Rapid Review of Digital Tablets for Use in Archaeological Fieldwork

Alexandra Kriti, Serenella Sessini, Rose Malik and Rob Wiseman

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ABOUT ARCHAEOLOGY ON FURLOUGH

When the spread of coronavirus COVID-19 forced the UK into shutdown in 2020, Archaeology on Furlough was set up to provide volunteer projects for archaeologists unable to work. Around 120 people registered via the website (www.archaeology-on-furlough.com), and most went on to be active participants in the eleven projects on offer. Participants included commercial field archaeologists and specialists, museum curators, retired archaeologists, and students unable to access laboratories or research facilities.

The projects undertaken by the volunteers involved collecting and analysing data on:

- Roman cultivation strips in the East of England
- gravegoods in the Iron Age, Roman and Anglo Saxon periods (Cambridgeshire and Oxfordshire)
- trauma in skeletons from the in the Iron Age, Roman and Anglo Saxon periods (Cambridgeshire and Oxfordshire)
- aurochs remains from Scotland, England and Wales
- Saxon houses from Scotland, Northern England and the Midlands
- henges excavated in Scotland, Northern England and the Midlands
- historic sheepfolds of the Lammermuirs Hills (Scotland)
- barrows and other Bronze Age sites on Dartmoor
- temples in Roman Britain
- decoration used in prehistoric Britain
- digital tablets for use in archaeological fieldwork.

Once completed, the grey literature project reports and datasets generated by the project teams will be made available via Cambridge University Library's Apollo repository (https://www.repository.cam.ac.uk/).

Projects were all conducted voluntarily, so that participants could comply with the requirements of the UK Government's Coronavirus Job Retention Scheme.

For many of the volunteers, Archaeology on Furlough was an opportunity to research unfamiliar topics, and discuss them with peers. For some, it was an opportunity to develop new skills, particularly research skills which they did not get the opportunity to use in their regular fieldwork. For a few, Archaeology on Furlough provided their first opportunity to write a report.

Archaeology on Furlough was also intended to provide support for archaeologists out of their normal workplaces. Volunteers used video conferencing and various message boards to keep in touch with one another.

Archaeology on Furlough was developed and coordinated by Rob Wiseman (Cambridge Archaeological Unit, Department of Archaeology, University of Cambridge).

SUMMARY: RAPID REVIEW OF TABLETS FOR USE IN ARCHAEOLOGICAL FIELDWORK

Over the last twenty years, digital technology has made great inroads into archaeological work in the UK. The last major part of archaeology which remains largely paper-based is fieldwork.

This project reviewed 35 digital tablets which might be suitable for recording archaeological data in the field. Some of these tablets are already used in UK archaeology; others are used in broadly comparable construction, mining and engineering environments.

This report is a non-technical review. It makes no recommendations about tablets suitable for use in UK archaeology. Rather, it outlines factors archaeological units need to consider when adopting tablets, along with the information systems they need to work in, if tablets are to be effective and efficient tools.

Tablets can be used in a variety of ways on archaeological sites:

- as a single onsite computer to replace central resources like site registers
- as stand-alone data recorders for field staff
- as part of an integrated information network linked to other databases, such as those generated by survey and specialists.

Archaeological units considering how to adopt tablets need think through how they will use the information generated on site, as this has important consequences for which tablets will be most suitable for their needs. Key factors that need to be considered include tablet's:

- physical suitability for site work
- battery life and recharging
- mobile connectivity
- central processing units (CPU), memory, and operating systems
- the software archaeological units plan to run on tablets.

The tablets reviewed fell into two main groups:

- *consumer tablets*—the type commonly used in offices and at home
- *rugged tablets*—designed for use in harsh outdoor work environments.

Rugged tablets are designed to resist impacts, water, dust, and extreme temperatures (-10° to 50°C); to be useable while wearing gloves; be readable in direct sunlight; and to have a battery life sufficient for an 8-hour day on site. Many tablets available in the UK have many additional features potentially useful in archaeology, such as built-in compasses, GPS, and high-resolution cameras.

The purchase price for the consumer tablets reviewed in May 2020 ranged between c.£300 and £1,100, while rugged tablets ranged between £300 and £2,900.

While funds-poor archaeological units may focus on purchase price when deciding which models to purchase, a more important figure is the *total cost of ownership* (TCO). While there are no studies of TCO specific to archaeology, in other industries studies have found the TCO of rugged tablets could be over 50% less than consumer tablets. Important contributors to long-term cost of tablets include:

- the cost of repairs and replacement units
- recurring costs of software and mobile connectivity
- IT maintenance and support for both staff and equipment.

A key factor that units should consider to manage costs are product warranties.

Because adopting tablets for archaeological fieldwork may double the number of computers that units are using, and increase their reliance on mobile technology, units also need to consider effective IT security for their expanded networks.

INTRODUCTION

Information technology has made steady inroads into archaeology over the last twenty years, displacing more traditional paper-based recording and reporting tools. Today, survey, graphics, and most aspects of publication are carried out digitally. The last major area which remains solidly paper-based is fieldwork.

Some archaeological units have started exploring digital recording. However, many lack information on the types of products available and the types of factors which need to be considered when choosing tablets.

This report is not intended as a comprehensive review of all products which would be suitable for archaeological fieldwork. Rather, it is intended as a starting point, so that units can get an initial idea of the options available, the costs involved, and some of the factors they need to consider.

This report is intended mainly for archaeological units, rather than sole operators (although we hope it will be useful to them as well). But archaeological units have to think about tablets and pads integrated into a larger IT system, and into a larger system for generating, analysing and managing information. That *information system* is the single biggest factor which archaeological units need to consider when deciding which tablets to acquire and use.

This report summarises the results of a rapid review of manufacturer's product information for digital tablets and pads available in May 2020.

Associated with this report is an Excel spreadsheet summarising characteristics of each individual tablet.

