICE COMPONENT COMMAND

5-32. During operations in a maritime-dominated environment, the Geospatial Enterprise section of the GPC disseminates TGD updates from national strategic organizations to the assigned theater engineering organization. The Geospatial Enterprise section synchronizes TGD updates or enhancements derived during tactical operations with theater strategic organizations. These enhancements include analysis such as beach landing suitability, trafficability studies, and geospatial decision aid specific to maritime environments. The Geospatial Enterprise section provides the SSGF for the ASCC headquarters COP. The CCP GET(s) provide the commander and planners knowledge of the physical dimension of the theater in support of planning efforts to achieve strategic objectives and provide the SSGF for the COP of the CCP.

THEATER ARMY ASSIGNED FORCES

5-33. During operations in a maritime-dominated environment, GET below the theater echelon facilitates the commander's knowledge of the physical dimension of the OE by providing tailored analysis and products. The GET synchronizes TGD updates and/or enhancements derived during information collection operations with the higher headquarters of the organization.

5-34. GET assigned to theater engineering organization(s) (TEC or theater engineer brigade) to disseminate TGD updates and/or enhancements to GET supporting tactical organizations operating in a defined theater and synchronize TGD updates and/or enhancements derived from within a defined theater with the associated theater GPC.

Appendix A
Conversion Charts and Formulas

This appendix is intended to provide geospatial engineers with a quick reference to units of measurement generally encountered and applied to standard and nonstandard geospatial products. This complies with AR 25-30, which states Army publications will use International System of Units (Metric System) measurements as required in Executive Order 12770. See Federal Standard 376B for a list of preferred International System units. Army publications using measured quantities will first express the amount in International System units and show the equivalent quantity in U.S. standard units in parentheses. Tables A-1 and A-2, and figure A-1, page A-2, are provided as references for hasty conversion calculations.

Table A-1. Metric conversion chart

U.S. Units	***Multiplied By***	***Equals Metric Units***
Inches	0.0254	Meters
Feet	0.3048	Meters
Yard	0.9144	Meters
Mile	1.6093	Kilometer
Nautical Mile	1.8520	Kilometer
Metric Units	***Multiplied By***	***Equals U.S. Units***
Meters	39.3701	Inches
Meters	3.2808	Feet
Meters	1.0936	Yard
Kilometer	0.6213	Mile
Kilometer	0.5399	Nautical Mile
Legend: U.S. United States		

Table A-2. Temperature conversion chart

Temperature	
(°F – 32) x 0.556 =	°C
°C (1.8) + 32 =	°F
Legend: °C Celsius; °F Fahrenheit	

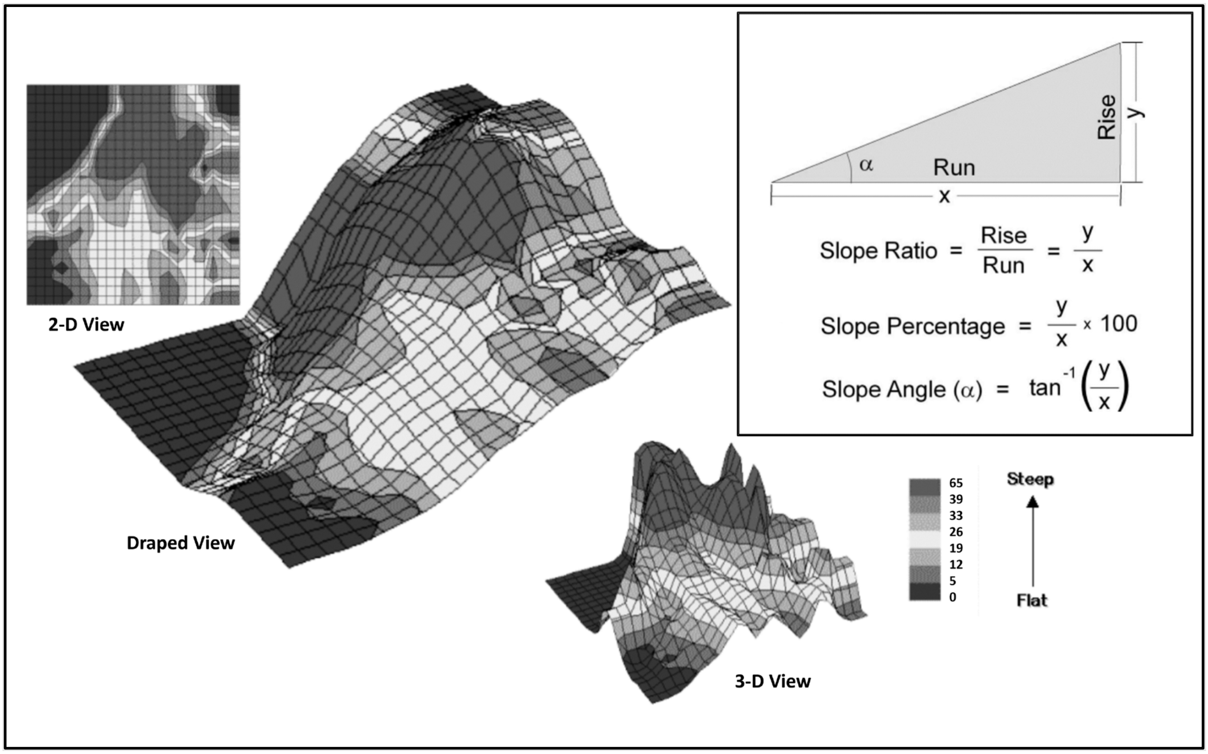

Figure A-1. Slope view and formulas

Appendix B
Terrain Characteristics

Terrain analysis is conducted to study the natural and man-made features in an area and evaluate the effects on military operations. This appendix describes the six terrain characteristics (hydrology, surface configuration, surface materials, vegetation, obstacles, and infrastructure) that geospatial engineers address during terrain analysis. These characteristics serve as the framework for describing the terrain in the OE. See chapter 1, paragraphs 1-15 through 1-17, and chapter 2 for data sources for the six terrain characteristics.

HYDROLOGY (SURFACE DRAINAGE)

B-1. Water is an essential commodity and is always an important factor in planning. It is necessary for drinking, sanitation, food preparation, construction, and decontamination. Support activities (helicopter maintenance, operation of medical facilities) consume large volumes of water. When untreated or stagnant, water can present health hazards. Drainage features (streams, rivers) can affect mobility and shape COA. Engineers are essential in providing water to Army forces and are responsible for finding subsurface water, drilling wells, and constructing, repairing, or maintaining water facilities. Geospatial engineers generate, manage, and analyze hydrologic data and work with ground survey teams and well-drilling teams to locate water sources. Geospatial engineers also produce geospatial information to help commanders and staffs understand the effects of surface drainage on operations.

WATER SOURCES

B-2. Water availability and consumption requirements vary based on the climate and topography of a region and the type and scope of operations. Geospatial engineers can help planners determine probable water sources on and below the surface through terrain analysis.

SURFACE WATER

B-3. Surface water is commonly selected for use in the field because it is the most accessible; however, it tends to be more contaminated than groundwater. Surface water resources are generally more accessible and adequate in plains and plateaus than in mountains. Good-quality water can be obtained in coastal areas, valleys, or alluvial and glacial plains. Although large quantities are available in delta plains, the water may be brackish or salty. Water supplies are scarce on lacustrine, loess, volcanic, and karst plains. Large springs are the best sources of water in karst plains and plateaus. In the plains of arid regions, water usually cannot be obtained in quantities required by modern armies, and when it is, it is generally highly mineralized. In the plains and plateaus of humid, tropical regions, surface water is abundant but is usually polluted and requires treatment. Perennial surface water supplies are difficult to obtain in arctic regions; in summer, they are abundant but often polluted.

