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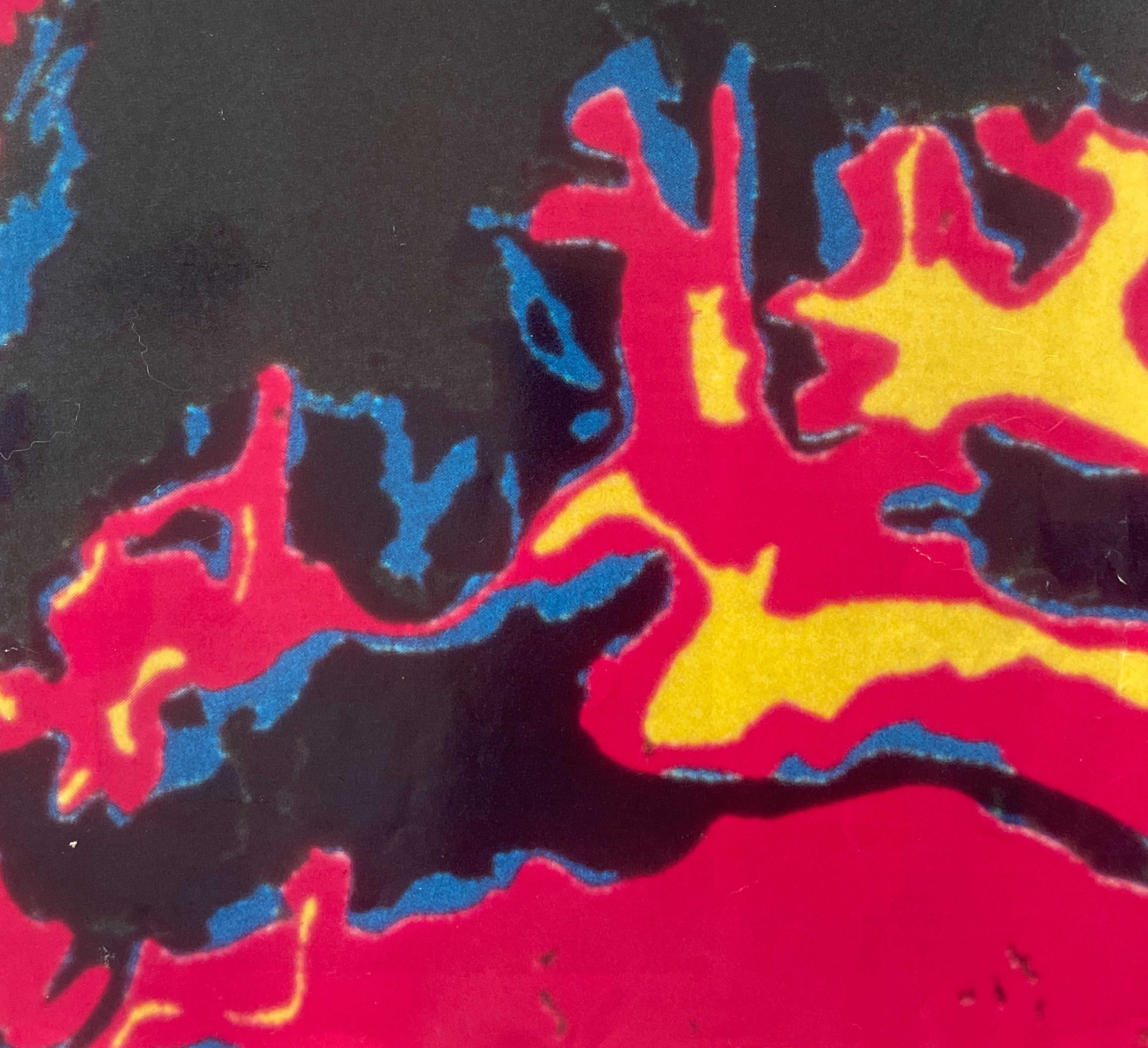

One of the largest geotechnical engineering projects ever undertaken could only be done with computers and some innovative management tools.

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ASSESSING THE WEST

Analyzing the geography, geology, flora and infrastructure in eight western states is a massive geotechnical project being undertaken for the military. But it is also producing benefits for civilians as immediate as notification of inadequate bridges and as long range as development of project management tools that are new to engineers.

The tools, all extensions of computer techniques, include computerized decision analysis, a multiple-layered geographic information system (GIS), statistical methods and rapid field characterization. They enable engineers to get a handle on one of history's largest geotechnical engineering projects.

So far more than 190,000 sq mi have been analyzed through research and field verification in the five year geotechnical and siting studies program being conducted for the United States Air Force by The Earth Technology Corp. The goal is to assist in identifying, characterizing and evaluating potential locations for deployment of intercontinental ballistic missile (ICBM) systems—underground storage, tractor/trailers, rail carriers and silos.

Because of the project's broad scope, its investigations range from subsurface geology to questions of road and bridge capabilities; dynamic loading; on- and off-road vehicle mobility; in situ soils testing and land use analyses for facilities siting. A companion program is studying the country's entire railway network. While the science and engineering are not revolutionary, the ways in which they are being applied often are. The immensity alone has demanded the development of well-coordinated and flexible project management.

The siting program targets the most favorable deployment areas, often with simultaneous investigations in several different states. The studies progress from broad regions to site specific analyses. Each phase typically reduces the overall area of investigation while increasing the level of detail.

