**How to be a Programmer: A**

**Short, Comprehensive, and**

**Personal Summary**

**by Robert L. Read**

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**Dedication**

To the programmers of Hire.com.

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How to be a Programmer: A

Short, Comprehensive, and Periii

**Chapter 1. Introduction**

To be a good programmer is difficult and noble. The hardest part of making real a collective vision

of a software project is dealing with one's coworkers and customers. Writing computer programs

is important and takes great intelligence and skill. But it is really child's play compared to

everything else that a good programmer must do to make a software system that succeeds for both

the customer and myriad colleagues for whom she is partially responsible. In this essay I attempt

to summarize as concisely as possible those things that I wish someone had explained to me when

I was twenty-one.

This is very subjective and, therefore, this essay is doomed to be personal and somewhat opinionated.

I confine myself to problems that a programmer is very likely to have to face in her work.

Many of these problems and their solutions are so general to the human condition that I will probably

seem preachy. I hope in spite of this that this essay will be useful.

Computer programming is taught in courses. The excellent books: *The Pragmatic Programmer*

[Prag99], *Code Complete* [CodeC93], *Rapid Development* [RDev96], and *Extreme Programming*

*Explained* [XP99] all teach computer programming and the larger issues of being a good programmer.

The essays of Paul Graham[PGSite] and Eric Raymond[Hacker] should certainly be read before

or along with this article. This essay differs from those excellent works by emphasizing social

problems and comprehensively summarizing the entire set of necessary skills as I see them.

In this essay the term *boss* to refer to whomever gives you projects to do. I use the words *business*,

*company*, and *tribe*, synonymously except that business connotes moneymaking, company connotes

the modern workplace and tribe is generally the people you share loyalty with.

Welcome to the tribe.

**Note**

If you are printing this for your personal use, you may wish to save paper by not printing

some of the appendices.

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**Chapter 2. Beginner**

**1. Personal Skills**

**1.1. Learn to Debug**

Debugging is the cornerstone of being a programmer. The first meaning of the verb to debug is to

remove errors, but the meaning that really matters is to see into the execution of a program by examining

it. A programmer that cannot debug effectively is blind.

Idealists that think design, or analysis, or complexity theory, or whatnot, are more fundamental are

not working programmers. The working programmer does not live in an ideal world. Even if you

are perfect, your are surrounded by and must interact with code written by major software companies,

organizations like GNU, and your colleagues. Most of this code is imperfect and imperfectly

documented. Without the ability to gain visibility into the execution of this code the slightest

bump will throw you permanently. Often this visibility can only be gained by experimentation,

that is, debugging.

Debugging is about the running of programs, not programs themselves. If you buy something from

a major software company, you usually don't get to see the program. But there will still arise

places where the code does not conform to the documentation (crashing your entire machine is a

common and spectacular example), or where the documentation is mute. More commonly, you

create an error, examine the code you wrote and have no clue how the error can be occurring. Inevitably,

this means some assumption you are making is not quite correct, or some condition arises

that you did not anticipate. Sometimes the magic trick of staring into the source code works. When

it doesn't, you must debug.

To get visibility into the execution of a program you must be able to execute the code and observe

something about it. Sometimes this is visible, like what is being displayed on a screen, or the delay

between two events. In many other cases, it involves things that are not meant to be visible, like

the state of some variables inside the code, which lines of code are actually being executed, or

whether certain assertions hold across a complicated data structure. These hidden things must be

revealed.

The common ways of looking into the ‘innards’ of an executing program can be categorized as:

• Using a debugging tool,

• Printlining --- Making a temporary modification to the program, typically adding lines that

print information out, and

• Logging --- Creating a permanent window into the programs execution in the form of a log.

Debugging tools are wonderful when they are stable and available, but the printlining and logging

are even more important. Debugging tools often lag behind language development, so at any point

in time they may not be available. In addition, because the debugging tool may subtly change the

way the program executes it may not always be practical. Finally, there are some kinds of debugging,

such as checking an assertion against a large data structure, that require writing code and

changing the execution of the program. It is good to know how to use debugging tools when they

are stable, but it is critical to be able to employ the other two methods.

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Some beginners fear debugging when it requires modifying code. This is understandable---it is a

little like exploratory surgery. But you have to learn to poke at the code and make it jump; you

have to learn to experiment on it, and understand that nothing that you temporarily do to it will

make it worse. If you feel this fear, seek out a mentor---we lose a lot of good programmers at the

delicate onset of their learning to this fear.

**1.2. How to Debug by Splitting the Problem**

**Space**

Debugging is fun, because it begins with a mystery. You think it should do something, but instead

it does something else. It is not always quite so simple---any examples I can give will be contrived

compared to what sometimes happens in practice. Debugging requires creativity and ingenuity. If

there is a single key to debugging is to use the *divide and conquer* technique on the mystery.

Suppose, for example, you created a program that should do ten things in a sequence. When you

run it, it crashes. Since you didn't program it to crash, you now have a mystery. When out look at

the output, you see that the first seven things in the sequence were run successfully. The last three

are not visible from the output, so now your mystery is smaller: ‘It crashed on thing #8, #9, or

#10.’

Can you design an experiment to see which thing it crashed on? Sure. You can use a debugger or

we can add printline statements (or the equivalent in whatever language you are working in) after

#8 and #9. When we run it again, our mystery will be smaller, such as ‘It crashed on thing #9.’ I

find that bearing in mind exactly what the mystery is at any point in time helps keep one focused.

When several people are working together under pressure on a problem it is easy to forget what

the most important mystery is.

The key to divide and conquer as a debugging technique is the same as it is for algorithm design:

as long as you do a good job splitting the mystery in the middle, you won't have to split it too

many times, and you will be debugging quickly. But what is the middle of a mystery? There is

where true creativity and experience comes in.

To a true beginner, the space of all possible errors looks like every line in the source code. You

don't have the vision you will later develop to see the other dimensions of the program, such as the

space of executed lines, the data structure, the memory management, the interaction with foreign

code, the code that is risky, and the code that is simple. For the experience programmer, these

other dimensions form an imperfect but very useful mental model of all the things that can go

wrong. Having that mental model is what helps one find the middle of the mystery effectively.

Once you have evenly subdivided the space of all that can go wrong, you must try to decide in

which space the error lies. In the simple case where the mystery is: ‘Which single unknown line

makes my program crash?’, you can ask yourself: ‘Is the unknown line executed before or after

this line that I judge to be executed in the about the middle of the running program?’ Usually you

will not be so lucky as to know that the error exists in a single line, or even a single block. Often

the mystery will be more like: ‘Either there is a pointer in that graph that points to the wrong node,

or my algorithm that adds up the variables in that graph doesn't work.’ In that case you may have

to write a small program to check that the pointers in the graph are all correct in order to decide

which part of the subdivided mystery can be eliminated.

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**1.3. How to Remove an Error**

I've intentionally separated the act of examining a program's execution from the act of fixing an

error. But of course, debugging does also mean removing the bug. Ideally you will have perfect

understanding of the code and will reach an ‘A-Ha!’ moment where you perfectly see the error and

how to fix it. But since your program will often use insufficiently documented systems into which

you have no visibility, this is not always possible. In other cases the code is so complicated that

your understanding cannot be perfect.

In fixing a bug, you want to make the smallest change that fixes the bug. You may see other things

that need improvement; but don't fix those at the same time. Attempt to employ the scientific

method of changing one thing and only one thing at a time. The best process for this is to be able

to easily reproduce the bug, then put your fix in place, and then rerun the program and observe

that the bug no longer exists. Of course, sometimes more than one line must be changed, but you

should still conceptually apply a single atomic change to fix the bug.