GROUNDWATER

B-4. Groundwater is usually less contaminated than surface water and is typically a more desirable water source. In arid environments, exploring and using groundwater can reduce the need to transport water to desired locations. Groundwater is easily obtained from unconsolidated or poorly consolidated materials in alluvial valleys and plains, streams and coastal terraces, glacial outwash plains, and alluvial basins in mountainous regions. Areas of sedimentary and permeable igneous rocks may have fair to excellent aquifers, although they usually provide less groundwater than areas composed of unconsolidated materials. Large amounts of good-quality groundwater may be obtained at shallow depths from the alluvial plains of valleys and coasts and greater depths in the terrace. Aquifers underlying the surface of inland sedimentary plains and basins also provide adequate water. Abundant quantities of good-quality water generally can be obtained from shallow to deep wells in glacial plains. Small amounts of water may be secured from shallow wells in loess plains and plateaus, but these supplies fluctuate seasonally. Plains and plateaus in arid climates generally yield small, highly mineralized quantities of groundwater. Following a severe drought, dry streambeds frequently can yield considerable amounts of excellent subsurface water in semiarid climates. Groundwater is abundant in the plains of humid, tropical regions but is typically polluted. In arctic and subarctic plains, wells and springs fed by groundwater above the permafrost are dependable only in summer; some sources freeze in winter, and subterranean channels and outlets may shift in location.

B-5. Wells may yield large quantities of water if they tap into underground streams. Wells that penetrate aquifers within or below the permafrost are good sources of perennial supplies. Adequate supplies of groundwater are hard to obtain in hills and mountains composed of gneiss, granite, and granite-like rocks. They may contain springs and shallow wells that generally yield water in small amounts. Shallow wells in low-lying lava plains normally produce large quantities of groundwater. Water is more difficult to find in lava uplands, wells are harder to develop, and careful prospecting is necessary to obtain adequate supplies. In wells near the seacoast, the excessive withdrawal of freshwater may lower the water table, allowing the infiltration of saltwater that ruins the well and the surrounding aquifer. Springs and wells near the base of volcanic cones may yield fair quantities of water, but elsewhere in volcanic cones, the groundwater is too far below the surface for drilling to be practicable. See TM 3-34.49/NTRP 4-04.2.13/AFMAN 32-1072 for additional information on the ability of rocks and soils to hold and transmit water. See DODD 4705.01E for surface, ground, and existing water facility information.

B-6. Vegetation is a good indicator of groundwater sources. Deciduous trees tend to have far-reaching root systems, indicating that a water table is close to the ground surface, while coniferous trees tend to have deep root systems, indicating that the water table is farther away from the ground surface. Palm trees indicate water within 2–3 feet, salt grass indicates water within 6 feet, and cottonwood and willow trees indicate water within 10–12 feet. The common sage, greasewood, and cactus do not indicate water levels. Other indicators of potential groundwater include—

- Crop irrigation.
- Karst topography.
- Snowmelt patterns.
- Wetlands.
- Springs.
- Soil moisture.
- Surface water.
- Wells and qanats.
- Urban areas.

SURFACE DRAINAGE

B-7. Surface drainage can significantly impact military operations. It can impede cross-country mobility, restrict road movement, and render land areas prone to flooding unsuitable for positioning forces. Planners must first analyze the flow and channeling characteristics of surface water, which can vary based on geographic location and seasonal weather patterns. Drainage features can be perennial (containing water most of the year), intermittent (containing water part of the year), or dry or cyclical (rarely containing water, such as wadis). Planners can then determine the effects of surface water on operations based on the capabilities of personnel, vehicles, and equipment. Geospatial engineers enable this analysis by acquiring or generating surface drainage data that includes the width and depth of streams and canals and the velocity and discharge of streams. They also obtain or produce information on dams, levees, and other drainage features and can create geospatial products that show the catastrophic effects if they fail.

B-8. Without geologic maps and data, drainage patterns can be studied to determine rock types and better understand the area structure and composition. The most common drainage patterns are shown in figure B-1.

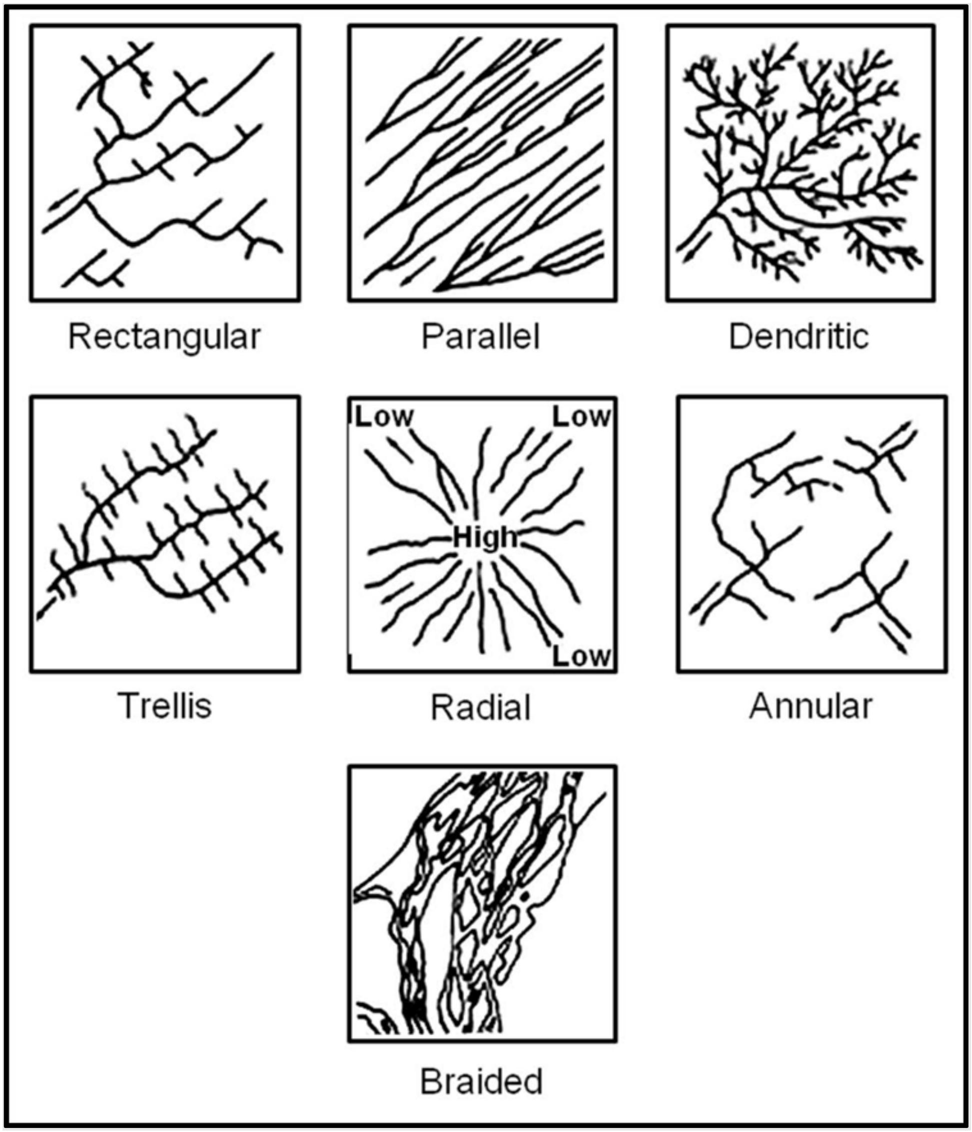

Figure B-1. Common drainage patterns

Rectangular

B-9. The rectangular drainage pattern, characterized by abrupt bends in streams, develops where a treelike drainage pattern prevails over a broad region and is generally associated with massive igneous rock. Metamorphic rock surfaces, particularly those composed of schist and slate, commonly have rectangular drainage. Slate possesses a particularly fine-textured system. The drainage pattern is extremely angular and has easily recognizable short gullies that are locally parallel.

