Integrated field management applications: Adopting field technologies to streamline information management

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- Teresa Loo, Senior Forest Analyst, Port Blakely Tree Farms
- Eric Lund, Wildlife biologist, Washington Department of Fish and Wildlife
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Executive summary

Imagine if forestry site preparation operators were provided with a digital display that provides optimised coverage of treatment areas, reminds them of treatment prescriptions, warns them when approaching boundaries and measures performance. Imagine if this information could be transferred via wireless back to the office to substantiate payment of contractors and record treatments for stand record management.

Imagine a future where log truck drivers have GPS maps guiding them on their route, and can see the relative positions of other trucks on the road network. Imagine if the loader operator could see the axle scales for each truck and could load each truck to its maximum capacity without ever exceeding the limits, and all documentation for each load could be transferred automatically from the forest to the mill.

Imagine if all forest and management information are accessible to decision makers and planners regardless of their locations.

Imagine if you could increase the accuracy of your forest information whilst making it more accessible to multiple parties and keeping it more up to date.

Imagine if all the docket books, check lists and the associated data entry could be replaced with quicker and more accurate methods to manage information.

All of these imaginings can be realised with today's technology. Indeed, most are already developed in some form or another. Yet in 2007 most forest organisations in the Pacific Northwest still used paper based field workflows. The only exceptions to this are forest inventory and log scaling, where handheld computers are widely used.

This project focuses on technologies that allow integrated management of field information. *Integrated* in the sense that information is shared between office and field in a seamless fashion. Interviews were held with private and public forestry companies, state and federal government agencies and software vendors. This report is the product of these interviews and associated research. All parties highlighted the fact that forestry companies in the Pacific Northwest are slow to embrace change. They tend to be reactive and only change when pushed by internal or external forces. Discussions with software vendors indicate that they are usually engaged when previous applications had passed their *use-by-date* as opposed to pursuits of efficiency.

Forest organisations acknowledge that technology can deliver advantages by increased efficiency, accuracy and providing information in various formats to aid or optimise decision making in the field. They agree that technology can increase the timeliness of information and make it accessible to multiple players without subsequent manual data entry which is commonly required with paperwork methods. Yet most of those interviewed have yet to utilize many of these new tools.

The case studies presented in this report provide a cross section of technologies to demonstrate possible applications in field forestry. They cover road maintenance optimisation, log haulage optimisation, forest stewardship planning and simple field data collections. These examples are from early adopters.

The development of integrated field applications requires integrated office systems. Many of the large Pacific Northwest forest companies--such as Rayonier, Green Diamond, Temple Island and Port Blakely Tree Farms--are currently upgrading their forest information management systems. These implementations consume much of the development budget and focus. Some stated plans for field applications had been put on hold until the enterprise[1] system is fully implemented. This process can take up to two years.

When discussing field applications that had been implemented, organisations universally highlighted the importance of creating a user friendly application. Field workers only adopt applications which saved them time and provided efficiencies in their work. Conversely, systems that added time or were poorly designed were often sent back to the drawing board. The best way to develop efficient field software designs is to consult field users in the development process and focus applications to meet the requirements for specific work tasks.

The market for forestry specific software is very small, with few vendors offering off-the-shelf solutions. Greater opportunity exists for organisations to customise or build software to meet forestry specific applications. Smaller companies tended to be the ones adopting off-the-shelf solutions with little customisation. Larger forestry organisations on the other hand often have internal resources to investigate options and run "request for proposal" procurement processes and engage software vendors to develop applications specific to their needs.

When developing field applications, partnerships with external software developers provides the best strategy to develop one-off applications. The specialised skills vendors develop in the field of mobile field based applications can be leveraged, instead of in-house staff going through the learning curve for one-off projects. In-house development should only be considered when multiple or complex long term applications are implemented ***and*** there is ongoing commitment and management support. Of the forestry organisations that were using field applications, it was rare to find them designed entirely by in-house staff. If in-house staff were used, they were more likely customising generic field software or using other software tools such as application builders.

There is a large range of hardware available to meet the rigourous demands of forestry field work. The evolution of mobile hardware is being driven by increasing consumer demand for highly portable technologies. The ruggedised market is supported by many allied industries, however, the smaller volumes and higher cost of construction will always see rugged mobile devices priced at a premium. When choosing field hardware it is important to consider the form factor, ergonomics, battery life, and compatibility with software and other peripheral field

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devices in use. The availability of suitable hardware was never cited as a problem for interviewees.

A number of impediments were raised in interviews with forest organisations. They ranged from the human, to quality control issues, pricing, and difficulties in encapsulating the decision making process in databases, which are rigid by design. Whilst none of these impediments are unassailable, all need careful consideration. The last point is probably the biggest hurdle. Most digital workflow requires clearly established business rules so that a database can be designed to match the task. Defining the way decisions are made and agreeing on unified business rules within an organisation can be surprisingly difficult. Furthermore, there is often variations between different regions' business rules and work flows. These variations add complexity to the design and administration of databases and associated applications. The easiest implementations are those that have well defined business rules and established work flows. The hardest areas for integrated field information systems are those with abstract, informal or fluid information management and decision making processes.

Discussions with one software vendor highlighted that new technologies often have transparent costs exposed up front, yet the true costs associated with traditional paper based work methods are often unknown or entrenched as costs of doing business. It was suggested that to fairly evaluate new proposals the hidden costs and risks associated with traditional workflows should be teased out for comparison. Another software vendor also lamented that customers often extrapolate from the small size of field devices, and cheap prices of consumer electronics, and expect small price tags for field software. Unfortunately the same economies of scale are not available in forestry field software, especially when applications are highly customised for each customer.

The adoption of integrated field information systems will the have greatest returns for the high value components of forestry businesses, such as optimising log haulage or road maintenance. It also has benefits to many other field activities, but detailed cost-benefit analysis should be undertaken to ensure adequate business cases exist. Cost-benefit analysis should attempt to tease out all the entrenched costs and risks involved in current work practises for fair comparisons to be made.

Integrated field applications require efficient synchronisation solutions to allow data to flow *to* and *from* the field with little user intervention. The two way flow of information requires complex synchronisation processes. Major software vendors such as Google and Microsoft have recently released synchronisation frameworks. The greater availability of synchronisation frameworks will take care of the underlying processes of transferring information between the office and field and allow software engineers to concentrate on the project at hand. Over time, this will see reduced development time and cost associated with programming field applications that are truly integrated with office systems. Such frameworks are also likely to support the rise of occasionally connected applications where field applications can synchronise more closely with servers when within range of a wireless signal, but work independently if no coverage is available. This project found no examples of occasionally connected applications in the Pacific Northwest.

When discussing technology, change is the norm. All of the underlying technologies (hardware and software) that make mobile computing possible will continue to develop and change over time. Forest organisations should keep a finger on the technology pulse and take advantage of technology when possible. It is clear that forestry is not working at the cutting edge (also referred to as the bleeding edge) of technology. Following allied industries with similar field work requirements such as utility companies could see forestry adopting new technologies after they have been field proven.

Australia is currently well positioned in its use of technology when compared to the forestry organisations in the Pacific Northwest. One of the biggest differences in forestry between Australia and the United States is the scale of forest industries. Large forestry companies in the United States may have up to twice the land base as the entire Australian plantation estate, and there are multiple large companies that operate at this scale. Originally, it was assumed scale extrapolated to innovation and use of technology. Whilst scale does provide diversity and there are some companies implementing and researching advanced technologies, the majority operate in a similar mode to the Australian forestry sector.

The decline in forest harvests from Federal lands in the Pacific Northwest has focused the majority of harvest on public and private forest companies. Although these companies work with thorough codes of practise and government regulation, they largely operate under a notification system. This means companies only need to notify the state forest agency (e.g. Oregon Department of Forestry) of their plans and explain measures that will be put in place to minimise environmental impacts. By contrast, Australian forest managers operate under an approval system with similar environmental standards. The burden of proof required of forest managers in Australia to get plans approved adds to greater paperwork in the planning process. This may create a greater impetus for Australian companies to invest in field based technologies to streamline the management of greater volumes of information in the planning and monitoring process.

Introduction

Intensively managed plantations and native forests require efficient information management systems for operational and strategic planning, stand record management, certification and reporting to internal and external stakeholders. The requirement for detailed information spans the entire rotation, from site preparation and planting to harvest and haulage logistics. Forest management requires efficient transfer of information between office and field. Traditionally, this is undertaken with extensive note taking, checklists and docket book systems. Many industries have moved from paper to computer based technology. Forestry is starting to adopt mobile technologies, but lags behind many other industries. Although field forest inventory and cruising systems have used mobile field computers for over two decades, this data usually flows one way (i.e. data is collected in the field and travels to the office) and being alphanumeric in nature, it represents a simple workflow. Similarly in the US, log scaling or log grading was computerized over 20 years ago using software and hardware systems similar to those used for inventory. But, beyond these basic data collection tasks, there have been few other fields of forestry which have seen similar levels of investment and customized solutions to manage field information.

A competitive global market for timber products has increased the need to efficiently manage every aspect of the forestry business. Furthermore, the amount of information required to intensively manage forests and plantations has increased dramatically with greater accountability for environmental compliance and certification. This equates to greater information transfer to and from the field, with a greater emphasis on real time information. For example, harvesting and haulage logistics are increasingly relying on real time information to coordinate delivery of loads to processors "just in time".

The application of field based computer technology to collect and manage field information has great potential to streamline many forestry functions. Field technology has now reached a maturity that is realistic for adoption for broader forestry use. The benefit of using integrated field computers to collect and manage information has a number of advantages including timeliness, accuracy, efficiency and the ability to increase decision support.

Timeliness

With careful consideration of work flows and business rules it is possible to customize solutions that manage information efficiently. Digital workflows reduce time delays typically experienced when paperwork is double handled for later data entry into computer systems. Foresters are typically time poor and often data entry falls down the priority list. This can mean that data *already* collected is not necessarily available to other colleagues and systems. By using new field technologies in the field and synchronizing with corporate databases, significant time savings can be made. Timeliness can also be enhanced by embedding technology into routine activities. For example, data loggers can be used in site preparation machines to record and report treatment area. Automation can save time because the digital data and information is readily available after download, without requiring secondary processes.

Accuracy

Applying validation rules at the point of entry can increase the accuracy of field data. These are pre-defined parameters that question users when a record is outside an expected range. Fixing downstream errors is expensive; therefore the ability to maintain high data standards at the point of capture increases the accuracy of information. Accuracy can also be enhanced through automation, simply by automatically populating data such as date, time, plot number, user names and machine identification. Other functions may be automated by obtaining the electronic inputs from tools such as GPS, laser range finders, bar code scanners or RFID scanners.

Efficiency

Digital workflows can offer efficiency gains by leveraging information. Leverage is a term derived from the mechanical advantage a lever can deliver in physical movements. In information technology (IT), leverage describes the ability to amplify value in information. If an organization invests time and money collecting information, then it should be used to its fullest extent. For example, when using a traditional paper based workflow, a log docket may be filled out for a load of logs, the docket is then handed to the weighbridge upon arrival at the mill, and then a copy may also be held by the haulage operator. The docket information is used to make payment to the haulage operator. In a digital workflow, the same information contained on the docket could be used to provide payment to the haulage operator, deplete roadside stockpiles, summarise mill deliveries by product, track contractor delivery performance over time and numerous queries or summaries, thus leveraging the original investment in information. Importantly, the additional benefits are achieved with little additional effort once a digital workflow is established.

Decision support

By providing pertinent information to field users, they are in a stronger position to make an informed decision. The object is to give field workers information to assist them in making decisions. Field computers can provide decision support by providing access to information using search and query tools, or by providing traditional information in more dynamic forms such as a moving map. Alternatively, decision support can be added to field work by guidance systems such as those commonly used in agricultural systems. Help pages can also be embedded in applications to assist users with definitions, prescriptions, codes of practice, diagrams, photos, video or audio.

Examples of decision support

Example 1

Moving maps provide situational awareness. Providing a colour coded operations map to a site preparation machine operator can help clarify different operational prescriptions for various treatment types, including environmental buffers. Therefore the machine operator can have easy visual representation of the plan that does not require significant map reading skills to decode. This can remove ambiguity in map reading and increase situational awareness of prescriptions. This example could be extended by using detailed terrain information from LIDAR to optimise treatment paths. These treatment paths could then be presented on a moving map for tree row ripping, or harvesting machines undertaking thinning operations

Example 2

Routine asset inspections often assess condition of high value infrastructure such as sealed roads, bridges and culverts. By having access to previous condition reports, and maintenance works at the time of an inspection, auditors can reassess previous condition reports and works to make an informed decision about the current condition. In this workflow example the knowledge base is being constantly built up to support future decisions.

This project focuses on integrated data management solutions where there is a systemized and integrated approach to passing and managing information between the office and field. The following sections will look at how information is currently managed, general trends in field information management, barriers to adoption, and potential solutions. An overview of available technology will also be given. Case studies will be used to illustrate a selection of solutions currently available. Finally there will be a discussion of future trends and the likely evolution of integrated field information management.

This project does not provide a gap analysis of the forest industry. Nor does it attempt to identify the greatest return on investment. Instead it provides an overview of options to streamline field information management, increase accuracy and efficiency and provide greater decision support in the field.

Current situation in the Pacific Northwest

Interviews with large publicly listed forest companies, privately owned companies, forest consultants and government agencies reinforced that in 2007, most information recorded by forest field workers is undertaken using traditional methods. Docket books, checks list, notebooks and annotations on maps are used widely to plan, monitor and record activities. It was widely acknowledged by those interviewed that field forestry is historically low tech and slow to embrace change. Technology has certainly changed the way inventory and log scaling are undertaken, but even here there some contractors still use paper inventory cards for timber cruising. Beyond inventory and log scaling almost all operations remain paper based, with large degrees of replication as information is first recorded at the field site and then entered into corporate applications back at the office.

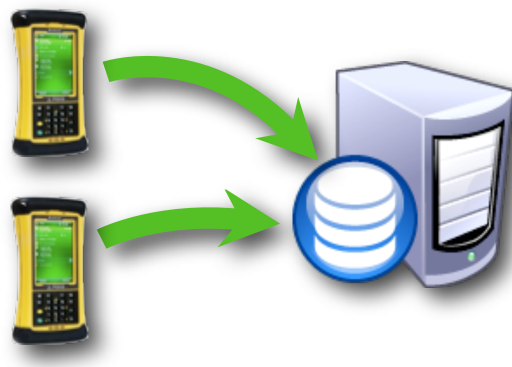
The use of GPS has permeated many field activities, but most GPS information is used to support traditional paper based workflows, and requires clarification, attributing and editing after downloading back at the office. The use of GPS receivers with detailed data dictionaries to ensure data collection matches the organisation's data model is far from universal. Furthermore, taking GIS layers from the office to the field for editing or updating is comparatively rare.

Why are inventory and log scaling work the main fields that have almost universally adopted mobile computers to enhance productivity, while other areas have not? Inventory and log scaling have a number of characteristics that make them amenable to digital workflows. These include:

- Information is largely data capture, with results only flowing one-way, from field to office (refer to figure 1).
- Specifications and structure of information are well defined with detailed business rules for each decision.
- Information is largely numeric and can be entered using keypads.
- The information is valuable, which requires trained staff to measure attributes with a high degree of precision and accuracy.

