# Enhancing forest machine efficiency

ONBOARD COMPUTER SELECTION AND IMPLEMENTATION GUIDE

*science for sustainable forest landscapes*

Supported by FWPA

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*Knowledge for a sustainable Australia*

This report is available from the website of the CRC for Forestry at http://www.crcforestry.com.au/ and the FWPA website www.fwpa.com.au

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The CRC for Forestry is an Australia-wide joint venture built on a foundation of nearly 20 years of successful collaboration among Australia's leading forest research organisations, companies and government agencies.

We are committed to the growth of a socially responsible and ecologically sustainable industry that makes an increasingly important contribution to the national economy.

Sustainable forest management is not possible without continued investment in research, so that proven science underpins our approach to management, particularly in a changing climate.

Our mission is to support a sustainable and vibrant Australian forestry industry through research, education, communication and collaboration.

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- promote internationally competitive and environmentally sustainable practices
- enhance employment opportunities
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# Introduction

International experience in forest harvesting has shown significant savings (more than 20%) can be made by using onboard computers to get expensive forest machines working more efficiently. Onboard computers work by identifying inefficiencies and areas for improvement, faster and more accurately than through human observation alone.

There is considerably less use of onboard computers in forest machines in Australia than in other countries where forestry is a major industry. This is largely because Australian machine owners do not have access to good information on what computers are available and which are best suited to different operational needs. This guide was written to provide that information specifically for onboard computers under Australian conditions.

The guide was written by CRC for Forestry staff, supported by Forest and Wood Products Australia (FWPA) and a number of forest owners/managers and forest contractors. It is based on more than a year of testing the range of available onboard computers in three major field trials covering different Australian forest harvesting systems and forest types. It is also informed by shared international experience and a number of smaller trials carried out to gain more information about specific onboard computer applications.

## Who should use this guide?

- Forest machine owners
- Forest owners or managers

## Important information to consider before using the guide

**Is an onboard computer the solution you need?**

Before using this guide, it's important to clearly identify the issue you want to resolve.

Onboard computers are ideally suited to resolving issues that require longer term data collection and analysis. For issues that are better addressed through short-term studies, or when quick results are required, the techniques described in the CRC for Forestry's "Machine Evaluation Toolbox"[1] should be considered.

**Cultural change**

Often the most difficult aspect of implementing an onboard computer data collection program is changing the culture of the organisation to ensure that accurate data are collected and used in the most effective manner.

Key people who will be involved in collecting, transferring and analysing the data need to be identified while planning implementation of onboard computers so that they can be part of the process. At this stage, operators should be asked to share their opinions about what is wrong with the existing system and where it could be improved.

1 For a copy of the Machine Evaluation Toolbox, contact the CRC for Forestry

If the system relies on input from operators, it's essential for them to be part of the process, and to understand the need for collection of accurate data, before an onboard computing system is implemented. The most effective way to get operators involved is to demonstrate how they will benefit from the use of onboard computers. This can take many forms, from simple performance feedback to financial rewards for demonstrably improved productivity or just making the job easier by reducing paperwork. For example, some forest machine operators are required to keep notes of shift start and stop times and major interruptions to work during the shift. The new onboard computer may be seen in a positive light if it replaces manual data collection. Keep in mind that what is important to the operators will probably differ from what is important to management.

When the onboard computer is implemented, operators will need to be trained in its use. Periodic reviews need to be scheduled to ensure the data collection process is delivering on what was promised and that the areas for improvement have been identified and acted on.

Purpose-built and Manufacturer computers not only collect data, they may also require data in the form of digital maps for navigation and display. Many forest owners/managers will not be anticipating this need and will need to change their work practices to achieve it. Most forest owners/managers currently transfer paper maps to machine owners and also may not have the data in the required format for the onboard computers.

### Data ownership

An issue that frequently arises when collecting data using onboard computers is who owns the data collected by the computer. This issue needs to be discussed between the machine owner and the forest owner / manager, preferably before data collection begins. A common resolution is for the data relating to trees (e.g. StanForD stem files) to be sent to the forest owner/manager and data related to the machine performance (e.g. StanForD operations follow-up files) to be kept by the machine owner.

### Data management

Onboard computers are capable of collecting a lot of data in a short period of time. Consideration needs to be given to how to manage this data, preferably before data collection begins.

Key points:

- **Storage.** Data need to be stored correctly so that files can be retrieved for later analysis. This could be as simple as labelling files and directories with the location and date that the data were collected. Many onboard computer data files store the date and time within the file. Ensure that the onboard computer time and date are correct when data are being collected.
- **Backup.** Regular backups should be done, either to an external USB memory drive or hard disk, or to an online backup site, many of which offer several gigabytes of storage at no cost.
- **Validation.** Where possible, data should be validated early in the data collection process. For example, verifying that utilisation recorded by the onboard computer is the same as that recorded by short-term manual observations.

Purpose-built and Manufacturer onboard computers generally have software to manage the data they collect. This software may perform some or all of the above functions.

However, Purpose-built and Manufacturer onboard computers may also require data input in the form of digital maps for navigation and display. Forest owners/managers may need to put in place processes to prepare, manage and deliver digital mapping data to machine owners who have Purpose-built and Manufacturer onboard computers that require it.


## How to use the guide

The online version of this guide has built-in navigation features that help you move quickly between sections of the document. External websites are denoted by underlined text and links to other sections of the guide are denoted by green text. You can click on any of these links to go to the location you want.

1. Find the application in the **table on page 5** that best matches your situation or requirements
2. Identify the suitable onboard computer(s) from the adjacent cell. Where there is more than one choice of onboard computer, the options are listed from most to least suitable.
3. Review all the options before making a decision, and consider factors such as price, applicability to the issue you want to resolve, ability to analyse outputs, and installation requirements such as access to power and need for an external antenna. An important consideration for simple onboard computers, particularly vibration sensors (but also GPS units to an extent), is that they have limited capabilities.
4. The guide has been written in simple and accessible language. However, in some places there is technical information that is necessarily complex.

   The "Professor" indicates each of these sections, and you may need specialist advice to implement the information provided.

   
5. Refer to the **Terminology section** for definitions of specialised or uncommon terms.

The following information is provided in the guide about each type of onboard computer to help you choose the right one for your needs:

- A broad description of the computer type
- Examples of commercially available units and approximate prices ($AUD)
- Important considerations in their use
- Case studies to show how others have used onboard computers to improve machine utilisation or productivity or to identify an issue. Each case study has a description of the problem and how the onboard computer was used to fix it. Indicative costs and returns are also provided.
- Implementation and installation notes. These are useful to compare different onboard computers and also as a guide after the computer has been purchased.

Troubleshooting information is also provided about each type of onboard computer to help you get your onboard computer working correctly.

| Application | Onboard computers (Most to least suitable) |
|---|---|
| Estimate harvester productivity | 1. Manufacturer<br>2. Purpose built<br>3. GPS |
| Estimate forwarder/skidder productivity | 1. Manufacturer<br>2. Purpose built<br>3. GPS |
| Identify inefficiencies (underutilisation, bottlenecks) | 1. Vibration<br>2. Purpose built<br>3. Manufacturer |
| Assess alternative harvest methods | 1. Manufacturer<br>2. Purpose built |
| Assess downtime (delay causes) | 1. Purpose built<br>2. Manufacturer |
| Assess long-term performance | 1. Vibration<br>2. Purpose built<br>3. Manufacturer |
| Continual improvement | 1. Purpose built<br>2. Manufacturer |
| Assess productivity under different working conditions | 1. Manufacturer<br>2. Purpose built |
| Cost model (rates) | 1. Manufacturer<br>2. Purpose built |
| Reduce fuel consumption | 1. Manufacturer[2]<br>2. Purpose built[2] |

2 Not available on all units. Check before purchase.

# Categories of onboard computer

## Vibration

### Description

Vibration sensors work by detecting vibrations made when a machine is active (working or travelling), which can be used to calculate machine utilisation. As these devices require no operator input, they can be mounted out of the way to capture realistic utilisation and delay results.

Vibration sensors are the modern equivalent of the clockwork vibration recorder.

### Potential uses

**Identify inefficiencies.** Utilisation data can be used to identify when machines are underutilised, which is often due to bottlenecks elsewhere (system balance problems).

**Assess long-term performance.** Long-term base levels of utilisation are used in machine cost calculations or as a starting point for a continual improvement program. Utilisation data should be collected for at least a month (preferably for several months) to account for peaks and troughs in activity.



### Important considerations

- Utilisation estimates from vibration sensors may be a combination of machine work and travel or other activities (e.g. brushing, stacking etc) that can give an inflated utilisation figure, particularly for machines such as harvesters and feller-bunchers.
- Cheaper units generally do not have data analysis software and so should only be considered by those with the necessary skills to analyse the data.
- Beyond their use to estimate utilisation and identify delay occurrence and duration, there is little scope for further analysis using vibration sensors. In particular, they cannot identify delay causes, which is essential to determine ways to improve machine performance. Use a Purpose-built or Manufacturer computer if this additional information is needed.
- As the units are all manufactured overseas, local support may be limited.

### Examples

The following is a selection of units whose primary function is to detect vibration. More sophisticated units with multiple features, including using the same strategy to detect machine movement, are described under “Purpose-built”.

| Name | Picture | Price (AUD$) | Website | Comments |
|---|---|---|---|---|
| MultiDAT Junior |  | ~$900 | www.feric.ca | Includes analysis software<br>Price is MultiDAT only |
| MSR 145 |  | ~$300 | www.msr.ch/en/product/msr145.php | Price is for vibration sensor only |
| Yellow Activity Monitoring System (YAMS) |  | ~$900 | www.ked.co.za | Includes analysis software<br>Price is for vibration sensor, data transfer unit and desktop reader<br>Additional vibration sensors are ~$440 |