Parallel

B-10. In the parallel pattern, major streams flow side by side in the direction of the regional slope. Parallel streams are indicative of gently dipping beds or uniformly sloping topography. The greater the slope, the more nearly parallel the drainage and the straighter the flow. Local areas of lava flows often have parallel drainage, even though the regional pattern may be radial. Alluvial fans may also exhibit parallel drainage, but the pattern may be locally influenced by faults or jointing. Because of the slope toward the sea, coastal plains develop parallel drainage overboard regions.

Dendritic

B-11. The dendritic drainage pattern is a treelike pattern composed of branching tributaries to a mainstream, characteristic of essentially flat-lying and homogeneous rocks. This pattern implies that the area was originally flat and is composed of relatively uniform materials. Dendritic drainage is also typical of glacial till, tidal marshes, and localized areas in sandy coastal plains. The difference in texture or density of a dendritic pattern may help identify surface materials and organic areas.

Trellis

B-12. In a trellis pattern, the mainstream runs parallel, and small streams flow and join at right angles. This pattern is found in areas where sedimentary or metamorphic rocks have been folded.

Radial

B-13. In a radial pattern, streams flow outward from a high central area. This pattern is found on domes, volcanic cones, and round hills. However, the sides of a dome or volcano might have a radial drainage system, while the pattern inside a volcanic cone might be centripetal, converging toward the center of the depression.

Annular

B-14. The annular pattern is a modified form of the radial drainage system and is found where a dome structure upturns sedimentary rocks. In this pattern, streams circle a high central area. The granitic dome drainage channels may follow a circular path around the base of the dome when tilted beds surround it.

Braided

B-15. A braided stream pattern commonly forms in arid areas during flash flooding. The stream attempts to carry more material than it is capable of handling. Much gravel and sand is deposited as bars and islands in the stream bed.

SURFACE CONFIGURATION

B-16. Surface configuration (surface roughness) refers to the physical shape of the terrain and includes—

- Elevation.
- Slope.
- Landform type.

ELEVATION

B-17. The elevation of a point on the surface of the earth is the vertical distance it is above or below mean sea level. Relief is the representation of the shapes of hills, valleys, streams, or terrain features on the surface of the earth. Local relief is the difference in elevation between points in a given area. The elevations or irregularities of a land surface are represented on graphics by contours, hypsometric tints, shading, spot elevations, and hachures. Geospatial engineers emphasize elevation to help commanders and staff determine how elevation will affect enemy observation by highlighting the terrain throughout the OE. Geospatial engineers utilize various elevation layers (DTED, SRTM, LiDAR) to visualize and create a shared understanding of the terrain.

SLOPE

B-18. The rate of rise or fall of a terrain feature is known as its slope. Slope affects the speed at which equipment or personnel can move. Slope can be categorized as gentle, steep, concave, or convex and expressed as the slope ratio or gradient, the angle of slope, or the percent of slope (see TC 3-25.26 for more information). The slope ratio is a fraction in which the vertical distance (rise) is the numerator, and the horizontal distance (run) is the denominator. The angle of slope in degrees is the angular difference that the inclined surface makes with the horizontal plane. The tangent of the slope angle is determined by dividing the vertical distance by the horizontal distance between the highest and lowest elevations of the inclined surface. The actual angle is found by using trigonometric tables. The percent of slope is the number of meters of elevation per 100 meters of horizontal distance. Slope information available to the analyst in degrees or ratio values may be converted to the percent of slope using a nomogram.

LANDFORM TYPE

B-19. Landforms are the physical expression of the land surface and are generally categorized into the following groups:

- Plains.
- Plateaus.
- Hills.
- Mountains.

B-20. Within each of these groups are surface features of a smaller size (flat lowlands, valleys). Each type results from the interaction of earth processes in a region with a given climate and rock conditions. A complete study of a landform includes determining its size, shape, arrangement, surface configuration, and relationship to the surrounding area. These landforms will include aspects of the major and minor surface features most commonly depicted on military maps and charts for tactical planning. Major features include hills, ridges, valleys, saddles, and depressions. While minor features include draws, spurs, and cliffs.

B-21. Subsurface configuration is the physical shape of terrain beneath the surface of the earth or a body of water and is not exposed at ground level. The most common are underground structures that can be natural or man-made. Geospatial engineering can assist in mapping possible underground facilities (tunnels, bunkers, sewer, water, and gas networks). See ATP 3-34.81 for additional information on the detection of subsurface structures.

SURFACE MATERIALS (SOILS)

B-22. Planners rely heavily on the results of surface material and soil analysis since variations in soil composition (soil type, drainage characteristics, and moisture content) can affect trafficability, road and airfield construction, and the ease of digging fighting positions in a specific area. Generating soil data normally requires extensive field sampling and the expertise of soil analysts. Once the data is acquired, geospatial engineers use it with standard geospatial products and imagery to create tailored geospatial products that enable the staff to further its analysis of the OE or specific AO and facilitate planning. The effectiveness of these products is directly related to the quality of available soil data. See TM 3-34.64/MCRP 3-17.7G for additional information.

B-23. For field identification and classification, soil is grouped into the following five major types:

- Gravel.
- Sand.
- Silt.
- Clay.
- Organic matter.

B-24. These soil types seldom exist separately. They are usually found in mixtures of various proportions, which contributes to their unique characteristics. Some soils may gain strength under traffic (compaction), while others lose it.

GRAVEL

B-25. Gravel consists of angular to rounded, bulky rock particles ranging in size from about 0.6–7.6 centimeters (1/4–3 inches) in diameter. It is classified as coarse or fine, well or poorly graded, and angular, flat, or rounded. Next to solid bedrock, well-graded and compacted gravel is the most stable natural foundation material. The weather has little or no effect on its trafficability. It offers excellent traction for tracked vehicles; however, if not mixed with other soil, the loose particles may roll under pressure, hampering the movement of wheeled vehicles.

SAND

B-26. Sand consists of angular or rounded rock grains that are 0.6 centimeters (1/4 inch) in diameter and smaller. Sand is classified as coarse, medium, or fine. Well-graded, angular sand is desirable for concrete aggregate and foundation material. It is easy to drain and ordinarily not affected by frost action or moisture. Analysts must be careful in distinguishing fine sand from silt. When sand is wet enough to become compacted or mixed with clay, it provides excellent trafficability. Very dry, loose sand is an obstacle to vehicles, especially on slopes. Under wet conditions, remoldable sands react to traffic, as do fine-grained soils.

SILT

B-27. Silt consists of soil- or rock-derived granular material with a grain size between sand and clay. It lacks plasticity and possesses little or no cohesion when dry. Because of its instability, water causes silt to become soft or to change to a quick condition (a hydraulic uplift phenomenon where water quickly saturates the material and reduces its cohesiveness and strength). When dry, silt provides excellent trafficability, although it is very dusty. However, silt absorbs water quickly and turns into a deep, soft mud (a quick condition) that impedes movement. When groundwater or seepage is present, silt exposed to frost action is subject to ice accumulation and consequent heaving.

CLAY

B-28. Clay generally consists of microscopic particles. Its plasticity and adhesiveness are excellent characteristics. Depending on mineral composition and the proportion of coarse grains, clays vary from lean (low plasticity) to fat (high plasticity). Many clays that are brittle or stiff in their undisturbed state become soft and plastic when worked. When thoroughly dry, clay provides a hard surface with excellent trafficability; however, it is seldom dry except in arid climates. It absorbs water very slowly but takes a long time to dry and is sticky and slippery. Slopes with a clay surface are difficult to maneuver or impassable, and deep ruts form rapidly on the ground. A combination of silt and clay makes a particularly poor surface when wet.