If these attributes are used as a starting point, those field tasks that have similar characteristics are also likely candidates to develop digital workflows. Conversely, field work that requires two way flow of information (to and from the office), lacks defined business rules, or has complex information (requiring more than keyboard interaction) are less likely candidates for digital workflows. This does not mean efficiencies can not be achieved, it is simply more complex.

Figure 1: Illustrates the flow of information in data capture scenarios. The field devices are represented by the yellow handheld devices, whilst the office system is represented by the office server with the blue database circle. The diagram depicts data capture, where information is always flowing from the field to the office in a one way flow (green arrows). The one way flow in data capture accumulates field information for some later management. Subsequent management of information is limited to office users.



What are business rules?

In a commercial environment businesses need to make decisions to drive the organisation in desired directions. Business rules govern decisions made at a tactical level. They may be thought of as a recipe of decisions made to manage projects or operations. In many forestry organisations, business rules may not be formally recorded, but they are usually part of the organisation's consciousness. Decision support tools need formalised business rules to define events such as how information flows between parties, what elements need to be considered and who signs off. Forestry functions that already have systems in place to store, query and report operations are likely to have well defined business rules. For example, inventory systems require detailed business rules to define how sample plots are selected and measured. Each decision undertaken in the inventory process is defined with rules to avoid unwarranted bias by field staff.

“If it ain’t broke, don’t fix it.” Why adopt new field technologies?

Commercial forestry operations generally have three operational groups which undertake management activities in the forest. These are:

Silviculture

- Associated with forest management and includes site preparation, weed control, planting, tending, pruning, fertilising, disease management and fire mitigation activities.

Forest Engineering

- Related to building and maintenance of harvesting and haulage infrastructure such as roads and bridges.

Harvesting

- Associated with harvesting and timber supply.

Obviously these groups have various degrees of overlap and interaction in day-to-day operations. Indeed, smaller operations may have people performing multiple functions. Information and knowledge is required to transfer between the groups in an efficient manner, to ensure information held by one group is available to others. Most forest activities conducted have three phases. First an activity is planned, then secondly it is actively managed to ensure the desired outcomes are achieved. Thirdly, at the completion of work, the accomplishments are recorded. Each of these three phases requires information flow to and from the field.
An integrated approach to managing information across various operational phases allows information assembled for planning the activity to be available for subsequent monitoring and reporting. It can also be shared across the organisation. For example the information about planted area, species and stocking will inform future inventory stratification and harvesting.

By recording information directly with digital technologies, GPS, field computers, data loggers or digital pens, the information is captured in a format that can be readily transmitted and shared with other staff and systems.

The following list of common forest activities highlight areas where technology can enhance outcomes. These examples are presented for illustrative purposes and not intended as an exhaustive list.

Site Preparation (including mechanical preparation of the site and treatments with herbicide and fertiliser)

- Plan site preparation activities using handheld field device and capture retention areas, buffers on streams, roads and treatment types.
- Record activity undertaken by each machine including operator undertaking work and treatment type.
- Provide machine operators with moving map to display treatment areas and prescriptions.

- Provide navigation assistance to optimise treatment area for operations such as contour ripping.
- Record statistics and provide live feedback to operator, row spacing, hours per hectare, area treated per day, etc.
- Variable application rates of fertiliser and herbicide using sensors or pre-defined soil classification maps.

Planting

- Plan planting operations by stocking, seedling types, species, and mark exclusion areas and buffers on streams and roads.
- Provide live feedback and statistics to planting crew of stocking and other specifications based on quality control audits.
- Record planted area updates for progress payments.
- Record survival rates over time.

Fertilising

- Plan fertilising operations with treatment type, area, map exclusion areas and buffers on streams and roads.
- Record progress of fertilising activities.
- Vary treatment rates based on site index and nutrient monitoring.

Roading and Infrastructure

- Asset management for roads, bridges, culverts, drainage structures and signage.
- Plan road maintenance and construction activities.
- Pro-active asset inspections.
- Record accomplishments as roads are built or maintained.
- Monitor production of machines rates and track costs.
- Optimise road maintenance activities

Fire Management

- Fire mitigation tasks such as managing fire infrastructure, road signage, road clearing, water points and fire breaks.
- Manage fire suppression activities, fire location, control strategies, and resources.
- Live tracking of strategic assets.
- Situational awareness of command posts, staging areas, and assembly areas accessing the same base information regarding fire activity, operational orders and resource levels.

Safety Management

- Manage and update risk assessments in at the work site.
- Document “tool box talks”.
- Provide centralised up to date safe working procedures for various tasks.
- Track compliance over time by recording field audits.

Operational and Certification Audits

- Certification audits taking previous results into the field to measure improvements.
- Audits of codes of practise to ensure compliance and track progress over time.

Harvest Management, with a strong emphasis on plantation or cut to length operation

- Plan harvesting activities including seasonality, roading requirements, log landings, traffic access, and turn around areas.
- Monitor and record harvesting progress over time.
- Provide harvest operators a moving map with treatment area, environmental exclusions, stream buffers, and prescriptions.
- Record area cut, product by shift and product by location.
- Record product distribution, which could be used to validate inventory to corroborate site index for future rotation planning.
- Harvesting operator could using moving map and accomplishment reports to systematically treat stands and ensure all areas are treated.
- Optimised harvest extraction rows provided on moving map, based on digital elevation mode.
- Harvesting patterns transferred to forwarder to show the distribution of products so forwarder operators can optimise roadside delivery, and ensure all products are transported to roadside (especially useful when operating in darkness).
- Forest and roadside inventory management based on measurements of harvested material.
- Simplified logistics with electronic timber haulage dockets, and reinforce chain of custody for certification.
- Logistics overview to assist in management of log haulage, and dispatch management.
- Moving map in haulage trucks to guide trucks to log landings.

This list of forest activities is meant to serve as a broad view of areas where technology can be implemented into routine field tasks to streamline the management of field information. Most of these activities are currently done using traditional paper based methods, but some early adopters are starting to implement new approaches and achieving greater efficiency. All can be improved with today's technology if greater efficiency is required.

What is happening to the core office information systems?

Most forest managers in the Pacific Northwest are reactive and only implement new solutions when traditional workflows expire, or when forced by new circumstances. For example, the Ministry for Forest and Range in British Columbia imposed regulations for all forest managers operating on crown land to submit electronic submissions. This drove investment in forest information management systems, which were unlikely to have been undertaken without regulation. The adage, "*if it ain't broke, don't fix it*" is evident, with numerous examples from those interviewed confirming hardware and software were only updated due to impending or actual failure of systems. Examples include software that was no longer compatible, or handheld computers that could no longer be purchased to run DOS programs. This occurred regardless of an organisation's size. One software vendor lamented that they were usually only called upon when previous systems had expired as opposed to a drive for efficiency or adding value to the business.

Obviously there needs to be a defined business case before deviating from standard practices. The business case should consider the broad benefits of a potential solution, together with the cost and risks involved. It should also be acknowledged that there are costs and risks involved in traditional work practices if organisations *do nothing* and maintain the status quo. Many of the costs and risks associated with traditional field workflows are entrenched, and accepted as "*business as usual"*. The business case of many mobile solutions may only be substantive when all of the costs and risks associated with traditional workflows are considered in balance. This is hard when many of the benefits and risks are intangibles such as timeliness, accuracy, efficiency, and decision support.

Many forestry organisations that had invested time and money into enterprise information management systems did not have a firm figure on these values. It was commonly seen as a cost of business. Therefore when going to market for a solution they were heavily focused on outcomes as opposed to the cost. Obviously successful vendors needed to be competitive on price, but the solution was the significant driver. Rarely was a budget capped before heading to market.

The regulatory environment and ownership significantly determines the value placed on documentation. Many regions with higher regulatory environments have a greater need to substantiate decision making, and a requirement for operational plans and audits for various activities. It is in these environments that mature integrated field information management solutions have the greatest benefit, as the information management is more complex, with a greater volume of information traffic.

Smaller scale forestry organisations tended not to have dedicated forest information management systems and relied heavily on spreadsheet programs like Microsoft Excel to organize much of the day to day information. Whilst spreadsheets are intuitive and flexible, they have a number of disadvantages when handling information with inherent relationships. Furthermore, they have limited ability to allow multiple parties to access information at any one time, making spreadsheets difficult to keep synchronised over time.

There are tremendous advantages in unifying the way that information is managed within a forestry organisation, whether at the local office level or across the entire organisation. Not only has information traditionally been double entered, but there is often duplication of effort within an office developing the same base information for various tasks. In many forest organisations much of the duplication occurs with spreadsheets. Whilst Excel has tremendous power, it can be inefficient if every group manages its information in isolation. Excel tends to be used for everything including project management, rostering, checklists and budgeting. The main issues surround collaboration and data integrity. Since only one staff member has access to a file, subsequent staff only have access to read-only versions. This can be inefficient, and often leads to fragmentation of information into smaller spreadsheets to avoid sharing violations. This issue of data integrity stems from Excel's immense flexibility which can be a double edged sword. The ease of crunching rows of numbers and summarising large data sets can be easily corrupted with errors that populate through subsequent calculations and data. Databases offer a safer alternative for valuable information. First, databases provide access to multiple simultaneous users. Second, information in databases interacts through queries and calculations. This provides a level of detachment which leaves the original base information secure, and less likely to be inadvertently corrupted. The use of databases also tends to build data assets over time as opposed to having numerous one-off spreadsheets managing bits of information on an ad-hoc basis.

The need for collaboration and document control has seen the development of a new genre of software. Programs that allow multiple users simulanteous access to information and track changers, manager user access permissions such as Visual Vault and MS Sharepoint. These can provide valuable business tools but the first step is to acknowledge Excel is not the universal business tool some people believe it is.

In the last five years the geodatabase or spatial database has evolved. These database systems allow the storage of spatial elements together with related information. This allows a single repository for GIS spatial elements and all the related data. GIS information is important because most forestry information is spatial. By using a geodatabase there is added dimension and depth to store, query and report on information. For this reason much of the discussion of integrated forest information systems hinge on modern GIS systems.

Many forest organisations interviewed are beginning to combine multiple databases and GIS systems into a single enterprise geodatabase. Software vendors also noted the trend for greater integration of systems. It is unrealistic to anticipate integrated *field* solutions, unless there are integrated office information systems. Field solutions are extensions of existing office systems and rely on a solid foundation. The theoretical evolution of integrated systems is presented in figure 2.

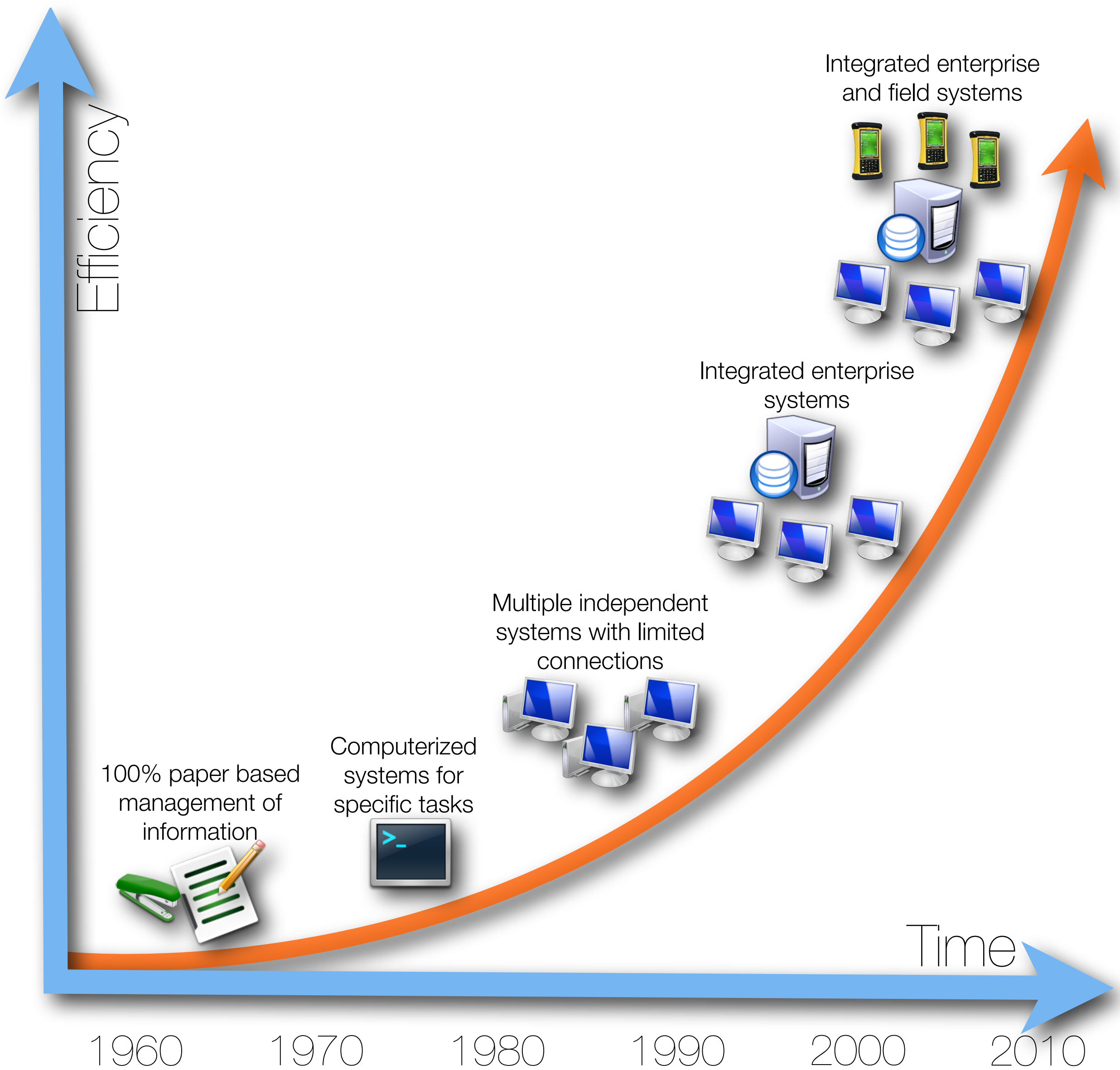
The Field Story – Why invest in field technologies?

Whilst mobile computers can offer efficiency gains by reducing double handling of information, a greater contribution comes from increased accuracy, and by providing decision support for field workers. Increasing accuracy in the field saves resources by reducing errors at some later stage and increases the value of any information gathered. By providing access to more information or more useful forms of information (GPS guidance as opposed to paper maps), field staff are presented with the best opportunity to make informed decisions.

Centralisation of work centres by some forest companies means staff can spend large amounts of time travelling between office and field locations. As mentioned earlier, many foresters are time poor, so limiting unnecessary travel can save time and transportation expenses. Consequently, it is desirable to maximise productivity whilst in the field by providing access to the best information and recording outcomes of fieldwork using consistent approaches. There are three aspects where better use of field technology can reduce field travel. First, unnecessary field visits can be avoided by having adequate information in the first place.

Second, by allowing field users to upload or download information remotely, unnecessary travel to simply transfer information can be avoided. Third, by making the most informed decision whilst in the field, subsequent repeat visits to *clarify* issues can be avoided.

Figure 2: Theorised evolution of information management systems over time with increasing efficiency as technologies are employed and integrated into a unified office and field system over time.



