Mac OS X on a Budget
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1 Introduction

1.1 Preamble

This is a practical paper, about a practical subject, for practical people. If you get nervous around things like screwdrivers and Lego, you'd best stick to writing software.

This paper is aimed at those who wish to run **Mac OS X**, but whose budget to do so is limited. It should help those who are familiar with traditional Macintosh hardware and software, but have little experience of Mac OS X; and more particularly it should help those who are more familiar with PCs than Macs. It is not intended as a source of information about older Mac OS issues, although it draws on sources of data about those.

My favourite quotation of this year comes from Bill Gates. In the continuing courtroom drama of the antitrust trial between the US authorities and Microsoft Corporation, Gates himself gave testimony under oath as an expert witness in April 2002. Here [reference 1] is Gates, speaking as Microsoft's "Chief Software Architect", stating his opinion of the doubtful value of modular coding practices:

"In a purely theoretical world, one could imagine developing modest software programs in such a way that any module could be swapped out in favour of a similar module developed by a third party … In the commercial world, it is hard to see what value such replace-ability would provide even if it is achieved."

To anyone with the slightest education in software engineering, this view is bizarre. Fortunately, the UNIX philosophy has been to construct operating systems out of "replaceable modules" from the very start, and Mac OS X is no exception. Consider the layered structure of Mac OS X, as Apple originally portrayed it in January 2000.

Mac OS X is – of course – derived from the NeXTStep operating system which Apple acquired when it bought NeXT for Christmas in 1996. As the foundation layer for Mac OS X, Apple has therefore adopted BSD, running over the Mach microkernel. While Apple has borrowed from various flavours of BSD, it has chosen to create its own particular variant, named "Darwin", to provide the BSD reference base for Mac OS X. Darwin, together with some other Apple software packages, is released as Open Source.

The benefits of founding Mac OS X on Open Source Software are the same benefits seen by all Open Source projects. The disadvantage, from Apple's commercial point of view, is that OS X can be hacked – hacked, not cracked – which allows it to be used in ways Apple has not intended. Oh well – that just goes with the Open Source territory…

So, in this paper, I shall cover two things:

- For those who prefer to play safe, how to choose a budget Mac for their OS X needs.
- For those who like to live dangerously, how to run OS X on unsupported hardware, and what kinds of issue that brings.

All recent Macs run the traditional Mac OS well, but Mac OS X makes different demands. Some recent Macs are not well suited to Mac OS X and are better avoided; while some older machines can be tricked out for Mac OS X with good results.

At the present time there are two reasons why OS X requires Mac hardware:

1 **Technology Constraints**: While Apple's internal labs undoubtedly test versions of Mac OS X for other hardware architectures, nothing is yet released, nor is likely to be before 2004. If you wish to explore Mac OS X right now, you need a Mac.

2 **Licencing Constraints**: Apple's software licence for Mac OS X states clearly that it is for use on an "Apple-badged computer". You have been warned…

1.2 Wealth Warning

Please be clear. Apple makes excellent computer products, which are good value when taking into account the quality of design, quality of construction, and added worth of the operating system and bundled applications. If you wish to run Mac OS X, and your budget is plentiful, your best value is – without doubt – to buy a new Macintosh system from your nearest Apple supplier, and enjoy the support and warranty that brings. However, "value" is not the same as "I can afford it". There are many reasons why you might not want a brand new system, but still want to run Mac OS X. Here are some:

- **Poverty**: You may be short of money, but still wish to use OS X. Maybe buying or upgrading a used system will get you what you want at a price you can afford.
- **Cash-flow**: Your organization may not permit the level of spending needed to buy a whole new Macintosh. Maybe you can build it up a piece at a time – "salami tactics" – in order to get the system you want.
- **Prototyping**: You may need to experiment with OS X before you can justify a full purchase. Maybe you can build a prototype system on lesser hardware to confirm whether or not the system will be right for you.
- **Networking**: You may wish to evaluate the network facilities in OS X. Even if your budget runs to one new Mac, it may not cover two or more needed for valid network tests. Maybe you can acquire the extra OS X nodes for your tests at budget prices.
- **Configuration**: At any given time, Apple makes only certain machines in certain form factors. If the current range can't supply your needs, maybe you can meet them by configuring an older model, to get a system with the mix of interfaces you want.
- **Availability**: You may already have an older machine capable of running OS X. Maybe you can convert it to run OS X for much less than a new machine.
- **Compatibility**: You may have a group of machines in a workgroup or a school, which you wish to keep at a compatible standard. Maybe you need to know what you can do to convert them all, economically, to run compatible versions of OS X.
- **Learning**: A good way to learn about technology is to pull it apart and put it together again – and make sure it still works afterwards. To build greater knowledge of OS X, maybe you wish to take this approach in order to learn from the experience.
- **Challenge**: Admit it to yourself. You just like exciting challenges, and you've already climbed K2 and Denali this week. An unsupported OS X install is calling for you.

Be clear again: by following these guidelines, you should be able to run Mac OS X for less **cash**, but you will still have to pay – mainly in **time** and **effort**. No free lunch!

Spend with care. It is too easy to waste money by spending it a little at a time, when better value would have been to find funding for all you need. Think before you start.

1.3 Acknowledgements

Much of this would have been impossible without the work of **Ryan Rempel**.

Ryan determined, early on, to use the available knowledge about NeXT Step and Rhapsody (the precursors to Mac OS X) to maintain the availability of OS X on older unsupported Macintosh hardware. Backed by **Other World Computing** [reference 2], Ryan has worked tirelessly for two years releasing the patches needed to get OS X running on older machines, and is constantly extending the reach of his knowledge and the range of supported equipment. Give the man a Nobel Prize.

Ryan's early efforts were complex to follow, but led to a simple, Open Source utility now called XPostFacto. If you use XPF, please help Ryan by paying to join his support list.

