TECHNICAL AND LOGISTICAL ISSUES IN MOBILE MAPPING IMPLEMENTATIONS

Mr. Jamie Ritchie, City of Phoenix Water Services Department, in conjunction with

Mr. Randal Rios, City of Phoenix Water Services Department;

Mr. Thomas Dollente, Spacient Technologies, Inc.; and

Ms. Maria Delgado, Spacient Technologies, Inc.

June 25, 2004

ABSTRACT

For the last two years, the City of Phoenix Water Services Department (WSD) had been involved in a mobile mapping project for its field services personnel. While political, cultural, and financial issues will always be part of any software implementation, the technical and logistical challenges of actually deploying a system are greatly increased when dealing with mapping systems for mobile users. This presentation highlights some logistical and technical focal points in a mobile mapping implementation. Integration teams must balance attention to the mobile devices, mobile operating systems, mobile middleware, physical appurtenances, networks (both terrestrial and wireless), databases, applications (GIS and others), and support/maintenance. The WSD implementation will serve as a case study. Their project used ESRI products and other technologies to satisfy the mobile mapping needs of more than 450 field users. Members of different technical groups from the project will provide insight from various perspectives.

INTRODUCTION

The purpose of this paper is to introduce concepts involved in mobile mapping system implementations for field services personal. The Mobile Application Program Solution (MAPS) project underway for the last two years at the City of Phoenix Water Services Department (WSD) will serve as a case study to highlight the issues and approaches for such projects.

Anyone attempting an information system project probably understands many of the risks and rewards inherent in those projects, but mobile computing introduces many unique issues. The inclusion of mapping information further amplifies those issues. Examples of these new issues include the geographical dispersion of the user base, the relative lack of experience that field users will have with computing, resistance to change that is especially strong in field operations groups, the technical adolescence of many mobile and wireless technologies, and the lack of a stable support structure for mobile systems.

The City of Phoenix provides a model case for the implementation of mobile mapping information systems to a large utility field organization. Phoenix is the sixth largest city in the US and the fastest growing over the last decade. This explosive growth has been accompanied by the rapid development of supporting water distribution and wastewater collection infrastructure. WSD currently serves an estimated population of 1.3 million people over a service area of 521 square miles.

The City's Water Service Department has a mission to become the "Best of Class" utility and is focused on maintaining a high quality, reliable infrastructure helping to satisfy its prime objective of excellent customer service. The project outlined in this paper, named the Mobile Applications Program Solution, or MAPS, involved extensive investigation into field operations work practices and data sources including mapping systems. The project began with intense analysis of the field operations, then development of a business case with real world return-on-investment (ROI) figures, and finally the design and implementation of a mobile computing solution to support the more than 450 field personnel in the City's combined Water Distribution and Wastewater Collection Divisions (WD/WC).

The City of Phoenix retained CH2M Hill and Spacient Technologies, Inc. (SPACIENT) to develop the functional specification and deliver an enterprise mobile GIS and field computing system for WD/WC. The overall objective of the MAPS project is to deliver and record essential data and information, in electronic form, for distribution and collection field service crews to enhance customer service and to improve operational efficiency.

WHAT ARE THE CHALLENGES?

The overall vision for many organizations contemplating or pursuing mobile mapping solutions for their field employees is usually related to improving efficiencies and customer service. Since most field organizations have such large potential for advancements in many areas, an organized approach is useful in order that high value features are pursued first. Additionally, the visibility of mobile mapping implementations (including the high cost) will immediately put the project under the spotlight.

Challenges in mobile mapping projects fall into three broad categories:

- **General Information System Project Challenges**: All IT projects have challenges. The consequences for a mobile mapping implementation in ignoring such basic issues are no less fatal than for any other project.
- **Mobile Computing Challenges**: As soon as field employees and mobile computers are combined, new challenges emerge with which that few organizations have had to contend.
- **Mapping Challenges in a Mobile Environment**: Lastly, the issues of sending mapping data to the mobile environment add another layer of complexity, danger, and benefits to the entire project.

General Information System Projects Challenges

Entire conferences have been and should be dedicated to this topic; this paper will not attempt to re-introduce the considerable literature and experience available to our industry. Instead, we'll highlight just two issues that stand out for mobile mapping projects:

- Strong project sponsorship and leadership are critical for the success of any information system project, but they are absolutely essential for a project as ambitious as mobile mapping. The long-term nature of the implementation needed to reduce risks in other areas, increases the chances that sponsors and leaders lose focus or just plain tire.
- The group leading the project effort should have substantial experience in crucial three areas: 1) utility technology projects, 2) mobile system implementations, and 3) GIS concepts, technologies, and technical approaches. Because all three of these areas provide competing and sometimes conflicting challenges, experience in identifying and prioritizing issues in your project is essential.