Technology available

Bits of the puzzle: Underlying technologies that make field technologies possible

Field solutions may include a selection of technologies. Understanding these technologies is important in understanding current options and emerging technologies, which is the focus of this chapter.

Enabling Technologies

There are a number of "enabling" technologies that make field computing possible. These include:

- *Global Position Device (GPS)* is becoming pervasive in everything from phones to car navigation systems, watches, and cameras. The ability to provide an accurate location in real time is changing field navigation. GPS provides the ability to spatially reference information. This effectively adds another dimension to which information can be stored, queried or referenced. The usefulness of spatial referencing should not be underestimated. No longer do you need a complex filing system to store information: if the location is known attributes can be viewed. Alternatively, it is possible to find record locations based on their attributes.
- *Rugged devices* are capable of handling vibrations, dust, water, heat, cold, and accidental drops on the ground. International standards (largely driven by military requirements) define many of the ruggedness criteria and allow comparison between products.
- *Battery technology* allows operation for one or more shifts of continuous operation.
- *Outdoor readable screens* allow colour screens to be read in direct sun light.

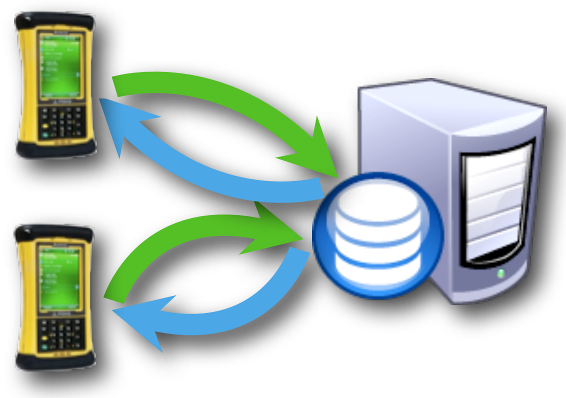
Synchronisation

A significant issue with integrated field information systems is the ability to efficiently get information to and from the field. Some field work requires data collection only (figure 1). This has a simpler information flow, as data is always transferring from the field and adding to the office data. It is a *one way* process where field information collection starts with a blank sheet, and information is transferred at the conclusion of work. The field information is always new to the office system, and is accumulative. This is described as "data capture."

With integrated field systems, there is information flowing to the field, where it is updated before being transferred back to the office at the end of the cycle (figure 3). The complexity of the integrated solution is that not all information coming back to the office is new or should replace existing information. Therefore a process is required to manage the two way flow of information between the office and field. This process is referred to as synchronisation.

The two way flow of information is more "data management" as opposed to simple "data collection" (see above).

Figure 3: This diagram represents a two way flow of information in integrated solutions where information from the enterprise server is downloaded to the field device (blue arrows), and field changes (additions, edits or deletions) are later updated back to the server (green arrows). The two way flow allows the ongoing management of field information by field or office users.



The ability to manage the synchronisation process can become incredibly complex. It may be simple if there is one field copy of the information, but what happens when multiple field copies exist, all with slightly different versions by the end of a day's work? You do not want to simply copy and paste field data onto the server, as this will either duplicate data that already exists or overwrite earlier work by other field or office users. Synchronisation solutions only update changed records, whether they are new, edited or deleted records. Text box 1 provides a summary of a familiar consumer synchronisation process.

Enterprise databases have evolved systems to manage complex synchronisation environments. They also have rules to manage conflicts where contradictory transactions occur for a single entry. One method to handle multiple parties' simultaneous use of a dataset is to have versions, allowing you to check out a version of the original data and at the conclusion of work the field copy is checked back in against the version, before changes are made to the master version.

Text box 1

A familiar synchronisation scenario

There are numerous synchronisation solutions available to keep an increasing array of consumer products up to date. This includes everything from Blackberry email devices, smart phones, MP3 media devices and personal digital assistants (PDA). Perhaps one of the widest used is the iPod media player produced by Apple Electronics. The iPod is a media device, which plays music and video, records audio and downloads music. The iPod has a companion program called iTunes that runs on a computer, and helps manage media and allows music to be played via the computer without the iPod. When the iPod (which is the field device in this example) is connected to the computer, iTunes automatically starts and launches a synchronisation process. Any new media on iTunes is transferred to the iPod and new media on the iPod is transferred to iTunes. This two way flow of information keeps the computer (iTunes) and the iPod synchronised.

The low level of interaction required by the user to keep the iPod up to date with iTunes is a key reason for the incredible uptake of this technology. iPod owners only have to connect the device with the computer and wait for the synchronisation process to check for changes and transfer files. There is no cutting and pasting files from one program to another, exporting music to folders, or launching third party synchronisation software.

The same low-level interaction is required for business systems. When multiple steps are required to manually convert, massage and transpose data, the level of efficiency declines and each step adds potential for error.

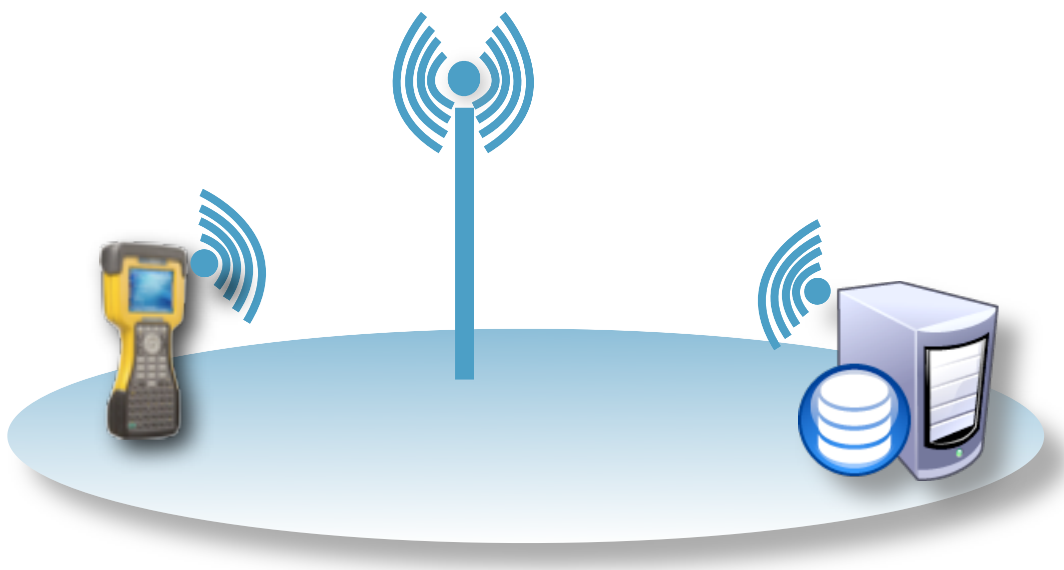
A consumer synchronisation process between the iPod (left) and iTunes running on a desktop computer (right). Simply connecting the iPod to the computer launches the synchronisation process. This elegant synchronisation solution has underpinned the iPod's success.

Making the connection: Synchronisation and communication technologies

The level of connectivity between the office and field system is largely determined by external factors. The underlying issue is communications infrastructure available for connecting field systems to office systems. One solution to keep information synchronised is to always work from the master copy in real time (figure 4).

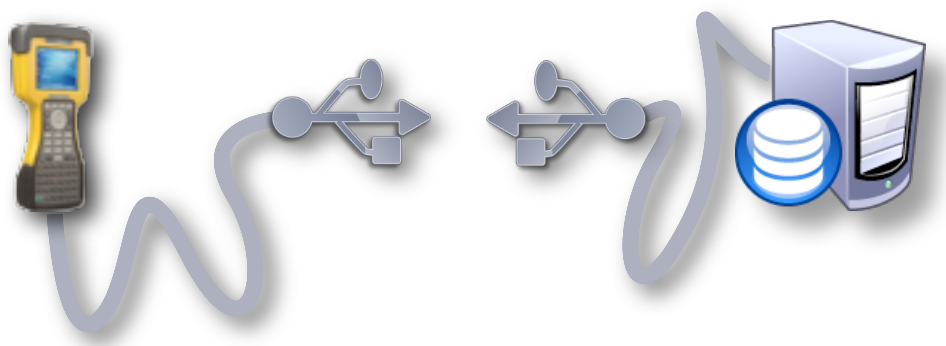
An advantage of online access to the master data is the ability to have access to all the latest information, whether it is from other field workers with live connections or from office staff also interacting with the same information. Having "*live*" access to enterprise data is the simplest way to avoid synchronisation issues and provides access to the latest information. Unfortunately it is difficult in most forest field situations due to limited or incomplete wireless coverage, latency (delays in getting information to and from the server), and limitations to bandwidth on current wireless and satellite networks, not to mention costs of continuous access to these services.

Figure 4: This diagram represents the live connection model where the field device has continuous connection (via mobile or satellite network) with the office server. The circle under the field device represents the coverage provided by a wireless network.



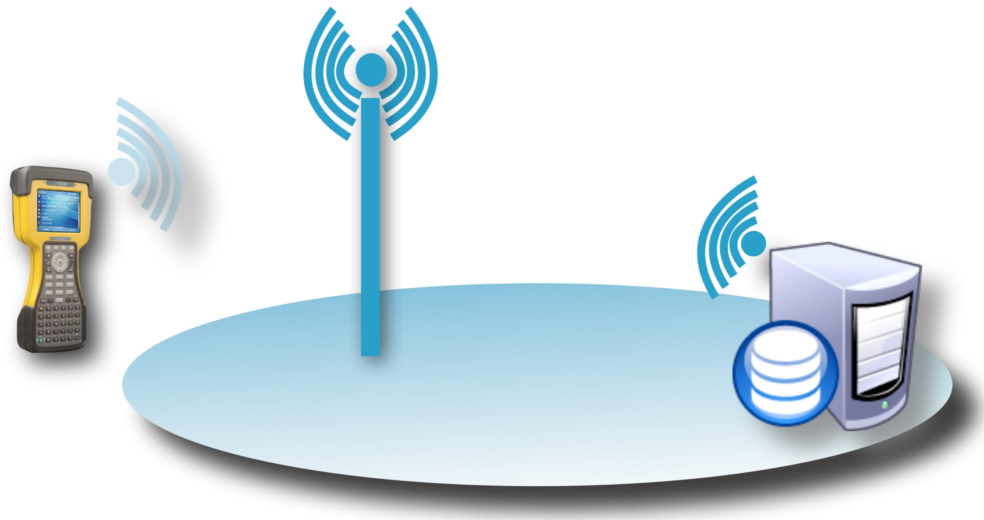
At the other end of the connectivity spectrum is a disconnected field user, where the device has no live connection with the office server (figure 5). The mobile device holds background information relevant for the particular task, which is edited, added to or deleted from. At the conclusion of work the device is synchronised with the server to exchange information. The iPod example described in text box 1 uses the disconnected model. Of the research undertaken for this project, no forestry organisations used the live connection model. The main impediment cited was poor or incomplete coverage over forest management areas.

Figure 5: Illustrates the disconnected environment, where the field device works off-line and has no communication link with the office server. All the data required for the days work must be stored on the field device. Under the disconnected model, units are updated by connecting them with a computer or the internet at the beginning and end of the data management cycle.



In between the live and disconnected model is the "occasional connected application" which is also referred to as "nomadic", where the field device moves between connected and disconnected environments (figure 6). The nomadic model has tighter integration with the office server. Although not working directly off the server as in the live model, the nomadic model will push and pull small updates (mini syncs) which keeps both the server and handheld device up to date in near real time when a connection is available. When disconnected, nomadic devices cache information on the device until the next connection. This is probably the best model, as it offers near real time information when connected, plus the flexibility to continue working when disconnected if coverage is not available. The technology to facilitate nomadic connection has only been available for the last few years.

Figure 6 shows the occasional connected application, where the field device is able to communicate using wireless networks when coverage connection is available. The field device in this model will store information locally and will only push and pull small updates to and from the server when network coverage is available. In this picture the field device is outside the range of the wireless network which is depicted by the circle encompassing the network tower and the office server.



Today, most field devices in forestry operate under the disconnected model. Typically, when it is time to transfer information between the field device and office server, the field device is physically taken to the office and connected to the office network via cable.

In 2007, ESRI (the largest supplier of enterprise GIS software) released a Mobile Software Developer Kit (refer to page 33). This software provides the ability for software engineers to customise mobile field solutions that require GIS maps access, and pass information back and forth using the occasionally connected applications. 3-GIS (an ESRI partner) is using the ESRI Mobile SDK as a tool to build customised solutions for customers. As noted earlier, this is a comparatively new communication model. However it will grow strongly with demand for mobile solutions.

Communication technologies

There are a number of options for communicating information between field and office. It was noted above that most forestry organisations tend to use physical connections where field devices are transported to the office and connected via cable for synchronisation. Other options include the use of wireless signals to make connections. These connections may access computers, office networks or the internet.

The Internet is often referred to as the information cloud. There are a myriad of routes between any two points, like the neural network in the brain or city road networks. If one is unavailable, others can be used. This provides a robust method to transfer information between office and field, and gives the flexibility to build a synchronisation solution from anywhere you have access to the Internet. Security issues need to be considered, but there are many solutions to transfer secure information over the Internet including encryption and virtual private networks.

Connections can be made with the following technologies:

- Download cables which physically connect field devices with office computers.
- Modems using standard phone lines can be plugged into the field device, and a connection can be made to the internet via a dial-up internet service provider (ISP). Modems can also allow direct connections back to offices if the office also has modems to allow incoming calls.
- Field devices that have embedded mobile phone capability can connect to the internet when wireless phone coverage is available.
- RF (Radio Frequency) using radio modems to transmit data wirelessly. This is a tried and trusted method and is most suited of short to medium distances or via repeater networks. This is probably one of the cheapest options for the live connection model.
- WiFi capable devices remove the need for physical connection between devices. This enables the transfer of information between a harvest at the log dump and a forester in the vehicle. It enables hot spots to be established at locations that have access to the communication network (either mobile or physical copper telephone lines). This could be where vehicles refuel or at weighbridges. These hotspots could act as the hubs to allow updates to be sent and received. WiFi connections also allow sharing of information between field workers.
- Bluetooth is a short range protocol often used by hardware devices. For example a GPS may provide locations to a data recorder via bluetooth. The main benefit of this technology is the reduction of cables between devices. It also removes the issue of compatibility of different plug formats required by proprietary devices.
- Wimax is a new wireless technology that has started to be incorporated in some Intel chips. Wimax will eventually replace WiFi. Wimax will provide WiFi-like communication at high speeds over greater distances, reportedly up to 50km. This will greatly benefit forestry by providing a communications solution capable of transmitting across forest stands and compartments. The range of Wimax will allow the evolution of mesh networks (refer to page 52).

Hardware

Field devices that can be used for integrated information systems contain a number of hardware and software technologies as mentioned above. This section will introduce many of the field hardware options, and provide a brief summary of advantages and disadvantages.

Laptops

The laptop has become ubiquitous as users seek hardware that offers greater flexibility than traditional desktop PCs. Laptops now outsell desktops in Australian and United States markets. Most are not designed for the rugged demands of field use, however, there is a niche range of fully rugged versions.

Advantages

- Can run familiar operating systems.
- Can have docking stations to enable use in vehicles. The dock provides power and secure support.
- Can be used in both office and field, which has greater utility for foresters with mixed management responsibilities as opposed to full time field workers.
- Large screen real estate.