Dan Knight runs the "Low End Mac" web-site [reference 3], which is an excellent portal into information about Mac-related topics, and in particular data for older Mac hardware. For understandable reasons, Low End Mac has only recently started to promote OS X.

Mike Breeden runs the "Accelerate Your Mac" web-site [reference 4], which acts as a portal for information about Mac hardware upgrades and tune-ups.

There are numerous web-sites now covering Mac OS X, Darwin and their BSD heritage. I will not reference them here, since they are still somewhat volatile. Just search the web.

1.4 What does "Budget" mean?

1.4.1 The Price of New Macs

For pricing in this paper, I have used UK prices, less local sales tax, converted to Euro at the rate of about £1 = €1.6. For rough comparisons, €1 = $1.

In early October 2002, typical UK prices for new budget Macs are shown in Table 1:

Table 1: Typical UK prices for new budget Macs

Model	processor	Screen	RAM(MB)/ Disk(GB)	Optical Drive	Graphics	Price in €uro
iMac	G3/600	15" CRT	128/40	CD-ROM	Rage 128	880
eMac	G4/700	17" CRT	128/40	CD-RW	GeForce 2MX	1,120
iBook	G3/600	12"TFT	128/20	CD-ROM	Radeon Mobility	1,360
iMac	G4/700	15"TFT	128/40	CD-RW	GeForce 2MX	1,360

These are Apple's base models at time of writing. Each is pre-loaded with OS X. In each category, spending more can get you more RAM, a larger disk, a faster processor and a more capable optical drive. Extra RAM is the best way of improving OS X performance. Other improvements will give you more capability, but little improved performance.

The bargains here are the eMac and the iBook. Each is outstanding in its way. If these will suit your needs, stop reading now, buy the one you want (more RAM!) and that's it.

1.4.2 The Price of Used Macs

I assume that "budget" means that you wish to run OS X for significantly less than €1,000. How much less depends on your needs and wants. How much a used budget Mac costs will depend on where you live. In the USA, with easy access to eBay, the prices are likely to be less than in Europe and other territories.

In early October 2002, typical UK prices for used budget Macs are as follows:

PowerBook G3/266   128MB/2 GB/CD   €800

iMac G3/266   160MB/6 GB/CD   €450

PowerMac 7600/132   64MB/2GB/CD   €150

Each of these can be coaxed into running Mac OS X. None of these will give stellar performance, but each will get you going for less money. Remember though that OS X itself will cost you at least €100 to obtain.

2 Understanding Apple's Technology

2.1 The Basics: Supported and Unsupported Installs

Whatever your motive, if you're doing Mac OS X on a budget you need to know your technology better than the average Macintosh user.

For Mac OS X, a "supported" system means one which Apple itself lists as approved for use with OS X. In practice, this means every Mac of any kind originally shipped with a PowerPC G3 or G4 processor, with one exception: the original PowerBook G3. However, there are some constraints, such as the graphics support. This varies with the version of OS X you use. To understand the issues, you need to know what graphics chipset you plan to use, and what OS X can do with that chipset.

An "unsupported system" is therefore anything else which can be persuaded to run Mac OS X by trickery. Apart from RAM and disk, there are four essential requirements:

- a processor Mac OS X will recognise;
- PCI architecture;
- Open Firmware;
- An optical drive from which to load OS X.

2.2 Recognised Processors

In the early 1990s, Apple, IBM and Motorola (AIM) agreed to co-operate to miniaturise IBM's RISC workstation processor architecture ("POWER") as a single scaleable microprocessor family to be called PowerPC. In contrast with the intel x86 architecture, PowerPC is naturally big-endian, although it can be run little-endian as well. The first PowerPC chip was the 601, and was a hybrid designed to link older and newer technologies. The true PowerPC (desktop) families began with the 603 and 604 series.

The 603 started life as a low-dissipation chip intended for budget and portable use. Apple used it successfully for PowerBooks and home computers. The 603 has a limited number of execution units, and lacks support for Symmetric Multi-Processing.

The 604 started life as a high-dissipation chip intended for workstations and servers. Apple used it as their principal cpu for professional computers. The 604 has many execution units, good floating-point performance, and in-built support for SMP.

From the 603, AIM derived the 750 family, known by Apple as "G3". This is a good performer, but like its parent lacks support for SMP.

From the 604, AIM derived the 7400 family, known by Apple as "G4". Motorola, who pioneered these designs, added an efficient vector-processor to the G4, like the SIMD components added to the Intel Pentium and AMD K6 architectures. Motorola's formal name for the vector processor is "Altivec". Because the Altivec SIMD unit can handle groups of four floating-point operands, using dedicated registers, it can provide close to a four times speed-up for code compiled to exploit it. See NASA's opinion [reference 5].

At time of writing, it is expected that Motorola will introduce a more advanced processor ("G5"?) in 2003, and expected that IBM will launch a 64-bit PowerPC micro-processor, complete with Altivec-compatible vector unit, in late 2002. However, neither of these is likely to appear in Macintosh computers this year (2002).

The officially recognized processors are therefore the G3 and G4. Unofficially, Mac OS X can be persuaded to run on the 603 and 604 as well. Remember, processors develop variants as they evolve throughout their product life. For example, the 604e (larger caches, higher clock-speeds) works better with OS X than the original 604.

2.3 The available versions of Mac OS X

2.3.1 What Apple has released

Ignoring its predecessors (NeXTStep and Rhapsody) Apple has so far made four public releases of OS X. All of these use a graphics library which Apple calls Quartz (derived from Adobe's Portable Document Format), with a look-and-feel which Apple calls Aqua.

Public Beta: released September 2000. This has little value. It is time-limited, and too flaky to be of interest except for museums. Recycle the CD as a drinks coaster.

10.0.x, aka Cheetah: released March 2001: Last update (to 10.0.4) released June 2001. This is of little practical use. While it will run stably, it lacks many important features, and differs significantly in interface from the later versions. However, it still has a value. Cheetah can be updated free-of-charge to OS X 10.1. You will need to obtain a copy of the update media, but the licence allows this. (I have several registered copies of OS X 10.0, but Apple itself only supplied me one copy of 10.1 with which to update them all.)