Sometimes, there are really several bugs that look like one. It is up to you to define the bugs and

fix them one at a time. Sometimes it is unclear what the program should do or what the original

author intended. In this case, you must exercise your experience and judgment and assign your

own meaning to the code. Decide what it should do, and comment it or clarify it in some way and

then make the code conform to your meaning. This is an intermediate or advanced skill that is

sometimes harder than writing the original function in the first place, but the real world is often

messy. You may have to fix a system you cannot rewrite.

**1.4. How to Debug Using a Log**

*Logging* is the practice of writing a system so that it produces a sequence of informative records,

called a *log*. *Printlining* is just producing a simple, usually temporary, log. Absolute beginners

must understand and use logs because their knowledge of the programming is limited; system architects

must understand and use logs because of the complexity of the system. The amount of information

that is provided by the log should be configurable, ideally while the program is running.

In general, logs offer three basic advantages:

• Logs can provide useful information about bugs that are hard to reproduce (such as those that

occur in the production environment but that cannot be reproduced in the test environment).

• Logs can provide statistics and data relevant to performance, such as the time passing between

statements.

• When configurable, logs allow general information to be captured in order to debug unanticipated

specific problems without having to modify and/or redeploy the code just to deal with

those specific problems.

The amount to output into the log is always a compromise between information and brevity. Too

much information makes the log expensive and produces *scroll blindness*, making it hard to find

the information you need. Too little information and it may not contain what you need. For this

reason, making what is output configurable is very useful. Typically, each record in the log will

identify its position in the source code, the thread that executed it if applicable, the precise time of

execution, and, commonly, an additional useful piece of information, such as the value of some

variable, the amount of free memory, the number of data objects, etc. These log statements are

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sprinkled throughout the source code but are particularly at major functionality points and around

risky code. Each statement can be assigned a level and will only output a record if the system is

currently configured to output that level. You should design the log statements to address problems

that you anticipate. Anticipate the need to measure performance.

If you have a permanent log, printlining can now be done in terms of the log records, and some of

the debugging statements will probably be permanently added to the logging system.

**1.5. How to Understand Performance Problems**

Learning to understand the performance of a running system is unavoidable for the same reason

that learning debugging is. Even if you understand perfectly and precisely the cost of the code you

write, your code will make calls into other software systems that you have little control over or

visibility into. However, in practice performance problems are a little different and a little easier

than debugging in general.

Suppose that you or your customers consider a system or a subsystem to be too slow. Before you

try to make it faster, you must build a mental model of why it is slow. To do this you can use a

profiling tool or a good log to figure out where the time or other resources are really being spent.

There is a famous dictum that 90% of the time will be spent in 10% of the code. I would add to

that the importance of input/output expense (I/O) to performance issues. Often most of the time is

spent in I/O in one way or another. Finding the expensive I/O and the expensive 10% of the code

is a good first step to building your mental model.

There are many dimensions to the performance of a computer system, and many resources consumed.

The first resource to measure is *wall--clock time*, the total time that passes for the computation.

Logging wall-clock time is particularly valuable because it can inform about unpredictable

circumstance that arise in situations where other profiling is impractical. However, this may not

always represent the whole picture. Sometimes something that takes a little longer but doesn't burn

up so many processor seconds will be much better in computing environment you actually have to

deal with. Similarly, memory, network bandwidth, database or other server accesses may, in the

end, be far more expensive than processor seconds.

Contention for shared resources that are synchronized can cause deadlock and starvation. Deadlock

is the inability to proceed because of improper synchronization or resource demands. Starvation

is the failure to schedule a component properly. If it can be at all anticipated, it is best to have

a way of measuring this contention from the start of your project. Even if this contention does not

occur, it is very helpful to be able to assert that with confidence.

**1.6. How to Fix Performance Problems**

Most software projects can be made 10 to 100 times faster than they are at the time that they are

first released with relatively little effort. Under time-to-market pressure, it is both wise and effective

to choose a solution that gets the job done simply and quickly, but less efficiently than some

other solution. However, performance is a part of usability, and often it must eventually be considered

more carefully.

The key to improving the performance of a very complicated system is to analyze it well enough

to find the *bottlenecks*, or places where most of the resources are consumed. There is not much

sense in optimizing a function that accounts for only 1% of the computation time. As a rule of

thumb you should think carefully before doing anything unless you think it is going to make the

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system or a significant part of it at least twice as fast. There is usually a way to do this. Consider

the test and quality assurance effort that your change will require. Each change brings a test burden

with it, so it is much better to have a few big changes.

After you've made a two-fold improvement in something, you need to at least rethink and perhaps

reanalyze to discover the next-most-expensive bottleneck in the system, and attack that to get another

two-fold improvement.

Often, the bottlenecks in performance will be an example of counting cows by counting legs and

dividing by four, instead of counting heads. For example, I've made errors such as failing to provide

a relational database system with a proper index on a column I look up a lot, which probably

made it at least 20 times slower. Other examples include doing unnecessary I/O in inner loops,

leaving in debugging statements that are no longer needed, unnecessary memory allocation, and,

in particular, inexpert use of libraries and other subsystems that are often poorly documented with

respect to performance. This kind of improvement is sometimes called *low-hanging fruit*, meaning

that it can be easily picked to provide some benefit.

What do you do when you start to run out of low-hanging fruit? Well, you can reach higher, or

chop the tree down. You can continue making small improvements or you can seriously redesign a

system or a subsystem. (This is a great opportunity to use your skills as a good programmer, not

only in the new design but also in convincing your boss that this is a good idea.) However, before

you argue for the redesign of a subsystem, you should ask yourself whether or not your proposal

will make it five to ten time better.

**1.7. How to Optimize Loops**

Sometimes you'll encounter loops, or recursive functions, that take a long time to execute and are

bottlenecks in your product. Before you try to make the loop a little faster, spend a few minutes

considering if there is a way to remove it entirely. Would a different algorithm do? Could you

compute that while computing something else? If you can't find away around it, then you can optimize

the loop. This is simple; move stuff out. In the end, this will require not only ingenuity but

also an understanding of the expense of each kind of statement and expression. Here are some suggestions:

• Remove floating point operations.

• Don't allocate new memory blocks unnecessarily.

• Fold constants together.

• Move I/O into a buffer.

• Try not to divide.

• Try not to do expensive typecasts.

• Move a pointer rather than recomputing indices.

The cost of each of these operations depends on your specific system. On some systems compilers

and hardware do these things for you. Clear, efficient code is better than code that requires an understanding

of a particular platform.

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**1.8. How to Deal with I/O Expense**

For a lot of problems, processors are fast compared to the cost of communicating with a hardware

device. This cost is usually abbreviated I/O, and can include network cost, disk I/O, database

queries, file I/O, and other use of some hardware not very close to the processor. Therefore building

a fast system is often more a question of improving I/O than improving the code in some tight

loop, or even improving an algorithm.

There are two very fundamental techniques to improving I/O: caching and representation. Caching

is avoiding I/O (generally avoiding the reading of some abstract value) by storing a copy of that

value locally so no I/O is performed to get the value. The first key to caching is to make it crystal

clear which data is the *master* and which are *copies*. There is only one master---period. Caching

brings with it the danger that the copy is sometimes can't reflect changes to the master instantaneously.

Representation is the approach of making I/O cheaper by representing data more efficiently. This

is often in tension with other demands, like human readability and portability.

Representations can often be improved by a factor of two or three from their first implementation.

Techniques for doing this include using a binary representation instead of one that is human readable,

transmitting a dictionary of symbols along with the data so that long symbols don't have to

be encoded, and, at the extreme, things like Huffman encoding.

A third technique that is sometimes possible is to improve the locality of reference by pushing the

computation closer to the data. For instance, if you are reading some data from a database and

computing something simple from it, such as a summation, try to get the database server to do it

for you. This is highly dependent on the kind of system you're working with, but you should explore

it.