## Sample outputs

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Utilisation daily | | | | |
| | | 2010/01/04 06:00:00 To 2010/01/29 05:59:59 | | | | |
| | | Schedule: 5x11 50Hr | | | | |
| | Totals per day are from 6:00:00 AM to 6:00:00 AM the following day. | | | | | |
| | Expected Schedule | Total work | Utilisation | Short delay <15min | Work incl short delay | Utilisation incl short delay |
| | (HH.MM) | (HH.MM) | (%) | (HH.MM) | | (%) |
| McK_Harvester | | | | | | |
| 2010/01/04 Mon. | 10.00 | 8.07 | 81.09 | 0.15 | 8.36 | 83.60 |
| 2010/01/05 Tue. | 10.00 | 9.19 | 93.20 | 1.01 | 10.33 | 103.29 |
| 2010/01/06 Wed. | 10.00 | 6.02 | 60.27 | 0.53 | 6.91 | 69.09 |
| 2010/01/07 Thu. | 10.00 | 7.03 | 70.57 | 0.29 | 7.55 | 75.47 |
| 2010/01/08 Fri. | 10.00 | 4.47 | 47.90 | 0.50 | 5.63 | 56.28 |
| 2010/01/11 Mon. | 10.00 | 1.27 | 14.49 | 0.38 | 2.08 | 20.84 |
| 2010/01/12 Tue. | 10.00 | 0.12 | 1.95 | 0.20 | 0.52 | 5.21 |
| 2010/01/13 Wed. | 10.00 | 9.00 | 89.85 | 1.11 | 10.17 | 101.73 |
| 2010/01/14 Thu. | 10.00 | 6.25 | 64.10 | 1.09 | 7.56 | 75.61 |
| 2010/01/15 Fri. | 10.00 | 6.34 | 65.58 | 0.25 | 6.97 | 69.70 |
| 2010/01/16 Sat. | | 1.33 | | 0.36 | 2.15 | |
| 2010/01/17 Sun. | | | | 0.02 | 0.04 | |
| 2010/01/18 Mon. | 10.00 | 3.09 | 31.54 | 0.25 | 3.57 | 35.65 |
| 2010/01/19 Tue. | 10.00 | 6.00 | 59.91 | 0.26 | 6.43 | 64.27 |
| 2010/01/20 Wed. | 10.00 | 6.41 | 66.79 | 0.32 | 7.21 | 72.14 |
| 2010/01/21 Thu. | 10.00 | 4.40 | 46.65 | 0.45 | 5.41 | 54.12 |
| 2010/01/22 Fri. | 10.00 | 4.11 | 41.80 | 0.14 | 4.41 | 44.13 |
| 2010/01/23 Sat. | | 2.00 | | 0.52 | 2.78 | |
| 2010/01/25 Mon. | 10.00 | 7.06 | 70.99 | 0.28 | 7.57 | 75.69 |
| 2010/01/26 Tue. | 10.00 | 1.43 | 17.21 | 0.14 | 1.95 | 19.52 |
| 2010/01/27 Wed. | 10.00 | 7.16 | 72.67 | 0.05 | 7.35 | 73.55 |
| 2010/01/28 Thu. | 10.00 | 4.37 | 46.21 | 0.19 | 4.93 | 49.33 |
| Sub-total / McK_Harvester | 190.00 | 107.45 | 56.71 | 12.08 | 119.89 | 63.10 |

Figure 1:
MultiDAT report showing the actual daily work against the expected schedule of 10 hours. Utilisation is shown with no delays and with delays less than 15 minutes, as these short delays are sometimes regarded as part of the productive time

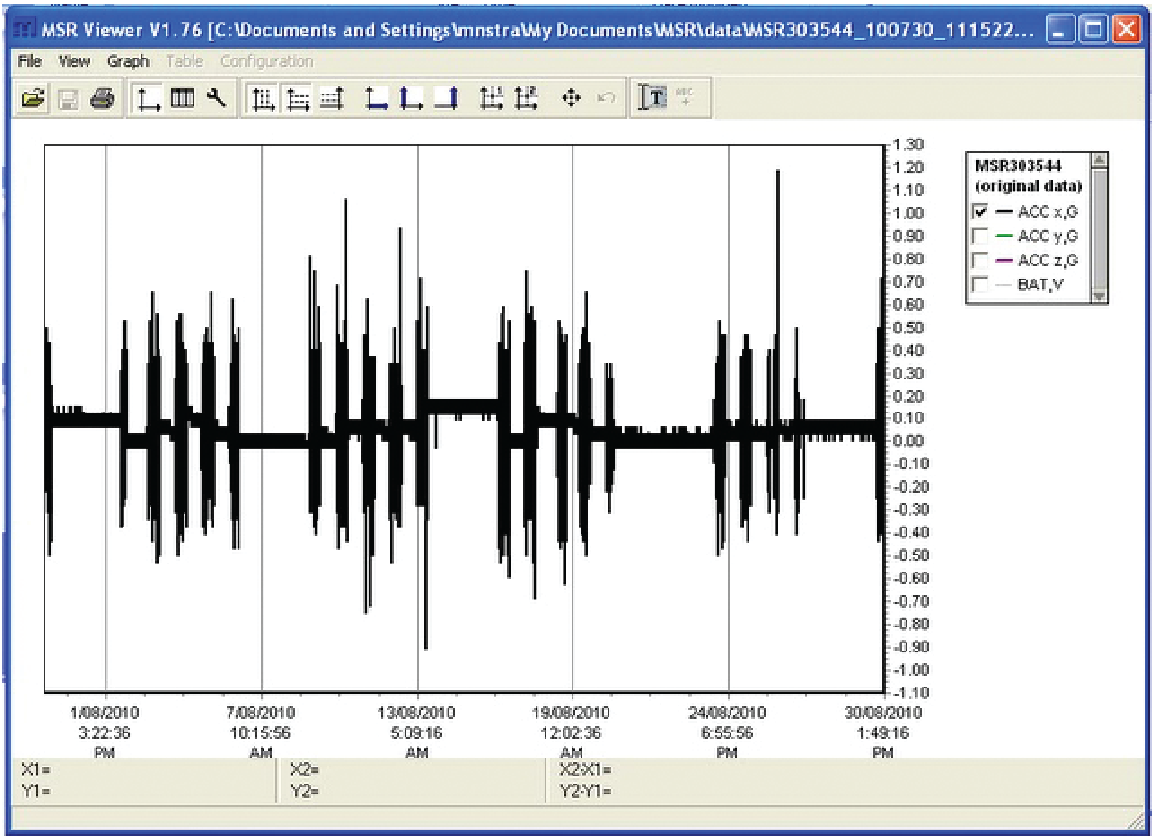



Figure 2:
MSR 145 vibration plot. Daily and weekly blocks of activity are clearly visible. The data can also be imported into Microsoft Excel for analysis



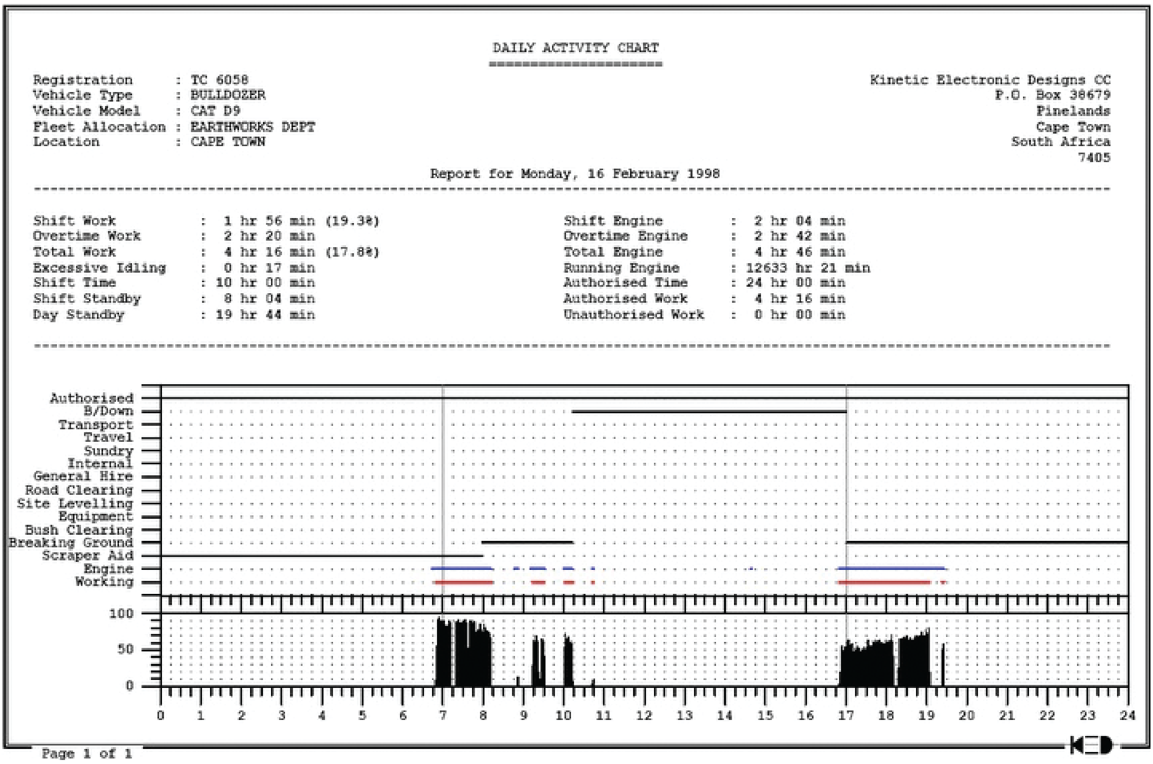



Figure 3:
YAMS daily activity chart. There are a range of pre-defined reports available to display YAMS data



## CASE STUDY 1.
## IMPROVING HARVESTING MACHINE UTILISATION

**Description:** A study of the utilisation of a four-machine native forest harvesting system in Victoria's Central Highlands identified a means of reducing a bottleneck on the log landing. Three of the machines had MultiDATs installed to estimate long-term utilisation and to investigate delay patterns. The harvester and skidder were found to be relatively underutilised (50–55% utilisation) compared with the excavator-based machine that was processing trees into logs and loading trucks on the log landing (70% utilisation). Typical utilisation of these three types of machine (based on figures from other studies) is ~65%. Examination of the pattern of delays revealed that the machine on the landing spent a significant length of time waiting for truck drivers to write sawlog details on a log docket after each log was loaded. This finding led the harvest contractor to have his operator load a truck completely and return to work while the driver noted the log details. The next change was to make truck drivers solely responsible for loading trucks using a spare machine. This resulted in up to three hours per day of machine time being freed for log processing activities on the landing, which considerably improved the throughput of logs.

An unexpected outcome was that the log transport was unable to deal with the increased log throughput. This highlights the need to consider all components of the wood supply chain when making any changes.

**Onboard computer costs** (Purchase, implementation and running): ~$10,000 (incl $2000 annual running costs)

**Returns:** ~$100,000/year (Excludes purchase and running cost of additional excavator. Used excavator purchase cost: ~$150,000)

See Figure 4 overleaf.




Figure 4:
Central Highlands (VIC) native forest logging

## CASE STUDY 2.
## EVALUATING MACHINERY REQUIREMENTS AND REDUCING IDLE TIME

**Description:** A two-week study of seven front-end loaders in a Canadian mill yard suggested they were underutilised. Before making a decision to reduce the fleet, MultiDATs were installed on each loader to track utilisation over a longer period to make sure there was no occasional busy period that required all the loaders. After six months of tracking, the company determined one less loader was needed as the six remaining loaders working at a higher level of utilisation were able to perform the work of the original seven loaders. This reduced costs directly through the reduction in operational costs and indirectly through better utilisation of the remaining loaders.

The company also monitored engine idling time and found the machines were left running during breaks and lunch time. To reduce excess idling the machines were modified to shut down automatically after three minutes of idling (to protect the turbo blowers from overheating).

Onboard computer costs (Purchase, implementation and running): ~$15,000 (incl. $2000 annual running costs)

Returns: ~$60,000/year from the reduction in machine numbers and $5,000/year from reduced idling fuel consumption.

## CASE STUDY 3.
## HARVEST SYSTEM BALANCE

**Description:** A contractor in eastern Canada suspected that he had a problem with the balance between the machines in his harvest crew. To find out what was happening he installed MultiDATs on his harvester and forwarder and tracked their utilisation for one year. The utilisation level for the harvester was excellent (85%). However, the forwarder had a much lower utilisation (65%).

To better balance his harvest system, the contractor decided to replace his forwarder with a combination forwarder/harvester machine and added a second harvester. This enabled him to cut an additional 34,000$m^3$ per year at a slightly reduced cost per $m^3$.