Mobile Computing Challenges

It's reasonably valuable during a mobile computing project to ask, "What is mobile computing and what does it mean to our project?" The following are different topics that tend to emerge for each and every mobile computing project for field operations users at utilities.

Note that we have highlighted "utility field operations" in this paper rather just simply "mobile computing users". The nature of the user base and their work environment is important to include in the analysis. As such, mobile users such as field engineers are less well represented in this paper.

- Distributed Reporting Locations for Field Users
  - WD/WC has 16 organizational groups reporting to 12 separate geographical locations. Additionally, touching organizations such as the mapping maintenance group and the customer services division are in still other locations. For a large utility, these are reasonable numbers. Users in such large organizations may be dispersed over a city, county, and often over several states.
  - Getting the data there and back is complex. Since many utilities do not have high numbers of users in field locations that have demanded high network bandwidth, those locations are often under-built with respect to networks.
  - Often, physical separation can also mean process separation. Culturally and organizationally, separate field locations can easily evolve into different processes whether formally or informally. Each yard can be a fiefdom of sorts and, since promotion to the leadership position of that location is usually a long term and final posting, there is lots of time to get established into a singular culture and process set. Field computing solutions break down those geographical barriers and also provide more visibility to upper management about how the operation is run on a detailed level. If a mobile computing solution is implemented without consideration to these sensitivities, surprising resistance may occur.
- Field Office Buildings
  - Regardless of whether they are dispersed (Spacient has worked with at least two organizations where field employees are indeed not dispersed), the actual structures used by the field forces are typically commensurate with the outdoor nature of their business. The buildings tend to be dirtier, older, and maintained at a lower level than the office employee counterparts. Network cabling and physical ports may not be adequate to support a mobile computing environment. Even power capacity and outlets can be challenges.
- Nomadic, Disconnected Computers
  - The goal of mobile computing – to un-tether the information system user from an immobile, dedicated computing paradigm – is also a prime source of problems. The word "paradigm" causes chagrin to some from its overuse during the Internet revolution, but it is appropriate in this context. Computing in general has grown up and matured in an environment where the computers were reasonably stationary. Even when notebooks came into heavy use, they tended to be used by only one person. With mobile computing, the devices are non-stationary and sometimes accessed by multiple users. Information technology underwent a large paradigm shift when personal computers

overtook mainframe access as the favored information access point in the late 80's.

- Many of the characteristics of computer systems and networks once taken for granted, are no longer true of mobile systems. The devices may be in use and in motion for a majority of the day. Most are built with a higher percentage of proprietary components and subsystems than standard computing equipment due to the demanding nature of their operating environments. Hardware failure rates are far higher than with standard workstations.
- Anti-virus systems have evolved quickly over the last few years, but are generally not configured to address the unique nature of the mobile field user community. Many centrally administered anti-virus systems work on a time window basis whereby a computer is updated at certain time windows on a regular basis. Updates to virus definition files can only be performed when the computer is online. In the case of the MAPS implementation, computers were on the network as little as 2 minutes per day. The application had been configured to anticipate low bandwidth connections and the need for field users to get away from the yard office as quickly as possible in order to deliver on ROI estimates. This fast and infrequent connection to the network invalidated some of the core assumptions about anti-virus systems. The issue was brought to light during the virus attached of August 2003 when virus mutations surfaced every few days. WD/WC has medium term solutions in place, but those will need to reassessed and modified as the computing and connectivity profile of the mobile devices undergoes planned changes in late 2004 and 2005.

- Computer Literacy of User-base
  - Many users do not have fluency in computers (although many do, we have a couple crew leaders that are close to attaining their bachelors degrees in computer science in part-time programs.) Some users have difficulty writing in English. Often this lack of computer literacy is cited in the fear of user rejection.
- Human User Interface Components
  - Human User Interface Components is a convoluted problems way of saying that the users need to generally use their eyes and hands to interact with a mobile computing system. For many of the users who are long term field workers, years and years of outdoor work (as well as just plain aging) has degraded their eyesight. Similarly, manual work tends to wear on the hands so manual dexterity using small implements such as keyboards or styli may not be at the level of a typical office user. Just selecting a key on a keyboard can be challenging.
- Aggressive Environment
  - Temperatures in Phoenix can exceed 120 degrees F in the summer. Surveys performed in 2002 in fleet vehicles in actual working conditions indicate that

temperatures can many times exceed 140 degrees F in parked trucks. The devices that we use are mounted in a location of maximum temperature, near the dashboard.

    - Dust is a pervasive issue in Phoenix regardless of the season. Failures of mobile hardware can rarely be traced directly to dust, but with all the expansion and communication ports on devices there are plenty of places for dust and grit to get into the devices.