**1.9. How to Manage Memory**

Memory is a precious resource that you can't afford to run out of. You can ignore it for a while but

eventually you will have to decide how to manage memory.

Space that needs to persist beyond the scope of a single subroutine is often called *heap allocated*.

A chunk of memory is useless, hence *garbage*, when nothing refers to it. Depending on the system

you use, you may have to explicitly deallocate memory yourself when it is about to become

garbage. More often you may be able to use a system that provides a *garbage collector*. A garbage

collector notices garbage and frees its space without any action required by the programmer.

Garbage collection is wonderful: it lessens errors and increases code brevity and concision

cheaply. Use it when you can.

But even with garbage collection, you can fill up all memory with garbage. A classic mistake is to

use a hash table as a cache and forget to remove the references in the hash table. Since the reference

remains, the referent is noncollectable but useless. This is called a *memory leak*. You should

look for and fix memory leaks early. If you have long running systems memory may never be exhausted

in testing but will be exhausted by the user.

The creation of new objects is moderately expensive on any system. Memory allocated directly in

the local variables of a subroutine, however, is usually cheap because the policy for freeing it can

be very simple. You should avoid unnecessary object creation.

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An important case occurs when you can define an upper bound on the number of objects you will

need at one time. If these objects all take up the same amount of memory, you may be able to allocate

a single block of memory, or a buffer, to hold them all. The objects you need can be allocated

and released inside this buffer in a set rotation pattern, so it is sometimes called a ring buffer. This

is usually faster than heap allocation.

Sometimes you have to explicitly free allocated space so it can be reallocated rather than rely on

garbage collection. Then you must apply careful intelligence to each chunk of allocated memory

and design a way for it to be deallocated at the appropriate time. The method may differ for each

kind of object you create. You must make sure that every execution of a memory allocating operation

is matched by a memory deallocating operation eventually. This is so difficult that programmers

often simply implement a rudimentary form or garbage collection, such as reference counting,

to do this for them.

**1.10. How to Deal with Intermittent Bugs**

The intermittent bug is a cousin of the 50-foot-invisible-scorpion-from-outer-space kind of bug.

This nightmare occurs so rarely that it is hard to observe, yet often enough that it can't be ignored.

You can't debug it because you can't find it.

Although after eight hours you will start to doubt it, the intermittent bug has to obey the same laws

of logic everything else does. What makes it hard is that it occurs only under unknown conditions.

Try to record the circumstances under which the bug does occur, so that you can guess at what the

variability really is. The condition may be related to data values, such as ‘This only happens when

we enter *Wyoming* as a value.’ If that is not the source of variability, the next suspect should be

improperly synchronized concurrency.

Try, try, try to reproduce the bug in a controlled way. If you can't reproduce it, set a trap for it by

building a logging system, a special one if you have to, that can log what you guess you need

when it really does occur. Resign yourself to that if the bug only occurs in production and not at

your whim, this is may be a long process. The hints that you get from the log may not provide the

solution but may give you enough information to improve the logging. The improved logging system

may take a long time to be put into production. Then, you have to wait for the bug to reoccur

to get more information. This cycle can go on for some time.

The stupidest intermittent bug I ever created was in a multi-threaded implementation of a functional

programming language for a class project. I had very carefully insured correct concurrent

evaluation of the functional program, good utilization of all the CPUs available (eight, in this

case). I simply forgot to synchronize the garbage collector. The system could run a long time, often

finishing whatever task I began, before anything noticeable went wrong. I'm ashamed to admit

I had begun to question the hardware before my mistake dawned on me.

At work we recently had an intermittent bug that took us several weeks to find. We have multithreaded

application servers in Java™ behind Apache™ web servers. To maintain fast page turns,

we do all I/O in small set of four separate threads that are different than the page-turning threads.

Every once in a while these would apparently get ‘stuck’ and cease doing anything useful, so far

as our logging allowed us to tell, for hours. Since we had four threads, this was not in itself a giant

problem---unless all four got stuck. Then the queues emptied by these threads would quickly fill

up all available memory and crash our server. It took us about a week to figure this much out, and

we still didn't know what caused it, when it would happen, or even what the threads where doing

when they got ‘stuck’.

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This illustrates some risk associated with third-party software. We were using a licensed piece of

code that removed HTML tags from text. Due to its place of origin we affectionately referred to

this as ‘the French stripper.’ Although we had the source code (thank goodness!) we had not studied

it carefully until by turning up the logging on our servers we finally realized that the email

threads were getting stuck in the French stripper.

The stripper performed well except on some long and unusual kinds of texts. On these texts, the

code was quadratic or worse. This means that the processing time was proportional to the square

of the length of the text. Had these texts occurred commonly, we would have found the bug right

away. If they had never occurred at all, we would never have had a problem. As it happens, it took

us weeks to finally understand and resolve the problem.

**1.11. How to Learn Design Skills**

To learn how to design software, study the action of a mentor by being physically present when

they are designing. Then study well-written pieces of software. After that, you can read some

books on the latest design techniques.

Then you must do it yourself. Start with a small project. When you are finally done, consider how

the design failed or succeeded and how you diverged from your original conception. They move

on to larger projects, hopefully in conjunction with other people. Design is a matter of judgment

that takes years to acquire. A smart programmer can learn the basics adequately in two months and

can improve from there.

It is natural and helpful to develop your own style, but remember that design is an art, not a science.

People who write books on the subject have a vested interest in making it seem scientific.

Don't become dogmatic about particular design styles.

**1.12. How to Conduct Experiments**

The late, great Edsger Dijkstra has eloquently explained that Computer Science is not an experimental

science[ExpCS] and doesn't depend on electronic computers. As he puts it referring to the

1960s[Knife],

...the harm was done: the topic became known as ‘computer science’---which,

actually, is like referring to surgery as ‘knife science’ --- and it was firmly implanted

in people's minds that computing science is about machines and their peripheral

equipment.

Programming ought not to be an experimental science, but most working programmers do not

have the luxury of engaging in what Dijkstra means by computing science. We must work in the

realm of experimentation, just as some, but not all, physicists do. If thirty years from now programming

can be performed without experimentation, it will be a great accomplishment of Computer

Science.

The kinds of experiments you will have to perform include:

• Testing systems with small examples to verify that they conform to the documentation or to

understand their response when there is no documentation,

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• Testing small code changes to see if they actually fix a bug,

• Measuring the performance of a system under two different conditions due to imperfect

knowledge of there performance characteristics,

• Checking the integrity of data, and

• Collecting statistics that may hint at the solution to difficult or hard-to-repeat bugs.

I don't think in this essay I can explain the design of experiments; you will have to study and practice.

However, I can offer two bits of advice.

First, try to be very clear about your hypothesis, or the assertion that you are trying to test. It also

helps to write the hypothesis down, especially if you find yourself confused or are working with

others.

You will often find yourself having to design a series of experiments, each of which is based on

the knowledge gained from the last experiment. Therefore, you should design your experiments to

provide the most information possible. Unfortunately, this is in tension with keeping each experiment

simple---you will have to develop this judgment through experience.

**2. Team Skills**

**2.1. Why Estimation is Important**

To get a working software system in active use as quickly as possible requires not only planning

the development, but also planning the documentation, deployment, marketing. In a commercial

project it also requires sales and finance. Without predictability of the development time, it is impossible

to plan these effectively.

Good estimation provides predictability. Managers love it, as well they should. The fact that it is

impossible, both theoretically and practically, to predict accurately how long it will take to develop

software is often lost on managers. We are asked to do this impossible thing all the time,

and we must face up to it honestly. However, it would be dishonest not to admit the impossibility

of this task, and when necessary, explain it. There is a lot of room for miscommunication about estimates,

as people have a startling tendency to think wishfully that the sentence:

I estimate that, if I really understand the problem, it is about 50% likely that we

will be done in five weeks (if no one bothers us during that time).

really means:

I promise to have it all done five weeks from now.