Disadvantages

- Generally heavy.
- Not suited for hand held use.
- Poor battery performance, usually less than half a shift between charges.
- Ruggedised laptops are expensive.
- Consumer grade laptops are not designed for general field conditions.

Tablet PCs

The tablet PC comes in two forms. One has a physical keyboard and touchscreen, the other has touchscreen only. Microsoft offers a Tablet version of Windows that allows stylus input, and the ability to have a virtual keyboard appear on the screen which can be interacted with via a stylus (pen). Windows Tablet has handwriting recognition software embedded as part of the operating system where writing on the screen is recognised and converted to text.

Advantages

- Allows stylus use, which permits written notes and draw on maps without using keyboards, mouse or touchpads.
- Runs full version of Windows XP and Vista (Tablet versions).
- Large screen real estate.
- Can have docking stations to enable use in vehicles. The dock provides power and secure support.

Disadvantages

- Handwriting recognition is not 100%. Just as not all handwriting is universally readable by people (e.g. a doctor's handwriting), computers have problems deciphering some writing styles. However if the users' handwriting is legible the software does a reasonable job at recognising it.
- Heavy rain drops, gloved or left handed users can falsely trigger screen input.
- Heavy for hand held use.
- Poor battery performance, usually less than half a shift between charges.
- Software needs to consider stylus interaction.

Ultra mobile PCs

This is a new genre in personal computers introduced to the market in 2005. It is designed to run the full version of Windows, but offer greater mobility than tablets or laptops. Some have miniature keyboards, whilst others rely on the tablet interface.

Advantage

- Small and lightweight.
- Runs the full version of Windows XP or Vista.
- Larger screen than other handheld devices.

Disadvantages

- Limited rugged versions currently available.
- Small keypad is difficult for large fingers.
- Software needs to consider stylus interaction.
- Battery life is usually less than shift length.

Pocket PCs – Hammer head style

These mobile devices are specifically made for mobile field workers. They can be easily clasped with a single hand around the middle of the body. This device uses Windows Mobile operating system.

Advantages

- True handheld device.
- Ergonomic design can be held with one hand.
- Fully rugged.
- Long battery life.
- Runs Windows Mobile operating system.
- Outdoor readable screen in direct sunlight.
- Has advantage of touchscreen or keypad (set by software).

Disadvantages

- Windows Mobile needs specialised programming and a conversion process is needed when sending files between Windows XP and Windows Mobile.
- Small screen requires careful programming to use limited space efficiently.

Pocket PCs - PDA style

The personal data assistant (PDA) style devices have evolved from the consumer grade PDAs which allow users to mobilise information such as calendars, address books, tasks lists, and emails. Most fully ruggedised devices run Windows Mobile (see above). Some are available with integrated GPS units, whilst others have expansion ports for additional memory or Compact Flash GPS, camera, RFID, and barcode scanners.

Advantages

- Light weight, small and easily to hold in one hand.
- Cheapest ruggedised field device.
- Rugged.
- Long battery life.
- Runs Windows Mobile operating system.
- Outdoor screen readable in direct sunlight.
- Some have number pads for numeric data entry.

Disadvantages

- Limited or no keypad for data entry. Relying mostly on stylus for data entry.
- Small screen requires careful programming to use limited space efficiently.
- Windows Mobile needs specialised programming and a conversion process is needed when sending files between Windows XP and Windows Mobile.

Smart phones

These devices are primarily a phone but with functionality for other tasks. There are six underlying operating systems for smart phones. These are Symbian, Linux, Palm, Windows Mobile, Blackberry and a stripped down version of Apples OSX. Software running on the smart phones must be compatible with the operating system.

Advantages

- Smart phones by default have access to wireless carriers and therefore have connections to the Internet.
- Can bundle phone and field device in one unit, which limits the number of devices needed.
- Low price driven by large consumer demand.
- Numerous operating systems available provide choice for software development.

Disadvantages

- Numerous operating systems causes compatibility issues if one software solution is needed to run on different operating systems.
- Very small screen and buttons limit use for data intensive tasks.
- Not ruggedised for intensive field use in harsh conditions
- Fewer integration options with GPS and other devices.

Proprietary data recorders

These solutions are self contained and generally designed for specific field functions, such as recording harvester head production statistics. Some may have an interface for external input by operators, such as a keypad or touchscreen, but others may be a closed unit that records some function information.

Advantages

- Can be built for harsh environments.
- Purpose built to meet specific tasks.
- Can be “idiot proof”.

Disadvantages

- Limited flexibility for use in other tasks that may evolve over time.
- Niche products with less competition in the market place.

Digital pens

Most digital pens use technology developed by Anoto. The pen has a camera near the nib that records a unique pattern of dots on the paper. This gives the pen a spatial reference for each pen stroke. The information can be transferred to a computer at the conclusion of work. There are many different flavours of this technology. Some are designed to be used with printed GIS maps, some record and store audio which can be replayed by choosing a section in the downloaded notes. Some use optical character recognition to convert pen stokes to digital text, which can be configured for database data collection forms.

Advantages

- Inexpensive.
- Easy to use technology with low “fear factor” for non-technical users.
- Rugged versions available.

Disadvantages

- Handwriting recognition will never be 100% accurate for all users.
- Does not provide any decision support.
- Requires use of specific paper.

Peripheral devices

There are a number of peripheral devices (refer to figure 7) that could be used in conjunction with the above hardware. These include GPS, laser range finders, laser relaskop (to measure tree diameter), bar code scanners, radio frequency identification (RFID) scanners, cameras and printers.

Figure 7: Peripheral hardware device that may be used to support field work activities

Barcode scanner *GPS Unit* *Laser Rangefinder*

Software

There was a time when some forestry organisations commissioned their own hardware to be built. Thankfully those days are well gone. Hardware can be readily purchased from a diverse field of vendors. The demand for rugged field hardware is driven by a range of uses from the military to surveyors, geologists, utility workers, natural resource people and service industries. This large user base is driving innovation and the evolution of hardware. Software on the other hand is somewhat more fragmented. There are some common elements in software such as GIS that have broad industry participation. However, forestry specific software has a much smaller user base.

How does an organisation source or develop software?

The options are to buy software "off-the-shelf", *or* develop it to specifications. If you developed independently, there is one further decision: in-house or outsource? This section will look at options available for acquiring or developing forest specific software.

Off-the-shelf field forestry systems

Most *off-the-shelf* systems for forestry are inventory based. Few systems are commercially available outside this domain. Those that are, tend to be small niche products. For example JRP Solutions (Canada) has developed a suite of handheld products to manage operational activities associated with planting, seedling orders and contractor payments. Tripod Data Systems (United States) has developed a program called SOLO Forest which is a forestry focussed mobile GIS program. It contains functions such as redlining, note taking, attributing, measuring spatial features (area, perimeter, bearing, distance), the generation of sample grids for inventory or quality control plots, tree height calculators, and tools to interact with spatial layers such as split and merge and buffer tools. Other niche, off-the-shelf products include systems for haulage tracking and electronic log delivery dockets, and proprietary data recorder solutions like Opti-grade (Refer to case study).

The off-the-shelf field solutions for forestry applications usually require some level of customisation or tailoring to ensure integration with current systems. If there are no in house systems it may be somewhat easier to install an off-the-shelf solution because it removes the integration hurdle. Refer to text box 2 for summary of off-the-shelf agricultural systems.

Text box 2

Off the shelf agricultural systems

Agriculture has many off-the-shelf field solutions available to increase cropping productivity. Most concentrate on optimising tractor coverage and minimising inputs. For example, there are a myriad of GPS guidance systems to steer tractors with centimetre accuracy. Ensuring complete coverage of the field in the most efficient pattern, allowing repeatable coverage on the same wheel tracks, ensures applications of herbicides, fertilisers and harvests are also optimised without crushing crops in the process. Ultraviolet sensors are used by some systems. A string of forward-looking sensors are mounted to a boom spray unit, and as a sensor sees an approaching weed, it will turn on the corresponding boom nozzle. This allows the efficiency of broadcast spraying with the cost and environmental benefits typically limited to spot spraying. Another method is the use of soil classification layers, or plant health layers derived from remote sensing, or soil mapping. These layers can be referenced by onboard software to vary fertiliser application rates on the basis of soil or plant nutrient status.

At the conclusion of work all the information is available for download to the farm computer. Information includes production rates, treatment area, treatment type and inputs such as seed, fertiliser, or herbicide. Agricultural contractors also use this information to substantiate invoices, whilst farm owners use this information to monitor operating costs, inputs, and harvest yields.

The differences between agriculture and forestry are largely related to scale and rotation length. Agricultural operators often visit the same paddock multiple times per year and individual management areas are less extensive when compared to forestry operations.

Information is generally managed on desktop computers, as opposed to enterprise server systems, with shorter time frames for managing information. The lack of enterprise systems makes it easier to adopt off-the-shelf solutions, as there are few integration issues. The short timeframes and smaller data sets means new systems can be adopted at the beginning of each season with limited need to convert existing information systems.

The long time frames of forestry operations require larger investment in stand record information to track and manage stands. The longevity of these systems mean it is harder to adopt new solutions without a detailed roll-over process to bring current stand records across.

Designing the software

There are a number of software tools to help design or customise software. Application builders are software tools that can be used to customise a core program into a focused tool, as opposed to developing a program from the ground up using detailed software code to define every action. The benefit of application builders is that they require lower technical literacy. However the draw back is the limitations imposed by the core program on which the application is based. This means the final product may have limitations that might otherwise be overcome if the program was designed from scratch. There are a growing number of application builders available, they include Arcpad application builder by ESRI , Data Plus by Electronic Data Solutions or Pointsync Pro by Mobile Dataforce (refer to figure 8 and figure 9 respectively). There is no easy way to compare all the options. Some have a strong GIS focus, whilst others are entirely non-spatial. Some have the option for both spatial and non-spatial applications to be built. It really depends on the specific solution that is being addressed. Wide research is suggested to consider the suite of options available. Refer to the Appendix for further links to other application builders.

Figure 8: Acpad application builder is software that can be used to customise attribute forms for spatial applications. The window (boxed in red) is a “what you see is what you get” (WYSIWYG) representation of what would appear on the display of the field device.

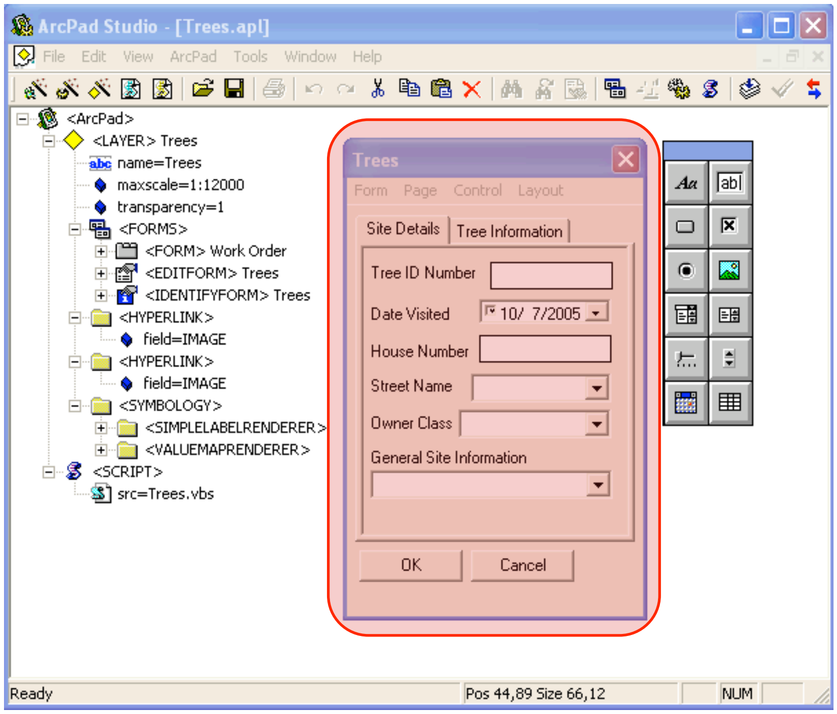
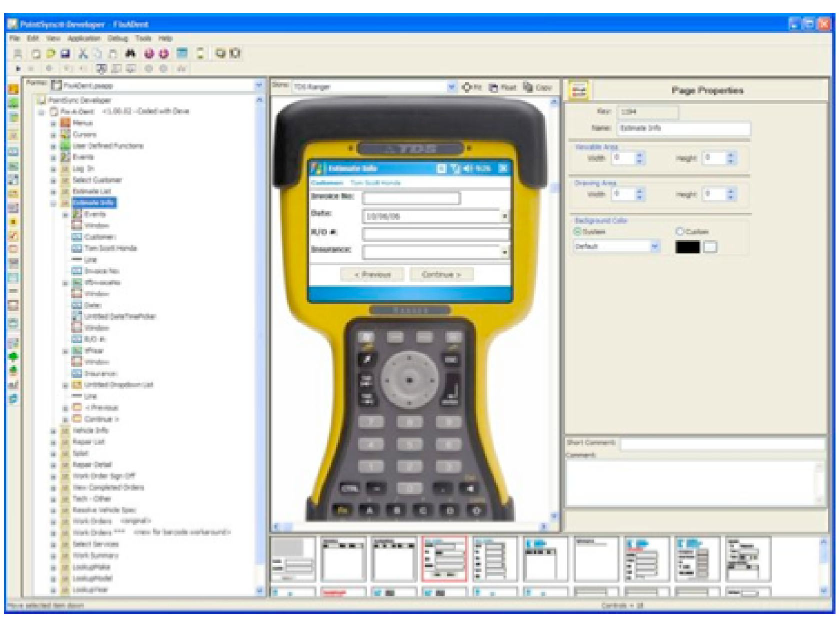


Figure 9: Illustrates a screenshot from Pointsync Pro by Mobile Dataforce. Application builders provide an interactive environment to build customised forms. Options from the left window can be dropped onto a form, and properties for each option are set in the right window. The bottom window provides access to other forms which have been built as part of the customised application.



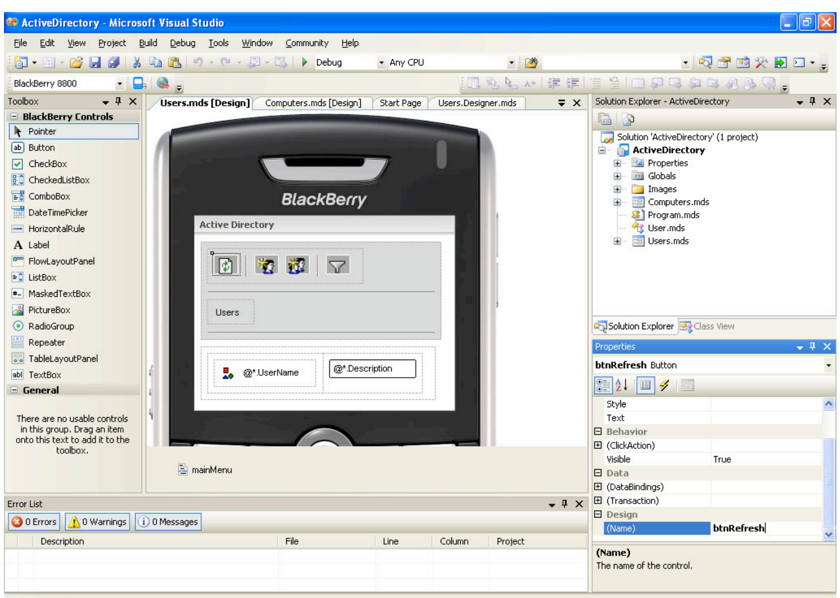
The other option is to develop applications from the ground up. This is the preferred route of most software engineers because it offers the greatest flexibility and freedom to develop focused applications. There are a number of software packages available for software engineers to design, build and debug code. Many have a graphical user interface and allow manipulation of elements of the user interface in a what you see is what you get (WYSIWYG) environment. These include:

- *Integrated Development Environments (IDE)* are software packages that provide software engineers with tools to compile, edit and debug code in a development space. Probably the best known IDE is Visual Studio by Microsoft. This program allows the development and publication of programs for Windows based platforms. Refer to figure 10.