10.1.x, aka Puma: released October 2001: last update (10.1.5) released May 2002, with security patches released up to August 2002. This is a stable and useable version of OS X. It is the baseline version for many OS X applications (such as Microsoft Office for X). If fully patched, it is reasonably brisk and secure, and its underlying UNIX can be used for X-Windows applications and UNIX command-line applications. It provides decent support for Java 2 (at v1.3.1). It runs well on G3 and G4 cpus (supported) and runs fairly well on 603 and 604 cpus (unsupported).

10.2.x, aka Jaguar: released August 2002: currently updated to 10.2.1. This is, in general, significantly improved over OS X 10.1.x. Many things work faster. Jaguar includes a new graphics scheme called "Quartz Extreme". This improves 2D graphics performance by drawing the screen image as an OpenGL scene, which can then be rendered more swiftly for display by a suitable OpenGL-capable graphics card. However, Jaguar at time of writing will only run on G3 and G4 cpus. Further, Jaguar is based on a later version of Darwin, including the compiler suite gcc 3.x and its libraries. Hence some code built for Puma will not work correctly on Jaguar until it has been recompiled.

2.3.2 What you should aim for

OS X 10.1.5: stable, reliable and secure; based on gcc 2.95; 2D Quartz acceleration down as far as the Rage Pro family; can use 603 and 604 cpus (unsupported).

OS X 10.2.x: newer and smarter, but not yet fully stable; based on gcc 3.x; Quartz Extreme when used with suitable graphics card; only for G3 and G4 cpus.

Apple's policy for selling Jaguar is to sell only the full version, not an upgrade from Puma (or Cheetah). This means that anyone who has bought a copy of Jaguar has a full licence for Puma which they can re-sell. Under EU law, a person who has bought a software licence is entitled to sell that licence separately from its original hardware. So a person who bought a Mac originally loaded with Puma is entitled to sell on that licence if they buy a copy of Jaguar to replace it. Hence, in the EU at least, there should be a ready market in pre-owned licences for Puma for use on Apple-badged computers.

2.3.3 PreBinding and OS X

In Mac OS X, prebinding is the process by which the system optimizes the dynamic links between applications on the system's boot volume and system libraries, to make those applications launch and load faster. Cheetah did not exploit prebinding. It is also compromised in many other ways. Puma introduced prebinding to speed up application launch times, and it is an effective improvement. There is no good reason to stick with 10.0, since if you own a legitimate licence for 10.0 you can update to 10.1 without charge.

An irritating consequence of Puma's prebinding is that every major installation of an OS X patch or an application causes the installer to run an extensive "Optimisation" phase, which is boring but necessary. In Mac OS X 10.2, Apple modified the approach to prebinding to eliminate this effect. On Jaguar, if the system discerns that prebinding information has become out-of-date, it automatically updates it to bring it back into line.

2.4 Graphics and Displays

For several years, Apple used only graphics chipsets made by ATI. More recently, Apple selected nVidia as a second source of graphics hardware. While OS X's Quartz is supported on anything from ATI Rage II onwards, some features demand better hardware. The cut-off points for each chipset family are these:

ATI Rage II: Basic OS X display; no acceleration features;

ATI Rage Pro: Basic 2D acceleration and QuickTime acceleration (10.1.5 or later);

ATI Rage 128: Full 3D acceleration;

ATI Radeon AGP: Quartz Extreme acceleration;

Nvidia GeForce 2MX (or better) AGP: Quartz Extreme acceleration.

In the professional desktop Mac systems, the graphics hardware can be replaced or upgraded via AGP or PCI slots, but all other types of Mac have fixed graphics hardware. Hence, if you need a particular graphics capability, you must ensure that the Mac you buy can handle it. This can be confusing. Each graphics chipset family has variants for different purposes, and it is sometimes unclear just what a particular Mac contains.

Mac OS X is very demanding of screen area. The large, "photographic" icons occupy many pixels, and the desktop can seem cramped on a small screen area. While OS X will support screen areas as small as SVGA (800x600) you would be unwise to contemplate a screen area smaller than XGA (1024x768) for everyday work.

2.5 External Interfaces

Macs have never had parallel interfaces. Apple's standard external interfaces are these:

Serial: Introduced in the original 1984 Macintosh, and improved over the years. Still found in some supported models, so has limited support in OS X.

ADB: The **Apple Desktop Bus** - an early daisy-chain bus mainly for mice and keyboards - still found in some supported models, so has limited support in OS X.

SCSI: The mainstay Apple expansion port for many years, and still found in some supported models, so has limited support in OS X.

Ethernet: Built into all supported Macs, so fully supported in OS X. Most supported models have Fast Ethernet or Gigabit-over-UTP.

USB: Introduced with the first iMacs in summer 1998. Now standard in all Macs, so fully supported in OS X.

1394: Apple invented this technology, under the brand "FireWire". Introduced in desktop models in early 1999, and now standard in all Macs, so supported in OS X.

WiFi: Apple pioneered this in conjunction with Lucent under the brand-name "Airport" Introduced with the first iBooks in late 1999, and now a standard option for all Macs.

2.6 Form Factors

In May 1998, at Apple's World-Wide Developer's Conference, Steve Jobs announced a new and simplified product policy for Apple. From that time on, Apple would focus on creating only two kinds of computer – the desktop and the portable – for two kinds of user – the professional and the consumer. Eventually the range consolidated like this:

Table 2: Apple's Product Policy

	Consumer	**Professional**
Desktop	iMac, eMac	Power Mac G3, G4
Portable	iBook	PowerBook G3, G4

The only significant variations to the range since have been the Power Macintosh G4 Cube and the Xserve. The Cube, available for only a year, was marketed as a "Designer Workstation" but has limited expansion. Its graphics is on an AGP card, so can be upgraded. The Xserve is designed as a 1U rack-mount system, mainly for use as a server. These designs are too specialized to be covered here.