ORGANIC MATTER

B-29. Chemically deposited and organic sediments are classified based on the mode and source of sedimentation. Chemically deposited sediment affects how soil is characterized. Some soils (such as silt and sand) may have been chemically altered to bond the organic matter to create a dust-free layer on top of the normal soil composition. The identification of highly organic soil is relatively easy. It contains partially decayed grass, twigs, and leaves and has a characteristic dark brown to black color, a spongy feel, and a fibrous texture.

SOIL CLASSIFICATION

B-30. Geospatial engineers use the two-letter abbreviations established in the Unified Soil Classification System to describe soil. The primary letters identify the predominant soil fraction:

- G—gravel.
- S—sand.
- C—clay (used only with fine-grained soil with 50 percent fines or greater).
- M—silt.
- O—organic (loam).

B-31. The secondary letters further describe the characteristics of the predominant soil fraction. The percentage of gravel, sand, and fines provides the information necessary to choose the primary letter. The secondary letters are—

- W—well-graded (used to describe sands containing less than 12 percent fines).
- P—poorly graded.
- M—silty fines (used with sands and gravels containing less than 5 percent but more than or equal to 50 percent fines).
- C—clay-based fines.

- L—low compressibility (described as fine-grained soils [silts, clays, organics]).
- H—high compressibility.

Note. See TM 3-34.64/MCRP 3-17.7G, Soils, chapter 5, figure 5-10, soil textual classification chart on page 5-33; and table 5-7, soil classification system on page 5-36 thru 5-37 for detailed soil considerations for compactability and loam considerations across soil fractions.

VEGETATION

B-32. Geospatial engineers generate and analyze vegetation data and create geospatial products to show the effects of vegetation on vehicular and foot movements, landing zones, drop zones, observation, and cover and concealment. Thorough analysis of vegetation data continually increases terrain visualization and furthers the commanders' ability to understand and exploit terrain characteristics in the OE, enabling the main effort, supporting effort, and reserve.

B-33. Trees can provide good cover and concealment and impede movement and maneuver. Large trees are usually spaced far enough apart to allow for the passage of vehicles, but this gap is often filled with smaller trees or brush that must be considered. Small trees are usually spaced closer together and do not offer a gap for vehicles; however, large, tracked vehicles can push the trees over depending on the diameter. Trees that have been pushed over tend to pile up and can block follow-on vehicles.

B-34. Trees are classified as deciduous (broadleaf) or coniferous (evergreen). Except for species growing in tropical areas and a few in temperate climates, most broadleaf trees lose their leaves in the fall and become dormant until early spring. Coniferous trees do not normally lose their leaves or needles and exhibit only small seasonal changes. Woodlands or forests are classified according to their dominant type of tree. A forest is classified as deciduous or coniferous if it contains at least 60 percent of the designated species. Wooded areas that contain less than a 60 percent mixture of either species are classified as mixed forests. Shrubs include a variety of trees whose growth has been stunted due to soil or climatic conditions. Shrubs comprise the undergrowth in open forests but are the dominant vegetation in arid and semiarid areas. Shrubs are normally not considered an obstacle to movement and provide good concealment from ground observation; however, they may restrict fields of fire. For terrain analysis, grass exceeding 1 meter (3.28 feet) in height is considered tall and may provide concealment for dismounted troops. Grass can improve the trafficability of soils.

B-35. Field crops represent the predominant class of cultivated vegetation. The size of cultivated areas ranges from a paddy field covering a quarter of an acre to vast wheat fields extending for thousands of acres. In a concentrated agricultural area where all arable land is used for the crop producing the highest yield, predictions on the nature of the soil can be made based on information about the predominant crop. For example, rice requires fine-textured soils, while other crops generally depend on firm, well-drained land. An area containing orchards or plantations usually consists of rows of evenly spaced trees, showing evidence of planned planting, which can be distinguished in aerial imagery. These areas are usually free of underbrush and vines. Rice fields are flooded areas surrounded by low dikes or walls. Some crops (such as grain) improve the trafficability of soils, while others (such as vineyards) present a tangled maze of poles and wires and create obstacles to vehicles and dismounted troops. Wheeled and some tracked vehicles cannot cross flooded paddy fields, although the fields may be negotiated when drained and dry or frozen. Sown crops (wheat, barley, oats, rye) are grown on a flat surface and impact movement and concealment differently than crops planted in furrows.

OBSTACLES

B-36. Obstacles refer to any physical characteristics of the terrain that impede the mobility of a force. All obstacles are existing or are reinforcing. Existing obstacles are inherent aspects of the terrain and can be natural, man-made, or a combination. Examples of natural obstacles include rivers, forests, and steep slopes. Examples of man-made obstacles include buildings and structures. Reinforcing obstacles are specifically constructed, emplaced, or detonated by military forces and are categorized as tactical or protective. See ATP 3-90.8/MCTP 3-34B for additional information on reinforcing obstacles.

B-37. Obstacles can have varying degrees of impact on different types of movement, such as ground (mounted or dismounted) or air movement or on different types of vehicles (wheeled or tracked). Obstacles to air mobility include mountains, power lines, and tall buildings that exceed an aircraft service ceiling, restrict nap-of-the-earth flight, or force an aircraft to employ a particular flight profile. The obstacle analysis performed by geospatial engineers provides the foundation for further staff analysis of the effects of obstacles and assessing the operational impacts based on areas of expertise. As discussed in chapter 1, geospatial engineers describe the terrain to the staff using geospatial products (such as the combined obstacle overlay) that facilitate further staff analysis of the OE.

INFRASTRUCTURE (MAN-MADE FEATURES)

B-38. Infrastructure and man-made features generally exist near and between urban areas. The level of detail in describing man-made features depends on the mission and the level of planning. In support of urban operations at the lower tactical levels, geospatial engineers emphasize the three-dimensional nature of the topography (supersurface, surface, and subsurface areas). Advancements in automated geospatial applications, such as the Urban Tactical Planner developed by the AGC, provide more detailed geospatial information and better visualization of the urban environment. See ATP 3-06 for additional information on analyzing an urban environment.

B-39. Man-made features can be grouped into broad, functional categories to help organize the analysis results and describe the terrain. These functional areas include the following:

- Industrial areas.
- Transportation areas.
- Commercial and recreational areas.
- Residential areas.
- Communication areas.
- Governmental and institutional areas.
- Military areas.

INDUSTRIAL

B-40. Industrial areas and facilities extract, process, and produce intermediate and finished products or raw materials. Examples include factories, warehouses, power plants, and oil refineries. Manufacturing plants are categorized as heavy or medium to light. Heavy plants contain distinctive structures (such as blast furnaces), while medium and light plants are usually housed in loft buildings where machinery can be removed. Industrial areas often develop on the outskirts of urban areas where commercial transportation is easiest. These areas may provide ideal locations for sustainment bases and maintenance sites.

TRANSPORTATION

B-41. Transportation areas and facilities are used for moving materiel and people. Geospatial engineers evaluate transportation features (networks and facilities) to determine the effects on likely operations. This includes highways, railways, and waterways over which troops or supplies can be moved.

ROADS

B-42. ATP 3-34.81 provides additional information on road classification, road characteristics, and limiting factors considered during route reconnaissance. See figure B-2 for generic road characteristics. Road characteristics include—

- Minimum traveled-way width.
- Road surface material.
- Obstructions.
  - Bridges and culverts.
  - Overpasses.
  - Cuts and fills.

- Restrictions.
  - Grades.
  - Curves.
  - Load-bearing capacity.

B-43. Roads are categorized within the following (see table B-1):

- All-weather, dual, or divided highway.
- All-weather, hard surface.
- All-weather, loose surface.
- Fair-weather, loose surface.
- Car track.