- *Application Program Interface (API)* are sets of routines provided in libraries to extend a language's functionality. For example, Map Suite by Thinkgeo allows users to extend the functionality of Visual Studio to provide map functionality for mobile applications. There are a huge number of APIs available. They can be thought of as a plugin for languages.

- *Software Developer Kits (SDKs)* are software packages that enable software engineers to develop applications for specific platforms. For example ESRI has recently released a SDK for the development of mobile mapping software on smart phone type devices.

Figure 10: Visual Studio is an integrated development environment. It looks similar to the application builders in Figure 8 and Figure 9. However, they offer a more detailed software engineering environment, where applications are built from the ground up using complex design, compiling and debugging tools. In this example an application is being designed for a Blackberry Smart phone.



What does the software look like?

Options for software are virtually limitless, almost to the extent that if you can imagine it, it is possible. Perhaps the hardest thing is finding the right software solution. A dichotomy in field software is delineated by the requirement to represent maps. Maps require some form of GIS display. Without maps the field software is usually presented with forms or tables (for example, truck delivery dockets can be represented on a electronic form with a similar format to paper forms). The two styles of field software are discussed below.

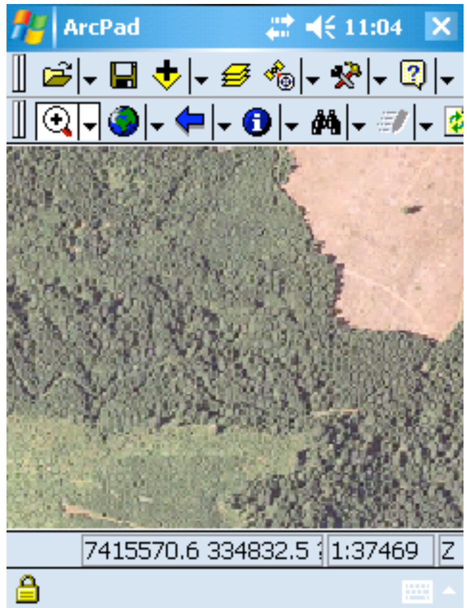
With Maps

Typically, information that needs visualisation with maps also has elements that are represented with data forms and tables. The data forms and tables hold detailed information relating to information on the map. Therefore, the map can be queried to bring up a table of information relevant to a specific timber stand or compartment. The table information is generally described as attributes of the spatial feature. For that reason most software that has map information generally has some interaction with attribute information in tables or forms.

Most map based field solutions will provide a moving map, where the field user's position is fixed in the center and the map pans under them as they travel (refer to figure 11). A number of other standard tools are also typical. These include:

- Tools to move the map around, such as pan and zoom.
- Drawing tools for freehand, lines, points or polygons.
- Selection tools to designate particular elements of the map and active them.
- Methods to turning layers on or off and changing the order in how they a drawn (top to bottom).
- Options to manage GPS functionality, on, off, start record, finish record, recording type (point, line or polygon).
- Tools to measure distances and areas.
- Search and query tools.
- Information tools.

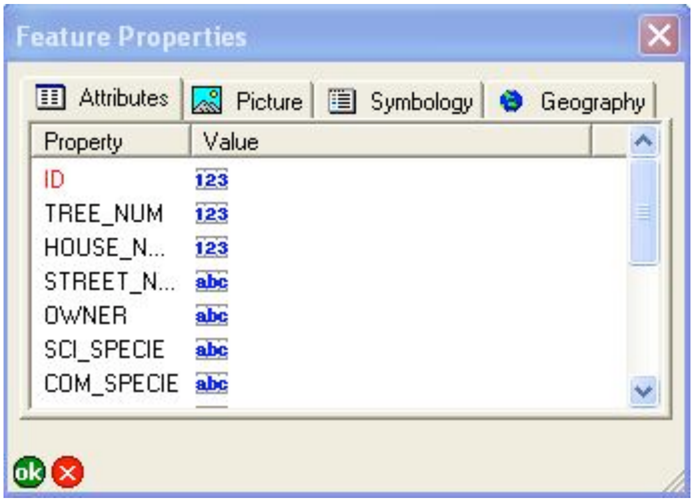
Figure 11: This screenshot is an aerial photo that is being used as a background layer for Arcpad on a PDA style mobile device. The buttons to activate various tools and controls can be seen across the top of the screen, with drop down arrows next to icons to provide more options for related tools and buttons. If the GPS was activated the photo would move to ensure the current location was always centered in the middle of the map.

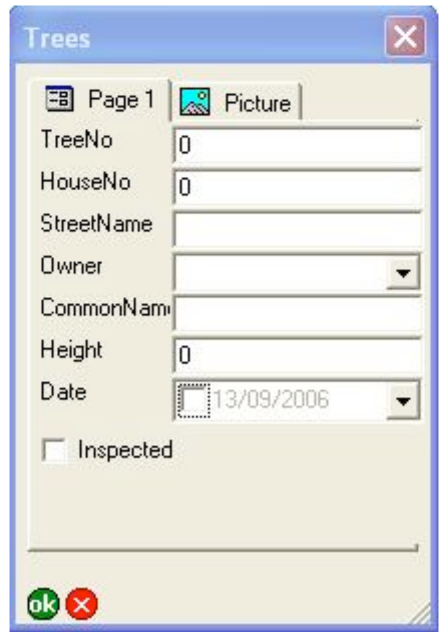


(image courtesy of Atterbury Consultants www.atterbury.com)

There are a number of software solutions that have map functionality. The largest off-the-shelf system is Arcpad offered by ESRI. Arcpad was one of the first widely available mobile GIS packages. It runs on Windows Mobile and full Windows (XP, XP Tablet, Vista, etc.). In its native state Arcpad is a mobile GIS. All the functionality and flexibility of a mobile GIS can be bewildering unless one is a technically advanced user. The purchase of Arcpad application builder allows developers to customise and focus the core Arcpad application for specific jobs. The ability to refine the functionality exposed to users allows the development of targeted and focused field applications. This may include large, easily recognised icons to perform routine tasks, and removal of unnecessary buttons and functions. The related attribute data can also be represented in user-friendly forms as opposed to the "out of the box" table view, which is not the most user-friendly or intuitive interface. See figure 12.

Figure 12: These screenshots from Arcpad illustrate how the attribute information, which is represented in a data table on the left, can be accessed via a custom made user-friendly form (right) by using Arcpad application builder. The form presents field names in plain English instead of the database field names. There are also drop down lists to select owner and date information, plus a tick box to indicate if a tree has been inspected.





Arcpad provides the ability to view, update, edit and delete spatial and related tabular information. There is some integration between their desktop GIS programs and Arcpad. Information being checked out of the desktop database travels with domains and layouts so that they appear the same on the field device. Complex relationships in the enterprise database are maintained in the exported version since Arcpad can handle "one to many" relationships. The check out and check in of versioned geodatabases handles synchronisation issues that can occur with multiple simultaneous field and office users accessing the same data. Despite all this, the method of getting information to and from the office is still a cut and paste routine which requires users to know the correct path for the data. This can become complex with multiple users.

Another application very similar to Arcpad is SOLO forest, by Tripod Data Systems (a Trimble company). This is a forestry focused spatial application which is designed to be used in conjunction with other software packages like specialised inventory programs.

Without Maps

Field software that do ***not*** require maps are generally form-based and are some-what simpler to design. A huge number of vendors offer application builders to transform paper workflows to digital workflows. There is no clear market leader in the field (e.g. Photoshop for photography, Excel for spreadsheets, MYOB for accounting). Forms based solutions can also be designed by software engineers with IDEs.

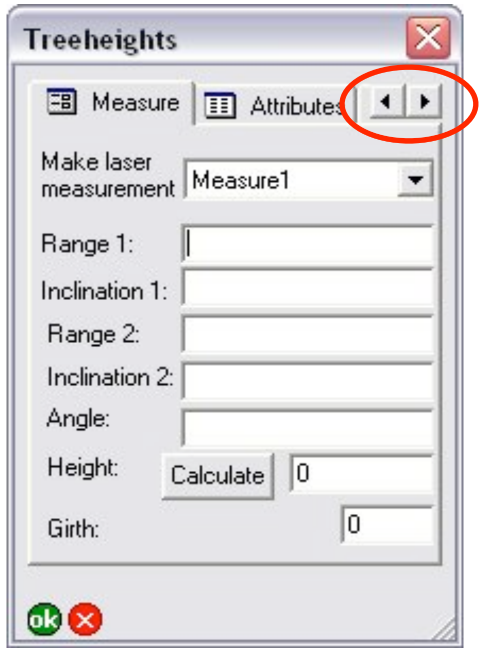
The size of the screen will greatly impact the look of the final product with screen real-estate driving efficient layout and design. For example software for handheld devices will often have tabbed windows to accommodate information, which could not fit on a single small window. Navigation buttons can be added to applications to move between multiple windows and progress through work in a logical order. Figure 13 provides an example of some of these space saving techniques.

Forms and tables will often use drop down lists or tick boxes to streamline the process of completing information, and limit options available (figure 12). The limiting options presented in tick boxes and drop down lists increases the accuracy of the data. Validation rules can also be applied to limit numeric values within a logical range. Forms may also have fields that are automatically populated with data, times, user information (based on log in), or entry of previous values. For example, a plot number may automatically increase incrementally from the last plot.

Conditional formatting is especially useful to maximise the use of space on small handheld screens. Conditional formatting is where subsequent steps are refined based on the user's responses. This limits the amount of unnecessary information on the screen, as the forms change to become more relevant and focused. For example, a road asset management form may require identifying the surface type. If the response is "sealed", then subsequent questions relating to gravel or natural surface roads are no longer relevant; instead fields that focus on sealed roads such as "seal condition" or "line marking" will be displayed.

Additional options include buttons to take a digital picture, open up forms to allow freehand sketches or signatures, record voice notes, or input from other devices like bar code or RFID scanners, laser range finders or GPS units.

Figure 13: Shows a field form used to calculate tree height. Across the top of the form tabs represent additional forms (Measure and Attributes). Tabs allow efficient use of space when screen real estate is limited. Also note the navigation arrows (circled in red), which can be used to move across and view additional tabs. The tabs may be thought of as different pages in a notebook.



The importance of standards

Standards play an important role in software. History has many examples where standards have driven the success of technologies. The world wide web was enabled by standards like HTML, JPEG and web addresses. Field software should embrace standards where possible. For example the Swedish Forest Research Institute (Skogforsk) in conjunction with leading European harvesting machine manufacturers coordinated a standard for harvester production. The standard covers data for:

- each log and stem to be described individually.
- a system for forwarder production reporting.
- routines for monitoring accuracy of harvester measurements.
- harvesting directives including maps that can be presented in GIS applications.
- operational monitoring with strict definitions of relevant key figures.

The standard, known as StanForD (Standard for Forest Data and communication), was originally developed using software code known as “Kermit”. This is currently being updated to a more useful XML code which is used widely today and easier to integrate with other modern solutions. Obviously anyone looking to work with and communicate data between mechanical harvesters should try to adopt this standard where ever possible. This will allow greater compatibility, allowing information to flow between harvesting heads and office systems.

Standards provide the ability for disparate software to interchange information. The key point is that regardless of the underlying architecture of the software, if packages can export and import information using common standards, there is much greater opportunity for information exchange between programs. Some important standards include:

- Shape Files are a GIS file type pioneered by ESRI.
- XML (Extensible Markup Language) is a way of exchanging structured information between programs.
- GML (Geographic Markup Language) is used for describe spatial information.
- KML (Keyhole Markup Language) is an XML based language used to describe spatial information in 2D or 3D. It was made popular by Google with the release of Google Earth.
- NMEA (National Marine Electronics Association) is a protocol to define satellite information received by GPS units.
- SQL (Structured Query Language) is a computer language used for relational databases.

The devil is in the details - getting all the pieces working

The development of integrated solutions requires information flow between the office and field in a two way process (refer to figure 3). Conceptually it may be very simple, but if office and field applications are developed in isolation there must be something placed in the middle to act as a translator. This adds complexity because now there are three applications that require ongoing support. Many software engineers shudder at the thought of integrating systems. Whilst integration between software programs is possible through the use of standard languages and formats, the devil is in the details.

Unfortunately many of the application builder style programs fit this three application process. There is the enterprise, “built” field application, and some middle pieces to translate between the two. The translator is often represented by a server program, which is involved in the synchronisation process. Because most Windows mobile devices rely on Microsoft Active sync when operating on the disconnected communication model, there may be four or more applications involved in the synchronisation process.

Ideally programs are designed to work with each other, so that the development of one is undertaken purely to satisfy compatibility with the other. Typically the enterprise information systems is put in place first with a known data model. The field solution is designed to meet this data model, and any changes in the enterprise model requires updates in the field software. Generally, different companies provide the enterprise and field software, and typically the field software bows to changes in the enterprise data model.

The difficulty of enterprise companies offering field solutions is related to regionalisation, where each region does things slightly differently, even within the same company. Weyerhaeuser, Cegena, and Inform all cited this as a major impediment, since each field system needs to be programmed slightly differently to match the region’s business rules.

Historically this is one of the reasons why enterprise developers have not been interested in field solutions. It is expensive to write unique software code for what is a comparatively small part of the enterprise solution. Consequently, smaller vendors have traditionally built field solutions for larger enterprise systems.

It is likely that companies that offer large enterprise forest information management systems will develop their own field solutions. At the very least partnerships are starting to appear where import and export formats are formally shared between enterprise and field software designers. Atlas Technology (New Zealand) offers their own field solutions which are integrated with the enterprise system. This is driven by demand from their New Zealand and Australian user base. This is seen by the company as value adding, since the core modules of the enterprise system have reached maturity. The field software adds a new product line and provides a marketing edge. Signs indicate other enterprise software companies may follow suit as the core modules of the enterprise system mature. One method to deal with regionalisation issues is for enterprise vendors to provide a basic "application builders" to allow some basic customisation of their applications, but maintaining the underlying core functionality.

Case studies

Tempus Microsystems

Grand Prairie Alberta Canada
www.tempusmicro.com

Tempus Micro Systems have an integrated solution for managing log haulage and includes three components:

- maximising the load capacity of each truck,
- assisting in truck cycling patterns, and
- administration of load manifests and driver log books.