2.7   RAM, MotherBoards and Chipsets

Mac OS X demands RAM. While it will run in 64 MB, it is then too slow for everyday use. In practice less than 128 MB is unusable for work, while 256 MB or more is highly desirable. This is partly because of the extravagant way in which OS X's Aqua graphics scheme uses RAM to buffer screen images.

The need for RAM seriously reduces the usefulness of some older Macs with OS X. Some machines have upper limits on RAM which are too low for comfort; others can accommodate plenty of RAM, but of a type which is rare and expensive.

Hence your choice of a used Mac for use with OS X must take account of the availability and cost of the RAM you will need. All recent Macs usable for Mac OS X take some kind of standard PC-compatible RAM (PC66, PC100, PC133 or DDR), as either normal SDRAM DIMMs, or as low-profile SO-DIMMS intended for use in notebooks.

For the desktop Macs with PCI slots, the capabilities of the machine are defined more by its motherboard than by the name on the case. Here is a short summary of the PCI slot motherboards able to run Mac OS X. For more detailed discussions, consult the Power Macintosh hardware pages maintained by NetBSD [reference 6] and OpenBSD [reference 7].

2.7.1   TNT, Nitro, and Tsunami – Old World ROM

These boards were launched as the "PowerSurge" range, and share many common features. The maximum specified bus speed is 50 MHz, although, because of the way the RAM is timed, this gives memory speed equivalent to a Pentium PC at 66 MHz. RAM comes as 168pin Fast Page Mode (or EDO) DIMMs, which are rare and expensive. The cpu daughter-board fits in a slot, similar to a Pentium II, and can be exchanged. There are two SCSI buses - one fast for internal use and one slow for external peripherals - and the boards have built-in Ethernet. The three-slot version (TNT, Nitro) has built-in graphics and was used in the Power Mac 7500, 7600, 7300, 8500 and 8600 series. The six-slot version (Tsunami) was used in the 9500 and 9600, and has some important differences. It lacks built-in graphics, so needs a suitable PCI graphics card. It has twelve rather than eight DIMM slots, and its Level-2 cache is soldered on, rather than being slot-fitted.

These boards can be temperamental about the combination of cpu, cache and RAM fitted to them. In theory, the memory manager can interleave the RAM to improve bus throughput, but in practice the DIMMs must be carefully matched for this to work without problem. However, once set up and working the boards are reliable.

2.7.2   Gossamer – Old World ROM

These boards were the first Apple G3 boards created for professional desktop machines. They were fitted in Power Macintosh G3 systems as desktops, minitowers, and all-in-one systems for education users. The nominal bus speed is 66 Mhz, but there are hacks to take the board to 75 Mhz or 83 MHz if you fit PC100 RAM and the rest of the board can keep up. These are the last desktop motherboards made by Apple with built-in graphics.

There are several revisions of the board, which give variations in the Boot ROM, IDE behaviour, and graphics performance. Select with care.

2.7.3 Yosemite – New World ROM

These boards were fitted in the Blue-and-White Power Macintosh G3 series. Though superficially similar to Gossamer, the boards have a faster bus at 100 MHz, support for FireWire and USB, and improved support for IDE drives.

Again, there are several revisions of the boards, which can affect hardware capability.

2.7.4 Yikes

A variant of Yosemite adapted to take the G4 cpu instead of the G3.

2.7.5 Sawtooth, and beyond

With the introduction of the full Power Macintosh G4 series, Apple created their first board with a true AGP slot for graphics. Over the years, the board has been progressively enhanced while keeping the same essential characteristics, gaining faster bus speeds, faster disk interfaces, and improved network interfaces.

3 Selecting a Used Budget Machine

3.1 General Criteria

Armed with all this information, what now should you do? I will assume that you do not want an Xserve, since it is too new and too specialized to be considered a budget item. Likewise, I shall assume you aren't after the Power Macintosh Cube, because if you are, you already know what you want. Instead, I assume you have one of four aims in mind:

- An affordable portable Mac OS X machine
- A low risk, low specification, supported desktop machine
- A low risk, high specification supported desktop machine
- A high risk unsupported machine

Here, though, you meet a significant problem. Apple revises the specifications for its models every few months. The specifications published on the Internet are very ragged – even Apple's own data. Once you have selected your style of Mac, and identified your candidate machines, you need to check the specifications carefully, and compare several source of data, to ensure that what you get will do precisely what you want.

3.2 Case 1 – Affordable Portable

The PowerBook G4 series, with its wide screen, and stylish Titanium case, cannot be considered a budget item. There are reports of poor Airport performance.

Hence a budget Mac OS X notebook is a G3. While the first iBooks (the curvy coloured models) have some good features, their screens support only SVGA which limits their use for OS X work. The new style white iBooks – "iceBooks" – introduced in May 2001, are much preferred. Late versions of the PowerBook G3 are all suitable machines, each with their better and weaker points. All these Mac G3 portables have built-in modems and built-in Ethernet (or Fast Ethernet). Table 3 lists affordable Mac OS X portables.

For a good mobile balance between size, weight, strength, battery life, and wireless networking, any of the **Lombard**, **Pismo**, and **iceBook** ranges can be tailored to suit your needs. The (black) Lombard and Pismo have expansion bays, which can be used for alternative media; while the (white) iceBooks are less flexible. Note that to add Wifi to Lombard and WallStreet you need a compatible PC card, such as a Lucent Orinoco.