Onboard computer costs (Purchase, implementation and running): ~$6,000 (incl. $2000 annual running costs)

Returns: ~$30,000 per year



Figure 5:
Forwarder working in eastern Canada (www.tigercat.com)

## Installation and Implementation

### Location

- Vibration sensors must be mounted securely against the body of the machine in order to pick up vibrations from machine activity. YAMS units should be located on the sides of the machine to best pick up machine activity. This is because YAMS units cannot be calibrated to allow for differences in sensitivity caused by orientation of the sensor.
- Avoid mounting the sensor where vibration is increased or decreased as this will lead to false readings. For example, a vibration sensor may be able to rock if attached to a flimsy mount or may be isolated from vibrations if placed in a storage pocket.
- Access to external power is required by some units e.g. MultiDAT Junior.
- Avoid locations where the unit could be knocked or damaged. Generic vibration sensors such as the MSR145 may not be waterproof or dustproof.



### Mounting

- Lighter units (e.g. MSR 145) can be mounted with domestic Velcro ®. Heavier units such as the YAMS and the MultiDAT Junior can be mounted using self-tapping screws or industrial strength Velcro ®.
- Some units require a specific orientation to work correctly (e.g. YAMS units need to be mounted vertically, as horizontal mounting may register engine idling as work because this orientation increases the vibration sensor sensitivity). Orientation is not critical for units that can be calibrated after installation (e.g. MSR 145 and MultiDAT Junior).

### Wiring

- The MSR 145 and YAMS use internal batteries. The MSR 145 is recharged via USB. The YAMS has the option to connect to the ignition to identify idling time.
- The MultiDAT Junior must be wired to the ignition to collect engine run time information and to power the unit. Optionally, a cigarette lighter plug can be soldered to the MultiDAT power cable to run the unit from a 12V or 24V socket.

## Data

### Downloading data

Some vibration sensors require purchase of additional hardware to download the data e.g. the YAMS uses a proprietary download unit and the MultiDAT requires a Personal Digital Assistant (PDA) (or laptop) with a 9 pin serial port and null modem cable (most USB—serial port adapters do not work, however the ATEN UC 232A adapter is known to work). Generic vibration sensors such as the MSR 145 download via a standard USB port.

The MultiDAT has an automatic download option for areas without mobile phone coverage that uses short-range radio transmitters to collect data from machine-mounted MultiDATs and stores it on a base station mounted in a vehicle. When the vehicle returns to mobile phone range, the data are downloaded from the base station to a central server.

### Data entry

Vibration sensors typically don’t require users to enter data. Some models of the YAMS can collect data on activities or delays or operators using a 12 position dial. The operator turns the dial to the position corresponding to the current predefined activity or delay.

**Data analysis**

Utilisation should be calculated in terms of the scheduled work hours for each day. For example, if an operator has a daily schedule of 10 hours, but only works 6 hours, the utilisation would be 60%.

To obtain a good understanding of long-term machine utilisation, data need to be collected over a minimum of one month, or even longer (as in Case Studies 2 and 3), to capture infrequent delay causes. For some machines, infrequent major delays can have a significant impact on their long-term utilisation.

## Troubleshooting FAQ

**Problem**

1. **No data collected**

   Not programmed correctly? The MSR 145 and MultiDAT Junior need to be programmed to collect data. See manufacturer's user guides for this information.

   No power? MultiDATs need to be connected to a 12V or 24V DC power source. YAMS and MSR 145 need charged batteries.

   Fault in unit? Vibration sensors are generally very robust, though faults are still possible. Units usually have one or more status lights to indicate correct operation.

2. **Utilisation higher or lower than expected.**

   First verify whether there is a problem by checking utilisation for a period of time (preferably at least several hours) by observing the operator and comparing the result with the utilisation calculated over this same period by the vibration sensor.

   Differences can be the result of:

   - Sensor not picking up vibration or picking up excess vibration. Check mounting point.
   - Conflicting definitions of utilisation. Vibration sensors will pick up vibrations when a machine is moving, working or performing other activities (e.g. clearing debris) and therefore can overestimate "true" utilisation. The "true" utilisation can be determined using a Purpose-built or Manufacturer onboard computer , or by applying a reduction factor estimated from a short-term observation. The second method will not pick up changes in work practices, e.g. harvesting a stand with more understorey requiring greater time spent brushing.
   - Incorrect calibration. The sensor may be set at the wrong sensitivity.
   - Long-term utilisation is generally less than short-term utilisation as it includes infrequent major delays such as significant breakdowns or wet weather delays.

3. Trouble communicating with the unit

   Incorrect cable? MultiDATs require a "null modem" cable (not a standard serial cable) connected to a serial port. Most USB to serial port adapters do not work, although the ATEN UC 232A adapter is known to work. Serial port adapters for PDAs can be used.



# GPS

## Description

GPS units have become commonplace both within and outside the forest industry. GPS is available as an option on the Purpose-built and Manufacturer onboard computers described in this guide and also as a stand-alone option. As a machine management tool, a GPS unit can be used to work out where and when a machine has been working.

The GPS units described in this section are GPS loggers that are able to store large numbers (thousands) of GPS points. Handheld navigational GPS units typically do not have the storage capacity required to work as a GPS logger.



## Potential uses

**Estimate harvester productivity.** GPS data can be used to estimate the productivity of a harvester in terms of the area harvested per unit of time. This can be combined with volume per hectare from inventory to estimate productivity per unit of time, or used as a planning tool to estimate the date a harvest will be completed.

**Estimate forwarder/skidder productivity.** GPS data can be used to estimate forwarder or skidder productivity by estimating the number of loads transported, average transport distance, total distance travelled and speed of loading and unloading. The number of loads transported is usually estimated by counting the times the machine crosses a "geofence", which marks the log landing or dump boundary. The geofence can be created manually in a Geographic Information System (GIS) or can be created using software supplied with some onboard computers (e.g. MultiDATs). Another technique estimates the number of trips by counting each time the machine turns approximately 180º i.e. heads back the way it has come (see **Data Analysis**).

Used in combination with the vibration sensors **described earlier in this guide**, data from a GPS can be used to split utilisation into travel and work components, which could be useful to identify inefficiencies in machine operation (i.e. when a machine is travelling more than expected for a machine of that type). GPS can also be used on its own to estimate utilisation by noting when a machine starts and stops moving each day and any significant lengths of time that the machine is stationary during that time.

GPS can be used to provide feedback to the operator on a screen showing where the machine is working and the location of hazards and no-go zones. The screen can also be used on a forwarder to display the location of cut wood using individual tree production (StanForD pri) files downloaded from a harvester equipped with a GPS and a Manufacturer onboard computer.

## Important considerations

- Most GPS analysis will require access to GIS software and the skills to use it. Note that Google Earth is not a GIS as it has limited analysis tools.
- High- and low-precision GPS loggers are available. Precision is generally improved by connecting to an external antenna. Not all units can do this.
- Tree canopies can interfere with GPS signals causing problems getting an accurate location. For harvesting this is generally only significant during thinning operations.

- The selected GPS must be able to record sufficient GPS points for the period of the study. Some units use a vibration sensor to limit recording to when the machine is moving, which reduces the points stored. Recording a GPS point every second (default on many units) will require ~90,000 points per day.
- Some GPS loggers are able to record points based on either distance or time, which can reduce the points stored. Time is generally more appropriate for a slow-moving machine (e.g. a harvester) whereas distance is more suited to a fast-moving machine (e.g. a forwarder or skidder).
- Recording GPS for more than one day requires a unit that can use external power and/or has a vibration sensor to shutdown and save power when no vibrations are detected.
- There are a number of external antenna cable connections. Make sure you get the appropriate one for your GPS.

## Examples

There are dozens of GPS loggers that could potentially be used to monitor forest machines. As mentioned above, the Purpose-built and Manufacturer onboard computers described in this guide also all have GPS as an option.

**Key features to look for include:**

- High-precision GPS receiver
- Adequate memory (inbuilt or via memory card) to record points required for at least a week. For units where the recording frequency can be reduced, 50,000–100,000 points is adequate. Loggers that record every second need a 650,000 point capacity
- Ability to alter the data collection frequency
- Ability to connect an external antenna[3]
- Long battery life or ability to connect to external power
- Vibration sensor to save power (only operates when vibration detected)



**Examples of stand alone GPS loggers include:**

| Name | Picture | Price (AUD$) | Website | Comments |
|---|---|---|---|---|
| Royaltek RBT-2300 |  | ~$100 | www.royaltek.com | External antenna port<br>External power<br>Adjustable time interval |
| Qstarz BT-Q1000XT |  | ~$150 | www.qstarz.com | Internal antenna only<br>External power<br>Vibration sensor |
| GlobalSat DG-100 |  | ~$70 | www.globalsat.com.tw | External antenna port<br>External power<br>Adjustable time interval |

3 Reradiating external antennas are available for GPS units with no antenna connection. However, these antennas may cost as much as or more than the cheaper internal antenna GPS units listed here.

## Sample outputs

The GPS points used in figures 7 and 8 could be produced using any GPS device


**Figure 6:**
**GPS points from a harvester displayed in Google Earth. This can be a useful way to get an overview of GPS data or see if the GPS is working correctly. Google Earth can read some GPS file types and import data directly from some GPS devices (see www.earth.google.com/intl/en/userguide/v4/ug_gps.html for details). Other file formats must be converted to Google Earth's KML format for import using a GIS or one of the free converters available**

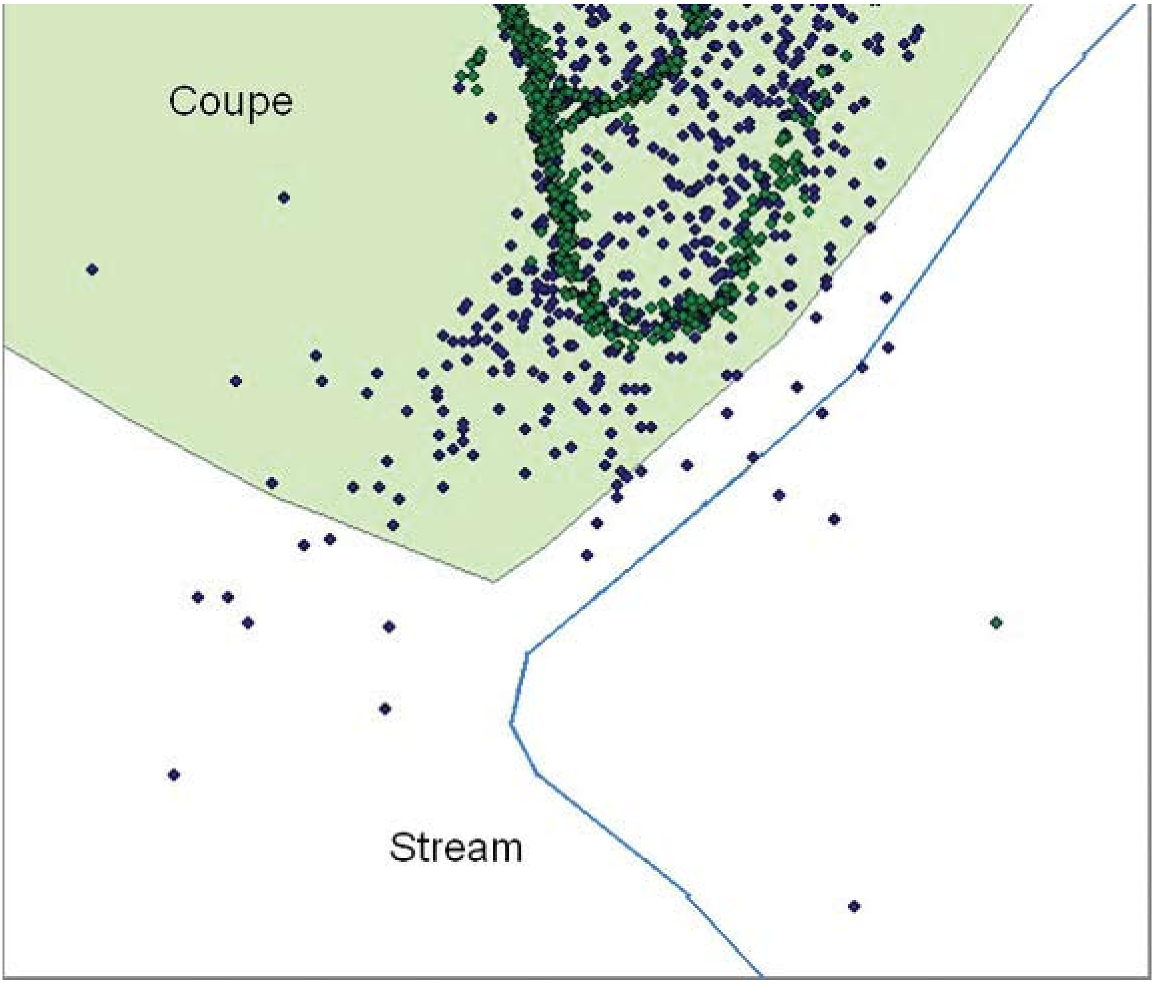



Figure 7:
GPS—High resolution (green dots) and low resolution (blue dots). The data were exported from two MultiDATs as ESRI shapefiles and displayed in ESRI ArcMap