Although various implementation options can be taken, the full system includes a scale on each axle group for the truck and trailer which is connected to a solid state computer (containing no moving parts such as fans or hard drives) running Windows XP. The computer has a touchscreen display for the driver. It communicates over short range with WiFi and long range with radio, cellular or satellite modem. Each truck is also fitted with a GPS unit to provide location information via modem.

The loader operator at the forest log landing also has a touchscreen display which connects via WiFi to the truck's computer. This enables the loader operator to view live feedback with a count down displayed as each load is deposited on the truck and trailer combination. This speeds up the loading process and optimises the weight for each axle group.

At the completion of loading, the loader operator transfers an electronic docket to the truck's onboard computer using WiFi. Many of the fields in these forms are automatically populated, such as time, date, loader operator, truck number, log stack, etc. Again, this saves time in the supply process.

At the mill, when the load passes over the weighbridge scale, the docket information is downloaded via WiFi to the Tempus server. This information is used to populate information required by the weighbridge. This administrative function reduces the need for manual paper-based docket systems and the resulting data entry and reconciliation.

Each truck is tracked via GPS. The manager, supervisor and dispatcher all have the ability to view live positions for each truck, including load status, speed, direction of travel, and a summary of hours worked by the driver. This information, combined with the ability to send text messages to drivers, allows greater oversight in dispatch management. Drivers also have the ability to use their truck's touchscreen to view live maps of other trucks. This allows drivers to drive more efficiently in cycles to minimise bottle necks. Moving maps also provide navigational assistance to drivers, which is especially useful when they enter new work areas. The maps provide navigational assistance by allowing drivers to find the shortest or alternate routes between any two points.

The touchscreen is the interface for the drivers' log book, where they can enter duty hour, safety checks, pre-trip and post trip checks, and the GPS can log driving hours. All this information is routinely downloaded to the central server. The server also records information on:

- *Driver statistics*: hours worked, number of loads hauled, driving habits.
- *Load statistics*: total loads hauled, type of load, weight, amount hauled to or from a specific place.
- *Engine data*: capture any information that the truck's engine computer generates, such as fuel consumption, mileage, speed, tachometer readings, temperature, or oil pressure.
- *Cycle statistics*: time for each section of the cycle, load and unload times, variations due to weather and road conditions.

Alerts can be set for managers that warn when pre-defined parameters have been reached. These could be spatial parameters when trucks move beyond pre-defined routes or area, or they could be defined as speed, hours worked, weight, etc.

Ongoing maintenance of the system is minimised since the truck's computers constantly look for updates on the server after each WiFi download at the mill. This enables future updates to be rolled out to all trucks in a coordinated fashion with minimal intervention.

The fleet management solution offered by Tempus Microsytems is noteworthy because it addresses three problems in log haulage delivery. It is an elegant solution integrating the way that information is handed between loader, truck and office. The return on investment the companies have experienced was stated as between 2 months to 1 year. The customers of this solution are usually haulage operators, since they have the most to save with increased performance per truck. However it could be argued that there are others who benefit. In a delivered sales arrangement, there is a vested interest in managing the wood flow efficiently, and in a stumpage situation mills have a vested interest to ensure wood flow is managed efficiently.

Tempus Microsystems is only 4 years old and has spend $4M developing the core-functionality of the system. There is a long list of future developments including ideas for harvesting machines. The price varies depending on functionality. A tracking only option can cost as little as $450 per truck, but the complete system is between $3600 and $6500 per truck, depending on the whether it is satellite or mobile phone based. Air time ranges between $25-$75 per month. The servers and software cost approximately $6000. All prices are presented in Canadian dollars.

Opti-Grade

Forest Engineering Institute of Canada
FP Inovations – FERIC Division
http://www.feric.ca/

Forestry road networks are largely natural or gravel surface roads, which require regular maintenance. If organisations over service roads, money can be wasted. Conversely, if the roads are under serviced, they deteriorate, adding to haulage times, fuel costs and truck maintenance costs. Opti-grade is a solution to optimise maintenance of unsealed roads. Data loggers record information from an accelerometer (mounted to the truck axle to measure road surface roughness), and GPS. The data recorders are fitted to a selection of trucks using the road network. The number of units needed depend on the size and distribution of the haulage fleet. Opti-grade data recorders should be fitted to enough trucks to provide a representative sample of the haulage network. As haulage trucks undertake their routine activities, road roughness, location (via GPS), and time of each reading is stored on a data logger. The driver is not required to interact with the data loggers, either to record the information or download. The information is transferred automatically as trucks reach download hubs set up at places like weighbridges or depots. All the data is transferred to a server via internet and analysed by an optimisation algorithm. The algorithm optimises grader time to ensure the roughest sections of each road are targeted with the limited grading resources. The roughness threshold can be set for different classes of roads, so major arterial roads are maintained to a higher standard than minor forest roads.

Some implementations in Canada have seen grading costs decline by 25%, and some cases cited by the developers indicate returns on investment were made within 6 weeks. Even if these figures are treated conservatively, substantial road maintenance savings can be made. Developers are working on producing a version which can be run as an extension of ESRI GIS software. Some customers have opted to customise their own optimisation algorithm but use the Opti-Grade Data recorders to acquire and transfer the information to servers.

The Opti-Grade system is another elegant solution because it provides unbiased assessment of road conditions with high sample rates. It is an example of an automatic process embedded into routine tasks, so no additional time is spent sourcing information, once the system is established. The information provided by the trucks can also form the basis to cycle time analysis, and provide detailed supporting information for road upgrade proposals.

Carto Pac Enterprise

Colorado State Forest Service, Forest Stewardship
http://www.spatialdatatech.com

Forest Stewardship programs rely on collaborative actions between government forest managers and private owners to develop, design and implement forest management plans.

A web application that allows the management of forest stewardship information (web-DET) was developed in a partnership between the federal USDA Forest Service, and the state forest agencies. Web-DET is used by federal and state level forest management agencies to record property details, contact information, and detailed stewardship plan information. It also provides a uniform system to the spatial display, analyse and report on stewardship activities.

The key drivers that saw the development of web-DET were:

- a desire to get away from first come first served distribution of government funds and to have a strategic distribution of funds based on resource requirements,
- increase accountability of program funds by providing greater accomplishment reporting, and
- an ongoing need to manage information relevant to stewardship plans.

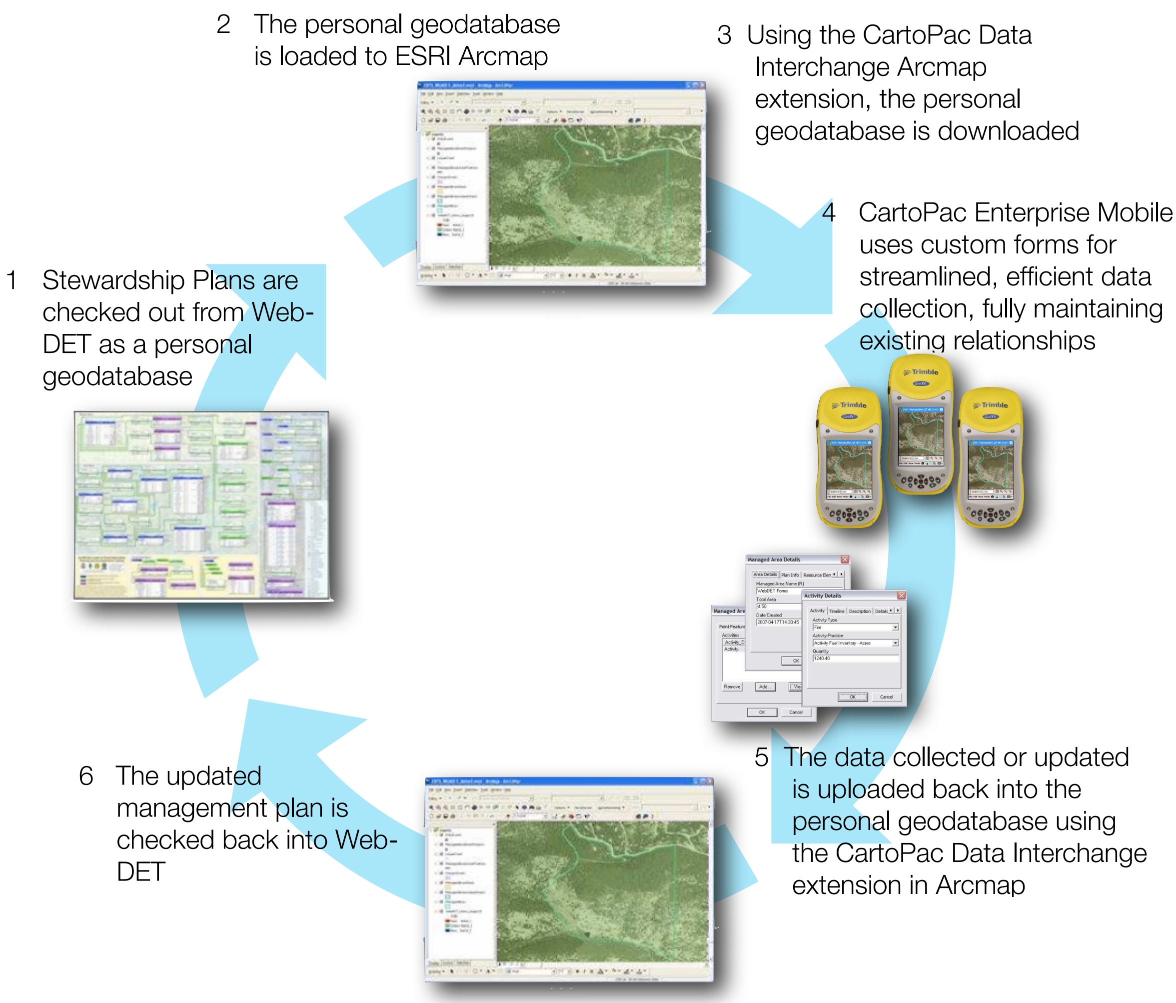
The Colorado State Forest Service adopted the web-DET program and worked with Spatial Data Technologies to develop an integrated field application to compliment the web-DET data model. The solution is a full *check-out*, *check-in* system which maintains the complex relationships in the enterprise database.

The field application was developed with CartoPac Enterprise, which is an application builder (refer to designing the software on page 31). This enables one to build field forms using the CartoPac user interface, and these forms can then be run on handheld devices. The CartoPac software on the mobile device has GIS map functionality, which works in collaboration with GPS units, and focused field forms to suit the particular task. CartoPac Enterprise was described by one Colorado State Forests Service forester as the “Holy-grail”. It provides the ability to build field applications that mirror the workflow and business rules of the office applications, and facilitates the transfer of information to and from the field.

The stewardship plan is first developed in the enterprise web-DET environment. This is then checked-out to a mobile device, and where it is available to field workers to update, edit or delete spatial or non-spatial attributes. Once field work is complete the data is checked back into the enterprise. The information flow is represented in figure 14.

One of the drivers for the use of web-DET for the Colorado State Forest Service was that federal funding for Forest Stewardship activities is tied to accomplishment reporting. CartoPac Enterprise provides a mobile application that enables individual forest stewardship management plans to be managed and updated in the field. The web-DET was cited as an important archival tool, as well as the providing a day-to-day management tool for current information. Traditionally, a large proportion of historic forest management information walked out the door as staff moved on. The geodatabase approach to storing and managing information is building up institutional knowledge with little additional input.

Figure 14: The information flow used by Colorado State Forest Service's implementation of CartoPac Enterprise in combination with the web-DET program.



Washington Department of Fish and Wildlife

Timber harvesting impacts on amphibians
Pendragon Forms
http://www.pendragon-software.com

Washington Department of Fish and Wildlife (WDFW) has established 18 catchments to monitor amphibians pre-harvest and post- harvest. The catchments have streams that range in length between 600 meters and 3 kilometres. They have recently changed from traditional paper based field work and now gather the field information on consumer grade PDA units.

The project made the shift to digital devices partially in response to errors that were occurring with paper records, and the time consuming task of transferring data and converting it into a useable form. The adoption of Pendragon Forms was made after recommendations from peers working in similar fields. The PDA digital workflow has is quicker and more accurate for users, providing savings in time and data quality.

Pendragon Forms is an application builder, which enables electronic data collection without high-level software engineering skills. The project was developed and implemented using biologists who possessed mostly self-taught IT skills with some peer and developer support. A good understanding of the workflow, or a good understanding of Microsoft Access, was considered a minimum prerequisite to customise Pendragon forms for mobile applications.

Pendragon software allows the creation of customised forms to match existing databases schemes, or it can create the access database from new designed forms. Most of the teething problems experienced during the project were associated with database design and related specifically to relationships and unique identification numbers.

A conscious effort was made to train field users with paper based work flows so they understood the underlying data before moving to digital workflows. Most field users were young and picked up the digital workflow as second nature. No data was lost over the field season. Some trouble was experienced with one PDA hardware brand, however the majority of units were Dell Axim X51 which proved reliable over the project. All units (12) were encased in weatherproof housings which provided a level of field ruggedness beyond the off-the-shelf design.

The PDA units were used in a disconnected communication environment, with units physically taken to the office at the end of the field week for downloading. The data is then downloaded to an Access database using both Microsoft Activesync and Pendragon SyncServer. The success of the first field season using Pendragon software for fieldwork has created the impetus to consider other field tasks that could benefit in a similar vein.

Although this case study is not a fully integrated information management solution, it represents an important step along the path that many organisations are making. The ease of adoption of form based (non-spatial) applications and the relatively low price for form building (application builder) software reduces the risk involved in embarking on digital data collection tasks. Pendragon is only one of many application builders available, which can synchronise in-house databases. The Pendragon software used in this case study can be extended to allow a two way information flow and synchronisation using the internet or over wireless carriers if desired. Therefore it may be the foundation for further projects that have greater integration, making enterprise information available to field workers.

Impediments to field technologies

One of the biggest technical impediments to developing new field solutions is the inherent flexibility of paper based workflows. So much so that many field tasks do not have formal business rules. Instead, decisions are made informally, and intuitively with ad-hoc field records. Notes are jotted in paper notebooks, pieces marked on maps and the field decisions are pieced together in the process. The inherent flexibility of field notes, checklists, and dockets should not be under estimated. If something new comes up notes can be taken and checklists can be modified. Conversely, database systems are more rigid and it takes time to change the data model to accommodate new or different data types. The database approach also requires detailed business rules to define how information is related, what is acceptable, and the order that information is recorded in. It may sound easy, but distilling a work practise into a single unified process is one of the most challenging impediments of integrated field information management systems. Many interviewees noted that it is difficult to get consensus within a region and almost impossible to get consensus between regions because each have their own unique circumstances.

The human element presents another impediment. Some field workers may not want to work with technology. Older forestry field workers may have little or no experience with computers or technology. Others feel threatened by technology that has the ability to record productivity, and see the potential to monitor their work, big brother style. Whilst these issues are not insurmountable, they are worthy of consideration, and may render any field based projects undone if not handled sensitively.

Deploying field devices as part of an integrated approach to managing forest information has the potential to leverage investments in office information management systems. Whereas enterprise office systems are seen as a cost of business, field components are carefully scrutinised and are seen as discretionary. Hence, many forest companies highlighted the cost of field solutions as an impediment. One software vendor made the comment that because field devices have small screens customers expect small prices for software. The reverse is more realistic given the time taken to highly customise applications that efficiently use the limited screen real estate, plus the requirement to enable complex synchronisation processes. Therefore, whilst office enterprise systems are seen as essential to the business, and somewhat inelastic to price, the cost of adding a field component to the enterprise system is often highly elastic with costs being a major impediment.