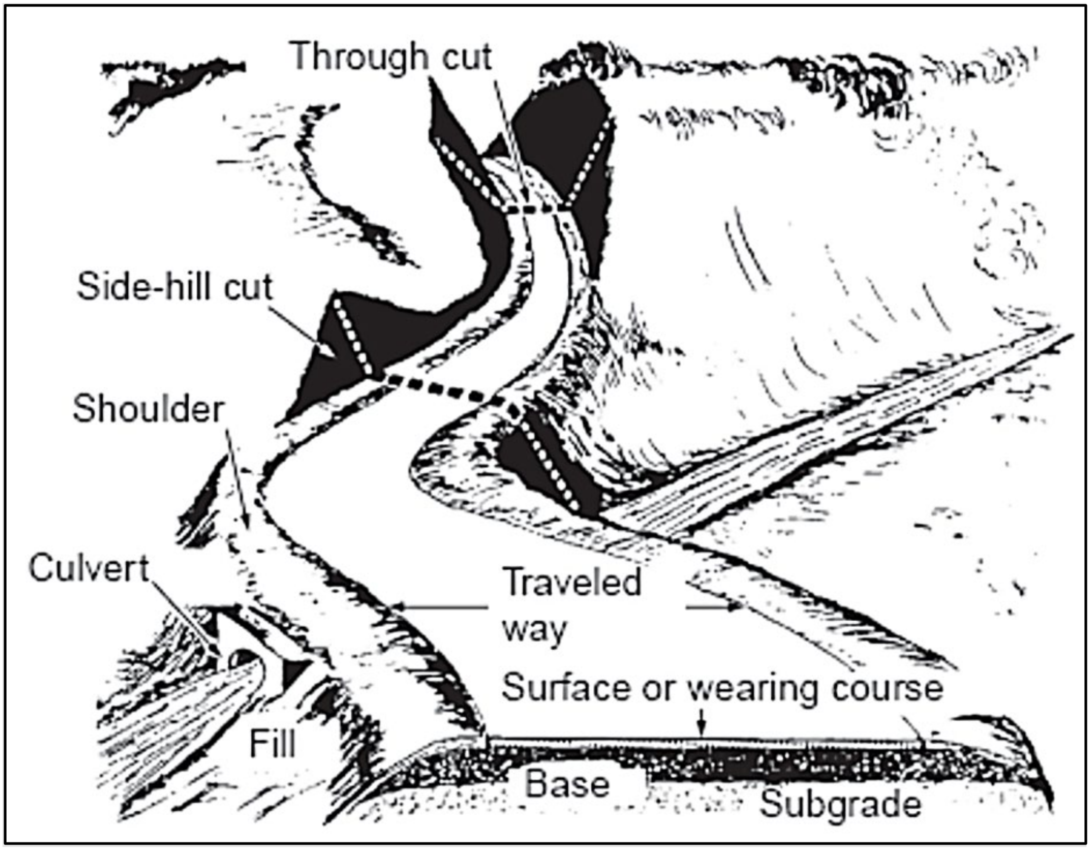

Figure B-2. Road characteristics

Table B-1. Road categories

Road Categories	***Description***
All-weather, dual, or divided highway	• Paved with concrete, bituminous surfacing, brick, or paving stone (waterproof surface). • Slightly affected by precipitation and temperature changes.
All-weather, hard surface	• Paved with concrete, bituminous surfacing, brick, or paving stone (waterproof surface). • Slightly affected by precipitation and temperature changes.

Table B-1. Road categories (continued)

Road Categories	*Description*
All-weather, loose surface	• Constructed of crushed rock, gravel, or smoothed earth with an oil coating. • Graded and drained, but not waterproof. • Considerably affected by rain, frost, or thaw and may collapse completely under heavy use during adverse weather conditions.
Fair-weather, loose surface	• Constructed of natural or stabilized soil, sand, clay, shell, cinders, or disintegrated granite or rock (includes logging roads, abandoned roads, and corduroy roads that can become quickly impassable in adverse weather).
Cart track	• Traveled natural pathways (includes caravan routes and winter roads that may become unable to accommodate four-wheeled military vehicles that are too narrow).

RAILWAYS

B-44. Railways can be highly desirable adjuncts to extended military operations. Railroads include all fixed property belonging to a line, such as land, permanent way, and facilities necessary for traffic movement and protection of the permanent way. This includes bridges, tunnels, and other structures. Railway analysis covers all physical characteristics and critical features of the existing system, including roadbed, ballast, track, rails, and horizontal and vertical alignment.

B-45. The gauge of a railroad is the distance between the rails. Railroad gauges are classified as wide, standard, or narrow. Wide gauges are 5 feet (1.5 meters) or wider and are mostly used by Russian, Finnish, and Spanish lines. Standard gauges are 4 feet, 8 1/2 inches (1.435 meters), used for main and branch lines in the rest of Europe and the United States. Narrow gauges are less than the standard gauge. Narrow gauges have limited use and are usually found in mountainous, industrial, logging, and coastal defense areas, mines, and supply dumps. In South and Central America, a 1-meter (3.28 feet) gauge is found in many places; however, many countries are now adopting the standard gauge because they import U.S.-made rolling stock.

B-46. Marshaling yards are used to sort freight cars. They are identified by a large group of parallel tracks with restricted (one- or two-track) entrances and exits called choke points. Service yards are normally found in or near marshaling yards and can be identified by the presence of roundhouses, turntables, service facilities, and car repair shops. Roundhouses are used for the light repair and storage of locomotives. The number of roof vents on top of the roundhouse indicates its capacity. Turntables are used for turning the engines around. Service facilities include coal towers, water towers, and coal piles. Car repair shops normally appear as long, low buildings straddling one or more tracks, with cars awaiting repairs on sidings adjacent to the buildings. Freight or loading yards are identified by loading platforms, freight stations, warehouses, and access to other means of transportation. Special loading stations are identified by grain elevators, coal and ore bins, oil storage tanks, and livestock pens with loading ramps.

B-47. Railheads are points of supply transfer from railroads to other forms of transportation and are generally found in small towns or cities where sidings and storage space already exist. Characteristics of a railhead include:

- Spurs and sidings from a main line.
- A road net (including narrow-gauge railroads) leading away from the area.
- Piles of materials stacked near the track trucks, wagons, or both (without order and organization into convoys or trains).
- Temporary dwellings (such as tents for housing troops guarding and handling supplies).

BRIDGES AND CULVERTS

B-48. All bridges present a potential restriction to traffic. Before using a bridge for military traffic, engineers must first determine if the bridge can safely support the loadings; for this purpose, the Army uses the military load classification (MLC) system. Several methods exist for determining a bridge's MLC, each with different degrees of complexity and accuracy. Important feature data include—

- Location.
- Type of gap being crossed.
- Overall length.
- Roadway width.
- Horizontal and vertical clearance.
- Military load classification (see note below).
- Number and length of spans.
- Type of span construction.
- Bypasses.

B-49. The common types of bridges are shown in figure B-3, page B-12. See ATP 3-34.81 for information on specific bridge characteristics used in determining bridge classification.

B-50. Culverts are grouped into the following four main categories:

- Pipe (most common).
- Box.
- Arch.
- Rail girder spans.

B-51. Culverts are usually of concrete construction, but corrugated metal and cast iron are also used. The pipes have different shapes and can range from 1 foot to several feet in diameter. Box culverts are used to a great extent in modern construction; they are rectangular in cross-section and usually made of concrete. A large box culvert is similar to a slab bridge. Arch culverts were used frequently in the past but are rarely constructed now; they are made of concrete, masonry, brick, or timber. Rail girder spans are found on lightly built railways or, in an emergency, on any line. The rails are laid side by side, keyed head to base, and may be used for spans of 3 meters (9.84 feet) or less.

