GIS As An Assured Mobility Enabler

The informational tenet of assured mobility (develop the mobility Common Operating Picture) [1] is possible through effectively seeing, visualizing, and conversing over the measurable elements of geographic features such as roads, bridges, and buildings. But what are these information requirements for the purveyors of the mobility BOS, chiefly engineers and military police[2]? Who has final authority over the measurement and accuracy of these geographic feature attributes in the first place? Moreover, who are the terrain management, measurement, and maintenance stakeholders? Without tackling these issues, we will not see the necessary synergy between several seemingly disparate Army cultures: the sapper, the topographic engineer, and the military policeman.

The article that follows is the result of a CGSOC independent study between MAJ Jack Haefner (Corps of Engineers) and MAJ Ross Guieb (Military Police Corps). Our goals were to not only discover the finer points of our battlefield mobility responsibilities, but also to delineate responsibilities and visualize the terrain in a manner meaningful to our trades. Our purpose from the onset was not to propose a maneuver support generalist. Rather, we envisioned a complementary partnership between the maneuver and mobility support manager (military police) and the mobility enabler (engineer).

Problem Statement

There currently is no method or system for allowing users to view and analyze a common feature in a manner specific to their mobility discipline. In other words, how can practitioners of assured mobility (engineer and military police, for example) collaborate about, examine and analyze a common geographic feature but retain those attributes specific to their trade?

To approach this problem, we found several issues that must be addressed:

- What are our language (data) requirements?
- What data elements are currently defined by MILSPEC or STANAG? Exactly what does the engineer and MP need to know above and beyond the published standards?
- How do we organize our data?
- How do we exploit this data?
- What do we do with the data—how can others benefit from our data collection efforts?

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[1] FM 3-34 (Draft), page 4-36, 15 Feb 03

[2] Engineers and Military Police are not the “owners” of the mobility BOS. We deliberately limited our study to two individuals for the purpose of this study: one Engineer and one Military Policeman.

Developing a Common Language

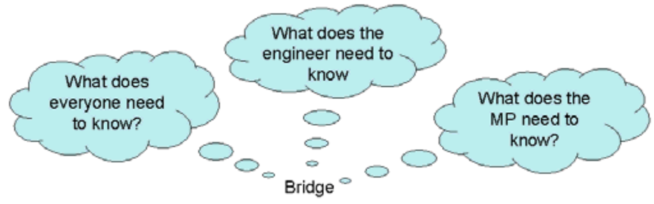


Figure 1. Common language requirements

Developing a common mobility language required a certain degree of restraint. Although our impulse was to break down every wall between the engineer and MP, we maintained our intent to not generalize the skills of each mobility stakeholder. In short, we wanted the solution to multiply the effects of our existing expertise, not replace them. We required that our solution built a Common Relevant Operational Picture (CROP): if it didn't synthesize data into a clearly understandable and meaningful picture specific to the engineer or military policeman (but not both), we would have missed the boat.

Our next step was to determine our data requirements[1]. Since our data would be rendered as vector data (a feature database of points, lines and polygons), we found reverse engineering to be most practical. We used one geographic feature for our study; we could easily apply our findings to other. Our example, a bridge point[2], suited our needs since it is a simple and prominent feature affecting mobility and has a particular—and differing—meaning to the MP and engineer. Again, what we learned can be extended to other features; a good starting point for all possible alternative features is a ubiquitous 1:50,000 TLM.

Although not nightstand reading, the NIMA Vector Product Format (VPF) MILSPEC family (VPF, DTOP, VMap, for instance) reiterated that VPF data will vary in attribute requirements by type: the fewest number of attributes stem from VMap 0 and VMap 1; the densest attributes will flow from DTOP. In addition, we found that the DTOP MILSPEC attributes for a bridge point covered a

Normalizing Data

Normalization reduces data space requirements by storing a simple and unique integer in the master (or primary) table and joining that "key" to a separate reference table. When inputting into the database, one designs the "look up" function so it is transparent to the user—only the definition is seen, but the integer (key) is stored. For example, if we had 300 bridges in our AOR, 200 of which were operational and 100 destroyed, we could store the words OPERATIONAL and DESTROYED 200 and 100 times respectively, but this would take space and be prone to errors.* Instead, we could normalize as follows: split the original table into two tables. In the first table (tblBridge), we would store only the integer key to the definitions in our second table. In the second table (tblExs), we would have two fields: the unique ID (existence) and the definition of that unique id. We would then populate the table with current DTOP definitions: 0 (UNKNOWN), 5 (UNDER CONSTRUCTION), 7 (DESTROYED), and 28 (OPERATIONAL). Thus, in our master table, we would only store the integer 1 or 2.