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ID | MACHINE | LATTITUDE | LONGITUDE | TIMETAG | DGF | GPSR | MOTIONSENS | |
| 2 | 1.00000 | 17.00000 | -37.41017 | 145.83852 | 20091117.155028 | OFF | CONT. | ON | |
| 3 | 2.00000 | 17.00000 | -37.41030 | 145.83865 | 20091117.162028 | OFF | CONT. | ON | |
| 4 | 3.00000 | 17.00000 | -37.41042 | 145.83848 | 20091117.165028 | OFF | CONT. | OFF | |
| 5 | 4.00000 | 17.00000 | -37.41040 | 145.83847 | 20091117.170354 | OFF | CONT. | ON | |
| 6 | 5.00000 | 17.00000 | -37.41000 | 145.83823 | 20091117.170626 | OFF | CONT. | ON | |
| 7 | 6.00000 | 17.00000 | -37.40967 | 145.83785 | 20091117.170726 | OFF | CONT. | ON | |
| 8 | 7.00000 | 17.00000 | -37.40933 | 145.83748 | 20091117.170828 | OFF | CONT. | ON | |
| 9 | 8.00000 | 17.00000 | -37.40898 | 145.83712 | 20091117.170928 | OFF | CONT. | ON | |
| 10 | 9.00000 | 17.00000 | -37.40863 | 145.83675 | 20091117.171029 | OFF | CONT. | ON | |
| 11 | 10.00000 | 17.00000 | -37.40897 | 145.83713 | 20091117.172402 | OFF | CONT. | ON | |
| 12 | 11.00000 | 17.00000 | -37.40932 | 145.83747 | 20091117.172500 | OFF | CONT. | ON | |
| 13 | 12.00000 | 17.00000 | -37.40965 | 145.83783 | 20091117.172600 | OFF | CONT. | ON | |
| 14 | 13.00000 | 17.00000 | -37.40997 | 145.83823 | 20091117.172701 | OFF | CONT. | ON | |
| 15 | 14.00000 | 17.00000 | -37.41045 | 145.83827 | 20091117.172813 | OFF | CONT. | ON | |
| 16 | 15.00000 | 17.00000 | -37.41055 | 145.83833 | 20091118.060917 | OFF | START | OFF | |
| 17 | 16.00000 | 17.00000 | -37.41063 | 145.83888 | 20091118.061131 | OFF | CONT. | ON | |
| 18 | 17.00000 | 17.00000 | -37.41092 | 145.83922 | 20091118.061654 | OFF | CONT. | ON | |

Figure 8:
Unprocessed MultiDAT GPS data. MultiDATs can export the data as points (displayed) or as a standard NMEA string or as an ESRI shapefile

## CASE STUDY 1.
## IMPROVING HARVESTER PRODUCTIVITY

**Description:** Tasmanian *Eucalyptus nitens* plantations grown for sawlogs are thinned at nine years of age, using a combination of row and bay thinning. A comparison of 3rd row and 5th row thinning in an operation with two small excavator-based harvesters and one forwarder identified an inefficient operational practice through the use of a GPS logger. Standard procedure was for the harvesters to travel back through the plantation to thin the next row rather than thinning in both directions, as is common practice in other plantation types. The reason given was that the harvesters had the cabin on the left so the boom blocked the operator's view when processing logs to the right. However, it is possible to process logs to the left in both directions in 5th row thinning, leaving the processed logs in the retained four row bays on alternate sides. In 3rd row thinning, the retained two row bays are too narrow to fit logs processed when returning as the logs would interfere with the machine processing the next row (see diagram below).

The GPS logger was used to estimate the speed of the machines when working and when travelling and hence the proportion of time spent in each activity. From these estimates it was found that thinning in one direction reduced productivity by 4–6% compared with thinning in both directions.

Onboard computer costs (Purchase, implementation and running): ~$6,000
(incl. $2000/yr running costs)

Returns: ~$24,000/yr



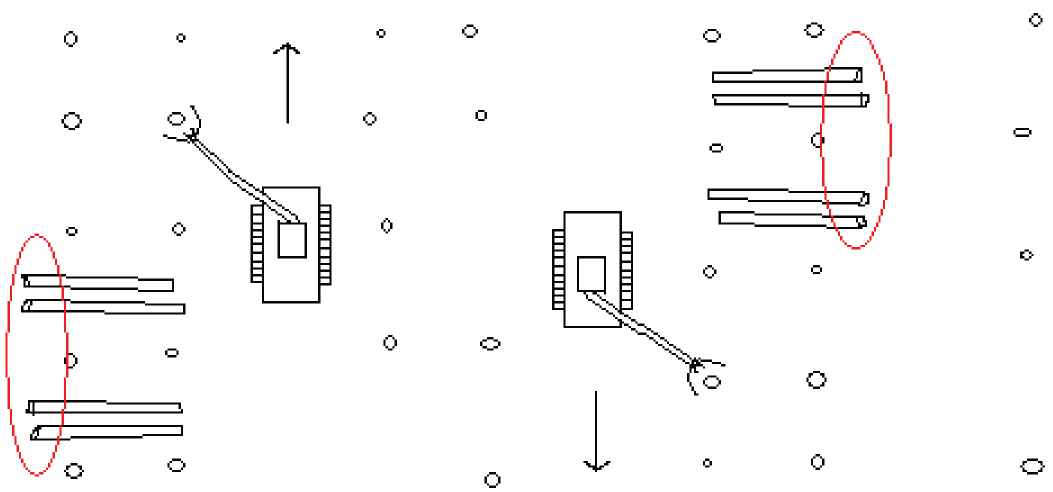


**Figure 9:**
**The ellipses show how log piles can encroach on the next row to be removed when third row thinning. This would not occur when fifth row thinning as there is a larger gap between removed rows**

## CASE STUDY 2.
## ESTIMATING SKIDDER PRODUCTIVITY

**Description:** A GPS logger was used to determine the productivity of a skidder operating in native forest in Victoria's Central Highlands. The GPS was fitted to a MultiDAT unit installed on the skidder. The GPS logger was set to collect points every 50 metres and every ten minutes to record positions when the machine was moving and stationary without using excessive memory space.

As described in the vibration sensor Case Study 1, there was significant underutilisation of the skidder and harvester in this operation. The average daily number of loads was 34. However, it was clear from the GPS analysis that the normal pattern of work for the skidder was to transport more logs early in the week (more than 50 daily loads) until the landing was full and then reduce the number of daily loads while carrying out other activities (e.g. assisting with debarking) until the landing stocks were reduced. This implies that the utilisation figures were inflated by activities other than log transport.

The returns estimated in this case study are the potential additional income generated by the skidder working at an average of 50 loads a day. To achieve these loads would require increased throughput at the landing.

Onboard computer costs (Purchase, implementation and running): ~$3,000
(incl $1000 annual running costs)

Returns ~$50,000/yr



**Figure 10:**
**Skidder paths drawn by plotting GPS points using a GIS (ESRI ArcMap)**

## CASE STUDY 3.
## IDENTIFYING SKIDDER MISUSE

**Description:** A South African forestry company installed a GPS tracking system in its fleet of more than 400 forestry machines and passenger vehicles as a management tool to determine (amongst other things) compartment coverage, vehicle location, working hours, distance travelled and fuel used. The system reports via the mobile phone network at 10 minute intervals to a website for analysis and display. It is an off-the-shelf fleet management system that was adapted for forestry use. A key objective of the system was to reduce use of vehicles for non-work purposes. Examination of the GPS data identified a skidder that was travelling significantly further each week than expected. When the track logs were plotted it was found that the skidder was being driven to a shop 20 km from the work site at the end of the shift on a weekly basis.

Although this type of misuse of machinery is unlikely to occur on Australian operations, there is still the potential for unnecessary travel in harvesting machines e.g. travelling to the roadside for breaks and travelling to and from the harvest area at the start and end of a shift. This extra travel can result in significant lost time during a day, particularly for tracked machines. Alternatives include taking breaks when close to a road and using one vehicle to transport operators to and from their machines.

Onboard computer costs (Purchase, implementation and running): Unknown

Returns: Unknown



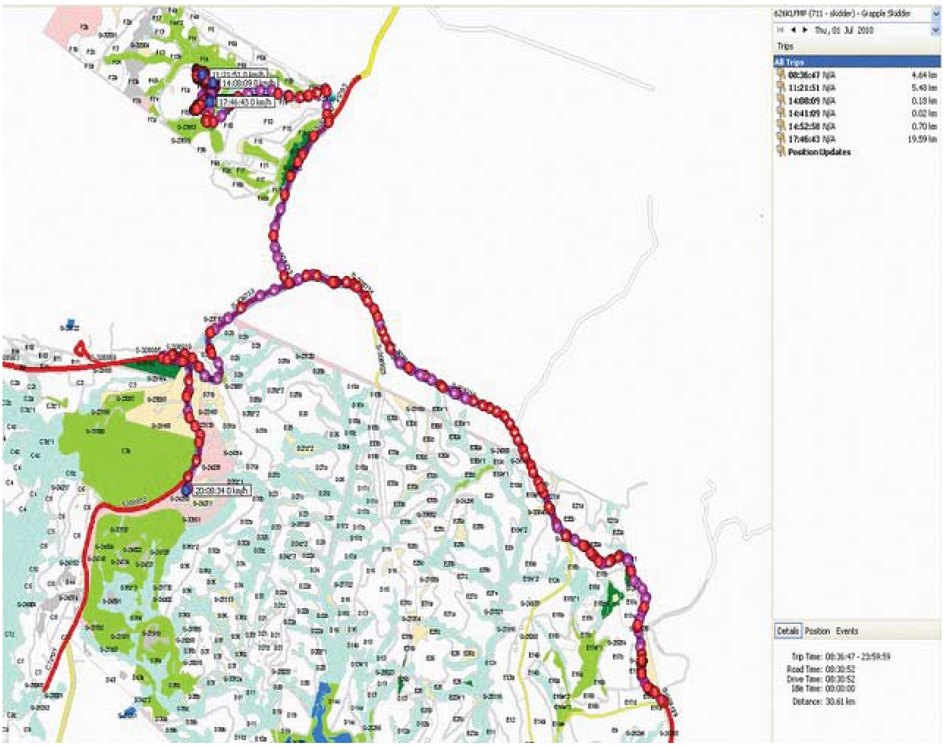



**Figure 11:**
**GPS track showing misuse of a skidder travelling to the shop on the lower right**

## Installation and Implementation

### Location

- **External antenna units**
  Location of the GPS logger is not critical, although consideration should be given to where the antenna lead will run. The antenna must be located on the machine cabin roof where it has a clear line of sight to the sky.
- **Internal antenna units**
  Loggers with an internal antenna require a clear line of sight to the sky to get adequate satellite reception. The front window is usually a good location.
- **External power**
  Some loggers can be connected to external power for long-term installation. This is done via a cigarette lighter socket.