This common interpretation problem requires that you explicitly discuss what the estimate means

with your boss or customer as if they were a simpleton. Restate your assumptions, no matter how

obvious they seem to you.

**2.2. How to Estimate Programming Time**

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Estimation takes practice. It also takes labor. It takes so much labor it may be a good idea to estimate

the time it will take to make the estimate, especially if you are asked to estimate something

big.

When asked to provide an estimate of something big, the most honest thing to do is to stall. Most

engineers are enthusiastic and eager to please, and stalling certainly will displease the stalled. But

an on-the-spot estimate probably won't be accurate and honest.

While stalling, it may be possible to consider doing or prototyping the task. If political pressure

permits, this is the most accurate way of producing the estimate, and it makes real progress.

When not possible to take the time for some investigation, you should first establish the meaning

of the estimate very clearly. Restate that meaning as the first and last part of your written estimate.

Prepare a written estimate by deconstructing the task into progressively smaller subtasks until each

small task is no more than a day; ideally at most in length. The most important thing is not to leave

anything out. For instance, documentation, testing, time for planning, time for communicating

with other groups, and vacation time are all very important. If you spend part of each day dealing

with knuckleheads, put a line item for that in the estimate. This gives your boss visibility into what

is using up your time at a minimum, and might get you more time.

I know good engineers who pad estimates implicitly, but I recommend that you do not. One of the

results of padding is trust in you may be depleted. For instance, an engineer might estimate three

days for a task that she truly thinks will take one day. The engineer may plan to spend two days

documenting it, or two days working on some other useful project. But it will be detectable that

the task was done in only one day (if it turns out that way), and the appearance of slacking or overestimating

is born. It's far better to give proper visibility into what you are actually doing. If documentation

takes twice as long as coding and the estimate says so, tremendous advantage is gained

by making this visible to the manager.

Pad explicitly instead. If a task will probably take one day---but might take ten days if your approach

doesn't work---note this somehow in the estimate if you can; if not, at least do an average

weighted by your estimates of the probabilities. Any risk factor that you can identify and assign an

estimate to should go into the schedule. One person is unlikely to be sick in any given week. But a

large project with many engineers will have some sick time; likewise vacation time. And what is

the probability of a mandatory company-wide training seminar? If it can be estimated, stick it in.

There are of course, unknown unknowns, or *unk-unks*. Unk-unks by definition cannot be estimated

individually. You can try to create a global line item for all unk-unks, or handle them in some

other way that you communicate to your boss. You cannot, however, let your boss forget that they

exist, and it is devilishly easy for an estimate to become a schedule without the unk-unks considered.

In a team environment, you should try to have the people who will do the work do the estimate,

and you should try to have team-wide consensus on estimates. People vary widely in skill, experience,

preparedness, and confidence. Calamity strikes when a strong programmer estimates for herself

and then weak programmers are held to this estimate. The act of having the whole team agree

on a line-by-line basis to the estimate clarifies the team understanding, as well as allowing the opportunity

for tactical reassignment of resources (for instance, shifting burden away from weaker

team members to stronger).

If there are big risks that cannot be evaluated, it is your duty to state so forcefully enough that your

manager does not commit to them and then become embarrassed when the risk occurs. Hopefully

in such a case whatever is needed will be done to decrease the risk.

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If you can convince your company to use *Extreme Programming*, you will only have to estimate

relatively small things, and this is both more fun and more productive.

**2.3. How to Find Out Information**

The nature of what you need to know determines how you should find it.

If you need information about concrete things that are objective and easy to verify, for example

the latest patch level of a software product, ask a large number of people politely by searching the

internet for it or by posting on a discussion group. Don't search on the internet for anything that

smacks of either opinion or subjective interpretation: the ratio of drivel to truth is too high.

If you need general knowledge about something subjective the history of what people have

thought about it, go to the library (the physical building in which books are stored). For example,

to learn about math or mushrooms or mysticism, go to the library.

If you need to know how to do something that is not trivial get two or three books on the subject

and read them. You might learn how to do something trivial, like install a software package, from

the Internet. You can even learn important things, like good programming technique, but you can

easily spend more time searching and sorting the results and attempting to divine the authority of

the results than it would take to read the pertinent part of a solid book.

If you need information that no one else could be expected to know for example, ‘does this software

that is brand new work on gigantic data sets?’, you must still search the internet and the library.

After those options are completely exhausted, you may design an experiment to ascertain it.

If you want an opinion or a value judgment that takes into account some unique circumstance, talk

to an expert. For instance, if you want to know whether or not it is a good idea to build a modern

database management system in LISP, you should talk to a LISP expert and a database expert.

If you want to know how likely it is that a faster algorithm for a particular application exists that

has not yet been published, talk to someone working in that field.

If you want to make a personal decision that only you can make like whether or not you should

start a business, try putting into writing a list of arguments for and against the idea. If that fails,

consider divination. Suppose you have studied the idea from all angles, have done all your homework,

and worked out all the consequences and pros and cons in your mind, and yet still remain

indecisive. You now must follow your heart and tell your brain to shut up. The multitude of available

divination techniques are very useful for determining your own semi-conscious desires, as

they each present a complete ambiguous and random pattern that your own subconscious will assign

meaning to.

**2.4. How to Utilize People as Information**

**Sources**

Respect every person's time and balance it against your own. Asking someone a question accomplishes

far more than just receiving the answer. The person learns about you, both by enjoying

your presence and hearing the particular question. You learn about the person in the same way,

and you may learn the answer you seek. This is usually far more important than your question.

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However, the value of this diminishes the more you do it. You are, after all, using the most precious

commodity a person has: their time. The benefits of communication must be weighed

against the costs. Furthermore, the particular costs and benefits derived differ from person to person.

I strongly believe that an executive of 100 people should spend five minutes a month talking

to each person in her organization, which would be about 5% of their time. But ten minutes might

be too much, and five minutes is too much if they have one thousand employees. The amount of

time you spend talking to each person in your organization depends on their role (more than their

position). You should talk to your boss more than your boss's boss, but you should talk to your

boss's boss a little. It may be uncomfortable, but I believe you have a duty to talk a little bit to all

your superiors, each month, no matter what.

The basic rule is that everyone benefits from talking to you a little bit, and the more they talk to

you, the less benefit they derive. It is your job to provide them this benefit, and to get the benefit

of communicating with them, keeping the benefit in balance with the time spent.

It is important to respect your own time. If talking to someone, even if it will cost them time, will

save you a great deal of time, then you should do it unless you think their time is more valuable

than yours, to the tribe, by that factor.

A strange example of this is the summer intern. A summer intern in a highly technical position

can't be expected to accomplish too much; they can be expected to pester the hell out of everybody

there. So why is this tolerated? Because the pestered are receiving something important from the

intern. They get a chance to showoff a little. They get a chance to hear some new ideas, maybe;

they get a chance to see things from a different perspective. They may also be trying to recruit the

intern, but even if this is not the case there is much to gain.

You should ask people for a little bit of their wisdom and judgment whenever you honestly believe

they have something to say. This flatters them and you will learn something and teach them

something. A good programmer does not often need the advice of a Vice President of Sales, but if

you ever do, you be sure to ask for it. I once asked to listen in on a few sales calls to better understand

the job of our sales staff. This took no more than 30 minutes but I think that small effort

made an impression on the sales force.

**2.5. How to Document Wisely**

Life is too short to write crap nobody will read; if you write crap, nobody will read it. Therefore a

little good documentation is best. Managers often don't understand this, because even bad documentation

gives them a false sense of security that they are not dependent on their programmers. If

someone absolutely insists that you write truly useless documentation, say ``yes'' and quietly begin

looking for a better job.