If populated with text, a query by bridge status would reveal every type: OPERATIONAL, DESTROYED, and all misspelled variants.

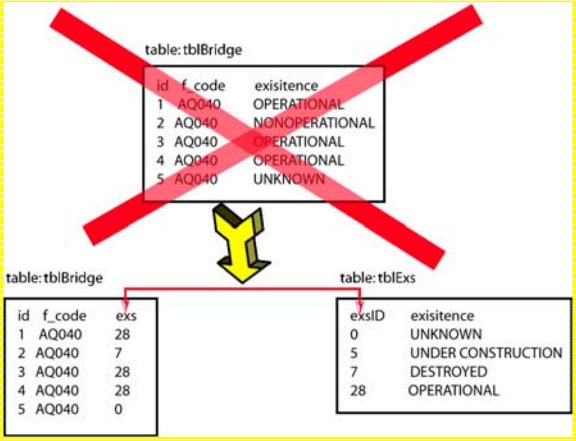


table: tblBridge

id	f_code	exisitence
1	AQ040	OPERATIONAL
2	AQ040	NONOPERATIONAL
3	AQ040	OPERATIONAL
4	AQ040	OPERATIONAL
5	AQ040	UNKNOWN

table: tblBridge

id	f_code	exs
1	AQ040	28
2	AQ040	7
3	AQ040	28
4	AQ040	28
5	AQ040	0

table: tblExs

exsID	exisitence
0	UNKNOWN
5	UNDER CONSTRUCTION
7	DESTROYED
28	OPERATIONAL

Figure 3. Data normalization

majority—but not all—of our information requirements (see Figure 2. Sample Attributes). To further enrich existing bridge attributes and meet our full requirements, we added the following to a separate database (see Figure 2. Sample Attributes[3]):

- Engineer:
  - Controlling authority (unit, command)
  - Mean flood stage (could be populated remotely, from ERDC (Engineer Research and Development Center) or other sources)
  - Photograph hyperlink (hyperlink to a file containing a recce photograph)
  - Abutment material (concrete, aggregate, etc?)
  - Abutment condition (good, cracked, etc)
  - Embankment slope (for adjacent bridging)
- MP:
  - Force Protection status (standoff from weapons system, overwatch, etc)
  - Last observation (date time group)

DTOP Attributes
- Row Identifier
- FACC Code*
- Bypass Condition Category
- Bridge Opening Type
- Bridge/Bridge Superstructure Type
- Existence Category
- Horizontal Clearance
- Identification Number
- Load Class Type 1
- Load Class Type 2
- Load Class Type 3
- Load Class Type 4
- Length/Diameter
- Material Composition Category
- Number of Spans
- Overhead Clearance Category
- Transportation Use Category
- Underbridge Clearance Category
- Minimum Traveled Way Width
- Width of Second Traveled Way
- Length of Greater Precision

Engineer Attributes
- Controlling authority
- Mean Flood stage
- Abutment Material
- Abutment Condition
- Embankment slope
- Hyperlink of photograph

MP Attributes
- Force Protection Status
- Force Protection Comment/Last Observation

* Feature and Attribute Coding Catalogue (FACC); coding scheme promulgated by the Digital Geographic Information Working Group (DGIWG) (www.digest.org)

Figure 2. Sample Attributes

Organizing the Data

Having considered several meaningful additional attributes, organizing and normalizing the data was required (see sidebar Figure 3. Data Normalization). Normalization greatly reduces the database size by minimizing redundancy. However, it must be noted that, although it is often preferable to normalize for space and bandwidth considerations, “joining the data” (i.e., linking between the key in the primary table and the related table), can have processing costs on the client side.

Our final model is shown in Figure 4. Final Data Model. Note we maintained all our DTOP attributes, even though few were populated. We did this based on access and data integrity of the original DTOP attributes. The efforts of those collecting the data could be forwarded higher at a later time, combined with existing attribute tables, and, perhaps ultimately replace the original erroneous values.