### Mounting

- The GPS loggers listed on page 17 can be attached with domestic Velcro®. Heavier loggers may require more secure mounting.
- External antennas generally have a magnetic base. This may not be sufficient to anchor the antenna on forestry machines. A small dab of silicone sealant will help secure the antenna. Also, make sure that there is little or no cable outside the cabin to avoid it getting snagged by debris. A protective dome covering the antenna should be used on feller-bunchers and harvesters where there is a risk of damage from falling trees and branches.

### Wiring

- If possible, feed the external antenna lead through an existing grommet to the unit. To reduce the chance of the lead snagging in the cabin, it should be fed under the interior trim or secured using cable ties or adhesive cable mounts.
- Some GPS loggers can be supplied with external power by using a car charger either supplied or as an option. Car chargers plug into a cigarette lighter.

## Data

### Downloading data

GPS loggers are typically downloaded using a mini USB cable and/or a Bluetooth connection and supplied software.

After installation it is a good idea to check that the logger is receiving a GPS signal by downloading data after a short period of running the logger.

### Data entry

GPS loggers do not require user data entry.

### Data analysis

Analysis of GPS data requires skills in the use of Microsoft Excel.

NOTE

**Data analysis: GPS distance**

There are a number of ways to estimate distance between two GPS points. The Spherical law of cosines is recommended as it is simple and accurate:

R = earth's radius (mean radius = 6,371km)
distance = acos(sin(lat1).sin(lat2)+cos(lat1).cos(lat2).cos(long2–long1)).R

Excel: =ACOS(SIN(lat1)*SIN(lat2)+COS(lat1)*COS(lat2)*COS(lon2-lon1))*6371

(Note that calculations are in radians).

**GPS speed**
First calculate the distance between the GPS points (see above). Speed is the distance divided by the time difference between the points.

**Number of skidder/forwarder trips**
The number of skidder/forwarder trips can be estimated by assuming that when the machine changes direction by approximately 180° it represents the end of a run to either drop off or pick up logs. The number of round trips is therefore half the number of turns. Some trial and error will be required to get the range around 180° that captures most return trips (they will rarely be exactly 180°).

The bearing can be calculated from two consecutive GPS points as follows:

$\theta$ = atan2( sin($\Delta$long).cos(lat2), cos(lat1).sin(lat2) – sin(lat1).cos(lat2).cos($\Delta$long) )

Excel: =ATAN2(COS(lat1)*SIN(lat2)-SIN(lat1)*COS(lat2)*COS(lon2-lon1),

SIN(lon2-lon1)*COS(lat2))

**Problem**

1. **No data collected**

   Not receiving a signal? This could be due to poor location of the unit or external aerial or may be due to surrounding trees or hills blocking satellite signals. Machines working in thinning operations typically have poorer GPS reception due to the retained trees.

   No power? GPS loggers wired to receive external power should be checked to ensure they are wired correctly.

   Fault in unit? GPS loggers are generally very robust, though faults are still possible. Units usually have one or more status lights to indicate correct operation.

2. **Utilisation higher or lower than expected.**

   First verify whether there is a problem by checking utilisation for a period of time (preferably at least several hours) by observing the operator and comparing the result with the utilisation calculated over this same period by the GPS.

   Long-term utilisation is generally less than short-term utilisation as it includes infrequent major delays such as significant breakdowns or wet weather delays.

3. **Inaccurate results**

   Accuracy of the results is dependent on the precision of the GPS and its ability to obtain signals from satellites. Generally, the more satellites in view of the GPS the better the result. However, if trees or hills block the satellite signals from the sides, accuracy can be poor as the only available satellites are clustered overhead. A small level of scatter of GPS points is normal, particularly when reception is poor.

   Use of a high-precision GPS and mounting an external antenna as high and unobstructed as possible will minimise these problems. Calculation of the apparent speed of the machine between GPS points can be used to identify and remove points where the estimated speed is greater than possible for that machine.

   If GPS readings have been set to occur using distance or time, check that the settings are reasonable based on the activity of the machine.



**NOTE**

Older base maps (roads, streams, topography, etc) used a different "projection" that will display GPS points ~200 m from their true location. The older maps use Australian Map Grid (AMG) 66 or AMG84. The updated maps use Map Grid of Australia (MGA) 94. In addition, roads and streams were often mapped less accurately in the past so that GPS points may appear incorrect relative to other map features. Updated maps may be available. In particular, many forest roads have been remapped recently for emergency vehicle use.

# Purpose built

## Description

Only two Purpose-built onboard computers were commercially available when the trials were conducted to support development of this guide: MultiDATs and RouteHawks. A third type—the FPDat—will be commercially available in Australia in the first half of 2011. A prototype was made available to the CRC for Forestry for testing.

RouteHawks and FPDats use touch screens to obtain user input and display the current location and productivity feedback. MultiDATs use buttons on the face of the unit to obtain user input. Productivity feedback is provided via the optional MultiPAD display.



## Potential uses

**Estimate harvester productivity.** Purpose-built units can estimate harvester productivity in terms of stems cut per unit of time through connection to the operation of harvest head components such as the circuit to operate the chain saw or shears. Details of these connections are machine-specific. See manufacturer's instructions.

If an optional GPS has been fitted, area cut per unit of time can be estimated from GPS points and combined with volume per hectare from inventory to estimate volume cut over time.

**Estimate forwarder/skidder productivity.** Purpose-built units can estimate skidder or forwarder productivity by the operator selecting the button or onscreen option corresponding to their current activity (travelling, loading, unloading, etc). This allows the duration of each activity to be measured.

If an optional GPS has been fitted, skidder/forwarder productivity can be estimated using a geofence or estimates of 180º turns to estimate the number of trips (see GPS Data Analysis section for details).

**Identify inefficiencies.** Purpose-built units can determine machine utilisation and identify underutilised machines and estimate long-term base level utilisation rates.

**Assess downtime (delay causes).** Purpose-built units allow operators to enter delay causes by selecting onscreen options or buttons. This can be used to assess downtime and identify areas for improvement and can also form the basis of a continual improvement program.

**Productivity and cost models.** Estimates of utilisation and stems (or volume) cut per hour or volume transported per hour can be used as inputs into a productivity model and combined with costs to create a cost model to estimate harvest rates. These models can be used to assess alternative methods.

**Fuel consumption.** RouteHawks are able to record estimated fuel consumption from the engine CanBus[4] , as will the FPDat. MultiDATs can also record this information but require purchase of a device that converts CanBus fuel consumption to data that can be recorded by a MultiDAT.

4 CanBus is a type of network that allows different parts of an engine or forestry machine to communicate using only two wires to replace the bundles of wires needed in the past.

## Important considerations

- An important consideration is the ease with which entry of activities or delay causes can be made by the operators, as operator "buy-in" is essential to accurate collection of delay causes or activity information.
- MultiDATs require purchase of a PDA with a 9 pin serial port and a null modem cable to collect data from each unit (A laptop with a serial port could also be used but these are very rare). Note that most USB-serial adapters do not work (The ATEN UC 232A adapter is known to work).
- RouteHawks and FPDats require an internet connection via the mobile phone network, radio or satellite to transfer data to a website for analysis and display. The phone modem needs to be purchased locally to ensure it complies with local regulations. For best coverage in Australia a Telstra modem with an external antenna socket is the suggested approach. MultiDATs and FPDats have an automatic download option for areas without mobile phone coverage that uses a vehicle-mounted base station (see **Downloading data for details**).
- An ongoing fee is required to use the RouteHawk and FPDat websites for data storage and report generation.
- Support is limited as all units are manufactured overseas and do not have local representatives.
- Use of GIS (RouteHawks and FPDats) requires digital maps of harvest areas supplied by the forest owner/manager.

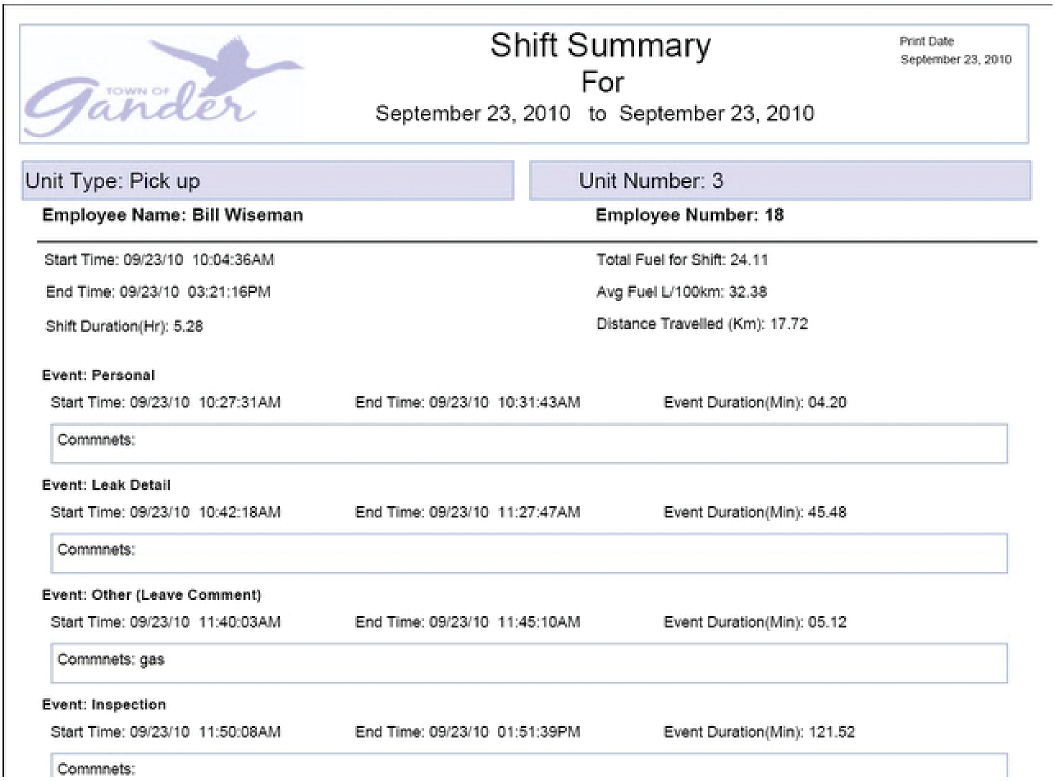
## Examples

| Name | Picture | Price (AUD$) | Website | Comments |
|---|---|---|---|---|
| MultiDAT |  | ~$1400 (low-precision GPS). ~$2100 (high-precision GPS) | www.feric.ca | Optional MultiPAD interface price: ~$450  |
| RouteHawk |  | ~$5000 | www.strongeng.com | An ongoing small fee applies per machine to process, display and store the data on a central server |
| FPDat |  | ~$4000 | www.fpsuite.ca/index.html | An ongoing small fee applies per machine to process, display and store the data on a central server |