Table 3: Typical Specifications of affordable G3 portables

Model	Speed cpu /bus	Max RAM (MB)	Disk Fit (GB)	Optical Fit	Graphics	Comments
WallStreet	233+/ 66+	128	2	CD-ROM	Rage LT Pro	Compromised: Best avoided
WallStreet II	233+/ 66/	192	4	CD-ROM	Rage LT Pro	Good basic model; Strongly built; 2 PC card slots.
Lombard	333+/ 66	384	4	DVD	Rage LT Pro	Slim and modern; USB built-in; Limited expansion 1 PC card slot
Pismo	400+/ 100	512	6	DVD	Rage 128 Mobility	Full featured; FireWire and USB; Airport Option; 1 PC card slot.
iBook Rev A	300+/ 66	320	3+	CD-ROM	Rage Mobility	Screen SVGA max.
iBook Rev B	366+/ 66	320	10	CD-ROM DVD	Rage 128 Mobility	Screen SVGA max.
i(ce)Book 2001	500+/ 66+	640	10+	CD-ROM DVD CD-RW	Rage 128 Mobility	Light and compact 12" XGA screen; FireWire and USB; No PC card slot; Airport Option.
i(ce)Book 2002	600+/ 100	640	20+	CD-ROM DVD CD-RW	Radeon Mobility	12" and 14" versions.

3.3 Case 2: Low Specification Supported Machine

3.3.1 The iMac option

Here the obvious candidates are the CRT iMacs. Technically speaking, the original iMacs were PowerBooks adapted to fit a desktop CRT case. As such, the early iMacs share similar strengths and weaknesses to the PowerBook G3s to which they are related. All iMac models support XGA display. All have USB ports and built-in Fast Ethernet. Early models have tray-loading CD-ROM drives and use SO-DIMM memory designed for portables. Later models have slot-loading drives, and use standard PC100 (or faster) SDRAM, with options for FireWire, Airport, and more capable optical drives.

The Rev A to D (Tray-loading) iMacs can be upgraded to faster speeds using parts from third-party manufacturers, such as Sonnet. Thus a Rev A model can be converted to run at 600 Mhz, with an added FireWire port. Likewise there are upgrades to change the original tray-loading CD-ROM for a CD-RW. Only you can decide whether such a radical improvement is worthwhile for an older machine.

You may need to update Firmware to run Mac OS X on an early iMac. Firmware updates can cause third-party RAM to become unrecognized. Check specifications before you try.

Table 4: Typical Specifications of CRT iMacs

Version	Speed cpu /bus	Max RAM (MB)	Disk Fit (GB)	Optical Fit	Graphics	Comments
Rev A	233 /66	128	4	CD-ROM	Rage IIc	Limited: Best avoided
Rev B	233 /66	256	4	CD-ROM	Rage Pro	Good basic model
Rev C	266 /66	256	6	CD-ROM	Rage Pro Turbo	Now comes in colours.
Rev D	333 /66	256	6	CD-ROM	Rage Pro Turbo	
Kihei	350+ /100	512	6+	CD-ROM DVD	Rage 128	Faster models have extra options for FireWire, Airport and more capable optical drives.
2000	350+ /100	1024	10+	CD-ROM DVD	Rage 128 Pro	
2001	400+ /100	1024	10+	CD-ROM DVD CD-RW	Rage 128 Ultra	Adds CD-RW versions

So your CRT iMac options boil down to three:

- For least hassle, carefully study specs, and buy the model which has what you want;
- For least money, buy an early model with enough RAM and use it exactly as is;
- For maximum flexibility, buy a Rev B, C, or D iMac and enhance it with upgrades to the standard you want.

3.3.2 The Desktop Option

The alternative to the iMac is to use a G3 desktop machine, either as a Beige case G3 (Gossamer) or a Blue-and-White (Yosemite). Since these take standard PC parts, like PC66 or PC100 SDRAM and IDE drives, they are easy to enhance for use with OS X.

Table 5: Desktop G3 Configurations

Version	Speed cpu /bus	Max RAM (MB)	Disk Speed	Optical Fit	Graphics	Comments
Gossamer Rev A	233+ /66	384	?	CD-ROM	Rage II+	Limited: Best avoided
Gossamer Rev B	266+ /66	384	?	CD-ROM	Rage Pro	Good Basic model
Yosemite	300+ /100	1024	33	CD-ROM	Rage 128 PCI	Revised coloured case; Adds: UDMA-33, FireWire and USB, Fast Ethernet.

3.4   Case 3: High Specification Supported Machine

The high-specification supported machines are, by definition, all G4 Minitowers. Since these can hold multiple hard drives, there is no standard disk fit. Any individual machine might have been built-to-order to a bespoke configuration. Likewise, the graphics cards may vary from standard. Hence select with care.

These systems are still highly regarded by professionals working in graphics and audio. They can be expensive to buy as used items. Dual processor systems are rare.

Dual processor models have been the 450DP, 500DP, 533DP, 800DP & 1 GhzDP.

Table 6: desktop G4 Configurations

Version	Speed cpu /bus	Max RAM (MB)	Disk Speed	Optical Fit	Graphics	Comments
Yikes	350+ /100	1024	33	CD-ROM	Rage 128 PCI	Limited options; Best avoided
Sawtooth	400+ /100	1536	66	DVD	Rage 128 AGP	Excellent basic model Adds Airport support; Adds UDMA-66
Mystic	450+ /100	1536	66	DVD-R	Rage 128 Pro AGP	Adds dual-processors; Adds Gigabit Ethernet; Adds Radeon option
Digital Audio	466+ /133	1536	66	CD-RW, DVD-R	Rage 128 Pro AGP	Adds 4th PCI slot; Adds GeForce 2MX
Quick silver	733+ /133	1536	66	CD-RW, DVD-R	GeForce 2MX or 3	Revised cpu variants
Quick silver 2002	800+ /133	1536	66	CD-RW, DVD-R	Radeon or GeForce 4	Revised cpu variants

3.5   Case 4: Unsupported Options

3.5.1   Processor upgrades.

With very few exceptions, Apple's policy has never been to support cpu upgrades in its computers. Apple expects you to run it exactly as you bought it until one of you dies.

With very few exceptions, the policy of the Mac hacking community has been to hack Mac hardware to within an inch of its life in order to stretch the bounds of what is possible, and to extend the life of machinery beyond natural reason.