There's nothing quite as effective as putting an accurate estimate of the amount of time it will take

to produce good documentation into an estimate to slacken the demand for documentation. The

truth is cold and hard: documentation, like testing, can take many times longer than developing

code.

Writing good documentation is, first of all, good writing. I suggest you find books on writing,

study them, and practice. But even if you are a lousy writer or have poor command of the language

in which you must document, the Golden Rule is all you really need: ``Do unto others as

you would have them do unto you.'' Take time to really think about who will be reading your documentation,

what they need to get out of it, and how you can teach that to them. If you do that, you

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will be an above average documentation writer, and a good programmer.

When it comes to actually documenting code itself, as opposed to producing documents that can

actually be read by non-programmers, the best programmers I've ever known hold a universal sentiment:

write self-explanatory code and only document code in the places that you cannot make it

clear by writing the code itself. There are two good reasons for this. First, anyone who needs to

see code-level documentation will in most cases be able to and prefer to read the code anyway.

Admittedly, this seems easier to the experienced programmer than to the beginner. More importantly

however, is that the code and the documentation cannot be inconsistent if there is no documentation.

The source code can at worst be wrong and confusing. The documentation, if not written

perfectly, can lie, and that is a thousand times worse.

This does not make it easier on the responsible programmer. How does one write self-explanatory

code? What does that even mean? It means:

• Writing code knowing that someone will have to read it;

• Applying the golden rule;

• Choosing a solution that is straightforward, even if you could get by with another solution

faster;

• Sacrificing small optimizations that obfuscate the code;

• Thinking about the reader and spending some of your precious time to make it easier on her;

and

• Not ever using a function name like ``foo'',``bar'', or ``doIt''!

**2.6. How to Work with Poor Code**

It is very common to have to work with poor quality code that someone else has written. Don't

think too poorly of them, however, until you have walked in their shoes. They may have been

asked very consciously to get something done quickly to meet schedule pressure. Regardless, in

order to work with unclear code you must understand it. To understand it takes learning time, and

that time will have to come out of some schedule, somewhere, and you must insist on it. To understand

it, you will have to read the source code. You will probably have to experiment with it.

This is a good time to document, even if it is only for yourself, because the act of trying to document

the code will force you to consider angles you might not have considered, and the resulting

document may be useful. While you're doing this, consider what it would take to rewrite some or

all of the code. Would it actually save time to rewrite some of it? Could you trust it better if you

rewrote it? Be careful of arrogance here. If you rewrite it, it will be easier for you to deal with, but

will it really be easier for the next person who has to read it? If you rewrite it, what will the test

burden be? Will the need to re-test it outweigh any benefits that might be gained?

In any estimate that you make for work against code you didn't write, the quality of that code

should affect your perception of the risk of problems and unk-unks.

It is important to remember that abstraction and encapsulation, two of a programmer's best tools,

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are particularly applicable to lousy code. You may not be able to redesign a large block of code,

but if you can add a certain amount of abstraction to it you can obtain some of the benefits of a

good design without reworking the whole mess. In particular, you can try to wall off the parts that

are particularly bad so that they may be redesigned independently.

**2.7. How to Use Source Code Control**

Source code control systems let you manage projects effectively. They're very useful for one person

and essential for a group. They track all changes in different versions so that no code is ever

lost and meaning can be assigned to changes. One can create throw-away and debugging code

with confidence with a source code control system, since the code you modify is kept carefully

separate from committed, official code that will be shared with the team or released.

I was late to appreciate the benefits of source code control systems but now I wouldn't live without

one even on a one-person project. Generally they are necessary when you have team working on

the same code base. However, they have another great advantage: they encourage thinking about

the code as a growing, organic system. Since each change is marked as a new revision with a new

name or number, one begins to think of the software as a visibly progressive series of improvements.

I think this is especially useful for beginners.

A good technique for using a source code control system is to stay within a few days of being upto-

date at all time. Code that can't be finished in a few days is checked in, but in a way that it is inactive

and will not be called, or in a branch of its own, and therefore not create any problems for

anybody else. Committing a mistake that slows down your teammates is a serious error; it is often

taboo.

**2.8. How to Unit Test**

Unit testing, the testing of an individual piece of coded functionality by the team that wrote it, is a

part of coding, not something different from it. Part of designing the code is designing how it will

be tested. You should write down a test plan, even if it is only one sentence. Sometimes the test

will be simple: ``Does the button look good?'' Sometimes it will be complex: ``Did this matching

algorithm return precisely the correct matches?''

Use assertion checking and test drivers whenever possible. This not only catches bugs early, but is

very useful later on and lets you eliminate mysteries that you would otherwise have to worry

about.

The Extreme Programming developers are writing extensively on unit testing effectively; I can do

no better than to recommend their writings.

**2.9. Take Breaks when Stumped**

When stumped, take a break. I sometimes meditate for 15 minutes when stumped and the problem

magically unravels when I come back to it. A night's sleep sometimes does the same thing on a

larger scale. It's possible that temporarily switching to any other activity may work.

**2.10. How to Recognize When to Go Home**

Computer programming is an activity that is also a culture. The unfortunate fact is that it is not a

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culture that values mental or physical health very much. For both cultural/historical reasons (the

need to work at night on unloaded computers, for example) and because of overwhelming timeto-

market pressure and the scarcity of programmers, computer programmers are traditionally overworked.

I don't think you can trust all the stories you hear, but I think 60 hours a week is common,

and 50 is pretty much a minimum. This means that often much more than that is required. This is

serious problem for a good programmer, who is responsible not only for themselves but their

teammates as well. You have to recognize when to go home, and sometimes when to suggest that

other people go home. There can't be any fixed rules for solving this problem, anymore than there

can be fixed rules for raising a child, for the same reason---every human being is different.

Beyond 60 hours a week is an extraordinary effort for me, which I can apply for short periods of

time (about one week), and that is sometimes expected of me. I don't know if it is fair to expect 60

hours of work from a person; I don't even know if 40 is fair. I am sure, however, that it is stupid to

work so much that you are getting little out of that extra hour you work. For me personally, that's

any more than 60 hours a week. I personally think a programmer should exercise noblesse oblige

and shoulder a heavy burden. However, it is not a programmer's duty to be a patsy. The sad fact is

programmers are often asked to be patsies in order to put on a show for somebody, for example a

manager trying to impress an executive. Programmers often succumb to this because they are eager

to please and not very good at saying no. There are four defenses against this:

• Communicate as much as possible with everyone in the company so that no one can mislead

the executives about what is going on,

• Learn to estimate and schedule defensively and explicitly and give everyone visibility into

what the schedule is and where it stands,

• Learn to say no, and say no as a team when necessary, and

• Quit if you have to.

Most programmers are good programmers, and good programmers want to get a lot done. To do

that, they have to manage their time effectively. There is a certain amount of mental inertia associated

with getting warmed-up to a problem and deeply involved in it. Many programmers find they

work best when they have long, uninterrupted blocks of time in which to get warmed-up and concentrate.

However, people must sleep and perform other duties. Each person needs to find a way to

satisfy both their human rhythm and their work rhythm. Each programmer needs to do whatever it

takes to procure efficient work periods, such as reserving certain days in which you will attend

only the most critical meetings.

Since I have children, I try to spend evenings with them sometimes. The rhythm that works best

for me is to work a very long day, sleep in the office or near the office (I have a long commute

from home to work) then go home early enough the next day to spend time with my children before

they go to bed. I am not comfortable with this, but it is the best compromise I have been able

to work out. Go home if you have a contagious disease. You should go home if you are thinking

suicidal thoughts. You should take a break or go home if you think homicidal thoughts for more

than a few seconds. You should send someone home if they show serious mental malfunctioning

or signs of mental illness beyond mild depression. If you are tempted to be dishonest or deceptive

in a way that you normally are not due to fatigue, you should take a break. Don't use cocaine or

amphetamines to combat fatigue. Don't abuse caffeine.