## Sample outputs

| | Total Delay |
|---|---|
| **Chipper003** | (HH.MM) |
| Breakdown | |
| 2010/12/15 Wed. | 0.20 |
| 2010/12/16 Thu. | 0.15 |
| Sub-total / Breakdown | 0.35 |
| Change chipper knives | |
| 2010/12/14 Tue. | 0.01 |
| Sub-total / Change chipper knives | 0.01 |
| Change flail chains | |
| 2010/12/08 Wed. | 1.10 |
| 2010/12/10 Fri. | 1.25 |
| 2010/12/16 Thu. | 2.00 |
| Sub-total / Change flail chains | 4.30 |
| Changing trucks | |
| 2010/12/07 Tue. | 0.17 |
| 2010/12/08 Wed. | 0.29 |
| 2010/12/09 Thu. | 0.20 |
| 2010/12/10 Fri. | 0.24 |
| 2010/12/14 Tue. | 0.16 |
| 2010/12/15 Wed. | 0.02 |
| 2010/12/16 Thu. | 0.16 |
| Sub-total / Changing trucks | 2.03 |
| Chipper shift | |
| 2010/12/09 Thu. | 1.09 |
| Sub-total / Chipper shift | 1.09 |

Figure 12:
MultiDAT delay causes. This report shows a daily summary of the pre-defined delay causes. The report was written using the MultiDAT's inbuilt report writer



Shift Summary
For
September 23, 2010 to September 23, 2010

Print Date
September 23, 2010

Unit Type: Pick up | Unit Number: 3

**Employee Name: Bill Wiseman** | **Employee Number: 18**

Start Time: 09/23/10 10:04:36AM | Total Fuel for Shift: 24.11
End Time: 09/23/10 03:21:16PM | Avg Fuel L/100km: 32.38
Shift Duration(Hr): 5.28 | Distance Travelled (Km): 17.72

**Event: Personal**
Start Time: 09/23/10 10:27:31AM | End Time: 09/23/10 10:31:43AM | Event Duration(Min): 04.20
Commnets:

**Event: Leak Detail**
Start Time: 09/23/10 10:42:18AM | End Time: 09/23/10 11:27:47AM | Event Duration(Min): 45.48
Commnets:

**Event: Other (Leave Comment)**
Start Time: 09/23/10 11:40:03AM | End Time: 09/23/10 11:45:10AM | Event Duration(Min): 05.12
Commnets: gas

**Event: Inspection**
Start Time: 09/23/10 11:50:08AM | End Time: 09/23/10 01:51:39PM | Event Duration(Min): 121.52
Commnets:

Figure 13:
RouteHawk shift summary report. Example of a pre-defined report produced from data uploaded to the RouteHawk online server




Figure 14:
FPDat website reporting (FPTrak). Example of a pre-defined report produced from data uploaded to the FPTrak online server

## CASE STUDY 1.
## IMPROVING HARVESTER UTILISATION

**Description:** A harvest contractor in western Canada installed MultiDATs in ~10 harvester-processors and found that the practice of the operators leaving the cabin to manually measure oversized logs for sawing reduced machine utilisation by 20%. As the log measurements occurred sporadically over the shift, the contractor previously had no idea of the total amount of time being lost. An additional crew member was hired specifically to measure the oversize logs. As machine running costs are much greater than wages, the savings gained through not having the harvesters idle while the operators measured the logs more than paid the additional wages.

Onboard computer costs (Purchase, implementation and running): ~$25,000
(incl. $5,000/yr running costs)

Returns: $50,000/yr savings (after paying for additional crew member)


**Figure 15:**
**Harvester operating on Vancouver Island, Canada**

## CASE STUDY 2.
## IMPROVING UTILISATION OF HARVESTERS AND FORWARDERS

**Description:** A harvest contractor in eastern Canada has been trialling the FPDat system on six harvesters and four forwarders. A key feature of the FPDat is that operators get constant feedback on key performance indicators (KPIs), such as machine utilisation, on a screen. When performance drops by more than a preset amount the operator is alerted by the KPI figures changing from green to red and flashing.

The contractor has noted that utilisation figures had increased by 10–15% to an average of 85–90% for most of his machines since installation of the FPDats as the operators have become much more aware of their utilisation figures.

Natural forest stands in eastern Canada have a mixture of merchantable and unmerchantable areas. The navigation function of the FPDat has helped to ensure that the increased utilisation is directed to useful activities as it reduces unnecessary travel time by allowing harvester operators to readily locate areas of merchantable timber within a stand and for night shift operators to navigate to where the day shift operator had been working.

Onboard computer costs (Purchase, implementation and running): ~$45,000
(incl. $5,000/yr running costs)

Returns: ~$200,000/yr savings



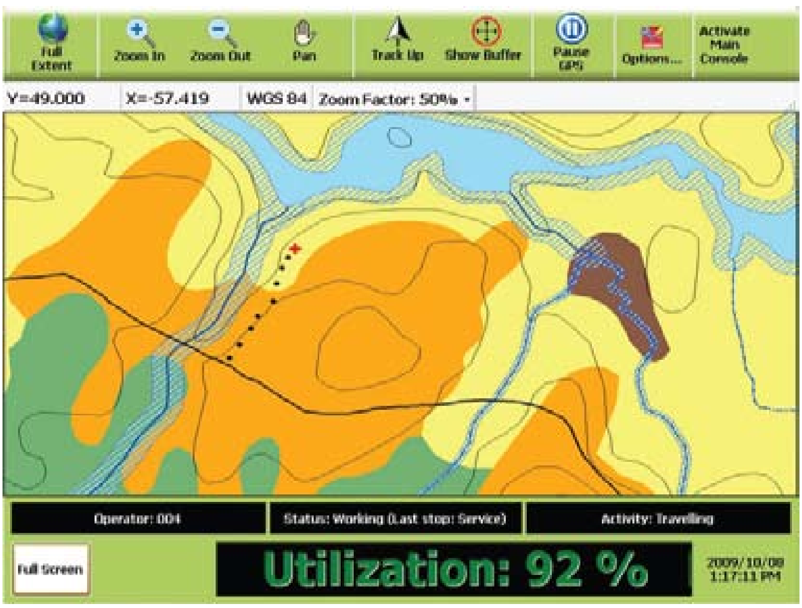



Figure 16: FPDat main screen showing current location on map relative to roads, streams, stream buffers and forest areas

## Installation and Implementation

The optional GPS units require an external antenna. See **GPS Installation and Implementation section**) for information on installing an external GPS antenna.

### Location

- Purpose-built units generally need to be located in reach of the operator and in their normal field of view when operating the machine to allow for operator login/out, entry of delay causes or activities and feedback to the operator (RouteHawk, FPDat and MultiPAD). MultiDATs can also be used with no operator input and in this case can be mounted in any suitable location.
- For units using a vibration sensor to detect activity (e.g. MultiDAT and FPDat) see also **Vibration Sensor location information**.



### Mounting

- Mounting will generally require construction of a bracket to meet the "Location" requirements. As all machine cabins are different, it may be necessary to create different brackets for each make and model of machine.
- For Purpose-built units that detect machine activity using vibration, the bracket construction and mounting must minimise vibration in excess of that transmitted through the machine frame, as additional vibration could affect results.

### Wiring

- Units should be hard-wired into the machine's wiring with a fuse to protect the unit. Wiring should be after the master switch to prevent battery drain after hours.
- Specific wiring details are available for each of the units. Refer to manufacturer's instructions.

## Data

### Downloading data

Increasingly, Purpose-built computers are being designed for automatic remote downloading of data. The FPDat and the RouteHawk send the data to a central web server via a mobile or satellite phone modem at regular intervals during the day (generally ~10 minutes). The data is processed and displayed on the website. Typically there is a charge per machine to access the data via the website. MultiDATs require a PDA (or laptop) with a 9 pin serial port and null modem cable (not a standard serial cable) to download data (most USB—serial port adapters do not work. The ATEN UC 232A adapter is known to work).

The FPDat and MultiDAT have an automatic download option for areas without mobile phone coverage that uses short-range radio transmitters to collect data from machine-mounted MultiDATs or FPDats and store it on a base station mounted in a vehicle. When the vehicle returns to mobile phone range, the data are downloaded from the base station to a central server.

**Data entry**

All Purpose-built units allow operators to enter activities and delay causes via buttons (MultiDAT) or onscreen (FPDats and RouteHawks). FPDats and RouteHawks require the operator to log in at the start of the shift and log out at the end. This is optional for MultiDATs. Operator login is particularly useful for machines that have a number of operators to allow issues to be pinpointed to a particular operator.

**Data analysis**

MultiDAT software provides a number of predefined reports and also allows users to create custom reports to analyse the data collected. Systems that deliver the data online generally have predefined reports that display machine performance over time. Systems that collect data in near to real-time have the ability to warn users of problems (such as long machine idle periods) as they arise. This feature is available in non-forestry systems and is most likely to become available for forestry systems in the near future.

If a GPS was installed, the GPS data can be analysed as described in the GPS Data analysis section.

## Troubleshooting FAQ

**Problem**

1. **No data collected**

   Not programmed correctly? All Purpose-built onboard computers require a degree of setting up to collect data accurately. Refer to manufacturer's instructions.

   No power? Purpose-built onboard computers need to be connected to a 12V or 24V DC power source to operate.

   Poor calibration? MultiDATs and FPDats must be calibrated correctly to detect activity using the vibration sensor. Refer to manufacturer's calibration instructions. RouteHawks collect activity using engine RPM.

   Fault in unit? Though rare, faulty units are still possible. Units usually have one or more status lights to indicate correct operation.

2. **Utilisation higher or lower than expected.**

   First verify whether there is a problem by checking utilisation for a period of time (preferably at least several hours) by observing the operator and comparing the result with the utilisation for the same period calculated from the unit.

   Differences can be the result of:

   – Not picking up vibration or picking up excess vibration. Check mounting point.
   – Incorrectly calibrated vibration sensor.
   – Detecting both working and travelling. MultiDATs and FPDats can be connected to other functions of the machine to distinguish working from travelling and hence get a more accurate picture of when the machine is working e.g. connection to a head function for a harvester or feller-buncher.
   – Long-term utilisation is generally less than short-term utilisation as it includes infrequent major delays such as significant breakdowns or wet weather delays.

3. **Trouble communicating with the unit**

   Incorrect cable? MultiDATs require a null modem cable (not a standard serial cable) connected to a serial port. Most USB to serial port adapters do not work (The ATEN UC 232A adapter is known to work). Serial port adapters for PDAs can be used.

   No mobile phone coverage? Fitting an external antenna may improve coverage.

4. **No entry of activities or delay causes**

   Operator "buy-in" is essential to collection of data on activities and delay causes. As this is in addition to their normal work, the operators will need a period to adjust to entering the data. This may take several weeks, depending on the individuals and the complexity of the data required.