- Vibration
    - Devices mounted in vehicles literally take a terrible pounding. While mounting is great for usability and security, it comes at a cost of almost constant vibration, especially in large construction trucks and vactors.

- Security
    - This topic includes security of hardware (devices will get stolen or lost) and data. It truly deserves its own paper. The industry approaches to security of mobile devices with the power of 21st century technologies are still adolescent.
    - Wireless networks open up security holes that do not exist with physically connected devices or fully disconnected devices. In the grander scheme of technology, computing is 40 years old; notebooks are 15 years old, the web, as we know it is effectively 10 years old, wireless data networks are only 5 years old at best. Security is a large issue with the wireless industry and advances are coming quickly[1].

- Emergency Operations
    - No matter where we work on this earth, natural disasters are inevitabilities. Utility managers can actually be held criminally liable for running their operations with disregard for the inevitable loss of connectivity or access to data centers. Nothing is bomb-proof (this phrase is, unfortunately, not simply a figure of speech anymore, but now a literal consideration.) Providing lifeline services to our communities puts us in a higher tier of obligation with respect to our choice of field computing technologies.

- Information Explosion
    - The lack of information systems in the field is not a static condition. All of us have been privy to a remarkable wave of enabling technology and a commensurate demand from our management to increase workforce efficiencies. More information is being pushed to all corners of a utility, this includes the field operations. But with such a push from many directions, even an experienced computer user with full time access to a computer would find the multiple systems and their interfaces mind-boggling. Even a single application, designed and developed with office users in mind, is risky to

[1] As an example, the day before the submission deadline for this paper, the IETF formally approved the 802.11i specifications, which directly address the substantial security concerns with early WiFi network specifications.

deploy to field users since the information density of office applications is generally way too high for field users. This leads to end-user acceptance issues.

    - Parallel information system projects rarely intersect conveniently. They have different milestones, budgeting sources, and business drivers. Yet mobile applications typically leverage multiple other information systems, many of which are in flux. The problem of coordinating integration of those systems to a coherent set of information to field users is daunting and a major risk factor for mobile implementations.

- End User Acceptance
    - At the inception of many projects, including the MAPS project, the number one risk is considered non-technical; it is the danger of rejection by the field users. Field users are often resistant to change, in a semi-antagonistic position with respect to management, and unionized.
    - Whether by outstanding management of the project or by underestimation of other issues, end user acceptance has not turned out to be the bane of field automation projects in Phoenix WSD or other utilities. Aggressive change enablement activities (a topic for another paper entirely!) are relatively inexpensive and provide high returns on investment. Instead, the number one issue facing mobile field computing implementations has been…
- System Support
    - Rarely are utility field operations organizations supported to the level required by mobile solutions. Most of the time, only a handful of persons and computers exist before mobile technology is introduced; afterward more than half of the organization’s employees can be primary users. Utilities do not usually have the staff positions to support the applications effectively.
    - The support that does exist is usually inexperienced in the type of support that must be provided to a mobile computing solution. Disconnected computers used by employees with wide ranges of computer literacy, often with no access to phones, working during all hours of the day and night – all these are typically foreign issues to a typical support team. Many support applications are built with core assumptions that are not valid for field organizations. For those who are familiar with your support systems, how many of those software packages assume that the person is available by phone or e-mail? How many assume that the computer is used by one and only one person?

Mapping Challenges in a Mobile Environment

Now let’s add in consideration of the mapping information being carried throughout the mobile system. It is useful to categorize all information to be referenced or created in the system. Some candidates for a mobile solution at a utility are:

- Facility schematics and construction details,
- Asset details (including maintenance schedules and histories),
- Operations information (e.g. SCADA output, work orders, forms),
- Employee information (HR),
- Stock, materials, and equipment information,
- Real-time location information (e.g. AVL), and of course
- Mapping information

This paper will focus on the effect that mapping information has on the overall mobile computing system, but as we'll discuss later, these other information categories will most likely be major component of the eventual solution. With the inclusion of mapping and location information, many of the mobile computing issues discussed above are amplified, some drastically.