Caveats

This report is not for IT technicians. It is for non-specialists considering what technology is available for recording archaeological data in the field and how it might be used. It uses a review of 35 widely available tablets to illustrate factors that might be relevant when choosing tablets suitable for use on archaeological sites. This report focusses primarily on hardware and its use: it does not deal with the complicated problem of software, although this is as crucial as hardware for field recording.

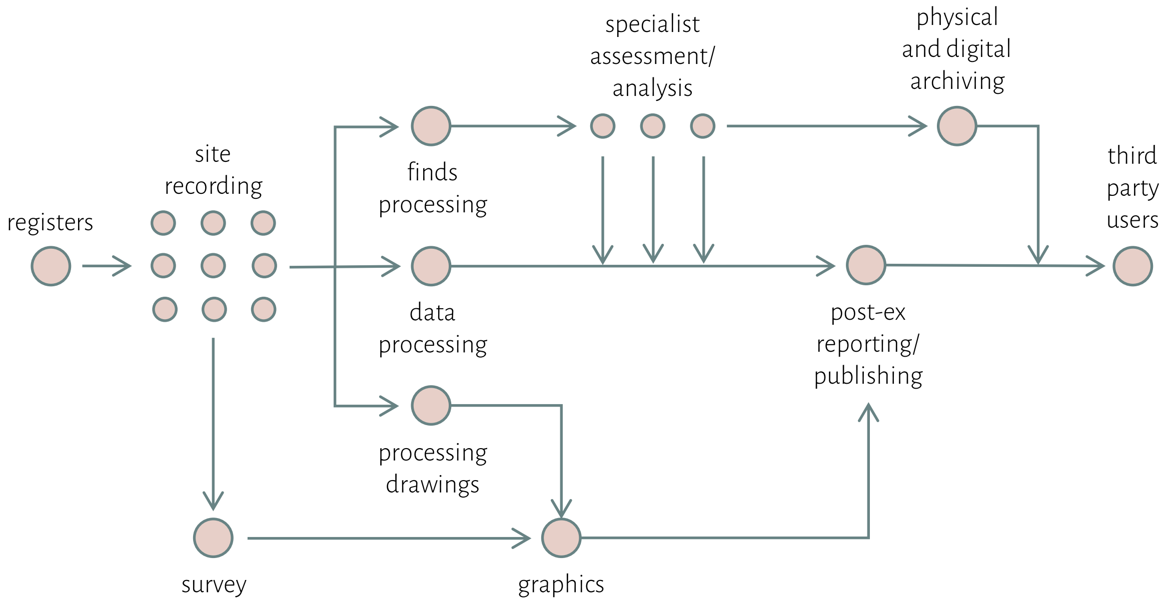
All of the information is based on material obtained from the manufacturer's product information accessed from their websites in May 2020. The authors have not field tested any of the products, and do not warrant that they are suitable for archaeological fieldwork. This report makes no recommendations about any tablets. Individuals and organisations considering use of tablets are urged to conduct their own research, and not to rely solely on the information in this report.

All of the authors participated in this project voluntarily and did not receive any payment from any source for compiling this information.

MANAGING INFORMATION IN ARCHAEOLOGY

The information system

At the heart of the archaeological process is *information*: creating information, processing information, reporting information, and ultimately others using information. Information moves through the archaeological process in a series of stages: fieldwork, survey, finds processing, specialist analysis, reporting, and so forth.



When archaeology is done by teams of any size—such as in most UK commercial units and university projects—information in each of these stages is usually handled independently. For example, most specialists have their own spreadsheets or databases, separate from the records generated from field staff; survey and graphics might rarely read contexts sheets, and work almost exclusively from drawings.

There are several problems with information systems which operate this way:

- they are *inefficient*, as they frequently involve duplicating or rekeying data
- they are often enormously *wasteful*—in other industries, independent systems frequently take on a life of their own, and fail to serve the needs of others outside, generating information that ultimately no one uses. In archaeology, anyone who has written a site report will know how little of what gets written on context sheets is actually analysed in any meaningful way, and even less actually gets reported in print. (Seen another way, this means that archaeological information currently suffers from a high degree of *degradation*.)
- they are vulnerable to *errors*—errors are difficult to detect, and even once an error has been identified, it is very difficult to correct across multiple systems (and efforts to 'correct' errors by, for example, one specialist, can create further errors for later users of the information, such as survey or graphics)

In UK archaeology over the last twenty-odd years, most sub-fields within archaeological units have adopted IT within their specialist areas—graphics uses graphics software like Illustrator and InDesign; survey uses GPS and CAD software; specialists use spreadsheets and databases like Excel and Access. But while this has created efficiencies within specialist areas, and allowed new types of analysis that would be difficult to do manually, most of these tools are not shared outside these sub-fields. Integration usually comes down to one or two people in post-excavation who have to reconcile and coordinate all of the different data streams.

This, it should be stressed, is not universal in UK archaeology, but it is common. Even basic information management—like typing context sheets into a database—does not happen in every unit or on every project.

Fieldwork

The one area of UK archaeology that has seen least use of IT has been fieldwork. In part, this is because it is expensive: field teams typically make up over half of all staff in commercial units, so equipping every person on site with digital technology is costly. But there is a second, equally important reason. Digitisation of fieldwork is potentially very disruptive to all of the other subfields. This disruption could be potentially transformative, but it could also generate major problems. This is because fieldwork generates the primary data which holds the rest of the information system together—contexts numbers, feature numbers, sample numbers, section drawings, and plans (whey they are still nor already recorded separately by survey teams). So, changing the way information is generated in the field impacts every subsequent stage of work. Consequently, successful introduction of digital technology into field recording involves introducing not just tablets or computers, but also designing a management system to control information as it moves through the archaeological 'information system'.