5. **Inaccurate GPS results**

Accuracy of the GPS results is dependent on the precision of the GPS and its ability to obtain signals from satellites. Generally, the more satellites detectable by the GPS the better the result. However, if trees or hills block the satellite signals from the sides, accuracy can still be poor as the only available satellites are clustered overhead. A small level of scatter of GPS points is normal, particularly when reception is poor.

Use of a high-precision GPS and mounting an external antenna as high and unobstructed as possible will minimise these problems. Calculation of the apparent speed of the machine between GPS points can be used to identify and remove points where the estimated speed is greater than possible for that machine.

If GPS readings have been set to occur using distance or time, check that the settings are reasonable based on the activity of the machine.

**NOTE**

Older base maps (roads, streams, topography, etc) used a different "projection" that will display GPS points ~200 m from their true location. The older maps use Australian Map Grid (AMG) 66 or AMG84. The updated maps use Map Grid of Australia (MGA) 94. In addition, roads and streams were often mapped less accurately in the past so that GPS points may appear incorrect relative to other map features. Updated maps may be available. In particular, many forest roads have been remapped recently for emergency vehicle use.



# Manufacturer

## Description

All modern forestry machines have an onboard computer. The simplest of these computers only controls machine functions and provides little or no useful information to improve machine performance. The Manufacturer computers considered in this guide are those capable of recording data according to the StanForD standard (see www.skogforsk.com), which covers all major forest machine manufacturers. These computers are available as an option on most forest machines. If not (generally on older or excavator-based machines), there are equivalent units from manufacturers such as Dasa (www.dasa.se), that can be retrofitted. For harvesters these are generally supplied by the harvester head manufacturer. The functionality available can differ between manufacturers depending on whether the manufacturer has only implemented the mandatory StanForD variables or has included some or all of the optional variables.

Manufacturer computers are the most expensive of the onboard computing options in this selection guide, but also offer the greatest scope for machine performance data collection. Some offer optional upgrades of software, such as John Deere's Timberlink system or optional hardware, particularly GPS and associated screens and software. Manufacturer GPS can be used to record locations of trees as they are cut, log landings and the quantity of logs at the landing, or to display the location of the machine and hazards and no-go zones. Units that display hazards can be set to warn the operator when they are approaching one of these zones or the stand boundary.

## Potential uses

**Identify inefficiencies.** Utilisation data is currently the weakest aspect of Manufacturer computers as they currently only record summary data (in Operations Follow-up (drf) files). Collection of utilisation data is switched off by default. When utilisation data are recorded, operators are required to select a delay cause from a set list for any delays over a predefined period (default = 15 minutes). The data can be used to identify underutilised machines and to estimate baseline utilisation as an input into a continual improvement program. The only caveat is that the requirement to enter a delay cause for longer delays may influence operator behaviour. Further analysis is limited, as the data is recorded as summaries for a day or longer and the duration, timing and cause of individual delays cannot be determined.

Operations Follow-up is an aspect of the StanForD standard that is under review and expected to improve significantly in the next few years.

**Estimate harvester productivity.** Manufacturer computers are the only type of onboard computer to record log and stem dimensions and volume as they take measurements of tree length and diameter as each tree is being processed. This feature is only available on single grip harvesters. Regular calibration of length and diameter measurements is essential to ensuring these measurements remain accurate. Accurate bark thickness estimates are also needed for the computer to convert overbark to underbark diameter.

Machine productivity is estimated using harvested volume in conjunction with productive machine hours derived while collecting utilisation and reported in Operations Follow-up files. Productivity is also reported in terms of stems cut per productive machine hour.

**Estimate forwarder/skidder productivity.** Measuring productivity of forwarders requires operators to enter the log type(s) and estimated weight of each load. If a load scale is fitted the weight data from it can be typed into the system. Production files from the harvester (individual tree (pri) or stand (prd)) can be copied to the forwarder to allow planning of forwarder trips and estimates of uncarted logs. Haulage distance is an optional output requiring a GPS to be fitted

**Productivity and Cost models.** Utilisation and volume cut per hour reported in Operations Follow-up files can be used as inputs into a productivity model and combined with costs to produce a cost model to estimate harvest rates. These models can be used to assess alternative methods.



**Fuel consumption.** This is currently optional under StanForD and availability of this feature would need to be checked before purchase, as it may be an extra cost option. Another consideration is that fuel consumption is estimated based on rpm, load factor etc rather than measured, and research by FPInnovations on trucks has found errors with this approach of up to 10%.

## Important considerations

- Local support is crucial to get Manufacturer onboard computers installed and running correctly, where these are being retrofitted to an existing machine. Most major forest machine manufacturers have local support.
- Many StanForD variables are optional and not collected by all Manufacturer computers. Check whether software updates can be obtained for the computer as it may be possible to install later versions of StanForD by upgrading the software.
- As the most expensive option, Manufacturer onboard computers should only be considered if the data required cannot be obtained using another onboard computer or if they are to be installed for another purpose. A typical example of this in the Australian forest industry is the requirement to optimise log bucking in exotic pine plantations. Manufacturer onboard computers are the only option in this case.
- Use of GIS requires digital maps of harvest areas supplied by the forest owner/manager.

## Examples

Each of the major forest machine manufacturers has their own proprietary onboard computers (e.g. John Deere's Timbermatic, Valmet's Maxi and Ponsse's Opti), which generally have similar capabilities. Some, such as the Dasa units, can be retrofitted onto most forest machines. Prices start at approximately $20,000 for a basic system. GPS and additional software components can incur additional costs.

Timberlink is a software tool available for late-model John Deere equipment (D series onwards) that allows detailed analysis of the activities of each machine split by operator, machine action (processing, travelling, moving grapple etc) and tree size. A Timberlink licence costs approximately $2000 per machine.

### Sample outputs

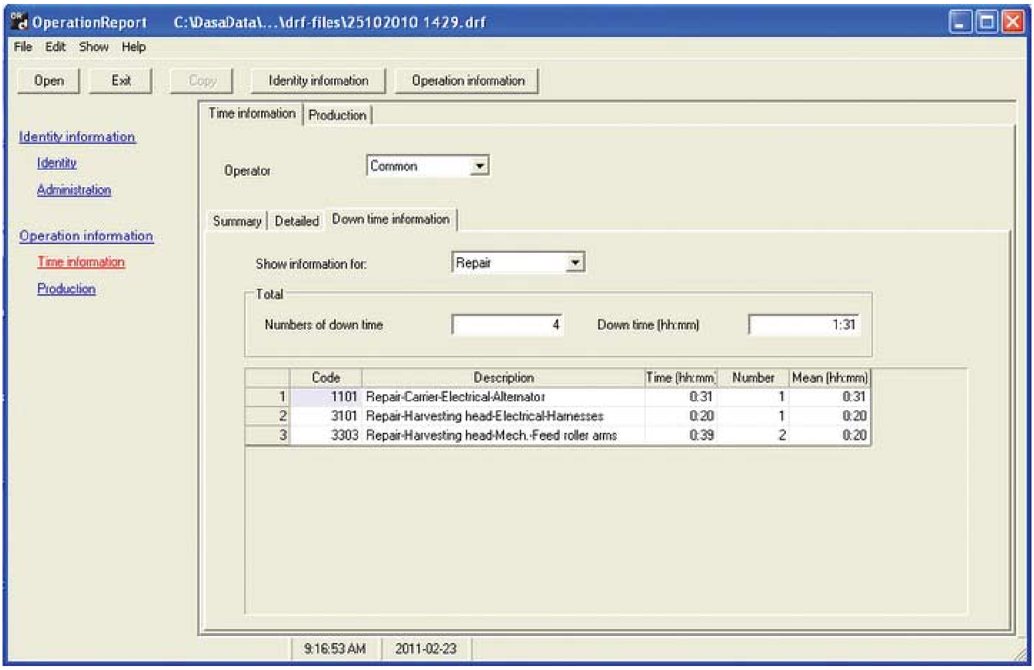



**Figure 17:**
**Dasa Operations follow-up report showing details of repair delays**



## CASE STUDY 1.
## IDENTIFYING CAUSE OF LOW HARVESTER PRODUCTIVITY

**Description:** A radiata pine harvest contractor needed to monitor the production of a new harvester operator who was producing less wood than expected. New operators are generally less productive and output can vary from day to day, making it difficult to interpret short-term observations.

The harvester was already fitted with a Dasa 4 onboard computer to allow optimised bucking. The operator's utilisation and production was monitored by switching on collection of Operations Follow-up data, which requires the operator to enter a cause for delays over 15 minutes (default time).

Analysis of two months of Operations Follow-up files (DRF files) showed that the operator's hourly productivity was acceptable. However, his daily production was low because he was not working the expected scheduled hours per day and working too few productive hours within this time. This had a flow-on effect of reducing the utilisation of the forwarders picking up the wood from this harvester and on the ability of the contractor to meet his weekly log quota.

Onboard computer costs (Purchase, implementation and running): $1,000 to collect and analyse the Dasa data.

Returns: ~$90,000/yr savings



**Figure 18:**
**Dasa onboard computer. Most actions can be done using the touch screen. A few actions, such as typing in a filename, require the use of a keyboard.**

## CASE STUDY 2.
## IDENTIFYING METHODS TO IMPROVE FORWARDER PERFORMANCE

**Description:** Timberlink software allows detailed comparisons of operator performance. An Australian radiata pine harvest contractor used Timberlink results to compare the performance of two forwarder operators in his crew. One operator was found to be moving 25% more wood than the other per day and using 20% less fuel to do so. Further analysis of the Timberlink results combined with observations of each operator's working patterns isolated the major reasons for the productivity differences. This information was then used to retrain the poorer performing operator.

Onboard computer costs (Purchase, implementation and running): ~$6,000 (incl. $2000/yr running costs)

Returns: ~$65,000 per year. Mostly through reduced costs associated with increased productivity