- Distributed Reporting Centers
    - The mass of data distributed over wireless or even shaky wired connections can bring a system to its knees or put it in a position comparable to molasses in winter. The application and the entire system must be tolerant of slim and unreliable bandwidths. The data transmission engines and protocols must be able to accept failures and provide re-transmission options.
    - Mapping data must be segmented into the smallest packets possible. ESRI's SDE architecture has been a boon to the mobile computing industry attempting to distribute mapping information, but there's still a long way to go in understanding how to deal with only partial updates to mapping information.
    - Not everyone needs all the information from maps all the time. This is true also of updates to the organization's mapping data. A person staffed in the northern district of a utility will probably not need mapping information about the southern district. But there may be persons who, over the course of a day or other short period, may in fact need data from various operating districts. A mobile application must first acknowledge the varying needs of users and devices with respect to mapping data, then provide a prioritization scheme that addresses the variation in as efficient and simple a manner as possible. Having said that, it's very difficult to first model the needs and then configure a system to service them effectively.
- Computer Literacy of User Base
    - The concepts used in GIS mapping such as layers, iconography, object attributes, etc. add another level of complexity to any application. While maps are a concept that can bring familiarity of an information system to a relatively inexperienced field user, the actual implementation of technology needed to provide maps can reintroduce confusion and anxiety to the environment.

  - Mapping information updates requires consumption of a precious commodity – time. Field users are often unwilling to tolerate the increase in time required to distribute mapping information over slow or unreliable networks.

- Human Interface Components
  - Once mapping is introduced to a field-computing concept, the options for device types and appurtenances reduce significantly. One of the major components to be considered is the device screen. For mapping to be utilized as a core component of the system, the screen must be large and vibrant enough to be viewed in multiple environments. These are generally:
    - In the office. Many computers will be used in an office environment either for work planning, training, group/crew meetings, etc. Some computer screens fare quite poorly in this seemingly benign environment.
    - In the vehicle. The actual condition is bright, indirect light. This is a difficult environment because transflective technologies depend on direct light. System powered technologies have difficulty in generating enough brightness and contrast because, although indirect, the light can be bright.
    - Out of the vehicle. The specific condition is bright, direct light. Out of the vehicle in shade would perform similar to in the vehicle in shade.
    - In the dark. The simplest of conditions for a screen, issues of darkness get transported to other interface elements such as the keyboard (can the users see the keys? They usually don't type by touch so they need to see the letters on the keys.)
  - Manipulating map elements is a more complex set of actions than a simple interface such as a web page can provide. Office users are used to zooming to a convenient scale (for a large, bright screen), selecting one or more map objects, and having a myriad of actions that can be performed on those objects. Such complexity is not successful for field users, who are sometimes using systems while wearing work gloves! One user of the MAPS system even indicated that he preferred to be standing outside his truck and leaning through an open driver-side window to view maps on a mobile device mounted in the center of the cab. Such contortions are not uncommon and responsible application developers and implementers must be able to deliver systems that conform to these new usage patterns.

- Security
  - When mapping is included as part of a mobile field computing solution, the security issues are heightened. The data being delivered to the field person through maps are some of the most telling data stores owned by a utility.
  - A choice must be made on whether the field user needs a wide set of data or a more restricted set. Restriction has two major drawbacks:

        - The data that is deployed in the restricted set is still sensitive. Restriction does not actually reduce the amount of effort or expense needed to secure an organization's asset information. In fact, it definitely increases it.
        - Due to current work roles and the tendency to reduce field force staffing levels, less people are being hired to perform more work. That means that a person (or device) may be called to interact with a wide set of information rather than the restricted one. Redeploying mapping data to handle the new need can be time consuming and cumbersome.

- Information Explosion
    - While mobile mapping typically delivers high value as a stand-alone system, the benefits multiply when the mapping information is integrated with operations information. The promise of the resulting integrated mapping system is too compelling to bypass. The question is then how to manage the information explosion so that field utility workers can leverage the combined data/information/knowledge of the organization's IT systems without reaching information overload.
- System Support
    - As soon as any location-based information is added to a mobile computing environment, the demands on support staff increase. The field users, being experts in the interpretation of maps, have heavy demands from any application that effectively removes their paper maps from circulation.
    - While many technical approaches exit to simplify the presentation of information to field users (e.g. web interfaces, lower information density, straightforward interface design) such answers are more difficult to come by for mapping information. Maps have been designed by mankind to convey a large set of information in a convenient shorthand method. Breaking some of the mapping constructs established over the past few millenniums is not an easy task. Therefore, the complexity and power of maps is usually retained. The entire information supply chain, starting with the system developers and finishing with the system support team, will invariably pay the price to deliver the mapping concept to field users in an non-diluted fashion.

A special issue that deserves to be separated for careful consideration is a general information system/project concept that is largely magnified by its perspective for a mobile mapping implementation. The issue is the concept of data ownership and delegation.

- Data Ownership
    - For any mapping project, the question should be asked as soon as possible, "Who owns the mapping data?" Some people may choose to shortcut the question by telling you who owns the GIS system. This is not the same thing! Even the owner of the GIS system rarely owns all the data within it. A utility may have it's own GIS implementation, but invariably some data is controlled

by other entities. For instance, the parcel dimensions and attributes are most likely owned and controlled by the county. The local utility simply uses that information for its own purposes. A better way to phrase the ownership question is, “Who is the final authority on the mapping data?” Of course, there may be more than one answer and therein lies part of the criticality of asking the question.