Fieldwork also poses another challenge to the introduction of digital recording on site: coordination. Most of the other parts of the archaeological process involve small numbers of people—specialists usually work as individuals, while survey and graphics rarely number more than a few people, even in large archaeological units. Consequently, coordinating information use in each of these subfields is relatively straightforward, and rarely needs more than face-to-face communication to manage. But fieldwork involves many, many more people. So digital technology in the field has to be coordinated much more formally. For example, even if every member of a field team is recording on a tablet, there still needs to be a centralised process for issuing context numbers consistently, compiling data on individual tablets, and backing all of the data all up to storage. Moreover, this needs to be done 'online' during routine use: the scale of fieldwork means it cannot be done in an ad hoc way.

Using digital technology on site

Faced with the constraints of cost, disruption and coordination, there are basically three models for introducing digital technology onto site.

Digital model 1: Replacing paper registers with digital records management

The most limited form of IT on site is a single device used to manage site registers and issue reference numbers for contexts, features, sections, plans, samples, small finds, photographs, etc.

For field staff, this involves a minor change from a paper register to a digital one, but it does have some advantages to other users later in the information stream.

- it automates and therefore reduces one key source of errors: issuing identification numbers. All specialists and finds processors can work from the one list, and if errors are identified, the central list can be amended just once.
- for surveyors in particular, a digital register makes checking that all features have been planned very much easier, as the numbers can be downloaded and checked off as features are recorded.
- if integrated with a digital site plan, recording of samples online means that samples can be plotted in near real time—allowing environmental specialists to provide feedback to field staff

- keeping registered digitally saves typing up a key list, which can speed up report writing (particularly for evaluations, which typically have to be delivered within a few weeks of fieldwork).

Delivering on the first three of these does require more than just a computer on site. There also needs to be a mechanism to transfer the data back to the office—such as broadband, Wi-Fi, or memory stick.

Digital registers do not actually require a physical computer on site. It is, for example, a few hour's work to make simple databases accessible via mobile phone. In the Microsoft suite of programs, for example, it is an hour's work to create mobile access to an Access database via Sharepoint and Powerpads. There are numerous other readily available ways of making databases accessible via smartphone.

Digital model 2: Replacing paper site records with digital recording

Using tablets to replace paper recording sheets is what is most commonly understood as 'digital recording on site'. In practice, current technology would not permit section drawings to be made digitally, but all other forms of record keeping and recording—including text, measurements, working photographs and even sketches—can now be done digitally.

In addition to the advantages of replacing paper registers listed above, recording site data digitally has the following advantages:

- It eliminates the need to re-key paper site records into databases, and so removes a major source of data degradation
- It removes most sources of error created in mis-transcribing reference numbers—a key source of errors, and one which is difficult to identify and correct
- Typing is somewhat faster that writing, so potentially saves time when recording
- If well-designed, it might help reduce some of the more unusably detailed and lengthy reporting, and create more consistency in some categories
- Databases can also do on-the-spot checks, to help ensure that essential information is not overlooked (as can happen very easily on paper forms).

While the cost efficiencies of most of these are impossible to quantify, it is possible to put some figures to the first item in this list.

Assume that is possible to transcribe 100 handwritten contexts sheets into a database per day. Then a large excavation which produces 10,000 contexts would take 100 person days to transcribe. Assuming the following purchase prices for a tablet (£500, £1500, £2000—figures discussed below), and the day rates for staff to rekey the data (£150/day, £175/day, £200/day), then the table below shows the number of tablets which could be purchased on the savings in data entry alone.

Charge-out rate	Purchase cost per tablet		
	Office-use only non-rugged tablet £500	*Entry-level rugged tablet* £1,500	*Well-equipped rugged tablet* £2,000
£150	30	10	7
£175	35	11	8
£200	40	13	10

As these figures indicate, replacing data entry on a single large excavation could recoup the cost of purchasing not only basic office-use-only tablets for the entire field team, but potentially site-suitable rugged tablets (which have a longer lifespan). Naturally, there are more costs involved in on-site digital recording: database design, IT support, staff training, and insurance amongst them. But even these crude estimates for a single large excavation do show the savings possible by eliminating one of the most tedious aspects of archaeological recording.

Many of the tablets reviewed contained cameras of a standard suitable for site recording (5–10 megapixels). A small number also featured inbuilt GPS, and most had telephony-based geolocation, which could also be used as a check on survey data. On small projects, such as test pits or watching briefs, the accuracy of GPS may be sufficient to remove the need for separate surveyors to attend site. In short, some tablets have potential to replace not just paper records, but also some site equipment such as digital cameras and low-level survey.

Digital model 3: Integrated information on and off site

Using tablets on site can replace paper recording with digital and produce direct cost savings. But the real power of using tablets comes from integrating them into a network, linking them both to on-site tools and also feeding data directly to survey, post-excavation and administration. This can greatly speed up the production of information and allow specialists to provide prompt feedback to staff on site. For example:

- On site, individual tablets can be linked, so they can be used for tasks such as requesting registration numbers from registers.
- Collated data from registers or context sheets can be used by surveyors as a checklist of all features that need to be surveyed.
- Harris Matrices can be constructed automatically, and potential conflicts identified automatically.
- Combined with survey data, it would be possible to build up site plans in near real time showing the location of excavated features, finds densities and samples features—all of which can be used to refine excavation strategies and provide feedback to staff on site.
- Report tables can be compiled automatically (e.g. for evaluation reports, it would be easy to automatically compile lists of features in each trench, as well as trench dimensions and depths, freeing up staff to use time to discuss archaeology rather than merely re-keying tabular data.)

As well as transferring data from site to office, information can also flow the other way. Administrative and operational information can be transferred directly from managers to staff on site. This would allow tablets to be used for:

- site inductions
- health and safety updates
- toolbox talks and other on-site training
- scheduling
- HR tasks, such as leave requests and timesheets.

Used this way, it would be possible to check that information has been read or completed—a very difficult task at present. (It is no secret that many units have difficulty getting site staff to read emails.)