Another impediments cited by software vendors for development of integrated field applications is related to the visibility of costs. Using traditional work practise it is difficult to see the cost related to duplication of effort, errors in data, less-informed field decisions, and slower access to information. However, when proposing an integrated field application, many of the costs come up front as hardware and software costs, which have greater transparency. The visibility of these costs, especially if they are technology focused and come from another budget source, was presented as an impediment for development. It is not that it may be more expensive in the long run. It was that the costs are more transparent and tangible, which means they are easier targets to cut from budgets in lean years.

Another commonly discussed impediment amongst interviewees was the time taken to research, recommend and project manage a new system. Simply stated one has to fall behind to get ahead, but when performance is managed by staying ahead there was little incentive to stick your head out and risk new approaches when it was not part of one's core duties. This is especially true when staff are not software specialists, and they do not have the specialised skills to identify enhancements to current enterprise systems. There was a feeling that there was a better way, but it was difficult to find the time to explore options and solutions. It raises the question of how forestry organisations foster new ideas. At one end of the spectrum companies such as Weyerhaeuser actively sponsor competitions for innovations. At the other end, some staff took the view "it was good enough for my dad, it's good enough for me".

Sometimes the GIS staff were cited as impediments for the development of field applications. It was suggested that they did not want field staff to have access to change corporate GIS layers. It was observed on multiple occasions that GIS staff did not want their information corrupted by inexperienced field staff. Even field data collected in accordance with business rules may need cleaning, to ensure the layers match up. GPS sourced data often comes with rough edges and extra squiggles, which are artefacts of fieldwork. Therefore, it is understandable that GIS staff are cautious of letting down their guard given the time and investment spent on most forest enterprise GIS datasets. This does not necessarily mean field workers should be excluded from accessing and editing base corporate information, just that quality assurance steps need to be built into the workflow to ensure all new data, edits or deletes have some data quality checks.

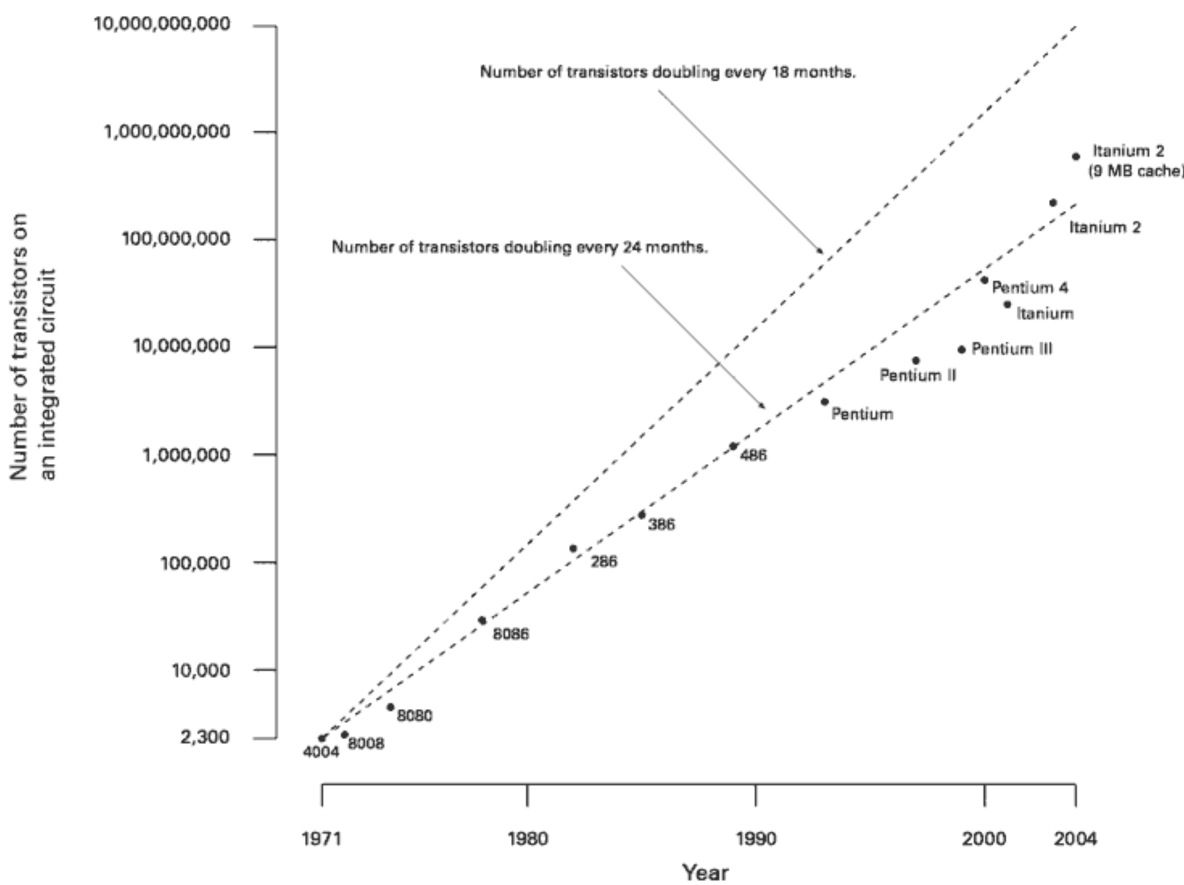
In some instances the base GIS layers may be less accurate than the GPS data. In these cases the issue is not absolute accuracy but making the new and edited data match the existing data layers so that they are contextually aligned. Again it is not a reason to limit field access, simply to ensure quality assurance processes.

What the future may hold

Before looking to the future, spend a moment to think of the past. In 1971 cutting edge microprocessors only had 2,300 transistors. Fast forward to 2005, Intel's server processors had in excess of 1 billion (10^9) transistors. This rate of growth in the development of transistors per microprocessor is described by Moore's Law which says processing power will increase exponentially, doubling every two years in the foreseeable future (refer to figure 15). Affordable hard drive capacity is developing at a similar pace.

If the focus is now turned towards the future, think of computers and field devices with 2, 4, 8, or 16 times the processing and storage capacity of today's devices. This is only 2 to 8 years in to the future. Eight years is not a long time in forestry, but technology will continue to evolve at a rapid rate. Therefore, field devices with greater processing power and storage capacity are just around the corner.

Figure 15: Represents a graph of the number of transistors on an integrated circuit over time. Extrapolation lines describe rates of growth if the number of transistors doubles every 18 months or 24 months. NB the Y-scale is logarithmic, which can mask the scale of the change over time.



www.en.wikipedia.org/wiki/Moore's_law

All of the technologies that enabled field computing to develop will continue to evolve over time. Consumer demand for recreational mobile devices is driving battery technology. Some promising options include fuel cell designs, which derive energy from a chemical reaction as hydrogen is combined with oxygen to produce water. Other promising battery technologies use nano technology to allow capacitors to act as energy stores, with the benefit that batteries could be charged in less than a minute. Battery technologies will be critical as micro processors demand more power and to allow greater endurance. The longer the battery-life, the more portable and efficient hand-held devices can operate (particularly those that require bright large screen displays), thus expanding the potential applications for forestry.

Future GPS technology will provide greater accuracy and reception under canopy. A Russian Global Orbiting Navigation Satellite System (GLONASS) is forecast for completion in 2009 whilst a European Satellite system “Galileo’ will be commissioned by 2013. Although designed to operate independently, new GPS are likely to have multiple sensors that will allow the use of satellites from multiple systems to increased accuracy. Increased accuracy of real time GPS will increase the utility, accuracy and timeliness of spatial information, particularly under forest canopies.

Remote sensing is likely to replace many traditional field information gathering and management activities, including inventory and surveying forest stand boundaries. The spatial accuracy of remotely sensed information from both aircraft and satellite is approaching that of ground based GPS data collection. Furthermore, Light Detection and Ranging (LIDAR) in combination with other remote sensing techniques (digital photography) is able to map the ground and tree canopy at high resolution to provide incredibly detailed information. Companies such as Image Tree are commercialising inventory systems using LIDAR technology. Together with spatially accurate high-resolution digital orthophoto layers, LIDAR will supplement, and eventually replace many existing field planning and auditing works.

User Interface

The interface is defined as the way that users interact with the technology. Today it is mostly via keyboard, touchscreen, stylus and mouse. The future holds a number of promising technologies.

The displays used on handheld devices are likely to become larger and lighter as digital inks are commercialised. Digital ink is a new display technology that is likely to take over from liquid crystal displays for field devices. They only consume power when the display is being refreshed or redrawn and is then viewable like printed inks. They also have the ability to be embedded into flexible sheets. In this way a digital map may be provided on large flexible sheets of plastic, without consuming any energy when information is not actively being refreshed. With current technology larger displays mean more power, and therefore it is not possible to develop mobile devices with large screens without access to a significant power source.

The interaction with displays is also likely to change with the development of multi-touch displays. With multi-touch, the user can interact with a screen using two or more fingers simultaneously to do things like drag images across the screen, zoom, and scroll. On larger devices it opens up the option for multiple users to interact with the information. Multi-touch touchscreens provide a better medium to interact with maps. Apple has released iPods and the iPhone multi-touch mobile devices, whilst Microsoft has developed kiosk style multi-touch tables.

There are a number of other interface alternatives in development. Voice recognition, where users utilise speech to interact with the computer, has evolved to a stage where it has been commercialised for some industry applications (e.g. warehouse inventory management). There is also an extension to Arcpad which accepts voice commands.

Other visualisation options that are being commercialised includes "*heads up*" displays where the user display is projected onto the lens of glasses. This give the impression of a large screen overlaid in your field of view.

Mashups

There is a trend towards integration of systems and exchanging information between systems. The term "*mashups*" was coined to described software programs that are comprised of elements from many different sources. It is particularly applicable to a new generation of Internet applications (also referred to as Web 2.0) where software pieces from various Internet applications can be incorporated into new tools. There is also a trend towards using web applications like Google Earth and Google Maps as a foundation for user friendly software tools (e.g. Google Earth may be used as the background for vehicle tracking application). As wireless Internet access continues to expand this trend is likely to increase in forestry applications, and provide a comparatively cheap foundation for future solutions.

Mesh networks

The longer range of Wimax technology may see the rise of mesh networks. Mesh networks are made up of multiple nodes, which communicate with neighbours to pass information back and forth. They are self healing, so that if one node is not responding traffic will go to the next closest node. Mesh networks are currently used in Australian Agriculture in a research and development phase, but future opportunities may be available in forestry settings. For example harvesters, haulers and foresters could be set up with Wimax to enabled mesh networking. The daily spread of workers could act as a network to get information flowing from the field to the office and back. The advantage of a mesh network over conventional wireless networks is that there is no network access fee, because information is flowing peer to peer between each node. It also is scalable and shifts its footprint with users work locations. The disadvantage is that it is not a regulated network with service coverage commitments.

Synchronisation

To date, many integrated solutions have been developed with customised solutions to enable information exchange between the enterprise server and field device. This has usually required multiple steps and processes to transfer information to and from the enterprise data set. Influential companies like Microsoft and Google are releasing developer frameworks that allow programmers a foundation to manage most of the synchronisation issues. Google's Gears allows next generation web applications to operate in an occasional connected environment. This means some applications that have previously required live connection to the Internet can be taken off-line as an occasional connected application whilst maintaining the application functionality. Microsoft in November 2007 released the Microsoft Sync Framework, which will provide the foundation for synchronising field devices. Indeed it allows users to leap frog data (peer to peer) and have it synchronised back to the server via other field workers.

The ability to have an occasionally connected application is greatly enhanced by these new developer frameworks released by Google and Microsoft. It acknowledges current limitations of continuous live connections to central servers. They allow integrated solutions with streamlined synchronisation processes to be developed with greater ease, since most of the synchronisation architecture is already developed and only needs customisation for the specific project. These synchronisation frameworks allow greater power at the field (client) end and reduce demand for continuous connection to the server. Currently there are very few occasionally connected applications in forestry. However, these frameworks are likely to enable future developments of this type.

Recommendations and conclusions

There are a number of software companies that offer customised field solutions. When provided with detailed specifications and defined business rules, customisation companies can write field applications for specific purposes using IDEs, APIs and/or SDKs. Because these are customised, they have the ability (to varying degrees) to integrate with information from existing enterprise systems. Vendors vary widely from small “back yard” outfits to large global vendors such as Trimble, Sanborne, ESRI and DPRA. Vendors that develop customised solutions refine software code used to undertake routine activities such as displaying a map, marking a GPS location or synchronising information. Being familiar with routine functions allows vendors to deliver efficient solutions without re-learning specialised skills each time. Those vendors that offer mobile software develop specialised skills working with mobile devices that are not typically found within most in-house forestry organisations.

When considering one-off field software applications, customised solutions from external providers may be more cost effective than in-house development because it removes the need for staff to learn new software tools. Furthermore, external providers may have a greater focus in keeping up with advances in technology and software trends. This often means greater capacity to support, maintain and update software after implementation.

Given the variety of providers available for customised solutions, forestry organisations should have a clear framework to rank vendors. Price alone may not represent the best value. Pacific Northwest companies listed the following points as important: the ability to develop good working relationships, support and training, ongoing maintenance, resources, timeliness of past work, software architecture and technology used, experience in like projects, past track record, location, longevity of the business and the future business plan. Many of the non-price attributes were highly weighted by forest organisations.

In-house staff can develop field software using many of the same software engineering tools used by consultants (i.e. IDEs, APIs, SDKs or application builders). As with any task, IT staff that routinely work within these software environments become more efficient. The use of internal IT skills is best suited when you have an ongoing commitment to support the project, or when multiple applications will be developed. Economies of scale are built up over time as IT staff become proficient with writing and supporting mobile applications.

Forest organisations usually have limited IT staff who are required to be generalists, providing a range of services. If developers are part of the general IT pool, it may be difficult to get access for specific projects. Furthermore, specialised in-house projects are exposed to higher risks as IT staff turn over in forestry companies with small IT pools.

The first priority for integrated field information systems is to develop the foundations of an integrated office system. There is no point having streamlined field information if the decision makers and project managers do not have the right tools to organise and manage the information. Discussions with companies and software vendors indicated implementations of integrated enterprise systems took in order of two years to fully implement. A number of field systems were put on hold until after the enterprise systems were in place.

When investing in integrated field information systems a clear business case needs to be developed. Technology is not the solution to every situation and unless there are defined business cases with understood business rules and process, it is not worth pursuing new systems. When exploring the business case it is desirable to look at the costs and risks associated with current work practises, together with those of the proposal. It is also worth consulting widely between sections and between regions. The connectivity between various operational sections may provide added integration and cost sharing opportunities. If field staff have a mobile computer which is used for asset inspections or operational planning and auditing, why not leverage the hardware investment and use it to manage field workers' time sheets and other administrative tasks?

The easiest solutions to integrate are those that already have well defined workflows. Look for paper-based systems that have docket books and check sheets that are required for business processes. If there is already an office database for these, it may simply be a matter of digitising the paperwork. Once a clear business case has been established, a decision needs to be made regarding the development path, whether it will be in house or outsource. Whichever route is chosen, sufficient resources should be allocated for the project. This should include development costs, hardware costs, upfront and ongoing software licenses, training and continued maintenance and support costs.