- Closely related to the ownership question is, “How is authority granted to other entities for accessing the data and presenting it outside the confines of the GIS application?” This is a question that can be more germane to mobile projects than the GIS system. This is because, in the past, much of the access to the mapping data was controlled by the GIS application and the data tended to be pulled directly from the GIS system and then ported quickly back. Mobile mapping systems break this paradigm down quickly. After their implementation, hundreds of separate copies of GIS information can move throughout the organization (and even outside it) with no real-time reference back to the GIS authority.
- What happens when the field user believes the data is wrong? Error identification and correction processes will exist at any organization that hosts mapping information. With the implementation of a mobile mapping system, such questions become more timely. The information flow from the mapping system to the end user back to the mapping system can accelerate to speeds not before imagined.

ANSWERING THE CHALLENGES

In this paper, we shall address the challenges posed above and their possible solutions in the context of the MAPS implementation at the City of Phoenix Water Services Department. While still underway as of mid-2004, the project has already established approaches for mitigating many of the risks involved in mobile mapping implementations.

In this section the authors offer a caveat. We believe it is difficult to be told what to seek out and what to avoid in a mobile mapping implementation. To some extent, the experiences and lessons learned of such a journey are non-transferable. But here are a few concepts to keep in mind as you enter the exciting, dangerous, and astonishingly promising world of mobile mapping.

Who is the Authority on the Utility Assets?

There are several possible answers to the question – GIS, paper maps, surveyor field books, etc. One option exists that is, unfortunately often "chosen" – there is no consistent, agreed up, widely advertised, and supported authority. Many systems can believe that they are most important and users of the information decide what they want to decide. This occurs often with "personalized maps" of field employees who write notes about assets on their paper maps, but who never follow the processes to inform the rest of the organization about their observations.

The question is a trick question of sorts. Invariably, there are different aspects to asset information – location, maintenance requirements, customer relationships, etc. – that infer that multiple systems may be authorities on any particular asset. Mobile mapping solutions must unabashedly answer this question with respect to where the system will sit on the authority scale.

At the inception of the MAPS project, the entire team was instructed, without equivocation, that the WSD GIS was the final authority on all asset location information. Not withstanding the other data carried in the GIS (such as the previously mentioned example of parcel information), that single statement avoided a lot of problems on the project. However, the issue we face on our project is that of proxies or systems that may have some authority regarding asset location delegated to them.

To illustrate the role of delegates or proxies to the authority, let's use a real example from the City of Phoenix. MAPS carries mapping information to the field and users may comment on missing or incorrect information that needs assessing and changing on the GIS system. For instance, during a recent water distribution line break, a new valve was inserted to an existing mainline. The field user identified the new valve and the location. Immediately, that information is available to all users of the mobile mapping system. If another crew rolls out the next day to do more work at that site, they will be able to see all the information from the previous day and how it relates to other map items. Yet, the maintenance management system must resolve the creation of at least two new assets, the valve itself and the two line segments created when a heretofore single line was cut. Both the mobile system and the CMMS must agree on how to treat the new field data. Who provides the asset ID's for the new assets? Has the initial report of the emergency repair been properly QA'd? What level of accuracy can be assumed by the means of measurements provided through the mobile system? The list of questions and issues can quickly become dizzying.

A good mobile system, especially one that includes mapping features, will place quality tags on every information item so that users can have perspective on the quality and timeliness of that data. So while the data may not yet be approved by a foreman or supervisor and while the mapping team has yet to confirm the data reported, the organization still has some indication that new data is being finalized. Secondarily, a good mobile system will provide conflict resolution for field information with respect to isolating the conflicts and resolving them so that data can be passed effectively to authoritative systems. MAPS does exactly that, allowing all users to see the data held in process while assigning the conflict items to individuals or groups that have the means to resolve the conflicts.

Cast a Wide Net During Conceptualization

While the system may be conceived as an immediate application of maps to the field user, the entire mobile computing platform will quickly be a magnet for a myriad of information solutions. This can be a good thing since 1) it creates support for your implementation across a broad-based group, 2) mapping concepts can drive the presentation of other typically non-mapping information such as human resources (HR) information, and 3) attainment of ROI goals will be easier with wider distribution of systems.

MAPS was conceived as a mobile field-computing platform to carry GIS and CMMS data to and from the field. At the beginning of the project, however, the team envisioned a project that could grow to cover other systems and define a field-computing standard for the entire WSD. Regardless of whether that happens or not, avenues to larger distribution of the system have been considered and are part of the expandability requirements of the system.