**2.11. How to Deal with Difficult People**

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You will probably have to deal with difficult people. You may even be a difficult person yourself.

If you are the kind of person who has a lot of conflicts with coworkers and authority figures, you

should cherish the independence this implies, but work on your interpersonal skills without sacrificing

your intelligence or principles.

This can be very disturbing to some programmers who have no experience in this sort of thing and

whose previous life experience has taught them patterns of behavior that are not useful in the

workplace. Difficult people are often inured to disagreement and they are less affected by social

pressure to compromise than others. The key is to respect them appropriately, which is more than

you will want to but not as much as they might want.

Programmers have to work together as a team. When disagreement arises, it must be resolved

somehow, it cannot be ducked for long. Difficult people are often extremely intelligent and have

something very useful to say. It is critical that you listen and understand the difficult person without

prejudice caused by the person. A failure to communicate is often the basis of disagreement

but it can sometimes be removed with great patience. Try to keep this communication cool and

cordial, and don't accept any baits for greater conflict that may be offered. After a reasonable period

of trying to understand, make a decision.

Don't let a bully force you to do something you don't agree with. If you are the leader, do what you

think is best. Don't make a decision for any personal reasons, and be prepared to explain the reasons

for your decision. If you are a teammate with a difficult person, don't let the leader's decision

have any personal impact. If it doesn't go your way, do it the other way whole-heartedly.

Difficult people do change and improve. I've seen it with my own eyes, but it is very rare. However,

everyone has transitory ups and downs.

One of the challenges that every programmer but especially leaders face is keeping the difficult

person fully engaged. They are more prone to duck work and resist passively than others.

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**Chapter 3. Intermediate**

**1. Personal Skills**

**1.1. How to Stay Motivated**

It is a wonderful and surprising fact that programmers are highly motivated by the desire to create

artifacts that are beautiful, useful, or nifty. This desire is not unique to programmers nor universal

but it is so strong and common among programmers that it separates them from others in other

roles.

This has practical and important consequences. If programmers are asked to do something that is

not beautiful, useful, or nifty, they will have low morale. There's a lot of money to be made doing

ugly, stupid, and boring stuff; but in the end, fun will make the most money for the company.

Obviously, there are entire industries organized around motivational techniques some of which apply

here. The things that are specific to programming that I can identify are:

• Use the best language for the job.

• Look for opportunities to apply new techniques, languages, and technologies.

• Try to either learn or teach something, however small, in each project.

Finally, if possible, measure the impact of your work in terms of something that will be personally

motivating. For example, when fixing bugs, counting the number of bugs that I have fixed is not at

all motivational to me, because it is independent of the number that may still exist, and is also affects

the total value I'm adding to my company's customers in only the smallest possible way. Relating

each bug to a happy customer, however, is personally motivating to me.

**1.2. How to be Widely Trusted**

To be trusted you must be trustworthy. You must also be visible. If know one knows about you, no

trust will be invested in you. With those close to you, such as your teammates, this should not be

an issue. You establish trust by being responsive and informative to those outside your department

or team. Occasionally someone will abuse this trust, and ask for unreasonable favors. Don't be

afraid of this, just explain what you would have to give up doing to perform the favor.

Don't pretend to know something that you don't. With people that are not teammates, you may

have to make a clear distinction between ``not knowing right off the top of my head'' and ``not being

able to figure it out, ever.''

**1.3. How to Tradeoff Time vs. Space**

You can be a good programmer without going to college, but you can't be a good intermediate

programmer without knowing basic computational complexity theory. You don't need to know

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1This term has several meanings, derived from ‘to hit’, but is particularly used by athletes to describe running out of blood

sugar or some other basic resource that manifests as a sudden, rather than gradual, degradation of performance or spirit. I

have been told it has an additional, and very different meaning, throughout some of the British Commonwealth.

``big O'' notation, but I personally think you should be able to understand the difference between

``constant-time'',``n log n'' and ``n squared''. You might be able to intuit how to tradeoff time

against space without this knowledge, but in its absence you will not have a firm basis for communicating

with your colleagues.

In designing or understanding an algorithm, the amount of time it takes to run is sometimes a

function of the size of the input. When that is true, we can say an algorithm's worst/expected/

best-case running time is ``n log n'' if it is proportional to the size (represented by the variable

n) times the logarithm of the size. The notation and way of speaking can be also be applied to

the space taken up by a data structure.

To me, computational complexity theory is beautiful and as profound as physics---and a little bit

goes a long way!

Time (processor cycles) and space (memory) can be traded off against each other. Engineering is

about compromise, and this is a fine example. It is not always systematic. In general, however, one

can save space by encoding things more tightly, at the expense of more computation time when

you have to decode them. You can save time by caching, that is, spending space to store a local

copy of something, at the expense of having to maintain the consistency of the cache. You can

sometimes save time by maintaining more information in a data structure. This usually cost a

small amount of space but may complicate the algorithm.

Improving the space/time tradeoff can often change one or the other dramatically. However, before

you work on this you should ask yourself if what you are improving is really the thing that

needs the most improvement. It's fun to work on an algorithm, but you can't let that blind you to

the cold hard fact that improving something that is not a problem will not make any noticeable difference

and will create a test burden.

Memory on modern computers appears cheap, because unlike processor time, you can't see it being

used until you hit the wall; but then failure is catastrophic. There are also other hidden costs to

using memory, such as your effect on other programs that must be resident, and the time to allocate

and deallocate it. Consider this carefully before you trade away space to gain speed.

**1.4. How to Stress Test**

Stress testing is fun. At first it appears that the purpose of stress testing is to find out if the system

works under a load. In reality, it is common that the system does work under a load but fails to

work in some way when the load is heavy enough. I call this *hitting the wall* or *bonking*1. There

may be some exceptions, but there is almost always a ‘wall’. The purpose of stress testing is to

figure out where the wall is, and then figure out how to move the wall further out.

A plan for stress testing should be developed early in the project, because it often helps to clarify

exactly what is expected. Is two seconds for a web page request a miserable failure or a smashing

success? Is 500 concurrent users enough? That, of course, depends, but one must know the answer

when designing the system that answers the request. The stress test needs to model reality well

enough to be useful. It isn't really possible to simulate 500 erratic and unpredictable humans using

a system concurrently very easily, but one can at least create 500 simulations and try to model

some part of what they might do.

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In stress testing, start out with a light load and load the system along some dimension---such as input

rate or input size---until you hit the wall. If the wall is too close to satisfy your needs, figure

out which resource is the bottleneck (there is usually a dominant one.) Is it memory, processor, Input/

Output, network bandwidth, or data contention? Then figure out how you can move the wall.

Note that moving the wall, that is, increasing the maximum load the system can handle, might not

help or might actually hurt the performance of a lightly loaded system. Usually performance under

heavy load is more important than performance under a light load.

You may have to get visibility into several different dimensions to build up a mental model of it;

no single technique is sufficient. For instance, logging often gives a good idea of the wall-clock

time between two events in the system, but unless carefully constructed, doesn't give visibility into

memory utilization or even data structure size. Similarly, in a modern system, a number of computers

and many software systems may be cooperating. Particularly when you are hitting the wall

(that is, the performance is non-linear in the size of the input) these other software systems may be

a bottleneck. Visibility into these systems, even if only measuring the processor load on all participating

machines, can be very helpful.

Knowing where the wall is is essential not only to moving the wall, but also to providing predictability

so that the business can be managed effectively.