Note. See TM 3-34.22/MCRP 3-17.1B, Military Nonstandard Fixed Bridging, chapter 3 [implements STANAG 2021 (Edition 5)], regarding military load classification (MLC) factors and determination methods.

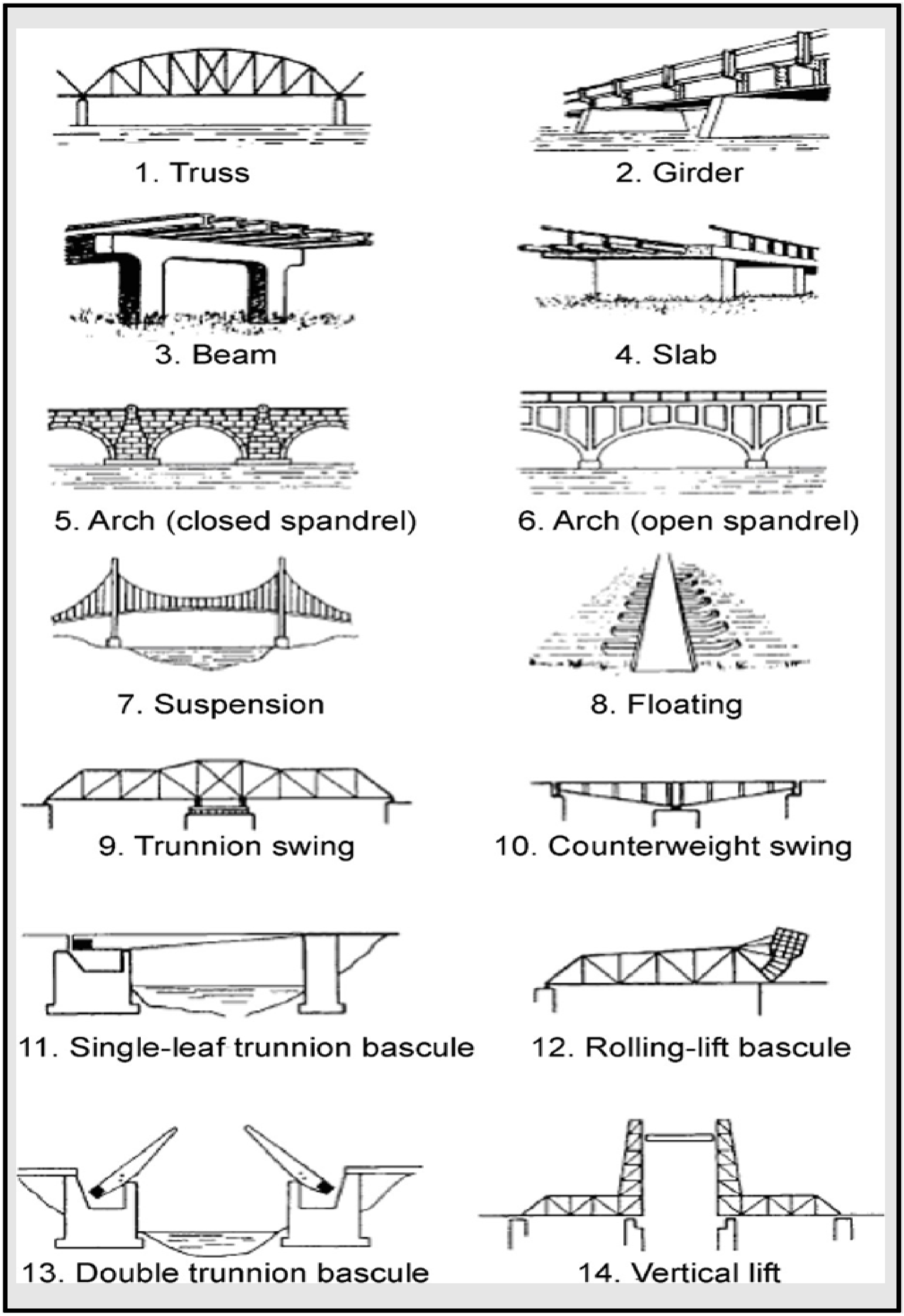

Figure B-3. Common types of bridges

TUNNELS

B-52. A tunnel is an artificially covered (such as a covered bridge) or underground section of a road alonga route. Important characteristics of tunnels include location, type, length, horizontal clearance, overhead clearance, alignment, and gradient. See ATP 3-34.81 for additional information on tunnel types and characteristics.

FERRIES

B-53. Ferries convey traffic and cargo across a water feature. These vessels vary widely in physical appearance and capacity depending on the depth, width, and current of the stream and on the characteristics of traffic to be moved. The capacity of a ferry boat is usually expressed in tons and the total number of passengers. The ferry boat is sometimes assigned a military load classification number. Climatic conditions have a marked effect on ferry conditions. Tide fluctuations, fog, ice, floods, and excessive dry spells can reduce the total traffic-moving capacity and increase the hazard of the water route. A ferry site is a place where ferries convey traffic and cargo. Important information about ferry sites includes the width and depth of the water barrier and the conditions of the approaches (such as clearance and load-bearing capacity). ATP 3-34.81 contains information on ferry reconnaissance and reporting.

FORDS

B-54. A ford is a shallow part of a body of water or wet gap that can be crossed without bridging, boats, ferries, or rafts. It is a location in a water barrier where the physical characteristics of current, bottom, and approaches permit the passage of personnel, vehicles, and other equipment where the wheels or tracks always remain in contact with the bottom. Fords are classified according to the crossing potential or trafficability for foot or wheeled and tracked vehicles. The ford stream bottom composition largely determines its trafficability. In some cases, the natural river bottom of a ford may have been improved to increase load-bearing capacity and to reduce the water depth. Improved fords may have gravel or concrete surfacing, layers of sandbags, metal screening or matting, or timber or wooden planking. The composition and slope of approaches to a ford also affect trafficability. Approaches may be paved with concrete or bituminous surface material, but they are usually unimproved and can be affected by inclement weather and vehicle traffic. Climatic conditions (seasonal floods, excessive dry seasons), current velocity, and debris presence are important factors in assessing stream fordability. ATP 3-34.81 contains information on ford reconnaissance and reporting.

B-55. Low-water bridges consist of two or more intermediate supports with concrete decking and are located entirely in ravines or gullies. During high-water periods, they are easily confused with paved fords because both are completely submerged. It is important to know the difference between this type of bridge and a paved ford because of corresponding military load limitations.

PIPELINES

B-56. Pipelines that carry petroleum and natural gas are an important mode of transportation, while rail, water, and road transportation are used extensively for transporting fluids and gases. The overland movement of petroleum and refined products is performed most economically and expeditiously by pipeline. Crude oil pipelines are used only to transport crude oil, while many refined product pipelines carry more than one product. These products are sent through the pipelines in tenders (or batches) to keep the amount of mixing to a minimum. Because of the vital link in the energy supply system of an industrialized country, coal and ore are also carried in pipelines as slurry.

B-57. Pipelines can exist above or below ground and may extend cross-country or follow the alignment of roads and railroads. When a pipeline crosses a stream or river, it is usually run along the stream bottom. Where streams are swift or beds may shift rapidly, the pipe can be attached to existing or special pipeline suspension bridges. Siphon crossings are used where necessary. When an increase or decrease of pressure is required, regulating features (pumps, compressors) are used. Pumping stations are used for liquid fuels, and compressor stations are used for gas. They are similar in appearance except for the cooling towers present at compressor stations.

B-58. Valves, manifolds, and meters are integral parts of any pipeline system and are located at frequent intervals along the pipeline and terminals. Valves protruding from the ground are often the only indicators of a pipeline alignment.