Maintain Focus the Benefits

Another paper regarding the ROI for the MAPS project is being presented at this ESRI 2004 User Conference. The implication for the technical and logistical aspects of the MAPS project is that there is always a guide to answering the puzzling questions that come up during the project.

MAPS was conceived as a phased project. From late 2002 to mid 2004, eight separate rollouts have occurred, introducing new users and functionality at each rollout. Invariably, there is competition for which system features to include in the next rollout. Using the ROI study, those features were easier to isolate and justify.

KISS for the Field Users

Keep It Simple Stupid. It's a mantra as old as the information technology industry itself. For field mapping applications, it's essential. Many of the challenges discussed earlier in this paper can be answered with KISS. Of particular importance is keeping the user interface as simple as possible, even if functional richness needs to be sacrificed.

On the MAPS project, we choose an interface that provides the highest chance for providing a simple interface, a web browser. While many of our users are far from being computer experts, it's also true that many have had at least some contact with computing. In many cases, our field users have had previous experience with the Internet and the World Wide Web. Aside from being familiar, that interface necessitates a reduction of complexity on the screen. While custom programming can create more sophisticated screen objects, the MAPS application avoids such sophistication. For initial rollout, we've chosen to leave tool bars and address bars on screen even though they add little or no functional value. The value they do add is a familiar setting for our new users. Once the system is fully deployed across the entire organization, we can slowly retire those training wheels. But the MAPS system should never fully abandon the KISS concept.

As part of that concept, we strive to limit the number of user interfaces that our field employees have to learn to one - MAPS only. All information that is required by our field users shall be ported through the MAPS interface. This greatly decreases training time for new features since the user is already comfortable with their interface. In addition, we can filter out unnecessary or low-value information that can effectively clog the screen.

It's a Mobile Project So Stay Mobile

The interpretation of this concept can be rephrased as "Keep the project going." If the recommendation to cast a wide net for conceptualization has been followed, there can be a sense that not all the pieces are in place to begin a mobile mapping project. There are plenty of reasons to see a landscape of imperfect conditions that may warrant waiting, but those will never go away. Some will be resolved, but others will rise to take their place. The fact is that most utility field environments are rife with dangers and difficulties for mobile mapping implementations. But also true is that so much potential exists for improvement in the organization, that some benefits can be attained almost immediately.

As stated earlier, the MAPS project is being pursued in a heavily phased approach. That concept has allowed us to capture the easiest and largest benefits very close to the beginning of the project. Other profound benefits still await us, but they are more complex and difficult. For instance, MAPS conceived as a mobile mapping and maintenance management interface. Nevertheless, the very first feature unveiled in the system and rolled out the field users addressed neither of those aspects. Instead, the elimination of paperwork was identified as an enormous waste of time and money within our organization, so we automated a form that every person uses everyday at least one time. Some users utilize that form more than ten times per day. Later, we added basic mapping targeted at the easiest mapping features that delivered the most value.

At the same time as we prioritized the benefits that may be delivered to MAPS users, we experienced delays in the implementation of our CMMS system. While integrating to the CMMS continues to be a prime business driver, we did not stop the project simply because an interfacing system was not ready. Plenty of other high value features may be implemented in the meantime.

In the end, we recommend that mobile projects take on the personalities mobile systems and field operations organizations, "Get the job done to the best of your ability and then get on to the next job."

This is Not Your Father's IT System

Simply raising the issues from the **Mobile Computing Challenges** section of this paper hints at the solutions that must follow. The following were and are some of our largest challenges:

- The device must fit the use. Some organizations have effectively deployed SPACIENT's Fieldport® solution (the core product upon which MAPS was built) using off-the-shelf, consumer-oriented technology such Handspring devices or non-hardened laptops. While those hardware choices proved to be effective, the Phoenix environment is one of the most demanding in the nation, due particularly to the heat and airborne particulates[2]. We chose only those devices that met military specifications. Yet we still experience device failures, but are confident that the rate has been minimized to as low as possible for our environment.
- Select the correct device, but always be on the lookout for changes. In order to follow this guideline, your application must support multiple types of devices and even multiple mobile operating systems. Also, the procurement process must support the attainment of new types of devices and new vendors. The MAPS project started out with devices from two manufacturers, but one has been shown to be ineffective for our usage profiles. We are in the process of evaluating other vendors and devices to keep our options open. Dependence on a single vendor holds risks that we have chosen not to take.
- For mobile computing solutions in a utility field organization, pay particular attention to all links in the information supply chain. Weak links in the chain may occur at the wide area network, local area network in old buildings, wireless networks (especially in high EMF areas or in subterranean facilities), truck mounts, and GPS antennae are all examples of things that, if taken for granted, can delay an implementation. We performed a thorough audit of our existing technical environment, yet still experienced numerous issues throughout the implementation.
- Some argue that the utility field employee user base is as unique as you'll find in the information systems industry[3]. Yet, we found that with proper attention to both the organization as a whole as well as individual users, we were able to generate substantial support for the system once deployed. In our initial assessment, the team identified individuals who might have the most confusion and difficulty with computers. Those persons were discretely introduced to computing concepts and even their mobile computers before their colleagues and were continually monitored for progress after their activation on MAPS. Many people who had been initially identified as "probable problem users" have instead ended up being shining examples of a successful mobile mapping user. They also are useful as motivation to other users, "If Bob can learn to run this thing, anyone can!"