There are a variety of ways that tablets can be connected. The break down into two basic forms:

- via open networks: e.g. public mobile networks, via dongles or inbuilt SIM cards
- closed networks: e.g. site-specific WLAN/Wi-Fi

MANUFACTURERS AND TABLETS REVIEWED

There are many tablets now available in the UK market. Most of the familiar *consumer tablets* are suitable for indoor and office use, although in some circumstances, they could be used on site. This review, however, focusses chiefly on those designed for site work — *rugged tablets* for workplaces such as construction, mining, engineering and farming. Those selected for review are a mix of those currently used by archaeologists (based on the personal experience of team members, an email to colleagues across the profession, and a post on the BAJR Facebook page in May 2020), as well as an online search for reviews of 'rugged' tablets. They are listed in Table 1.

Manufacturer	Models	Website
Apple	iPad iPad Air iPad Mini iPad Pro	https://www.apple.com/uk/ipad/
Dell	Latitude 7220EX	https://www.dell.com/en-uk/work/shop/laptops/sc/laptops/latitude-laptops
Getac	A140 F110 K120 UX10	https://www.getac.com/us/products/tablets/
MobileDemand	xTablet 1180 xTablet A1180 xTablet Flex 10A xTablet Flex 10B xTablet T1150 xTablet T1270 xTablet T1540 xTablet T1680 xTablet T8650	https://www.ruggedtabletpc.com/
Panasonic	Toughpad FZ-F1 Mk1 Toughpad FZ-M1 Mk Toughpad FZ-M1 Mk3 Toughpad FZ-G1 Mk4 Toughpad FZ-G1 Mk5 Toughbook CF-33	https://business.panasonic.co.uk/mobile-solutions/products-and-accessories
Samsung	Galaxy Tab Active Pro Galaxy Tab Active2	https://www.samsung.com/uk/tablets/all-tablets/?rugged
Senter	ST935 ST935E ST935H ST935K	https://www.senter-e.com/rugged-tablet-pc/
Zebra	ET56 (ET5 series) XBOOK L10 XPAD L10 XSLATE L10 XSLATE R12	https://www.zebra.com/gb/en/products/tablets.html

Table 1: Tablets reviewed and sources of information

PHYSICAL CHARACTERISTICS OF TABLETS FOR SITE WORK

All tablets will work on site in the short term, but to survive site conditions in the longer term, they will generally need to be what manufacturers term 'rugged'. 'Rugged' does not have a specific definition, but key characteristics which appear essential for use on archaeological sites are:

- hand-held for extended periods (i.e. less than c.1.5 kg)
- impact resistant
- water- or rain-resistant (an IP code of IP65 or better)
- dust proof (an IP code of IP65 or better)
- resistant to temperature extremes (typically -10°C to 50°C compared with consumer tablets which typically operate at 0°C to 35°C)
- a touchscreen which is responsive while wearing thick gloves
- readable in daylight (typically measured using the ratio between screen brightness measured in cd/m^2 and screen reflectance)
- a sufficiently large screen so they can be read easily and a wide variety of information entered on them (a common minimum is 8 inches diagonally for a handheld device and 10 inches for a tablet)
- a battery life which allows a full day's work on site without recharging (a minimum 8 hours)

Several other attributes are potentially useful, although not essential:

- glare-resistant screen
- scratch-resistant screen
- supports use of a stylus as well as touchscreen
- gyroscope (to make the tablet stable).

Table 2 shows attributes of each of the tablets reviewed in their native format—that is, without optional extras (so, for example, most regular tablets are not impact or scratch resistant, although it is possible to purchase impact-resistant casing and scratch-resistant screen coatings. These, however, are not part of the 'native format' of the tablet.)

Note that the absence of an entry may indicate only that the information was not available in the online product information.

Optional extras

Beyond the basic requirements for satisfactory use on site, there is a huge range of add-ons possible. Some are potentially useful for archaeological fieldwork, such as:

- inbuilt compass
- inbuilt GPS
- inbuilt camera with resolution suitable for archaeological photos (10 MP)

Other options identified in our review included 3D cameras, barcode scanners, magnetic stripe readers, fingerprint security, accelerometer, barometer and proximity sensors.

maker	model	weight (g)	screen size	daylight readable	gloved input	waterproof	impact resistant
Apple	iPad	483	10.2"				
	iPad Air	456	10.5"	Y			
	iPad Mini	300	7.9"	Y			
	iPad Pro	471	11"/12.9"	Y			
Dell	Latitude 7220EX	1650	12"–14"	Y	Y	Y	Y
Getac	F110	1390	11.6"	Y	Y	Y	Y
	K120	1800	12.5"	Y	Y	Y	
	UX10	1220	10.1"	Y	Y	Y	
MobileDemand	xTablet 1180	1470	10.1"	Y	Y	Y	Y
	xTablet A1180	1200	10.1"		Y	Y	Y
	xTablet Flex 10A	1100	10.1"				
	xTablet Flex 10B	1050	10.1"				
	xTablet T1150	1350	10.1"	Y		Y	Y
	xTablet T1270	1950	12.2"	Y	Y	Y	Y
	xTablet T1540	1100	10.1"			Y	
	xTablet T1680	1230	11.6"	Y	Y	Y	Y
	xTablet T8650	1345	8"				Y
Panasonic	Toughpad FZ-F1 Mk1	277	4.7"	Y	Y	Y	Y
	Toughpad FZ-M1 Mk2	540	7"	Y	Y	Y	Y
	Toughpad FZ-M1 Mk3	540	7"	Y	Y	Y	Y
	Toughpad FZ-G1 Mk4	1100	10.1"	Y	Y	Y	Y
	Toughpad FZ-G1 Mk5	1100	10.1"			Y	Y
	Toughbook CF-33	279	12–14"	Y		Y	Y
Samsung	Galaxy Tab Active Pro	653	8"	Y	Y	Y	Y
	Galaxy Tab Active2	419	10.1"	Y	Y	Y	
Senter	ST935	1014	10.1"	Y	Y	Y	Y
	ST935E	1014	10.1"	Y	Y	Y	Y
	ST935H	900	10.1"		Y	Y	Y
	ST935K	—	10.1"	Y	Y	Y	Y
Zebra	ET56 (ET5 series)	745	10.1"	Y	Y		Y
	XBOOK L10	2100	10.1"	Y	Y	Y	Y
	XPAD L10	1400	10.1"	Y	Y	Y	Y
	XSLATE L10	1300	10.1"	Y	Y	Y	Y
	XSLATE R12	1340	12.5"	Y		Y	

Table 2: key physical characteristics of the tablets reviewed

Certifications

There are three main certifications for physical ruggedness of tablets:

- *Ingress Protection (IP) Code* — which rates the degree of protection against dust and water. The IP factor comprises two numbers: the first is a rating of dust protection, the second is water protection.