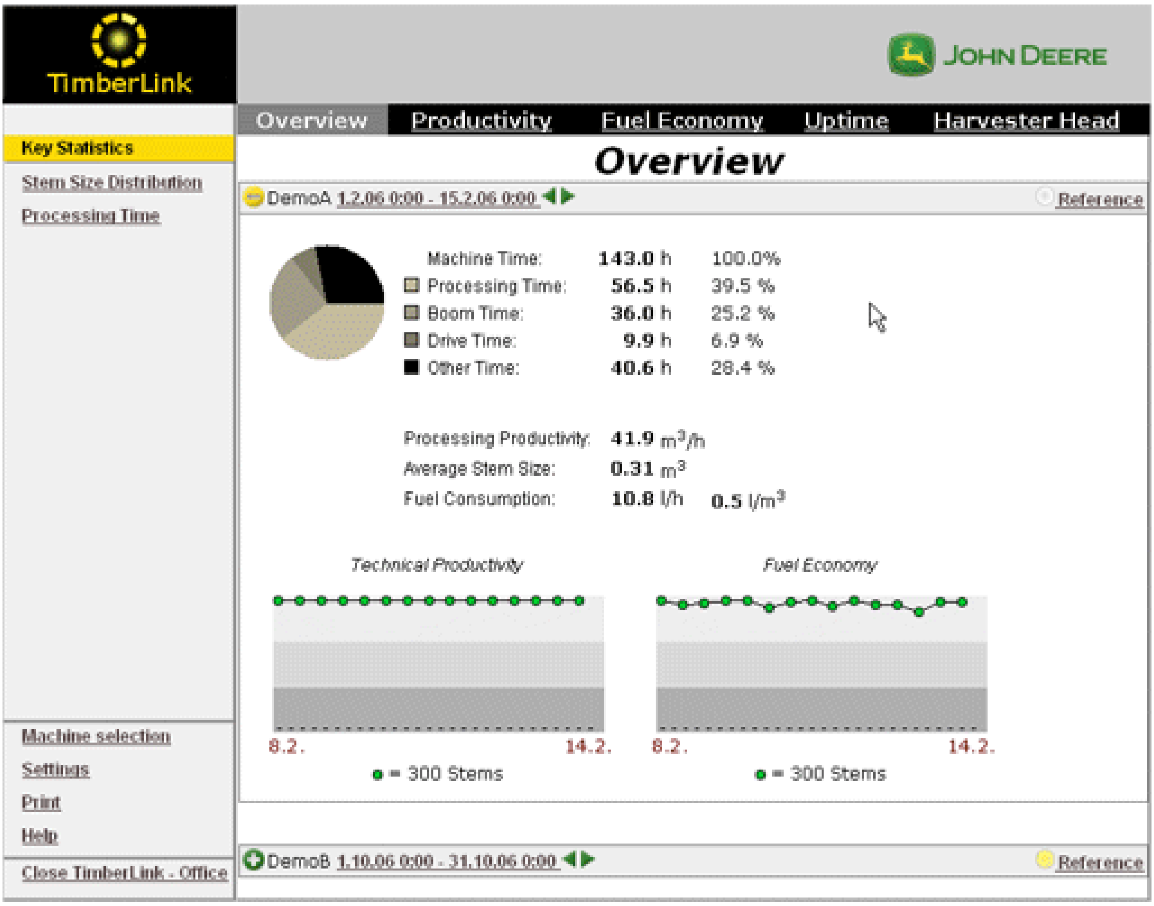



Figure 19:
Timberlink overview screen

## CASE STUDY 3.
## HARVEST HEAD EFFICIENCY IMPROVEMENT

**Description:** Timberlink software displays detailed performance information against tree and log size, which are the major factors influencing harvester productivity. The owner of a forest harvester operating in Sweden used Timberlink results to determine that it was taking one second longer than expected to feed a stem and find the cutting window for each log compared with the reference figure for that model of harvester and piece size. This seemingly trivial amount of time per log added up to 3 hours of lost production per week and the use of an extra 40 litres of fuel.

This example illustrates where an onboard computer is required to pinpoint the exact cause of a problem. The only alternative would be a detailed time and motion study requiring specialised analysis skills.

Onboard computer costs (Purchase, implementation and running): ~$3,000
(incl. $1000/yr running costs)

Returns: $25,000 per year from cost savings



**Figure 20:**
**John Deere harvester working in Sweden**

## Installation and Implementation

The preferred approach is to purchase a Manufacturer onboard computer as a factory installed option when a machine is purchased, as this overcomes potential installation issues with wiring a complex computer into an existing machine. If installation after purchase is required it must be done by a trained installer, as it involves linking into the systems that control the functioning of the machine so there is a high potential for mistakes with significant consequences and downtime.

Basic skills in the use of Manufacturer onboard computers can be gained through on-the-job training. However, effective use of Manufacturer equipment requires training by specialised training staff. The ability of the manufacturer to provide this training should be considered in purchase decisions.

## Data

### Downloading data

Data is generally downloaded using a USB memory drive. Transfer via mobile phone may also be available. See manufacturer's documentation for details.

### Data entry

Data entry is required to log on and log off the onboard computer at the start and end of a shift and to record delay causes if they are being recorded. See manufacturer's documentation for details.

### Data analysis

Manufacturer onboard computers all have reporting facilities that primarily report on the information in Operations Follow-up files.

### Utilisation

If possible, calculate utilisation in terms of the scheduled work hours for each day. Operations Follow-up (DRF) files express utilisation as a percentage of the hours the operator is logged on for the day. This approach masks when the operator has worked less or more than the scheduled hours. DRF files also show the number of hours worked each day allowing calculation of utilisation as a percentage of scheduled hours.

To obtain a good understanding of the long-term machine utilisation, data need to be collected over weeks or months to capture infrequent delay causes. Infrequent major delays can have a significant impact on long-term utilisation.

### GPS

See GPS Data analysis section.

### Productivity

Harvester productivity is highly dependent on tree size and to a lesser extent on factors such as slope and the number of products cut per stem. Operations follow-up files include productivity ($m^3$/hr) and average tree size, which can be used to develop a curve of productivity against tree size. The curve can be used in rate setting and as a guide to assess the impact of changes in working practices and equipment changes on productivity.

Forwarder productivity is highly dependent on transport distance and piece size. As with harvester productivity, a curve of forwarder productivity against transport distance can be developed to assist in rate setting and evaluating working practice and equipment changes.

## Troubleshooting FAQ

**Problem**

1. **No data collected**

   No Operations Follow-up data? Operations follow-up data collection is switched off by default. The machine operating manual will describe how to switch it on. Note that switching on the Operations Follow-up files will require operators to enter a delay cause for delays over 15 minutes (default). Until a delay cause is entered the machine cannot be operated.

   No GPS locations? When a GPS is retrofitted there may be one or more settings that need to be altered to record GPS locations in StanForD files such as pri and stm files. Details will be in the machine operating manual. There have also been instances where the GPS software has been set to the northern hemisphere and so the machine location does not display on the map in Australia. Check for a setting to correct this problem.

2. **Utilisation higher or lower than expected.**

   First verify whether the problem is your perception of what utilisation should be or a problem with the onboard computer. This can be done by checking utilisation for a period of time (preferably at least several hours) by observing the operator and comparing the result with the utilisation calculated by the onboard computer.

   Manufacturer onboard computers use the logged on time to calculate utilisation, which can hide poor and exceptional performance as someone working less than their scheduled hours can have the same calculated utilisation as someone else working more than their scheduled hours.

3. **USB memory reports full when there is space available (See note).**



**NOTE**

Manufacturer onboard computers use USB memory devices to transfer data collected in the field to systems in the office. These USB devices can report they are full when they still have space available. This can happen when the USB memory device has been formatted as “FAT”. USB memory can be formatted as “FAT” or “FAT32”. The major difference is that a USB device formatted as FAT can’t store as many files as FAT32. This can be a problem when copying PRI or STM files from a Manufacturer onboard computer to a USB memory device as a new file is created for each tree cut resulting in thousands of files being generated each week.

Before using a USB memory device to transfer data, check to confirm it is formatted to FAT32. USB memory devices can be reformatted on a desktop PC or laptop. However, this deletes all the existing files so they must be backed up elsewhere before formatting.

4. **Inaccurate GPS results**

Accuracy of the GPS results is dependent on the precision of the GPS and its ability to obtain signals from satellites. Generally, the more satellites detectable by the GPS the better the result. However, if trees or hills block the satellite signals from the sides, accuracy can still be poor as the only available satellites are clustered overhead. A small level of scatter of GPS points is normal, particularly when reception is poor.

Use of a high-precision GPS and mounting an external antenna as high and unobstructed as possible will minimise these problems. Calculating the apparent speed of the machine between GPS points can be used to identify and remove points where the speed is greater than possible for that machine.

If GPS readings have been set to occur using distance or time, check that the settings are reasonable based on the activity of the machine.

**NOTE**

Older base maps (roads, streams, topography, etc) used a different "projection" that will display GPS points ~200 m from their true location. The older maps use Australian Map Grid (AMG) 66 or AMG84. The updated maps use Map Grid of Australia (MGA) 94. In addition, roads and streams were often mapped less accurately in the past so that GPS points may appear incorrect relative to other map features. Updated maps may be available. In particular, many forest roads have been remapped recently for emergency vehicle use.



# Terminology

| TERM | DEFINITION |
|---|---|
| **9 pin serial port** |  (www.thefullwiki.org) |
| **Assess alternative harvest methods** | Alternative methods being assessed could be use of different combinations of equipment, or different ways of operating with the same equipment |
| **Brushing** | Clearing understorey vegetation |
| **Continual improvement program** | Examining a process (such as harvesting) to identify inefficiencies, making changes and monitoring their impact. Improvements can take the form of small, incremental changes or significant, broader changes |
| **Cost model** | Cost models allow estimation of harvesting costs for different harvesting methods and working conditions (e.g. slope, tree size). To build a cost model, utilisation and productivity are required for each modelled machine under the conditions covered by the model |
| **ESRI** | ESRI is the largest producer of GIS software worldwide. Its desktop software is ArcView or ArcMap |
| **Geofence** | A virtual "boundary" around an area that exists in a global positioning system (GPS) or a geographic information system (GIS). Used to monitor the number of trips of a machine across the boundary. For example to count forwarder, skidder or truck trips |
| **GIS** | Geographic Information System. Computer program that allows digital geographic data to be created, analysed and modified |
| **GPS** | Global positioning system. Uses signals from a network of satellites to determine the location of a receiver on the earth's surface. To determine a location accurately requires signals from satellites evenly spread across the sky |
| **Map Projection** | Coordinates are projected to enable real-world locations to be displayed on a two-dimensional map. The latest projection used in Australia (Map Grid of Australia) is sufficiently close to the projection used by GPS (WGS84) for the purposes of forest harvesting |
| **NMEA** | National Marine Electronics Association. A standard file format used by most GPS devices |

| TERM | DEFINITION |
|---|---|
| **Null modem cable** | Serial ports have a transmit pin and a receive pin. Null modem cables swap these wires internally so that signals from the transmit pin on one device appear on the receive pin on the other device |
| **Operations Follow-up files** | Operations Follow-up files (StanForD DRF files) are a key source of information about machine productivity and utilisation. Refer to the manufacturer's instructions for information on collecting and viewing/exporting these files |
| **PRI file** | Individual tree productivity file collected using the StanForD standard. Describes the log products cut from a tree (see www.skogforsk.com for details) |
| **Productive Machine Hours** | Hours that a machine actually works. It can be expressed as PMH0 (excluding all delays); or PMH15 (including delays up to 15 minutes) |
| **Productivity** | The definition of productivity varies between machines. For harvesters it is expressed as volume (or weight) of wood cut per hour or day. For forwarders and skidders it is expressed in terms of volume (or weight) of wood transported per hour or day. For chippers it is expressed as the volume (or weight) of wood chipped per hour or day. Hours can be expressed as productive or scheduled machine hours. Wood cut or transported per litre of fuel is another productivity measure sometimes used |
| **Productivity model** | Productivity models predict the production of a machine under different working conditions (e.g. slope, tree size). To build a productivity model, utilisation and productivity are required under the conditions covered by the model |
| **Scheduled Work Hours** | Hours that a machine is scheduled to work, but may not work due to delays. Also known as Scheduled Machine Hours |
| **Shapefile** | Shapefile is a file format created by ESRI. Shapefiles can contain one of three data types: points, lines or polygons (shapes) |
| **StanForD** | The standard for collection of operational, locational and tree data from harvesting machinery. Only applies to Manufacturer systems. See www.skogforsk.com for details |
| **STM file** | Individual tree stem file collected using the StanForD standard. Describes the log products and the stem shape of a tree. (see www.skogforsk.com for details) |
| **Utilisation** | Utilisation is the proportion of scheduled time for a day that the machine actually works. It can be split into travel and work to give a better picture of the machine's activities |

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