---

[2] Other environmental factors are important as well, such as the movement of devices from an air conditioned environment to severe heat and back as well as the atmospheric moisture combined with heat which we experience during our monsoon season of late summer.

[3] Medical doctors are possibly the only users who clearly surpass utility field employees in unique challenges as computing system users.

- Be ready to be disconnected at any time. Even with attention and upgrading of the network, we continue to consider options in MAPS whereby individuals or entire groups may be disconnected for long periods of time. During our monsoon season, very high winds, intense rain, flooding, and widespread power outages are common. If any of our mobile users are burdened with an information system that demands connectivity in order to be effective, we have failed to provide a sufficiently robust system. When connection is made, MAPS prioritizes the data stream such that a sudden loss of connectivity will have as little effect on employee effectiveness as possible.

Support is King

A largest issue that emerged at the beginning of the project and continues to be problematic is user support. Before MAPS, our division supported just over 60 users of information technology services; by the end of the MAPS rollout, we expect that number to easily rise to more than 400. Clearly, the technology support presence needed to increase.

Yet the scale of the issue is even greater than one might expect from just the user count. These users work on shifts that are different from our typical support teams. Crews arrive at their reporting locations as early as 5:30 AM and are gone before 7:00 AM. Operations are 24x7 so that weekends and nights now have numerous MAPS users. Staffing a support organization to cover all these users to equal service levels is challenging.

Added to the schedule complexity is the mobile nature of the hardware and software. Currently we support more than 150 database instances, but can only touch (even with our remote management tools) a handful at any one time. Others are stored in backup mode at each location waiting for the inevitable catastrophic failure of a field device, yet they are difficult to update and maintain. The problem of anti-virus distribution has been detailed earlier in this paper, but other such issues continue to vex our small support team.

Lastly, the nature, sophistication, and personalities of our end users require a high level of face-time from our support team. While it’s impossible to be on a first name basis with each user, it sure is handy when you are on the radio with a field user who is trying to explain exactly the problem he is experiencing on his device.

In the end, the ability for users to feel comfortable and happy in using their system is almost always directly proportional to the overall success of the system, so the support team is closely tied to that end.

THE MAPS MOBILE SOLUTION

It should be recognized that not all desired functionality could be immediately implemented and that different features will require very different levels of investment and implementation time frames. During the first phase of the project existing hardware, communications, and software systems within the WD/WWC divisions were reviewed in the context of the project. These have an important impact on the implementation sequence since aspects of all three components are necessary as building blocks for particular elements of functionality. The key components of the MAPS system that was ultimately delivered were:

Hardware

The selection of mobile computing devices for the MAPS system required rigorous evaluation of hardware due to the climate and operating conditions, and the known fact that many projects fail due to unreliable or poorly performing mobile devices. For MAPS, two ruggedized mobile computing device manufacturers that best met the requirements of WSD field crews, MicroSlate and Panasonic Toughbook. Additionally, each device was delivered with built-in GPS and wireless capabilities for WiFi and/or wireless data services.

Mobile Application Software

MAPS was designed using Fieldport® mobile GIS and field computing software from SPACIENT, a web-based application that works with the ESRI ArcGIS platform. The software has functionality for system administration, field workflow, work orders, paper work and forms, mobile GIS mapping, timekeeping and management performance reporting.

System Integration Application (EAI)

During the project, WSD also commissioned development of an enterprise integration software application (EAI) that will ultimately provide a common interface to many of the software applications in the department. This should ease the MAPS integration effort, since a common portal can be integrated rather than a number of disparate applications. However, this project is in the initial phases and the sequence and timing of development has not yet been defined.

ESRI GIS

Migration of WSD's ESRI GIS to the geodatabase structure of Version 8 precluded early integration. This situation was further complicated by the planned release of ESRI's Version 9 in 2004, which is expected to include some functionality that would be significantly beneficial to the MAPS project. Therefore, initial mobile GIS functionality focused on delivery of water/wastewater quarter section maps, followed by ESRI ArcGIS 9 integration.

Hansen CMMS

The implementation of the Hansen CMMS was delayed and integration with MAPS may be superseded by the enterprise integration platform development described above.