The result is that numerous dedicated Mac hackers have devised ways over the years to run Mac operating systems on unsupported machines. Special credit is due to those who have run Mac OS 8 on an SE/30, and converted the Color Classic to be a Power Mac.

There are three obvious ways to create an unsupported OS X machine:

1   **Simple cpu upgrade**: Take a supported system, but change the cpu for a newer or faster processor.
2   **Unsupported system**: Take an unsupported system, and install OS X on it as is.
3   **Unsupported system with cpu upgrade**: Take an unsupported system, and change its cpu to a G3 or G4, before installing OS X in the new configuration.

3.5.2 CPU upgrade in Supported System

Several companies provide cpu upgrades to permit this. Some have an unreliable commercial history. Upgrades are available for systems based on the Gossamer, Yosemite, Sawtooth, and many later motherboards, Upgrades are also available for various models of iMac and PowerBook. There can be issues caused by incompatibilities between G3 and G4 cpus, and issues of incompatibility with system ROMs or other hardware. When they work, the results can be spectacular, but only you can decide whether or not you are prepared to spend the money and risk creating an unsupported machine this way.

The fullest collection of data on these options is at [reference 4]. Study before you buy.

3.5.3 Original Processor in Unsupported System

To do this you need to use Ryan Rempel's freeware utility called "XPostFacto". At time of writing, Ryan is maintaining active development of XPF. Rather than reproduce all his data, it is best to refer you to his web-site [reference 2], which has up-to-date information. Unsupported installs are available for systems based on the TNT, Nitro and Tsunami motherboards. Ryan has had limited success with other consumer Macs and with some older PowerBooks, but at time of writing I would not recommend these for serious work.

Except for the original Power Mac 7500, these systems all shipped with versions of the 604 cpu. Hence, at time of writing, you can only use Puma, not Jaguar, on these systems.

3.5.4 New Processor in Unsupported System

To do this you must again use XPostFacto, but you must also deal with added complications:

a   **Enabling the Level-2 cache**: The original level-2 cache fitted to these boards was a special DIMM, fitted in a special slot, connected direct to the system's main bus. Any newer cpu (G3, G4 or newer) will have a backside or processor-direct cache. Mac OS X needs to be told about the presence and configuration of this cache. There are freeware utilities to do this.

b   **G3/G4 speculative execution**: The G3 and G4 have more aggressive policies for speculative execution of code than did the 603 and 604. To ensure successful operation in a PowerSurge motherboard, the NVRAM of the board needs to be patched to match. There are utilities to do this.

c   **Fallback if your cpu fails**: Since you configure both the board and the OS X kernel to match the fitted processor, it is important to decide what you will do if the cpu card fails. You do not want to be left with a failed system whose data you can no longer retrieve because your original cpu will not work in the current configuration. A simple policy is to ensure that your system is dual-boot, so that you can revert to Mac OS 9 for emergency repairs.

Despite these complications, with careful choice of parts you can create an unsupported system able to run Mac OS X at speeds close to a recent G4 system. Likewise, you can create a system able to do things an iMac can't do, such as route between multiple physical Ethernets. Only you can decide whether this is worth time, effort and money.

4   Worked Examples

4.1   Dual-booting, Partitioning, and the Reasons Why

For budget users of Mac OS X, I recommend that you install OS X and Mac OS 9 on separate partitions (or separate drives if you have them). This simplifies the set-up of dual-booting arrangements. Unless you are supremely confident that you will never want to boot your system in the traditional Mac OS, set it up as dual boot, so that you have access to an alternative environment for reconfiguration, repair and recovery if need be. I shall assume these partitions are called "System Disk 9" and "System Disk X".

Here are two examples of budget Mac OS X in everyday use.

4.2   Supported Example – budget Portable running Jaguar

For business presentations, I use a Pismo PowerBook, known as "ratmobile".

The later G3 PowerBooks and iceBooks make excellent Mac OS X portables. Many users favour the Pismo, because of its combination of features:

- USB and FireWire (though not the fastest FireWire in the world);
- Built-in Fast Ethernet and Airport;
- Hot-swap Expansion bays for storage devices;
- Relatively easy access to internal hard drive and RAM.

In the UK, a used Pismo costs about €1,350. Ratmobile arrived with 192 MB RAM and an internal Hard Disk Drive of 6 GB. For first experiments, I partitioned this drive into 4 GB for System Disk X and 2 GB for System Disk 9. Once I had checked ratmobile's behaviour under Puma, I bought and installed a larger HDD of 20 GB, now partitioned as 8 GB for System Disk X, 8 GB for Work Space and the rest for System Disk 9. Ratmobile is now running OS X 10.2 (Jaguar). My first attempt was to update the already installed OS X 10.1.5. While the result worked, it seemed temperamental. Instead, I tried the alternative Jaguar option of "archive and install", which captures the user directories but re-installs the OS from scratch. From experience, I would recommend this approach.

Any similar G3 PowerBook, with not less than 128 MB RAM, and not less than 4 GB Hard Disk, should run either Puma or Jaguar satisfactorily.

4.3   Unsupported Example - Dumpster Desktop running Puma

At the other budget extreme, meet Escargot, a rock-bottom system running at warp factor zero. In the UK, the parts for a system like this can be bought used for around €200.

4.3.1   Escargot's Hardware

Escargot is an experiment in how slow a Mac OS X system can get and still not be technically dead: Escargot is a Power Macintosh 7500 (TNT) motherboard, in its standard desktop case, but fitted with a 150 MHz 604 processor card taken from another system. Escargot has an unexciting configuration for its type: 64 MB RAM, 256K Level-2 cache, 2 MB VideoRAM, and two internal 50-pin SCSI drives. The smaller disk of 1.2 GB is split into 1 GB for System Disk 9 running 9.1, and the rest as spare. The other disk of 2 GB is devoted to OS X, running 10.1.5. As can be seen from demonstration, Escargot works perfectly well – albeit slowly. I could make Escargot slightly slower by substituting a 120 MHz 604 (if I had one), reducing the RAM, or removing the L2 cache – but the machine is suffering enough already.