PORTS AND HARBORS

B-59. Ports are located along seacoasts, navigable rivers, or inland waterways where ships may discharge or receive cargo. Principal port facilities are berthing spaces, storage spaces, cargo-handling equipment, cargo transshipment facilities, and vessel-servicing facilities. Ports may have various structures affording berthing space or may be any place where a vessel can be produced more quickly. These structures include piers, moles, and wharves or quays. Piers project into the water at an angle with the shoreline and are supported by pilings driven into the harbor bottom. Moles are of solid construction. Wharves and quays are parallel to the shoreline, while piers and moles are perpendicular to it. Most landing structures are piers or wharves. The World Port Index (WPI) contains the location and physical characteristics of the facilities and services offered by major ports and terminals worldwide. Specific WPI entries can be retrieved from the online database through the NGAs Maritime Safety Information site at https://msi.nga.mil/Publications/WPI.

B-60. Harbors are areas where the anchorage and shore are protected from the sea and storms by natural or man-made barriers (seawalls, breakwaters, jetties, moles). Areas that do not have these protections but are still suitable for vessel anchorage are open anchorages or roadsteads. A good harbor consists of deep water, adequate protection from storms, enough space to accommodate many vessels and a shoreline that can be developed as a port and site for industry. Harbors may be situated on the sea, estuaries, or inland lakes and rivers.

B-61. Important factors concerning ports and harbors include water depth, bottom characteristics, tidal fluctuations, discharge volumes and river flow velocity, tidal and river currents, landmark locations, and underwater obstacle locations. Engineers, divers, and other specialists perform surveys to acquire basic information about the shoreline, water depth, bottom character, and existing structures (harbors, wharves). See TM 3-34.73 for additional information.

B-62. Dredging operations require detailed topographic and hydrographic surveys and data on tidal range, tidal prism, flood stages, velocity, and other hydrographic characteristics, including the status of siltation and scour. Other information requirements include data on bridges, breakwaters, jetties, piers, islands, overhead and submarine cables, and vessels (type and size) scheduled to use the waterway. See ATP 4-15 for additional information.

AIRFIELDS AND HELIPORTS

B-63. Airfields and heliports are classified by the degree of permanence and type of aircraft (fixed or rotary wing) they are designed to support. An airfield consists of runways, taxiways, and parking areas that may be permanent, temporary, or natural. A heliport is an area specifically designated and marked for helicopter landings and takeoffs. The surface of the pad may be natural, temporary, or permanent.

B-64. Runways are the most significant feature of an airfield. Detailed information concerning runways, taxiways, and parking areas is essential in properly evaluating airfield capabilities. The length, width, load-bearing capacity, and pavement condition influence the type and amount of traffic an airfield can accommodate. Taxiways are access paths to parking aprons, hangar aprons, and handstands or revetments. A parallel taxiway parallels the runway but is usually narrower. Under emergency conditions, it may be used as a runway; however, it should not be reported as a runway. Airfield capacity is described by stating the maximum number of aircraft on the ground, which is the maximum number of aircraft that can be accommodated on an airfield.

B-65. Geospatial engineers, intelligence analysts, and other specialists provide baseline information on available airfields and heliports in the operational area or specific AO based on a broad view early in the planning phase. As required, more specific information is generated from airfield assessments performed by engineer assessment teams or survey teams or because of reconnaissance operations.

COMMERCIAL AND RECREATIONAL

B-66. Commercial and recreational areas and buildings (shopping centers, parking lots, stadiums, sports fields) are where the major business and recreational activities occur in an urban area. Larger open areas (parking lots, sports fields) can serve as landing zones and artillery firing positions. Large, covered areas or areas with containment (stadiums, arenas) can provide locations for displaced civilians, interrogation centers, and detainee holding areas and collection points.

RESIDENTIAL

B-67. Residential areas and associated buildings, which can be found dispersed throughout an urban area, are where civilians live. Large, suburban areas (or sprawl) normally form on the outskirts. Residential areas often consist of row houses or single-family dwellings set in a grid or ringed pattern in a planned development project. Schools are often located throughout residential areas.

COMMUNICATION

B-68. Communication buildings and structures (such as communication towers) transmit information and data from place to place. They provide the means for operating telephone, radio, television, and computer systems.

GOVERNMENTAL AND INSTITUTIONAL

B-69. Governmental and institutional areas and facilities constitute the seat of legal, administrative, and other governmental functions or serve as public service institutions (universities, hospitals) for a country or political subdivision. This wide-ranging category includes embassies, universities, hospitals, police and fire stations, courthouses, and prisons.

MILITARY

B-70. Military areas and facilities are used for controlling, billeting, training, or transporting military forces. Fortifications and military installations may be found in or near urban areas worldwide.

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Appendix C

Army Geospatial Data Sources

This appendix is intended to provide geospatial engineers with a quick reference to primary authoritative Army geospatial data sources. These sources ensure that all warfighting functions have relevant, accessible, and scalable geospatial capabilities. GPCs and the U.S. Army Corps of Engineers AGC are at the heart of this endeavor. (See figure C-1, page C-3, for GPC global footprint.).

ARMY GEOSPATIAL CENTER

C-1. The AGC—located in Alexandria, Virginia—coordinates, integrates, and synchronizes geospatial information and standards across the Army; their mission statement reads, in part, "Deliver vital engineering solutions, in collaboration with our partners, to secure our Nation, energize our economy, and reduce disaster risk." A comprehensive list of all geospatial data types and data sources would be overwhelming; however, the AGC has links to important authoritative data sources associated with NGA, such as GRiD, Map of the World, Global Enhanced GEOINT Delivery (G-EGD), USGS, and AGC-hosted GPC sites. Geospatial engineers at all echelons are encouraged to become familiarized with the below sites hosted by AGC that provide vital repositories and request for information resources:

- Army Geospatial Center
- U.S. Army Map Resources (secret internet protocol router: www.maps.army.smil.mil)
- Joint Engineer Common Operating Picture
- Reach back Engineer Data Integration

ORDERING THROUGH AGC

C-2. AGC allows users access to its geospatial data and products via secure online repositories at AGC Ordering. It also gives users the capability of having that data physically shipped to their location using various interfaces: Standard Ordering Form, CMB Online, or DataDoors:

- AGC CAC Site – Online Data Direct Download
- CMB Online - Interactive Ordering
- USACE - AIP - Advanced Imagery Platform
- Historical Photographic Analysis Request Form

METHODS FOR PROVIDING FEEDBACK ON GI&S DATA SOURCES

C-3. AGC created the GEOFR and GEOIR to provide a means and mechanism for routing geospatial feedback to AGC for further dissemination to the appropriate GPC. Once the data is verified through the appropriate GPC, the data will then be added to the SSGF holding. Links to these reports can also be found in DAPAM 525-95. Completed GEOFR and GEOIR reports can be emailed to the AGC military support team for dissemination to the appropriate GPCs/GETs. Email reports to the AGC military support team.

- milSuite Geospatial Feature report (GEOFR)
- milSuite Geospatial Issue Report (GEOIR)

GEOSPATIAL PLANNING CELLS

C-4. See chapter 3, paragraph 3-26, for a description of the roles and responsibilities of geospatial planning cells. The links below may require common access card authentication and/or access request to access. Some GPCs host data on other networks, enclaves, and domains. Contact and coordination with GPCs for available geospatial data is highly encouraged to ensure shared knowledge across theaters. AGC-hosted GPC links can be found at U.S. Army Map Resources.

5TH GPC—USPACOM (USINDOPACOM)

C-5. Stationed at Fort Shafter, Hawaii, and supports the U.S. Pacific Command.

- NGA-hosted 5th GPC

132ND GPC—U.S. CENTRAL COMMAND.