Arizona BlueStake

Arizona Bluestake has implemented a web-based locating service that is currently being tested. This new system provides improved functionality for both requestors and locators and will ultimately be integrated within the MAPS system.

Yard Infrastructure

Maintenance yards are inevitably aggressive working environments and issues regarding intranet connectivity, work station space and power outlets had to be addressed at several yards prior to implementation of the MAPS system. However, these efforts were less demanding in some yards than others and this was one of the drivers in determining the sequence of roll out to the yards.

Each of these could have been perceived to present an obstacle to implementing a mobile computing system. However, in this project the approach has been to identify valuable functionality that could be achieved immediately and implement that rather than wait for other systems to be completed. In retrospect, this approach has been extremely beneficial allowing early adoption of mobile technology and incremental training of the staff.

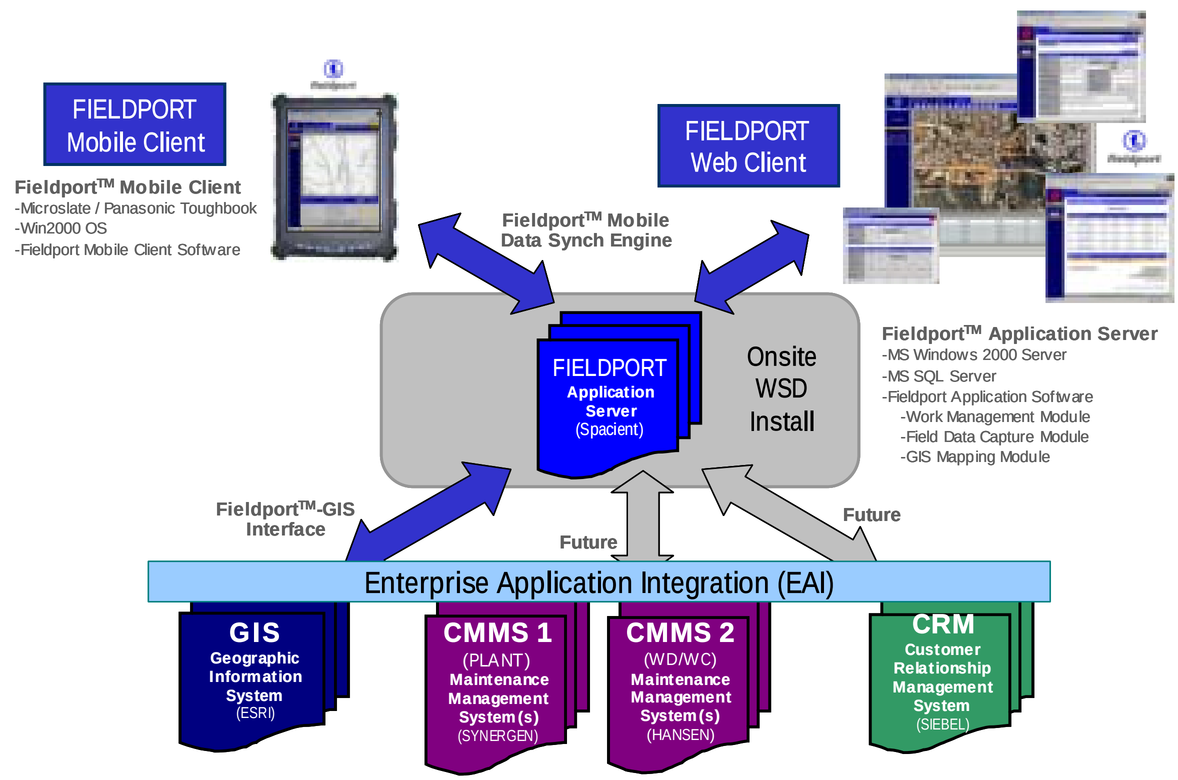

Figure 1: MAPS Computing Environment

AUTHOR INFORMATION

Primary Author:

Mr. James Ritchie
City of Phoenix
200 West Washington Street
8th Floor
Phoenix, AZ 85003
US
602.256.4281
jamie.ritchie@phoenix.gov

Co-Authors:

Mr. Randal D. Rios
City of Phoenix
6202 North 24th Street
Building 2
Phoenix, AZ 85016
US
602.262.4896
randal.rios@phoenix.gov

Mr. Thomas V. Dollente
Spacient Technologies, Inc.
445 South Figueroa Street, Ste. 2600
Los Angeles, CA 90071
US
213.612.7734
tom@spacient.com

Ms. Maria L. Delgado
Spacient Technologies, Inc.
445 South Figueroa Street, Ste. 2600
Los Angeles, CA 90071
US
213.612.7734
maria@spacient.com