It is worth noting that nothing remains static over time. Field technologies will continue to evolve, as do business processes. Project managers need to be realistic about the projected lifespan of projects and allow sufficient resources over the project lifecycle. The objective should be to keep solutions up to date with business processes or have sufficient resources to implement new solutions at the end of the current lifecycle.

Every technology will have "teething" problems during implementation. A number of factors can limit the impact of teething problems. These include thorough testing, targeted training for users, phased introduction to limit potential impacts, and high level support. One forest manager commented that you don't want to burn up the good will of field workers by releasing buggy or ineffective software. He considered it especially important to thoroughly debug and test field solutions before release.

It is important for software engineers to understand the work tasks and understand the workflow. Many of the successful data entry solutions mimic existing paper based workflows that have evolved and stood the test of time. It is critical to understand the decision making process from the field workers' point of view. A couple of successful forestry field technology companies (JRP systems and Tempus Microsystems) were born from experiences that designers gained as students working in forest field operations. This provided the fundamental understanding of business cases and workflows.

The importance of the user interface design is critical. This was emphasised by all organisations interviewed for this project. Field workers do not need a computer; they need a tool that helps them with their work. If a solution adds time and is more difficult to use than past work practises, it is unlikely to be adopted. The down stream benefits of a digital workflow do not necessarily provide tangible benefits to field staff. Therefore, field solutions need to have direct benefit for field staff who use them on a daily basis. Without this, it is difficult to get users onboard.

The best way to get field staff "buy-in" is to involve end users in the development process so that they understand the objectives of the project, they have input into design, and the final solution is not unexpected. There are numerous examples of systems with proven efficiencies failing in implementation because the user base did not embrace the technology. Therefore a technical solution is not enough, it needs broad support from the user base. There may be certain users that do not cope with changes to digital workflows. Resistance to change is not the sole preserve of digital workflows. Genuine cases of staff unable to cope with digitised workflows are rare. Examples that were cited by companies tended to be field users near the end of their career who have entrenched patterns of work and who had little exposure to digital technology in the other parts of their life. Typically even non-technical field staff adopted digital workflows if the user interface was well designed, it provided tangible benefits (quicker, easier, or added decision support), and training was provided during implementation.

The return on investment (ROI) from adoptions of new technologies has been difficult to gauge. None of the companies interviewed have attempted to calculate returns on investment for enterprise applications. Many see the enterprise applications as a "cost of business" and adopt the best solution for the business. Certainly this has been the case for most large scale forest management organisations. Software vendors on the other hand tend to have quantified examples describing ROI, which they use for marketing purposes. Anecdotally, one software vendor noted that if a handheld solution has a ROI of greater than 1 year, they find it is difficult to make the sale. This seems relatively short, but it shows that the tipping point for companies is low. It demonstrate the risk perceptions, with ROI over a year seen as too high. It could be that other areas of the business have greater need for what is often limited capital.

The question of return on investment is also different to different players. Accountants view investment in tangible financial terms, but foresters, who are typically time poor, search for time efficiencies. It may be that forest workers can get more done as opposed to getting the same amount done and saving money overall.

Discussions with the University of Washington Precision Forestry branch indicate many organisations see mobile field solutions as high risk, which means there needs to be an demonstrable business case before adoption. To date, organisations rightfully favoured systems that offer a high value proposition, such as systems that offer haulage optimisation or streamline log haulage logistics. Although credible business cases can be made for adoption of technology in routine field functions such as planning, auditing and reporting of forest management activities, the perceived risk may be too high for new technologies.

Many forestry organisations in the Pacific Northwest are going through a process of implementing enterprise data management systems and combining or integrating various disparate systems into unified geodatabases. As the enterprise systems mature, organisations are likely to look further down the line and address further efficiency gains. The business rules and work flows developed for enterprise systems can largely be applied to field applications. This trend is also occurring in many large Australian forestry organisations. With increased emphasis on efficiency and reducing the cost in commercial forest operations, it is likely that field computers will become ubiquitous in many field activities. Whilst there are some impediments to adoption of new field technologies, there are no major barriers. As the technologies continue to mature and solutions are pioneered by earlier adopters, risk perceptions will change.

The last five to ten years has seen fundamental changes to the ownership patterns of industrial forest timberland in the United States. These changers occurred because of shareholder pressure and unfavourable tax treatments of traditional publicly listed companies when compared with real estate investment trusts (REITs) and timber investment management organisations (TIMOs). The change has seen the end of vertically integrated companies where large industrial owners that owned forests and processing facilities were effectively forced to sell off their forestland to remain competitive and to meet shareholder expectations. These ownership changes have seen a fundamental change in forest management priorities. No longer are large industrial land owners managing the forest primarily to supply their processing facilities. Shareholders are demanding that industrial forest owners are financially and investment focused to provide returns to shareholders and investors. They are driving forest owners to seeks new ways of making a financial return beyond merely selling timber. This could include selling forest land as real-estate, conservation easements or selling hunting rights. The focus is not purely timber and keeping processing facilities supplied.

So how does this affect integrated field information systems? Interviews with software vendors suggested that the stronger investment focus within TIMOs and REITs is driving greater use of technology. They are seeing enterprise forest management systems develop greater links with accounting, valuation and optimisation packages. The new industrial timberland owners have a greater need for financial reporting and cost benefit analysis. One forester working for a TIMO pointed out that time-poor foresters in lean TIMO or REIT forest companies need solutions to save time and manage the information burden. If they can provide clear return on investment, then they are likely to be adopted. Furthermore, REITs and TIMOs have a narrower field of focus compared to the vertically integrated owners of the past. Whereas vertically integrated owners tended to focus capital investment on high value components of the supply chain, which tended to be the processing mills, REITs and TIMOs only have the land management component of the supply chain to concentrate investment and management.

When forest managers in the Pacific Northwest were asked “why isn’t there greater use of technology in forestry, for example in comparison to Scandinavia or processors further down the supply chain?”, the responses ranged from, i) historically cheap land, ii) cheap fuel and transportation, iii) historically large timber supply from government land and iv) historically vertically integrated companies with other priorities for capital. Interestingly, all of these positions have changed dramatically over the last decade with shifts in ownership, changes in public land use and most recently with increased fuel costs. The United States has become more dependent on the import of timber (primarily from Canada). The competitive global market when combined with the aforementioned changes may create greater impetus for efficiently managed field information and methods to undertake field activities.

Australia has had a long standing trade deficit in forest products. A range of incentives have been in existence since the 1960's to expand the Australian plantation forestry sector. The latest wave of stimulus (launched in 1997 with the 2020 vision) has seen the rise of a vigourous hardwood plantations sector, which is starting to reach maturity. The new breed of hardwood plantation companies (termed-Managed Investment Schemes or MIS) are commercial entities with a strong financial focus. Competition between MIS companies, rising prices for new land and investor expectations all add pressure for MIS managers to run a tight ship. Any advantages or efficiencies are exploited. Increased use of integrated field information management systems has the potential to play an important role in providing increased efficiency.

Bill Gates once said that "the first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency." Technology needs to be appropriate. Technology for technology's sake is not a solution for anything. Forestry organisations tend to be late adopters when compared with other industries. There are a number of service and utility industries in the United States that have mobile computers embedded into their daily field roles. Example include emergency management agencies (police, ambulance, fire), telecommunications field staff, and couriers such as the United States Postal Service and Fed-Ex. Many of the underlying software and hardware requirements (synchronisation, mobile GIS, GPS, communications) of these industries can be applied to forestry. Sears department stores implemented delivery optimisation and GPS route guidance for delivery drivers. This system alone increased profitability by 15%. Telstra in Australia is looking to implement a similar system for optimising the fleet of service technicians. Portland traffic police use Pocket PC's with windows mobile to query enterprise databases in real time whilst ticketing offenders to ensure they have a full history of outstanding infringements and warrants. Municipality utility workers are receiving electronic work orders wirelessly on tablet PC's and ticking off accomplishments and wirelessly downloading detailed utility plans to assist in their functions. Agricultural GPS guidance and variable rate application systems have increased yield and reduced input costs. All of these industries can be used as benchmarks for forestry applications and solutions.

Information is power. Managers need accurate and timely information to provide a common operating picture to base decisions upon. At the conclusion of this project, it was found that there is a huge number of hardware and software solutions available, but understanding the work task is the most important component. The work task, business rules and work flows need to be clearly defined before exploring solutions. Starting with a pre-defined technology and shopping it around to find a solutions is unlikely to provide the best outcome.

Appendix

Precision Forestry

Precision forestry Links
http://eng.auburn.edu/programs/bsen/research/off-highway-vehicle/precision-forestry/related-links.html

FPInnovations FERIC
http://fec2007.feric.ca/ - Canadian research and solution provider - solutions including Opti-grade and
Multi-DAT

Universities

Oregon State University - College of Forestry
http://www.cof.orst.edu/

University of Minnesota - Forest Resources
http://rsl.gis.umn.edu/fieldforest.html

University of Washington - Precision Forestry Collective
http://www.cfr.washington.edu/research.pfc/

Auburn University - Precision Forestry
http://eng.auburn.edu/programs/bsen/research/off-highway-vehicle/precision-forestry/index.html

Mississippi University Spatial Information Technologies Laboratory
http://www.cfr.msstate.edu/forestry/sitl/sitl.htm

Open source

Mobile Solutions - Open source
http://wiki.osgeo.org/index.php/Mobile_Solutions

Quantum GIS - Open source
http://qgis.org/content/view/106/79/

Free GIS data sources
http://www.freegis.org/database/?cat=1&_ZopeId=77587397A3C.99PQU6o

Mobile GIS Links

GIS Lounge-Mobile and Field GIS Links
http://gislounge.com/ll/mobilegis.shtml

Enterprise solutions

Cengea Solutions
http://www.cengea.com/app/

Lanworth
http://www.forestone.com/index.html

DPRA - Timberlands Information Management Solutions (TIMS)
http://www.dpra.com/index.cfm/m/217

INFORM - Network for Management Systems
http://informgis.com/products/forest_management.htm

SANBORN :: Forestry and Ecosystem Management
http://www.sanborn.com/solutions/forestry_ecosystem.asp

ATLAS Technology
http://www.atlastech.co.nz/home.aspx

Application Builders

3-GIS - Chameleon

ArcPad Application Builder
http://www.esri.com/software/arcgis/arcpad-appbldr/about/forms.html

BrightXpress Mobility Suite - Australian Provider
http://www.brightxpress.com/contactus.html

DataPlus - Electonic Data Solutions
http://store.elecdata.com/dataplus/

MobileFrame
http://www.mobileframe.com/products/architecture.aspx

MobileDataforce - PointSync
http://www.mobiledataforce.com

Pen Dragon

http://www.pendragon-software.com/

Pronto
http://www.prontoforms.com/

Spatial Data Technologies
http://www.spatialdatatech.com/

API, SDK IDE's

ArcGIS Mobile SDK
http://www.esri.com/software/arcgis/arcgismobile/index.html

GeoMicro
http://www.geomicro.com/company/contact.asp

ThinkGeo - GIS Mapping, Geocoding and Vehicle Tracking Solutions
http://thinkgeo.com/

SYWARE - mobile database
http://www.syware.com/products/visual_ce.php?gclid=CJqDwJv2i4sCFSSQYAodHm9ySA

"Off-the-shelf" Systems

ALDATA Software Management Inc. Chain of custody, log yard inventory, docketing systems
http://www.aldatasoftware.com/

Cypress Timber Management Software - appraisal valuation tools
http://www.americanforestmanagement.com/cypress.shtml

JRP Solutions - Forestry planting software designed for foresters, tree planters, and nurseries.
http://www.jrpltd.com/products.html

SOLO Forest - Forestry specific mobile GIS mapping application
http://www.tdsway.com/products/solo_forest

Tempus Microsystems - Electronic docketing and tracking software
http://www.tempusmicro.com/

TreeWorks Urban Forestry solutions
http://www.kenersongroup.com/treeworks.asp

Syncrhronisation and conversion tools

ActiveSync
http://www.microsoft.com/windowsmobile/activesync/default.mspx

FME - Spatial Data conversion tools
http://www.safe.com

Go Sync
http://www.tctechnology.com/

Microsoft Sync Framework
http://msdn2.microsoft.com/en-us/sync/default.aspx

Hardware

Hardware - links
http://www.directionsmag.com/companies/category/Hardware/

Juniper Systems
http://www.junipersys.com/products/products.cfm?id=99

Rugged PC Review
http://www.ruggedpcreview.com/

Tripod Data Systems
http://www.tdsway.com/

Agricultural Hardware

Trimble - AgGPS 170
http://www.trimble.com/aggps170.shtml

Trimble - AgGPS EZ-Guide Plus
http://www.trimble.com/aggps_ezguide_plus.shtml

Topcon Precision AG
http://www.topconpa.com/products_steer_guid.htm

PrecisionAg Works
http://www.precisionag.com

Digital Pens

Digital Pen Systems
http://www.digitalpensystems.com/

Livescribe- digital pens
http://www.livescribe.com

Anoto - Digital Pens, holder of the original license
http://www.anoto.com

ADAPX - Digital Pens which integrate with ESRI mapping products
http://www.adapx.com/

Customised Solutions

D.R. systems - Customised mobile forestry data capture solution
http://www.drsystemsinc.com/

Mason Bruce and Girard   Forest and Environmental consultants with mobile GIS and ArcPad customisation experience.
http://www.masonbruce.com

Atterbury Consultants - Portland based forest consultants with extensive moible GIS experiences
http://www.atterbury.com/index.htm

RIA Mobile GIS - Australian mobile developer specializing in Arcpad customization
http://riamobilegis.com.au/index.htm

Other Technologies

ImageTree - Inventory from LIDAR
http://www.imagetreecorp.com/home.html

RFID Journal - Loggers Use Tags to Track Trucks, Timber
http://www.rfidjournal.com/article/view/2007/1/1

Log Tracking RFID System
http://www.log-tracking-system.info/pdf/lts_flyer_en.pdf

Government

Forest Information Management - British Columbian public private industry group working to improve electronic submissions of forest management data.
http://www.fimbc.ca/default.htm

Forest Stewardship Spatial Analysis Project - WebDET
http://www.fs.fed.us/na/sap/webdet/index.shtml

Pacific Northwest Forest Inventory and Analysis
http://www.fs.fed.us/pnw/fia/

Forest Stewardship Program USDA Forest Service
http://www.na.fs.fed.us/ra/SpecialInitiatives/webdet/sib06_webdet.htm

Standards

StanForD - European standard for capturing and exchanging forest information.

Mesh sensor networks

Meraki
http://meraki.com/about/-Wireless mesh network

CSIRO Wireless Sensor Network Devices
http://www.ict.csiro.au/page.php?cid=87

Miscellaneous

Agriculture and Forestry: Software Links
http://dmoz.org/Business/Agriculture_and_Forestry/Forestry/Software/

Canadian Forestry Software Links
http://www.canadian-forests.com/software.htm

Computerworld - Mobility & Wireless - Background information on mobile and wireless technology in Australia
http://www.computerworld.com.au

NaviGadget - Consumer navigation technology
http://www.navigadget.com

Remsoft Inc. - Software for Sustainable Growth
http://www.remsoft.com/news.php?id=46