C-6. Stationed at Shaw Air Force Base, South Carolina, and supports the U.S. Central Command.

60TH GPC—U.S. EUROPEAN-AFRICA COMMAND.

C-7. Stationed at U.S. Army Garrison Wiesbaden, Hesse, Germany, and supports the U.S. European-Africa Command.

517TH GPC—U.S. EUROPEAN-AFRICA COMMAND

C-8. Stationed at USAG Italy, Vicenza, Italy, and supports the U.S. European-Africa Command.

512TH GPC—U.S. SOUTHERN COMMAND

C-9. Stationed at Fort Sam Houston, Texas, and supports the U.S. Southern Command.

543RD GPC—U.S. NORTHERN COMMAND

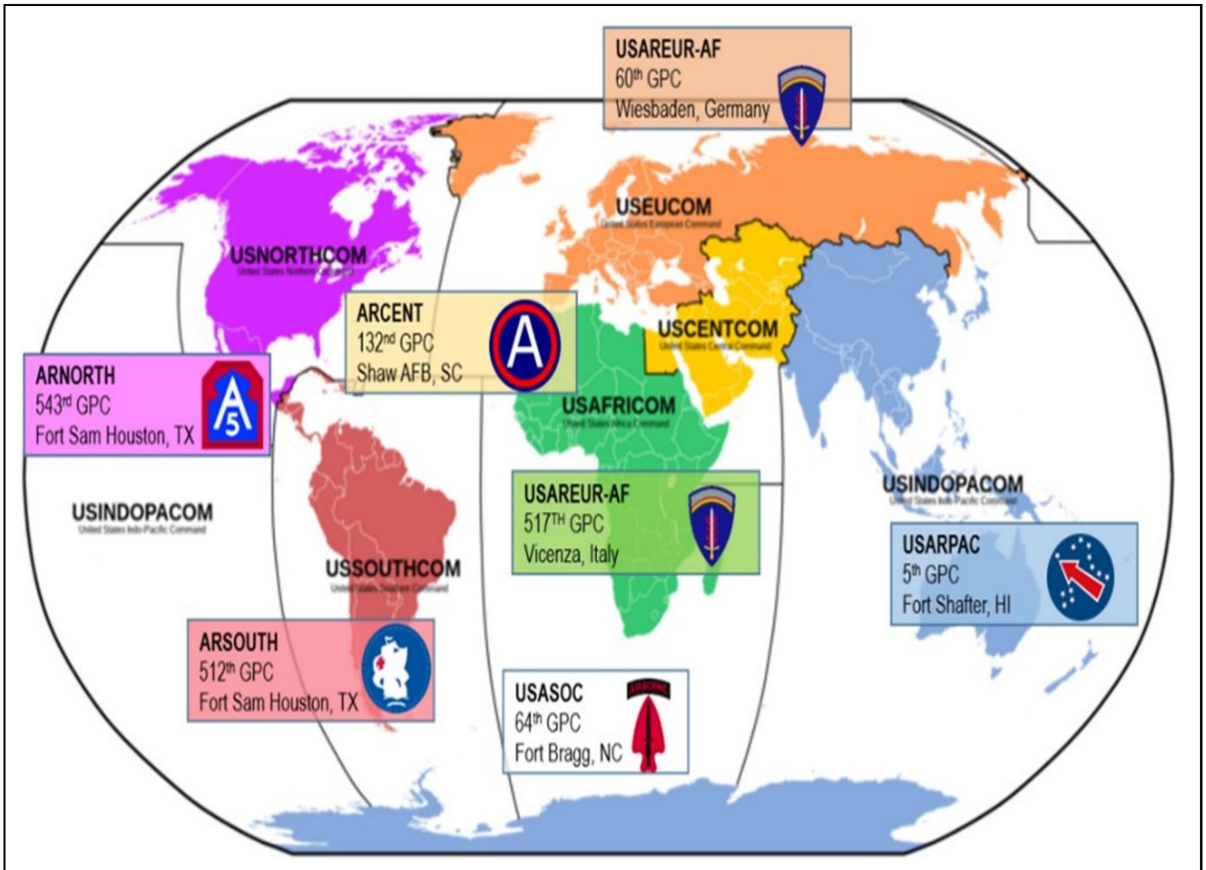
C-10. Stationed at Fort Sam Houston, Texas, and supports the U.S. Northern Command.

- Esri-hosted 543rd GPC

64TH GPC-USSOCOM

C-11. Stationed at Fort Bragg, North Carolina, and supports the U.S. Special Operations Command.

- Esri-hosted 64th GPC



Legend:

ARCENT	United States Army Central
ARNORTH	United States Army North
ARSOUTH	United States Army South
GPC	Geospatial Planning Cells
HI	Hawaii
NC	North Carolina
SC	South Carolina
TX	Texas
USAFRICOM	United States Africa Command
USAREUR-AF	United States Army Europe and Africa
USARPAC	United States Army Pacific
USASOC	United States Army Special Operations Command
USCENTCOM	United States Central Command
USEUCOM	United States European Command
USINDOPACOM	United States Indo-Pacific Command
USNORTHCOM	United States Northern Command
USSOUTHCOM	United States Southern Command

Figure C-1. GPC locator

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Glossary

The glossary lists acronyms and terms with Army or joint definitions. Terms for which ATP 3-34.80 is the proponent are marked with an asterisk (*).

SECTION I – ACRONYMS AND ABBREVIATIONS

ADM	Army Design Methodology
ADP	Army doctrine publication
AGC	Army Geospatial Center
AGE	Army Geospatial Center
AO	area of operations
AOR	area of responsibility
AR	Army regulation
ASCC	Army Service component command
ATP	Army Techniques Publication
C2	command and control
CBRN	chemical, biological, radiological, and nuclear
CCIR	commanders critical information requirements
COA	course of action
COE	common operating environment
COP	common operational picture
CPCE	command post computing environment
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
DA Form	Department of the Army Form
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
EEFI	essential elements of friendly information
FM	Field Manual
G-2	assistant chief of staff, intelligence
GD&I	geospatial data and information
GEOFR	geospatial feature reports
GEOINT	geospatial intelligence
GEOIR	geospatial issue reports
GET	geospatial engineering team
GGDM	ground-warfighter geospatial data model
GI	geospatial information
GIS	geospatial information systems

GI&S	geospatial information and services
GMAD	generate, manage, analyze, disseminate
GPC	geospatial planning cell
IPB	intelligence preparation of the battlefield
JP	Joint Publication
LiDAR	light detection and ranging
LOC	lines of communication
LOS	line of sight
MCE	mounted computing environment
MDMP	military decision-making process
NGA	National Geospatial-Intelligence Agency
NSG	National System for Geospatial Intelligence
OAKOC	obstacles, avenues of approach, key terrain, observations/fields of fire, cover/concealment
OE	operational environment
OIC	officer in charge
OPORD	operation order
SSGF	standard and shareable geospatial foundation
TC	training circular
TEC	Theater Engineer Command
TGD	theater geospatial database
TM	technical manual
U.S.	United States
USC	United States Code

SECTION II – TERMS

common operational picture

A display of relevant information within a commander's area of interest tailored to the user's requirements and based on common data and information shared by more than one command. (ADP 6-0)

***complex terrain**

A geographical area consisting of one or more of the following: an urban center larger than a village, or two or more types of restrictive terrain or environmental conditions occupying the same geographic location.

***geospatial data and information**

The geographic-referenced and tactical objects and events that support the unit mission, task, and purpose.

***geospatial decision aids**

Tailored geospatial products that support operational level planning processes and mission execution and provide commanders and their staff with an understanding of the physical environment.

***terrain analysis**

The study of the terrain's properties and how they change over time, with use, and under varying weather conditions.

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ATP 3-34.80

26 March 2024

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