0: no protection	0: no protection
1: solids up to 50 mm	1: dripping water
2: solids up to 12 mm	2: dripping water (tilted)
3: solids up to 2.5 mm	3: water spray
4: solids up to 1 mm	4: splashing water
5: dust; limited ingress	5: water jets
6: total protection against dust	6: a nozzle under pressure
	7: immersion, 1m for 30 minutes
	8: submersion at depth under pressure

  Because tablets on archaeological sites may be exposed to dust, mud and being dropped in water, a code of IP65 seems a minimum requirement.

- *MIL-STD-810* — a US Military Standard that addresses a broad range of environmental conditions, including exposure to high and low temperatures, rain, humidity, sand and dust, shock and vibration. Claims that commercial products comply with MIL-STD-810 need to be treated with caution, as there is no agency which certifies compliance. The manufacturer may have engineered the product to meet MIL-STD-810 in theory, but not tested the product in the field, or they may have 'tested' the product using their own methods.

- *Impact*—usually rated as the height from which a tablet can be dropped a fixed number of times without failing, or the height than an object (usually a steel ball) can be dropped onto the screen without cracking it.

BATTERIES

Because field archaeologists need to operate independently, usually without opportunities to recharge devices while working, it is important that tablets have the capacity to operate for a minimum of an eight-hour working day.

Measuring battery charge

Battery capacity is usually measured in mAh (milliampere hours) or Wh (watt hours). While this is a good general basis for comparing battery life between similar devices, in practice this can be affected by many factors. Generally speaking, average laptop batteries have a capacity around 5000mAh or 50–60Wh. Mobile devices are often less than this but can be expected to be considerably more energy efficient. Mobile operating systems (iOS and Android) usually run on more energy efficient hardware than Windows-based devices, and also tend to have more energy-saving features to help conserve battery life without significantly impacting performance. Consequently, a battery capacity lower than a regular laptop my still be sufficient for a full day's site work.

It is also useful to consider figures provided by the manufacturer regarding the length of time the battery will power the device (usually provided in hours for certain activities, such as for watching video, browsing or on standby). Some caution does need to be taken with these claims as there is no consistent method for measuring the length of time for which the battery will power the device, and it may vary significantly between manufacturers and device types.

Among the factors that can drain the battery power more quickly, and impact battery life, are activities such as:

- watching videos
- using programmes which require large amounts of processing or involve data-intensive tasks (such as working with large and complex spreadsheets or databases),
- accessing the internet, particularly using a mobile/4G connection. (Certain webpages will also use more processing power when open; Gmail is often given as an example of this).

Recharging

For field archaeologists, a key question about batteries is how they can be recharged, particularly as this might interfere with fieldwork. There are basically three alternatives:

- charging the unit by plugging it into a power supply — which, for field archaeologists, means time in the site hut while the device recharges.
- using a device with rechargeable batteries. This involves powering the device down, replacing the battery with a freshly charged one, then rebooting the tablet.
- using a device with a 'hotswap' — a small internal battery that allows the tablet to operate for a few minutes while the main battery is swapped with a fresh one, minimising downtime.

Manufactures will often supply details of the expected time to fully recharge the battery from empty, which can help when comparing them. Some devices also offer 'fast charging'. One fast charging feature will allow the battery to be charged more quickly, using a more powerful charger. Another feature will allow rapid charging of the battery up to a certain level, without fully charging it, in order to allow you to resume working quickly with only a brief period of recharging. These can be useful when there are limited opportunities for charging during a day, but if the device is only likely to be charged overnight then this should be sufficient to charge the device fully, and consequently a 'fast charging' facility offers little benefit.

Where battery capacity is not sufficient to last between charging opportunities, another option is to purchase an external battery pack (available for most devices). These allow batteries to be recharged often several times, depending on the device being charged and the capacity of the battery pack. Like all external devices however, external batteries increase the opportunities for connection failures and device faults.

Battery replacement

Battery lifespans are measured in cycles (number of times the battery can be depleted and then recharged). Around 500 charges should be expected for most modern batteries. As batteries are charged and re-charged, the maximum capacity will reduce, and so the length of time the device can be used for on a full charge will be less. Eventually, the battery will need to be replaced to restore the full capacity.

Devices vary in terms of the difficultly and expense when replacing this battery, although batteries which are more difficult to replace will usually be expected to maintain capacity for a greater number of cycles. In most modern devices, the lithium-ion batteries used are in-built within the body of the device and replacing them requires specialised intervention.

PROCESSORS, OPERATING SYSTEMS, AND MEMORY

At the core of tablets are the central processing unit (CPU), operating system and memory. Together, these three establish the tablet's computing power, speed and capacity. The also constrain the types of programs that can run on tablets and influence how they interact (or fail to interact) with the rest of the unit's computer network.

Software

Although this report is intended to be about hardware, a key factor in selecting tablets is the software that organisations will wat to run, as much of this is specific to particular operating systems.

The limited number of apps currently designed for recording archaeological field data are mostly platform specific:

- iDig Apple iOS
- ARK OpenSource
- Ishtar OpenSource
- FAIMS Android
- Iium Android

Organisations which do not wish to use pre-designed systems like these will need to either design their own databases using software they already employ (e.g. Access, Filemaker, OpenOffice) or else custom design apps for tablets. Whatever option organisations select, there are two basic constraints:

- the operating systems required to support the database or custom apps
- the operating system and databases used in the rest of the organisation. A basic problem with all databases is data exchange, so consistency of software is important. Poor integration between data recording in the field and databases in the office can have potentially calamitous consequences on data quality and workflow.