In the first phase, area verification studies examined 22 potential locations and 190,000 sq mi. The second phase shifted to six locations and 55,000 sq mi. In the current phase, site characterization studies are developing detailed analyses of land use and infrastructure data on two possible locations covering 45,000 sq mi. This analysis is necessary to draft preliminary plans for layout of new or upgraded facilities.

In the Advanced ICBM Program, the candidate sites are existing military installations; planners must assess their missions, personnel and facilities and capacities to absorb a new mission. Also evaluated are the natural, legal and socio-cultural environments of each installation and its surrounding area.

Field work has been conducted in major portions of Arizona, New Mexico, Texas, Wyoming, Colorado, Nebraska and Montana. Its parameters have been shaped by some extraordinary considerations. In one possible basing mode—the tractor/trailer—the proposed vehicle is twice the length of a standard tractor/trailer, weighs about 200,000 lb and must be able to retract its wheels and anchor itself into the ground. This raises unique questions about vehicle mobility and soil strength.

Instruments on truck speed fieldwork in rough terrain; engineers use laptops and modem to relay data back to headquarters.

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The challenge of size is compounded by the need to manage a constantly moving target. Many of the program's elements are still under design or subject to change from a number of sources, including the Air Force, other defense contractors, various regulatory agencies and Congress. Engineering teams must coordinate with local Air Force officials and regulators during the permit process and field work.

QUANTIFYING RISKS

The framework for managing this project took considerable thought and effort to design. Its major elements include decision analysis, a geographic information system (GIS) and a technique called rapid field characterization.

Decision analysis allows ranking of seemingly unrelated factors before deciding how to proceed. It replaces more subjective analyses with statistical methods of quantifying and comparing risks. A computer helps score the collected data; sophisticated formulas help quantify the uncertainty in field measurements—an issue of concern to all civil engineers.

An example is determining the ideal desert areas for the tractor/trailer to travel. Among the issues to be considered are the geology, soils, slope and potential for flooding. One expert in mobility may rank slope as having greater importance than geology. Another expert may disagree. These individual assessments can be combined, compared and assigned the appropriate weight by using a computer, substituting what once might have been a pure judgment call with a mathematical system of setting priorities and determining risk. Quantifying this procedure not only provides reproducible results, but allows the engineer the opportunity to assess the effects of changing priorities.

Decision analysis is used extensively by the military and is gaining increasing acceptance by civil engineers for projects such as dams and power plants. Its importance will only increase as society becomes more and more risk oriented. Data collection supports the process.

The Geographic Information System (GIS) used in the Air Force's ICBM program is the technology's largest application to date. The software integrates multiple topical maps so that the Air Force can study the impact of various siting considerations at once. As many as 12 to 13 geographic considerations—each of those already representing any number of combined data sets—may be run simultaneously and weighted to obtain selective answers. Work that might take weeks or months by hand takes the computer days or even hours.

The layers currently built into the GIS include population centers, environment, roads, bridges and culverts, Air Force policy constraints, cost, soils, terrain, flood plains, land use and travel distances—all gathered from aerial photographs, field studies and published sources. Once these are assigned weights using, in part, the statistical methods which help pinpoint variables, the data can be translated into siting decision maps. The weights can be changed, or new factors introduced at any time and another map will be produced.

Rapid field characterization methods developed by Earth Technology researchers have taken existing technology a step further than many conventional testing methods, which are too slow for a project encompassing such vast territories. To meet the need, a hydraulically operated miniature cone penetrometer and a companion soil sampler were designed for this job. They are mounted on the back of a standard pickup truck and field crews use lap-top computers to send test results to headquarters via modem.

Another sophisticated measurement technique, spectral analysis of surface waves, was developed by researchers at the University of Texas, Austin. It establishes profiles of soil stiffness near the surface and may prove valuable for pavement assessment. Project engineers are looking into developing other new tools, including a nonradioactive in situ moisture measurement system using penetrometer probes.

In addition to using statistics to extrapolate data from a small to a large scale, project engineers are employing thermal modeling and evaluating the effectiveness of existing soil moisture models, essential in determining what happens to soil over time. This work may redefine models for agriculture, hazardous waste and cold regions.

INFRASTRUCTURE DATA

Other agencies have benefited from the enormous database assembled for the Air Force studies. Field engineers have reported bridge conditions to local, state and FHWA officials, spurring action in many cases. The road and bridge questions being examined are common to civil engineering and include the quantification of road characteristics, road to off-road transitions and bridge load capacities, along with assessment of off-road terrain. A primary focus is predicting road behavior under maximum loading.

A more unusual challenge is the study of dynamic loading. At stake is assessing how well a vehicle will meet its performance objectives in a launch or blast environment, where the loads will have varying rates, magnitudes and directions. Characterizing the shear strength of the most variable part of the soil is a difficult and atypical engineering problem, compounded by the need to conduct tests in all types of climate conditions. Most engineering projects have the luxury of scraping off the upper 6 in. of earth to establish a strong foundation; not so in this scenario. The engineer must work with this soil, plants, roots and all.

While the field work being conducted may eventually yield new data or new testing methods, it's what can't be seen in this project that may have the most lasting impact: the broad scale application of innovative project management tools such as decision analysis, statistics, GIS and rapid field characterization. These valuable tools can bring greater speed, accuracy and flexibility to any project, whatever its size.

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