The GIS

The final step to harnessing this data and building our CROP was integration into a GIS. A GIS is essentially an interface for querying, analyzing and viewing spatial databases (i.e., databases with informational elements that can be tied to the surface of the earth). The power of a GIS is unlocked in its ability to analyze these features based on the attributes ("show me all bridges MLC 60 and higher") and their relationship to each other ("show me all primary routes passing over MLC 60 and below bridges).

Note that our data resides both locally and remotely (see Figure 4. Final Data Model). We stored our raster map background locally, but the bridge feature is being served from a map server (ArcIMS)[4]. The engineer and MP then relate their separate local database tables to the same collection of features. The bridge feature can then be symbolized based on the specific needs of either the engineer *or* the MP. In figure 5, the engineer has the bridge symbolized based on status; the MP has symbolized the bridge at based on FP status. Again, these are two different views at two different locations; the feature is served remotely over a secure Internet, but specific data required by the user resides locally. As long as there is a unique identifier for the record (id, for instance), we can build the connection.

Systems Integration

Unfortunately, current ABCS and MCS-L builds do not easily crosstalk with industry-standard geospatial data[5] without use of a DTSS Overlay Provider. In addition, MCS-L does not allow users to relate or join external user-defined databases to overlays. However, our solution could be easily integrated into future ABCS builds as well MCS-Engineer (under development). Our solution incorporated feature serving via ArcIMS and symbolization/analysis in ArcGIS. Since both the DTSS Map Server in future DTSS builds and C/JMTK will probably be reliant on ArcIMS technology, the DTSS Map Server could also function as a feature server. In addition, since MCS-Eng is essentially an ArcGIS extension, our symbolization methodology could function within MCS-Eng with little modification. Furthermore, other datasets such as non-NIMA data (locally procured data, data from Field Force Engineering , etc) could also be further enriched with our method.

What is so compelling about a GIS solution is both its potential for specificity but also its ability to reach across many seeming disparate disciplines. Although our solution was built with an eye towards mobility support, the principles we set forth could also be applied to other facets of engineering (construction, for instance) as well as non-engineering applications (transportation tracking via ArcIMS in USAREUR, for instance). In short, when we can tie a piece of information to the ground, it becomes geospatial information; anytime we can view and analyze physical placement and spatial relationships, we're on to something bigger.

Using Microsoft Access versus a larger enterprise database was only one possible solution. We endeavored to initially use tools on hand with little additional cost. Features could also be delivered over a network (using an enterprise or larger spatial database such as ArcSDE), but we felt serving with ArcIMS gave the designer needed control. If requirements balloon (remember, our development was for only one feature (bridges) in a very small area), migration to an enterprise database or spatial data server might be necessary.

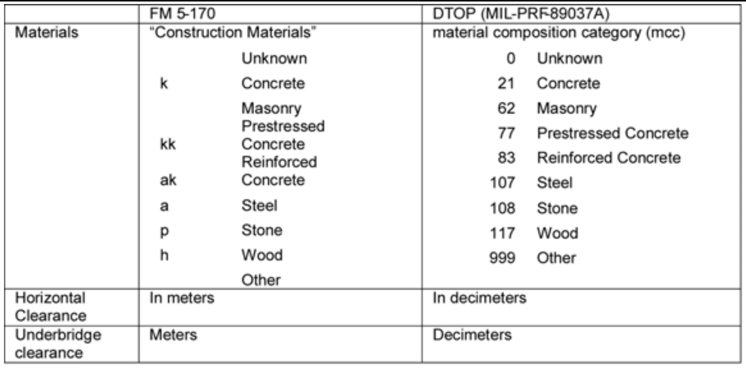
Challenges with This Solution Set

We identified the following challenges to this experiment:

Data simplicity is a constant battle. Any information system, including GIS, can quickly take on a life of its own. There is not one commander out there that wouldn't want to have absolutely complete information: 100% accurate and 100% of all possible attributes. Thus, standards need to be established (SOP or policy) on what to collect, when to collect it, and to what accuracy. As collection efforts increase, so does the data storage requirement and the need for skilled database managers.

Positional Accuracy. Changing positional information in a distributive environment is not only difficult, but also fraught with potential risks. Again, there needs to be standards promulgated regarding authority to make changes and QC of the same. By and large, positional information must be closely controlled. We envisioned ArcIMS feature serving to be an acceptable solution for this quandary.

Need to establish and train measurement standards. Note that the measurement standard for horizontal and under bridge measurement is in meters for the sapper and decimeters by DTOP MILSPEC (see Table 1. Bridge Data Inconsistencies). If users will potentially collect the data, they need to understand the standards.