Operating systems

An operating system (OS) manages the computer's memory and processes, as well as all of its software and hardware. It allows communication between the machine and the operator without the use of an exclusive programme's language. When multiple programs are running at the same time, they require access to the computer's central processing unit (CPU), memory, and storage. The operating system coordinates all of these as to ensure each program operates smoothly and without delays, obstructions or 'freezing'. An operating system is pre-loaded on any machine, but it is possible to upgrade or even change operating systems. The three most commonly used operating systems for tablets are:

- *Apple iOS*: easy to learn and use, with a massive selection of third-party software—well over a million apps. The iOS is somewhat limited compared with a desktop operating system, e.g. there is no universal file browser (rather than a central repository of files, each application has its own collection). Nonetheless, iOS has support for displaying two applications at once, and Apple advises that the next version will bring a better file system.
- *Google Android*: first created for smartphones, and consequently it is somewhat more limited than a desktop operating system, although still more flexible than Apple's iOS. While there is a huge selection of Android apps, only a small percentage have been formatted to run on large, high-resolution screens of the types fitted to most tablets. (These smartphone apps look fine on smaller tablets.)
- *Microsoft Windows*: By far the most powerful operating system available for tablets. Windows 10 has been updated by Microsoft for touchscreen-based devices. It can run all the legacy software created for Windows 7 and 8, as well as earlier versions. However, some of this software has not been modified to be touch-friendly so a stylus or a mouse is sometimes necessary.

Table 3 shows the operating systems used in the tablets reviewed.

maker	iOS, ipadOS	Android	Microsoft Windows 10
Apple	Y		
Dell			Y
Getac			Y
MobileDemand		Y (A1180)	Y
Panasonic		Y (Mk 1, Toughbook)	Y (all models)
Samsung		Y	
Senter		Y (ST935H, ST935K)	Y (all models)
Zebra		Y (all models)	Y (all models)

Table 3: operating systems used in the tablets reviewed

A key factor in selecting an operating system involves how they will integrate with existing computer systems. As noted earlier, if all field staff are equipped with tablets, then the result for archaeological units may be a doubling the number of computer peripherals used by the organization. While it is certainly not impossible to run several different operating systems, it is certainly be more complex that using just one. Running several different operating systems also requires the unit to have the appropriate technical and IT support.

The Central Processing Unit (CPU)

A key factor which influences the choice of operating system and software is the CPU (central processing unit). There are two main types used in tablets:

- Cortex processors produced by ARM—used in Samsung and Apple tablets. Android and iOS are designed for this type of architecture.
- x86 processors produced by Intel and AMD—Windows was designed for this type of processor architecture.

Except for Samsung and Apple (which are exclusively operating with ARM architecture processors), the rest of the tablet manufacturers are offering the option to choose between an Android or Windows-based machine.

The type of processor also heavily affects price and battery life. In general, the faster the processor, the more elaborate the hardware needs to be, and consequently the more energy is required for the tablet to function.

ARM—Cortex processors

Most tablets use processors produced by a company called ARM. The most commonly licensed and manufactured ARM processor series falls under the Cortex-A umbrella, which has 7 different designs and 9 different models. These are:

- Cortex-A5 – Single core, low power consumption, frequencies between 300 and 800 MHz
- Cortex-A8 – Decent processor, generally single or dual core, frequencies between 600 MHz and 1.5 GHz
- Cortex-A9 – Arguably the most popular processor, dual core, frequencies between 800 MHz and 2 GHz
- Cortex-A12 – Slightly better than the A9, up to four cores and frequency up to 2 GHz
- Cortex-A15 – Features 32-bit design, usually dual core or quad core, frequencies between 1 and 2 GHz
- Cortex-A17 – More efficient 32-bit design than the Cortex-A15, up to 4 cores, frequencies between 1.5 and 2 GHz
- Cortex-A53 – First generation of 64-bit processors, between 1 and 4 cores

- Cortex-A57 – Slightly better than the A53, more commonly used in computers than in tablets, between 1 and 4 cores
- Cortex-A72 – Latest 64-bit processor, also often used in computers
- the number of cores a certain processor has, which doesn't mean the more cores a processor has, the better it is.

The number of cores on the ARM architecture has an impact on the tablet's performance, as some applications that are designed to use multiple cores. Consequently, the same application can run at different speeds across different tablets, depending on memory, the graphic processor and the operating system of the device.

AMD and Intel—x86 processors

AMD and Intel are major suppliers of the x86 processors which are most commonly used on devices that run the Microsoft Windows operating system. (As noted above, Microsoft Windows was designed for this type of processor architecture. It can also run on ARM-based processors, but they may not perform as well, unless tailored by the tablet manufactures for the purpose.)

Here is a list of x86 processors used in tablets, ranked from least to most powerful:

- AMD E1-7010 (least powerful)
- AMD E2-7110
- AMD E2-9000
- AMD A4-1200
- AMD A4 Micro-6400T
- AMD A6-1450
- Intel Atom x5 Series
- Intel Atom x7 Series
- AMD A10 Micro-6700T
- Intel Core M 5Y10
- Intel core m3-6Y30
- Intel Core m5-6Y57
- Intel Core m7-6Y75
- Intel Core i3-5005U
- Intel Core i3-6100U
- Intel Core i5-5200U
- Intel Core i5-6200U (most powerful)

Memory

Tablets have two different types of memory:

- ROM (read-only memory) holds instructions for starting up the computer.
- RAM (random access memory) is where information and data currently in use is stored, so that it can be accessed quickly. RAM is volatile, which means the data is lost every time the computer is switched off, unlike ROM which is non-volatile.