Escargot has three optional additions in its three PCI slots. One is a Belkin USB card (sold for PCs). One is a similar Belkin FireWire card (also sold for PCs). The last is a DEC DE500 fast Ethernet card, originally fitted to a Digital PC. In each case, when running under OS X, the card just works.

4.3.2   Escargot's System Software

At time of writing, there is no way to run Jaguar on the 603 or 604 processors. The best you can do is 10.1.5, and it is important to reach that patch-level. The reason is security. Apple has released a variety of security patches to Puma during the last year, many dealing with issues detected in Open Source components like Apache and OpenSSH, so it is desirable to patch to the maximum. (This is starting to remind me of Solaris…)

Table 7: Full Install and Patch Sequence for Puma

Step	Aim	Needs	Details
1	Format HDD	Apple's Drive Setup Utility	Boot from System Disk 9; Reformat System Disk X as "Mac OS Extended" format.
1	Install 10.0	OS X 10.0 Install CD; XPostFacto	Insert CD. Start XPF. Using XPF, reboot from CD to install on to System Disk X.
2	Configure 10.0	Personal Details	When machine restarts automatically, key in personal details and internet settings.
3	Install 10.1	OS X 10.1 Upgrade CD; XPostFacto	Reboot from System Disk 9. Insert CD. Start XPF. Using XPF, reboot from CD to UPGRADE the installation on System Disk X.
4	Update "Software Update"	SecUpd7-18-02forv10.1 .dmg	After restart, install this package. This patch corrects security issues in the Software Update utility. It supersedes earlier patches from October and November 2001.
5	Update to OS X 10.1.5	MacOSXUpdateCombo10.1.5 .dmg	Install this package. This patch supersedes all earlier point releases of 10.1.x, and incorporates Security patch from April 2002.
6	Patch Open Source (1)	SecurityUpd2002-08-02 .dmg	Install this package. This patch also incorporates general security patch from July 2002.
7	Patch Open Source (2)	SecurityUpd2002-08-20 .dmg	Install this package.
8	Patch Networking	NetworkingUpdate .dmg	Install this package. This patch improves network reliability
9	Patch IE	Internet Explorer v5.1.4	There may be a more recent version covering additional security issues !

In addition, Apple detected some security issues with the Apple Software Update process itself, so it has also released certain critical updates which you must apply before you can pull in the rest of your patches. This means that the required patch order for Puma has changed substantially during its life. The current version of Software Update is generally well-behaved, and will usually get it right if you follow its instructions to the letter.

The exact install instructions depend on where you're starting from. If you have a late-release version of the Puma Installation disks, then you are already part-patched, and so need to follow the correct patch sequence from that point. I can't describe here all possible variations. Instead I have shown in Table 7 the full patch sequence for building Escargot from scratch. I assume use of the lowest possible sources, being the two "early-adopter" install CDs: the original release of 10.0, and the original update CD for 10.1.

If you simply follow Apple's Software Update mechanism, it should get the sequence correct for you automatically. It will also combine some of these steps, to reduce the time taken. If you are unable to use Software Update for some reason (perhaps because you work from behind a strict FireWall) you can apply the patches in the correct sequence by downloading them as Disk Image (.dmg) files from Apple's support web-site, and installing them individually.

4.3.3 Escargot's Applications Software

Once you have completed the full patch sequence, you have a Mac OS X 10.1 system which is as patched as it can get for operating system, networking, and security issues. The system will currently occupy 1.4 GB of hard drive. What else you choose to install is up to you, and to how much disk space you wish to use. Apple's own additions are available from Apple's web-site, and should be installable using Software Update. Other additions are available from third-parties. Here are some suggestions:

1   Apple's language sets for Chinese, Korean, Portuguese, or Scandinavian languages;
2   Apple's Development Tools for OS X 10.1 (minus documentation to save space?);
3   The Darwin tools, available as a package from web-sites which support Darwin;
4   Xfreee86, distributed as "XonX", together with X applications;
5   The OS X Package Manager, giving control of the configuration of OS X packages;
6   The Fink Package Manager, giving access to UNIX software appropriately packaged;
7   Apple's Java update, to give improved Java 2 compatibility;
8   Your favourite Java tools or applications;
9   Additional development languages, such as Python and PHP;
10 Additional Carbon applications, or OS X native applications to suit.

As a demonstration machine, Escargot shows that all these things are possible, even on a system as humble as this one. If you try a budget system like this it may inspire you to find the funds for a real Mac OS X system, or at least to buy more RAM, more disk space, and perhaps a faster cpu card to give the budget system better performance

I emphasise that a system like Escargot can be built exactly as it is. No cheating is necessary. You do not need to configure the system with faster components or more RAM just in order to build it. It is perfectly feasible to build a machine running OS X using only a basic TNT system with a 604 cpu, 64 MB RAM, and a 2 GB HDD. Obviously you will need a CDROM you can boot from, and the means to load all the patches from Internet, CD or LAN, but otherwise it's straightforward. It is a testament to the robustness of OS X that it can be installed on this limited hardware without kernel panics or any other problems. (Just take three days off, have plenty of coffee and pizza handy and put something soothing on the hifi.)

4.3.4 Alternative OS approaches

A system like Escargot is equally suited – perhaps more so – to running another form of Open Source UNIX such as OpenBSD or YellowDog Linux. If you are not happy with OS X on such a system, try one of these alternatives.

With few exceptions, the Power Macs which can run Mac OS X are the same Macs which can run other flavours of BSD or run Linux. All need the same essentials: recognized processor, PCI architecture, Open Firmware, and the means to install the distribution. The one difference is in cpu support. The Linux kernel includes support for the PowerPC 601 processor, whereas at time of writing no version of BSD can support this processor.

However: there is good exchange of information between the BSDs and the Linux community concerning support for older Mac hardware. This helps to boost peripheral support for Mac OS X. For example, Linux has provided the basic floppy driver for Mac OS X (although – so far – it doesn't work for me !).