	FM 5-170		DTOP (MIL-PRF-89037A)	
Materials	"Construction Materials"		material composition category (mcc)	
		Unknown	0	Unknown
	k	Concrete	21	Concrete
		Masonry	62	Masonry
	kk	Prestressed Concrete	77	Prestressed Concrete
	ak	Reinforced Concrete	83	Reinforced Concrete
	a	Steel	107	Steel
	p	Stone	108	Stone
	h	Wood	117	Wood
		Other	999	Other
Horizontal Clearance	In meters		In decimeters	
Underbridge clearance	Meters		Decimeters	

Table 1. Bridge Data Inconsistencies.

Data lifespan. Despite the efforts of the 81T Topographic Analyst, this data that may be greatly improved in theater will not find itself incorporated into NIMA databases. Although this may change in the future, a topographic engineer is not currently considered a "trusted source" for national-level data.

Who has the authority for feature measurement? It is not unrealistic to expect multiple parties to measure the MLC of a bridge. Consider that an MP may conduct a hasty recon initially, then a Cavalry Scout, then a detailed engineer recon, then a reach back assessment by WES. Do we capture all the metadata about each measurement (who, what, when, how, etc?). What about lifespan data of a bridge based on wear and tear, damage, etc? Who will have final authority over potentially contentious measurements? [6]