Both operating systems and software require RAM to operate. Operating systems in particular use a large fraction of the available RAM—for example, the Android operating system needs at least 1GB of RAM to perform correctly. If the tablet has only limited RAM, this can constrain the software that can be operated. If tablets are used to store site photographs, they will require image processing software, which may require over 500 MB. Web browsers and some email software can also consume 500–1000 MB. Databases can also be memory hungry, depending on how much data they are expected to store as well as its complexity. (Demands on RAM can also increase if staff download their own apps onto tablets.)

Trying to run programs on a device with insufficient RAM can affect its performance. To prevent this, tablets and other portable devices are usually designed to close apps which are not being used in the foreground when they start to run out of RAM. The consequence however is that, in tablets with limited RAM, applications need to re-open each time the user switches between apps. Apart from being slow, this also forces the tablet to use more processing power, and therefore consume the battery charge faster.

Memory can be expensive—especially when it is required for many tablets. When buying tablets therefore, archaeological units need to balance the cost against purchasing the memory they need to drive the operating system and software they will use, with sufficient allowance for future expansion during the tablet's lifetime. An important first step in deciding how much RAM to provide on machines has to involve an inventory of all the major applications that will need to be installed, along with the operating system which will support them.

CONNECTIVITY

Tablets need to work not just as stand-alone devices, but as parts of an information system so that data can be transferred on and off them. This means they need to interconnect readily. Interconnections for data transfer fall into a number of groups.

- *General-purpose ports*—USB was standard on all tablets reviewed (although varying between USB 2 and 3, plug types A, B and C, along with mini-USB options). Ethernet and HDMI are options on some models.
- *Bluetooth* for short range connections—standard on all tablets reviewed
- *Wi-Fi*—standard on all tablets reviewed.
- *Mobile broadband*—optional SIM card on all models other than those manufactured by Senter.

Wireless internet connection options

Internet accessibility from mobile devices, such as tablets, can be achieved in various ways, ranging from access to a public Wi-Fi hotspot to the creation of a private internet network. However, the geographical coverage, data transfer speed and network safety may vary, and are affected by the site location, number of users and infrastructure available.

For devices which do not have their own inbuilt connections to public broadband, there are broadly three ways to create connections:

- *Dongles*: create an internet connection for an individual device, using mobile phone network. They do not create a Wi-Fi network accessible to other devices nearby.
- *Mobile broadband*: these connect to mobile broadband and emit a Wi-Fi signal. Most support multiple devices at once, including smartphones and tablets. Their signal can be enhanced using external antenna ports or hotspot boosters. This allows the device being left in the on-site facilities and its signal reaching out to the archaeologist/users on site.
- *WiMAX*: A family of wireless broadband communication which transmits through a stable antenna rather than a modem. WiMAX creates a private Wi-Fi network extending over miles which can be accessed using devices equipped for WiMAX.

SECURITY

Security risks come in several forms: the data transferred to or stored on tablets, the loss or corruption of archaeological data when transferred off tablets, and the risk of virus, malware and other hostile attacks.

Sensitive data

While the bulk of archaeological data gathered on tablets will not be sensitive data, if tablets are used for wider administrative tasks (such as HR), they can store legally protected personal data. Tablets need to be subject to the same data protection standards as office computers.

Data transfer and corruption

The largest risk to data on tablets is failure to transfer it off the device, or back it up in the event of a device failure. This risk can be largely mitigated in the case where devices are connected to a larger via Wi-Fi, because automatic data transfer or backup routines can be installed. Devices where data has to be manually transferred — via external memory devices or by cable — are at a much higher risk of seeing data lost.

External threats

The greatest external security risk that tablets pose to archaeological organisations, is via their connections to organisation's computer servers. Left unprotected, these can provide an entry for hacking, phishing and data theft, as well as the installation of viruses, spyware, trojan and other forms of malware.

In-built protection

Since 2018, most equipment for WIFI networks uses Wi-Fi Protected Access 2 (WPA2), which uses a secure key to encrypt the transmitted data. This security mechanism has become the default configuration for wi-fi networks and must be supported by all wi-fi devices in order for them to be compliant with the 802.11 standard. Devices produced from 2019 onwards have started using the WPA3 standard which has higher levels of security. However, many public Wi-Fi networks will continue to run WPA2 and won't provide the enhanced security.

Enhanced network protection

The only way of enhancing security on public Wi-Fi networks is to use a Virtual Private Network (VPN). A VPN extends a private network across a public network and enables users to send and receive data across shared or public networks as if their computing devices were directly connected to the private network. Applications running across a VPN may therefore benefit from the functionality, security, and management of the private network. Encryption is a common, although not an inherent, part of a VPN connection.

Software

All devices utilising a Wi-Fi network should be equipped with an antivirus software which is regularly updated.

PRODUCT SUPPORT

Manufacturers usually provide the option of a warranty or support package. Amongst the rugged tablets reviewed, some provide optional product support to their customers. This might cover the repair of the hardware in the case of an accident, or it can be the customisation and upkeep of certain features of the software. The manufactures who offer any of these options were:

- *Apple*: The authentication data are encrypted and protected by the Secure Enclave iPadOS, and its feature Intelligent Tracking Prevention that operates in Safari helps protect against websites collecting personal data. Automatic Updates in iPadOS are free and they can be downloaded wirelessly as soon as they're released. Finally, there is a 1-year limited manufacturer warranty against defects in materials and workmanship for any new Apple-branded product.