**1.5. How to Balance Brevity and Abstraction**

Abstraction is key to programming. You should carefully choose how abstract you need to be. Beginning

programmers in their enthusiasm often create more abstraction than is really useful. One

sign of this is if you create classes that don't really contain any code and don't really do anything

except serve to abstract something. The attraction of this is understandable but the value of code

brevity must be measured against the value of abstraction. Occasionally, one sees a mistake made

by enthusiastic idealists: at the start of the project a lot of classes are defined that seem wonderfully

abstract and one may speculate that they will handle every eventuality that may arise. As the

project progresses and fatigue sets in, the code itself becomes messy. Function bodies become

longer than they should be. The empty classes are a burden to document that is ignored when under

pressure. The final result would have been better if the energy spent on abstraction had been

spent on keeping things short and simple. This is a form of *speculative programming*. I strongly

recommend the article ``Succinctness is Power'' by Paul Graham[PGSite].

There is a certain dogma associated with useful techniques such as *information hiding* and *object*

*oriented programming* that are sometimes taken too far. These techniques let one code abstractly

and anticipate change. I personally think, however, that you should not produce much speculative

code. For example, it is an accepted style to hide an integer variable on an object behind mutators

and accessors, so that the variable itself is not exposed, only the little interface to it. This does allow

the implementation of that variable to be changed without affecting the calling code, and is

perhaps appropriate to a library writer who must publish a very stable API. But I don't think the

benefit of this outweighs the cost of the wordiness of it when my team owns the calling code and

hence can recode the caller as easily as the called. Four or five extra lines of code is a heavy price

to pay for this speculative benefit.

Portability poses a similar problem. Should code be portable to a different computer, compiler,

software system or platform, or simply easily ported? I think a non-portable, shortand-

easily-ported piece of code is better than a long portable one. It is relatively easy and certainly

a good idea to confine non-portable code to designated areas, such as a class that makes database

queries that are specific to a given DBMS.

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2At the time of this writing Michael Tiemann is the CTO of RedHat.

**1.6. How to Learn New Skills**

Learning new skills, especially non-technical ones, is the greatest fun of all. Most companies

would have better morale if they understood how much this motivates programmers.

Humans learn by doing. Book-reading and class-taking are useful. But could you have any respect

for a programmer who had never written a program? To learn any skill, you have to put yourself in

a forgiving position where you can exercise that skill. When learning a new programming language,

try to do a small project it in before you have to do a large project. When learning to manage

a software project, try to manage a small one first.

A good mentor is no replacement for doing things yourself, but is a lot better than a book. What

can you offer a potential mentor in exchange for their knowledge? At a minimum, you should offer

to study hard so their time won't be wasted.

Try to get your boss to let you have formal training, but understand that it often not much better

than the same amount of time spent simply playing with the new skill you want to learn. It is,

however, easier to ask for training than playtime in our imperfect world, even though a lot of formal

training is just sleeping through lectures waiting for the dinner party.

If you lead people, understand how they learn and assist them by assigning them projects that are

the right size and that exercise skills they are interested in. Don't forget that the most important

skills for a programmer are not the technical ones. Give your people a chance to play and practice

courage, honesty, and communication.

**1.7. Learn to Type**

Learn to touch-type. This is an intermediate skill because writing code is so hard that the speed at

which you can type is irrelevant and can't put much of a dent in the time it takes to write code, no

matter how good you are. However, by the time you are an intermediate programmer you will

probably spend a lot of time writing natural language to your colleagues and others. This is a fun

test of your commitment; it takes dedicated time that is not much fun to learn something like that.

Legend has it that when Michael Tiemann2 was at MCC people would stand outside his door to

listen to the hum generated by his keystrokes which were so rapid as to be indistinguishable.

**1.8. How to Do Integration Testing**

Integration testing is the testing of the integration of various components that have been unit

tested. Integration is expensive and it comes out in the testing. You must include time for this in

your estimates and your schedule.

Ideally you should organize a project so that there is not a phase at the end where integration must

explicitly take place. It is far better to gradually integrate things as they are completed over the

course of the project. If it is unavoidable estimate it carefully.

**1.9. Communication Languages**

There are some languages, that is, formally defined syntactic systems, that are not programming

languages but *communication languages*---they are designed specifically to facillitate communica-

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tion through standardization. In 2003 the most important of these are UML, XML, and SQL. You

should have some familiarity with all of these so that you can communicate well and decide when

to use them.

UML is a rich formal system for making drawings that describe designs. It's beauty lines in that is

both visual and formal, capable of conveying a great deal of information if both the author and the

audience know UML. You need to know about it because designs are sometimes communicated in

it. There are very helpful tools for making UML drawings that look very professional. In a lot of

cases UML is too formal, and I find myself using a simpler *boxes and arrows* style for design

drawings. But I'm fairly sure UML is at least as good for you as studying Latin.

XML is a standard for defining new standards. It is not a solution to data interchange problems,

though you sometimes see it presented as if it was. Rather, it is a welcome automation of the most

boring part of data interchange, namely, structuring the representation into a linear sequence and

parsing back into a structure. It provides some nice type- and correctness-checking, though again

only a fraction of what you are likely to need in practice.

SQL is a very powerful and rich data query and manipulation language that is not quite a programming

language. It has many variations, typically quite product-dependent, which are less important

than the standardized core. SQL is the *lingua franca* of relational databases. You may or may not

work in any field that can benefit from an understanding of relational databases, but you should

have a basic understanding of them and they syntax and meaning of SQL.

**2. Team Skills**

**2.1. How to Manage Development Time**

To manage development time, maintain a concise and up-to-date project plan. A project plan is an

estimate, a schedule, a set of milestones for marking progress, and an assignment of your team or

your own time to each task on the estimate. It should also include other things you have to remember

to do, such as meeting with the quality assurance people, preparing documentation, or ordering

equipment. If you are on a team, the project plan should be a consensual agreement, both at the

start and as you go.

The project plan exists to help make decisions, not to show how organized you are. If the project

plan is either too long or not up-to-date, it will be useless for making decisions. In reality, these

decisions are about individual persons. The plan and your judgment let you decide if you should

shift tasks from one person to another. The milestones mark your progress. If you use a fancy

project planning tool, do not be seduced into creating a Big Design Up Front (BDUF) for the

project, but use it maintain concision and up-to-dateness.

If you miss a milestone, you should take immediate action such as informing your boss that the

scheduled completion of that project has slipped by that amount. The estimate and schedule could

never have been perfect to begin with; this creates the illusion that you might be able to make up

the days you missed in the latter part of the project. You might. But it is just as likely that you

have underestimated that part as that you have overestimated it. Therefore the scheduled completion

of the project has already slipped, whether you like it or not.

Make sure your plan includes time for: internal team meetings, demos, documentation, scheduled

periodic activities, integration testing, dealing with outsiders, sickness, vacations, maintenance of

existing products, and maintenance of the development environment. The project plan can serve as

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a way to give outsiders or your boss a view into what you or your team is doing. For this reason it

should be short and up-to-date.

**2.2. How to Manage Third-Party Software Risks**

A project often depends on software produced by organizations that it does not control. There are

great risks associated with third party software that must be recognized by everyone involved.

Never, ever, rest any hopes on *vapor*. *Vapor* is any alleged software that has been promised but is

not yet available. This is the surest way to go out of business. It is unwise to be merely skeptical of

a software company's promise to release a certain product with a certain feature at a certain date; it

is far wiser to ignore it completely and forget you ever heard it. Never let it be written down in any

documents used by your company.

If third-party software is not vapor, it is still risky, but at least it is a risk that can be tackled. If you

are considering using third-party software, you should devote energy early on to evaluating it.

People might not like to hear that it will take two weeks or two months to evaluate each of three

products for suitability, but it has to be done as early as possible. The cost of integrating cannot be

accurately estimated without a proper evaluation.

Understanding the suitability of existing third party software for a particular purpose is very tribal

knowledge. It is very subjective and generally resides in experts. You can save a lot of time if you

can find those experts. Often times a project will depend on a third-party software system so completely

that if the integration fails the project will fail. Express risks like that clearly in writing in

the schedule. Try to have a contingency plan, such as another system that can be used or the ability

to write the functionality yourself if the risk can't be removed early. Never let a schedule depend

on vapor.