5 Summary and Conclusions

This paper is intended to help those who wish to run Mac OS X but have limited funds.

By building Mac OS X on an Open Source base, Apple has made it possible to install OS X in unsupported ways.

If your livelihood depends on using a supported computer, you should run Mac OS X on a budget by buying a new budget Mac from your nearest reseller, and enjoy all the benefits of warranty and manufacturer's support.

If you wish to use OS X in a more experimental capacity, there are many ways to run Mac OS X on older Mac hardware, and there is much to be learned from doing so.

In all cases, learn the hardware specs. Watch out for limitations with RAM, graphics support, disk speeds, and external interfaces.

To speed up Mac OS X, first install more RAM. Then add still more…

For portables, recent G3 PowerBooks and iceBooks give good results.

For basic desktops, most early iMacs and G3 desktop machines give adequate results.

For advanced desktops, G4 minitowers are best. Check specifications with care.

For unsupported installs, PowerSurge machines (TNT, Nitro, Tsunami) work reliably.

In general, machines which can run Mac OS X are the same as those which can run BSD or Linux. Use those projects for information to resolve driver and hardware issues.

6 References

1   In the US District Court for the District of Columbia,
    Civil Action No. 98-1233 (CKK),
    Direct Testimony of Bill Gates, given under oath 18 April 2002.

2   http://eshop.macsales.com/OSXCenter/XPostFacto/

3   http://www.lowendmac.com/

4   http://www.xlr8yourmac.com/

5   An Evaluation of PowerMac G4 Systems for FORTRAN-based Scientific Computing
    with Application to Computational Fluid Dynamics Simulation;
    Craig A Hunter, NASA Langley Research Center, June 2000.

6   http://www.netbsd.org/

7   http://www.openbsd.org/

[This document was written in Microsoft Word, running native on Mac OS X]

Budgeting: Mint will automatically suggest a budget for you based on your income and goals. You can factor in one off expenses and of course recurring monthly costs. Bill Tracking: All your bills are clearly labelled and managed in one place. MoneyWorks was one of the first ever finance apps for Mac and made its debut on OS X way back in 1992 – before Windows 95 was even invented. If you're a treasurer and use Quicken to keep track of your organization or company budget, MoneyWorks may be ideal for you as it's designed for small businesses, organizations and accountants in mind. Budget – $39.95 – I have smart friends that swear by Budget, so apparently it's a great app. It's certainly feature rich and full of stellar reviews, competitively priced, and has been around a while, but at a risk of sounding shallow, I just don't think it LOOKS that good, especially compared to the some of the alternatives. If you can put the appearance aside, then Budget could be a great software option for managing your finances. Squirrel – €14.99 – Free beta test – Squirrel won an Apple Design Award in 2008 for the best Mac OS X Leopard Student Product, which is no small feat. If it has A The Mac OS X EULA says something like "thou shalt not install OS X on non-Apple-labeled hardware". Does this make home built Macs or PCs running OS X... Does this make home built Macs or PCs running OS X illegal? Or is that "-labeled" bit the key? I got to wondering about this after reading about Psystar. Didou. Posts: 4,190 +10. Jul 22, 2008. #2. (LOW BUDGET) (self.mac). submitted 1 year ago by NotSoAndre. I'm blown away by my Mid-2012 MacBook Pro's performance now. I haven't gotten anything malicious either, but you can still get viruses and malware on a Mac. The OS isn't locked down, you can install and run whatever. The thing is just that not that much malware for macOS exists, and via common points of malware distribution most malware is usually Windows-specific. Apple does indeed have security to help protect against unwanted software which makes it far harder to discreetly install malicious apps, but far from 'difficult'. It's just not incentivised for malware devs to do so. The OS is still far more careful with executing un

We have listed 15 Mac OS X You Need A Budget alternatives which includes commercial, freemium, free and open source options.Ä HomeBank is a personal accounting software package that runs on OpenBSD, Linux, FreeBSD, Microsoft Windows, Mac OS (via macports or homebrew) and AmigaOS. Money Manager Ex. Open Source. Money Manager EX is a simple money management software, released free and available for Windows, Linux, MacOS, Android and iOS. KMyMoney. Open Source. KMyMoney strives to be the easiest open source personal finance manager to use, especially for the non-technical user. choose Mac OS Extended (Journaled) f. Click Erase g. Close Disk Utility When the installer asks you where to install, choose Catalina. Upon completion, the system will automatically restart. Press the hotkey to choose boot device (F12 for Gigabyte mobo)Choose USB At the Boot Screen, choose MojaveComplete macOS installation.Â While installing Mac OS X on a PC is a tricky process in itself, updating your "Hackintosh" can be another challengeâ€¦ kextcache.com. If you wanted to Multiboot this system Either with Clover or OpenCore Follow Use the website on your Mac and their free App on your iPad, iPhone or Android device (the Apps have a subset of the functionality of the website). Share. Improve this answer.Â Create budgets and then track and analyze your spending with customizable reports and charts. Synchronize your handheld with your desktop computer to stay on top of your finances whether you're at home, on the road, or in the office. I've used Splashmoney since the Palm OS days, and I've stuck with it mainly because it handles direct OFX downloads from my various banks. Budget â€" $39.95 â€" I have smart friends that swear by Budget, so apparently itâ€™s a great app. Itâ€™s certainly feature rich and full of stellar reviews, competitively priced, and has been around a while, but at a risk of sounding shallow, I just donâ€™t think it LOOKS that good, especially compared to the some of the alternatives. If you can put the appearance aside, then Budget could be a great software option for managing your finances. Squirrel â€" â‚¬14.99 â€" Free beta test â€" Squirrel won an Apple Design Award in 2008 for the best Mac OS X Leopard Student Product, which is no small feat. If it has Appleâ€™s stamp of approval, itâ€™s probably a pretty great app although I have yet to test it myself.