- *Dell*: McAfee antivirus software can be installed with various lengths of subscription, depending on the value of the purchase. A 3, 4 or 5-year ProSupport is available, depending on the value of the purchase. Finally, there is option to add a 3-year accidental damage protection.
- *Getac*: Optional features, such as barcode readers etc., and multi factor ID authentication features can be opted out or customised. 3-year bumper-to-bumper hardware repair warranty.
- *Mobile Demand*: xProtect hardware repair warranty for 1 or 2 years, depending on the value of the purchase.
- *Panasonic*: Panasonic COMPASS is a package of services with the aim to customise any aspect of the Android applications. That includes operating version of the Android, configuration and staggering of certain certifications and licences, updating of management services and device and data security solutions. 12-month repair warranty
- *Samsung*: Knox Security and Knox Customisation. Knox Security aims to secure from potential theft of the device, or a cyber-attack. Knox Customisations aims to the alteration of the applications appearance as to project a company's logo, and to limit authorisation of use for out-of-business purposes.
- *Senter*: 12-month hardware repair warranty.
- *Zebra***:** 12-month hardware repair warranty. Software updates are available for a period of 90 days.

IT SUPPORT

As noted earlier, if units equip all of their field staff with tablets, this may double the number of computers being operated by the organisation. These devices can have the same power as desktop computers and will require just as much IT support. The demand to operate, maintain, and update an army of tablets, as well as to secure the dissemination of data from and to them, requires the care and attention of IT specialist(s) who will collaborate efficiently with the archaeologists. This expertise may be either in-house or outsourced. Both involve costs in the longer terms.

Supporting product customisation

As noted at the start of this report, tablets can be customised with the addition may peripheral devices and additional features. Because tablets will be subject to harsh conditions on site, and not only end products, but also as part of the whole new digital data flow in archaeology, it is important that customisation, upkeep and general housekeeping of devices received the appropriate specialist support.

COST

Cost of purchasing tablets

Consumer tablets with a 10" screen, 32–64GB of memory, and a RAM of 2–4 GB have a starting price of c. £300–600, depending on model and operating system. They are not designed to be waterproof, dustproof, impact resistant, used in extreme temperatures or used with gloves, and they may be difficult to read in daylight.

Of the rugged tablets reviewed, c. 60% had a minimum of 128 GB of memory and c. 75% had a minimum RAM of 4 GB. This makes them more powerful computers than entry-level consumer tablets. However, extra capacity means a higher price-tag: the biggest cost drivers of tablets are memory, processing, and operating system. Unsurprisingly, the additional power of rugged tablets means they are correspondingly more expensive than consumer tablets, even before the design factors to make them rugged are considered. Table 4 shows the approximate range of starting prices reported in May 2020 for tablets with a screen size of 10" or greater, and no separate keyboards (higher-end units have a greater number of features installed as standard, inflating their price.)

maker	rugged	RAM (min.)	storage (min.)	screen size	cost*
Apple	N	2–6 MB	32–128 GB	10.2–12.9”	£300–£1,100
Senter	Y	2–3 GB	32 GB	10.1”	£300–£500
Samsung	Y	4 GB	64 GB	10.1”	£300–£700
Mobile Demand	Y	4–8 GB	64–256 GB	10.1–11.6”	£300–£1,900
Zebra	Y	4 GB	64 GB	10.1–12.1”	£1,300–£1,900
Panasonic	Y	4–8 GB	128 GB	10.1–12”	£1,900–£2,500
Getac	Y	4–8 GB	128–256 GB	10.1–12.5”	P.O.A.
Dell	Y	8 GB	512 GB	12”	£2,700–£2,900

Table 4: approximate ranges of costs of the tablets reviewed in May 2020.
**Costs have been rounded and placed into £200 cost brackets.*

Total cost of ownership

Purchase price is only part of the *total cost of ownership* (TCO)—and in most industries, not the dominant item. A study by VDC in 2010 (Krebs 2010) found the average annual TCO of consumer tablets was $7,330 while rugged tablets had a TCO of $3,423. Over five years, the average TCO of using consumer tablets was $36,648 compared with $17,113 for rugged tablets.

Table 5 summarises major costs for archaeological units adopting tablets.

Phase	Type	Item
Upfront	Hardware	Purchase of tablets
		Purchase of peripherals/optional equipment
		Purchase of WLAN/WWAN/dongles for on-site connectivity
	Software	Initial purchase of operating system and applications
		Costs of developing custom applications
	Support	Purchase of warranties/insurance
		Integration with existing computer systems/servers
		Initial training for users
Ongoing	Hardware	Cost of equipment repairs
		Replacement of broken equipment
	Recurring	Upgrades to operating systems and software
		Cost of mobile connectivity
	Support	Lost staff time and productivity when broken equipment is unavailable
		System maintenance over time
		Technical support for users (internal)
		Technical support from suppliers or third-party vendors
		Maintaining security (software, VPN)
		Ongoing training for users, and induction of new users

Table 5: major cost components in the use of tablets

As the table above indicates, the bulk of ongoing costs are in ongoing support, rather than hardware costs. If archaeological units focus on simply acquisition costs, they may be overlooking the real costs of running tablets in the field.

An important component of ongoing costs is the failure rate. Consumer tablets have a lifespan in industrial settings of typically 2–3 years, whereas rugged tablets are typically 4–5 years. While the upfront costs of consumer tablets may be only a third or less than rugged tablets, this cost difference is eroded within a few years. Consumer tablets may also require optional extras — like impact-resistant cases, styluses, glare- and scratch-resistant screen covers, and external cameras — to be useable on archaeological sites. As well as adding costs above the baseline purchase price, optional extras also provide more opportunities for items to be broken or unusable.

Downtime because equipment is broken or being repaired is another potential cost. While site staff may record excavation data on paper, this data still needs time to be rekeyed, as well as creating opportunities for errors.

For archaeological units, purchasing a tablet for every member of the field team may effectivity double the number of computers in use by an organisation. This will demand good integration with existing computer servers (which is why the question of tablets' operating systems is a key issue). Doubled computer usage also needs appropriate IT support, and costs for this need to be factored in. The annual salary costs for adding a single IT post may equal the cost for equipping a team of 20 with rugged tablets.

Finally, training is essential to get the full value of tablets for recording information on site. While some checks can be built into software, to ensure staff do not overlook key data, properly trained staff are the best insurance against poor-quality data.

REFERENCES

Krebs, D. 2010. Total Cost of Ownership Models (3rd ed.) VDC Research.