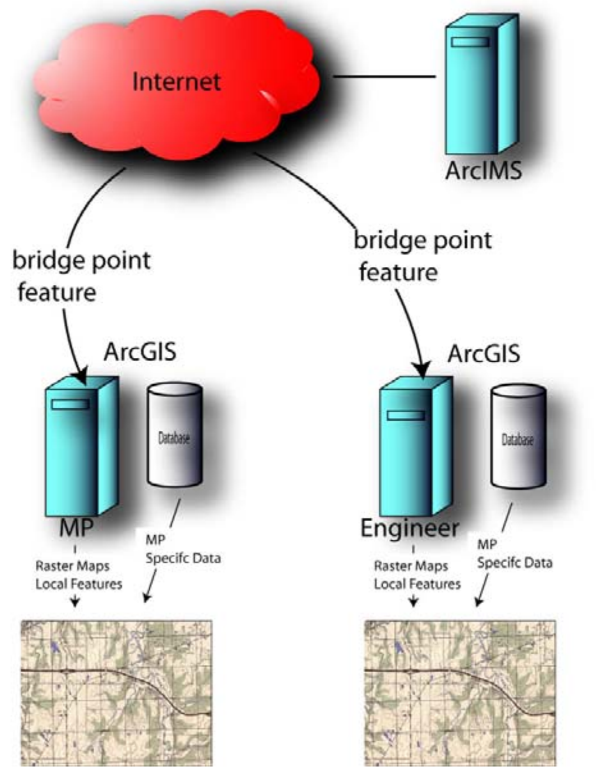


Figure 4. Final Data Model

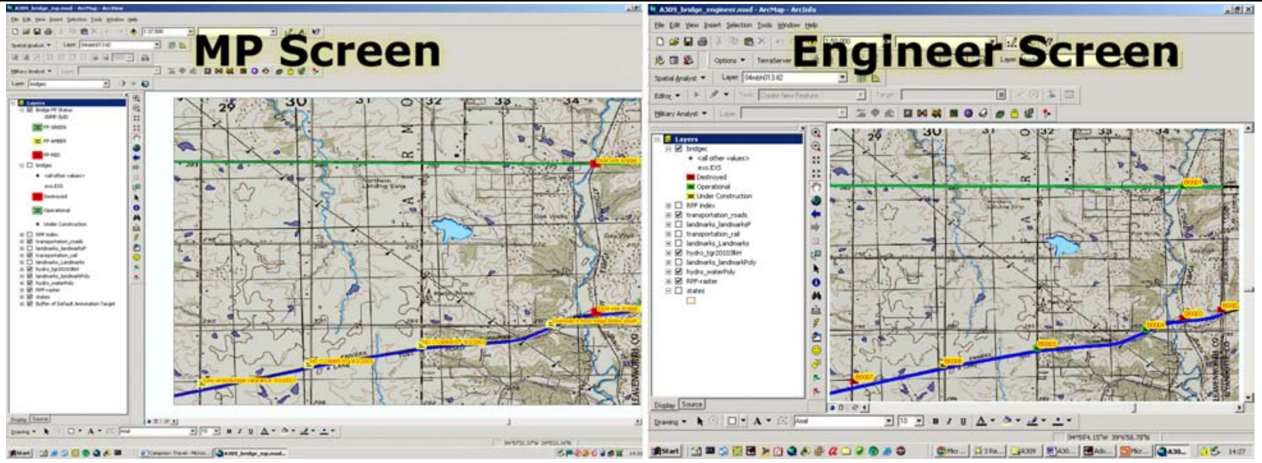


Figure 5**. Final Screens. Raster map background and vector data stored locally; bridge data served from Internet Mapping Server. Note that same bridge is rendered differently based on use: MP symbolizes bridges by force protection status; engineer symbolizes same bridge by operational status.**

Closing

Not until we develop a mutual understanding between the engineer and military police communities will we have assured mobility. Although we have proposed a new set of technological tools, the human dimension and principles of data sharing we have shown are solution non-specific. Building a mobility generalist is not the solution. Rather, if we do the soul-searching required to identify our data requirements and relate them to centrally controlled and served geographic features, we can effect positive outcome in all mobility operations (offense, defense, stability, and sustainment).

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[1] Incidental to research, we required a firm understanding of geospatial data (types, accuracy and datums) as well as relational database design. See "Enabling Situational Awareness With Geospatial Data: Engineers Allowing Commanders to 'See First, Act First, and Engage Decisively'", Army Engineer, March/April 2002.

[2] A bridge can be cartographically symbolized differently based on scale. At a large scale a bridge may be symbolized as a small line feature. At a small scale, it will be symbolized as a dimensionless point.

[3] There exists a gap between these required attributes and collection methods. Since many VPF products arrive to the customer with unpopulated (or dated) attributes, there needs to be a systematic approach to populating. If populated from national technical means they are either a) attributed by NIMA from an imagery source (not necessarily ground-truthed) or b) partially populated by the EAC topographic battalion or Division Terrain Team.

Since technical reconnaissance is an engineer task, current engineer forces can provide assistance to terrain teams to satisfy many of these requirements. What's more, much of this data is germane to current engineer operations, be it LOC analysis, construction estimates, etc. However, our research found few real-world examples of these data requirements being worked into the R&S plan (engineer technical recon assets notwithstanding). As a result, we identified several doctrinal and training shortfalls:

- Few of the above (useful) attributes are identified on DA Form 1249, Bridge Recon Form. In addition, several attributes do not match existing military specifications (see Figure 2. Sample Attributes).
- The only detailed description of measurement standards for structures is contained in FM 5-33, Terrain Analysis. These standards, although dated, may or may not be used by those outside of the topographic disciplines. Measurement methods and standards aren't identified in FM 5-170 or in MTP task books.

Timing of measurements is also of valid concern. The 50 different measurements of a single bridge may not be valid during OBSINTEL assessment, but it may be during MOOTW transition. Regardless, what happens to the initial limited measurements of a feature? The importance of these is not immediately relevant to initial combat operations in an AOR, but during transition to peace operations, they take on a life of their own.

Finally, one relatively untapped sector of engineer integration into the R&S Plan is using GIS to analyze

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the data culled from the collection matrix. The discipline of geostatistical analysis allows the GIS operator to develop models of trends and conditions.

[4] Note: A file server and a map server are not the same. A file server merely stores any data file for prescribed access. A map server delivers either a fully composited, dynamic map or the features (either individual or bundled as map services).

[5] For those unfamiliar with MCS-L, user defined overlays are possible and georefenced, but they do not integrate into other industry standard GIS packages. Data can be exported into XML files, but these would have to be translated back to an industry standard format such as ArcGIS Shapefiles (.shp) or MapInfo Files (.mif).

[6] If the engineer community captures this data, do they then assume an additional role of "manager of all TO structures?" Doctrine doesn't solely delineate responsibilities for objects directly relating to mobility and counter mobility (e.g., roads, bridges). A cursory review of doctrine and several division and corps SOPs yielded no practice for analyzing relationships between route status and bridges. In short, mobility assessments can often be nothing more than the DTO chairing a regular movement control meeting with the ADE/DIVENG, Provost Marshall, G2, G3, and DISCOM providing route information. Although human coordination is an essential battle rhythm event, it can be fraught with inaccuracies and falls short of building a COP.