**2.3. How to Manage Consultants**

Use consultants, but don't rely on them. They are wonderful people and deserve a great deal of respect.

Since they get to see a lot of different projects, they often know more about specific technologies

and even programming techniques than you will. The best way to use them is as educators

in-house that can teach by example.

However, they usually cannot become part of the team in the same sense that regular employees

are, if only because you may not have enough time to learn their strengths and weaknesses. Their

financial commitment is much lower. They can move more easily. They may have less to gain if

the company does well. Some will be good, some will be average, and some will be bad, but hopefully

your selection of consultants will not be as careful as your selection of employees, so you

will get more bad ones.

If consultants are going to write code, you must review it carefully as you go along. You cannot

get to the end of the a project with the risk of a large block of code that has not been reviewed.

This is true of all team members, really, but you will usually have more knowledge of the team

members closer to you.

**2.4. How to Communicate the Right Amount**

Carefully consider the cost of a meeting; it costs its duration multiplied by the number of partici-

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pants. Meetings are sometimes necessary, but smaller is usually better. The quality of communication

in small meetings is better, and less time overall is wasted. If any one person is bored at a

meeting, take this as a sign that the meeting should be smaller.

Everything possible should be done to encourage informal communication. More useful work is

done during lunches with colleagues than during any other time. It is a shame that more companies

do not recognize nor support this fact.

**2.5. How to Disagree Honestly and Get Away**

**with It**

Disagreement is a great opportunity to make a good decision, but it should be handled delicately.

Hopefully you feel that you have expressed your thoughts adequately and been heard before the

decision is made. In that case there is nothing more to say, and you should decide whether you

will stand behind the decision even though you disagree with it. If you can support this decision

even though you disagree, say so. This shows how valuable you are because you are independent

and are not a yes-man, but respectful of the decision and a team player.

Sometimes a decision that you disagree with will be made when the decision makers did not have

the full benefit of you opinion. You should then evaluate whether to raise the issue on the basis of

the benefit to the company or tribe. If it is a small mistake in your opinion, it may not be worth reconsidering.

If it is a large mistake in you opinion, then of course you must present an argument.

Usually, this is not a problem. In some stressful circumstances and with some personality types

this can lead to things being taken personally. For instance, some very good programmers lack the

confidence needed to challenge a decision even when they have good reason to believe it is wrong.

In the worst of circumstances the decision maker is insecure and takes it as a personal challenge to

their authority. It is best to remember that in such circumstances people react with the reptilian

part of their brains. You should present your argument in private, and try to show how new knowledge

changes the basis on which the decision was made.

Whether the decision is reversed or not, you must remember that you will never be able to say ‘I

told you so!’ since the alternate decision was never fully explored.

**3. Judgement**

**3.1. How to Tradeoff Quality Against Development**

**Time**

Software development is always a compromise between what the project does and getting the

project done. But you may be asked to tradeoff quality to speed the deployment of a project in a

way that offends your engineering sensibilities or business sensibilities. For example, you may be

asked to do something that is a poor software engineering practice and that will lead to a lot of

maintenance problems.

If this happens your first responsibility is to inform your team and to clearly explain the cost of the

decrease in quality. After all, your understanding of it should be much better than your boss's understanding.

Make it clear what is being lost and what is being gained, and at what cost the lost

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ground will be regained in the next cycle. In this, the visibility provided by a good project plan

should be helpful. If the quality tradeoff affects the quality assurance effort, point that out (both to

your boss and quality assurance people). If the quality tradeoff will lead to more bugs being reported

after the quality assurance period, point that out.

If she still insists you should try to isolate the shoddiness into particular components that you can

plan to rewrite or improve in the next cycle. Explain this to your team so that they can plan for it.

NinjaProgrammer at Slashdot sent in this gem:

Remember that a good design will be resillient against poor code implementations.

If good interfaces and abstractions exist throughout the code, then the

eventual rewrites will be far more painless. If it is hard to write clear code that is

hard to fix, consider what is wrong with the core design that is causing this.

**3.2. How to Manage Software System Dependence**

Modern software systems tend to depend on a large number of components that may not be directly

under your control. This increases productivity through synergy and reuse. However, each

component brings with it some problems:

• How will you fix bugs in the component?

• Does the component restrict you to particular hardware or software systems?

• What will you do if the component fails completely?

It is always best to encapsulate the component in some way so that it is isolated and so that it can

be swapped out. If the component proves to be completely unworkable, you may be able to get a

different one, but you may have to write your own. Encapsulation is not portability, but it makes

porting easier, which is almost as good.

Having the source code for a component decreases the risk by a factor of four. With source code,

you can evaluate it easier, debug it easier, find workarounds easier, and make fixes easier. If you

make fixes, you should give them to the owner of the component and get the fixes incorporated

into an official release; otherwise you will uncomfortably have to maintain an unofficial version .

**3.3. How to Decide if Software is Too Immature**

Using software other people wrote is one of the most effective ways to quickly build a solid system.

It should not be discouraged, but the risks associated with it must be examined. One of the

biggest risks is the period of bugginess and near inoperability that is often associated with software

before it matures, through usage, into a usable product. Before you consider integrating with

a software system, whether created in house or by a third party, it is very important to consider if it

is really mature enough to be used. Here are ten questions you should ask yourself about it:

1. Is it vapor? (Promises are very immature).

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2. Is there an accessible body of lore about the software?

3. Are you the first user?

4. Is there a strong incentive for continuation?

5. Has it had a maintenance effort?

6. Will it survive defection of the current maintainers?

7. Is there a seasoned alternative at least half as good?

8. Is it known to your tribe or company?

9. Is it desirable to your tribe or company?

10. Can you hire people to work on it even if it is bad?

A little consideration of these criteria demonstrates the great value of well-established free software

and open-source software in reducing risk to the entrepreneur.

**3.4. How to Make a Buy vs. Build Decision**

An entrepreneurial company or project that is trying to accomplish something with software has to

constantly make so-called *buy vs. build* decisions. This turn of phrase is unfortunate in two ways:

it seems to ignore open-source and free software which is not necessarily bought. Even more importantly,

it should perhaps be called an obtain and integrate vs. build here and integrate decision

because the cost of integration must be considered. This requires a great combination of business,

management, and engineering savvy.

• How well do your needs match those for which it was designed?

• What portion of what you buy will you need?

• What is the cost of evaluating the integration?

• What is the cost of integration?

• What is the cost of evaluating the integration?

• Will buying increase or decrease long term maintenance costs?

• Will building it put you in a business position you don't want to be in?

You should think twice before building something that is big enough to serve as the basis for an

entire other business. Such ideas are often proposed by bright and optimistic people that will have

a lot to contribute to your team. If their idea is compelling, you may wish to change your business

plan; but do not invest in a solution bigger than your own project without conscious thought.

After considering these questions, you should perhaps prepare two draft project plans, one for

building and one for buying. This will force you to consider the integration costs. You should also

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consider the long term maintenance costs of both solutions. To estimate the integration costs, you

will have to do a thorough evaluation of the software before you buy it. If you can't evaluate it,

you will assume an unreasonable risk in buying it and you should decide against buying that particular

product. If there are several buy decisions under consideration, some energy will have to be

spent evaluating each.

**3.5. How to Grow Professionally**

Assume responsibility in excess of your authority. Play the role that you desire. Express appreciation

for people's contribution to the success of the larger organization, as well as things as that

help you personally.

If you want to become a team leader, instigate the formation of consensus. If you want to become

a manager, take responsibility for the schedule. You can usually do this comfortably while working

with a leader or a manager, since this frees them up to take greater responsibility. If that is too

much to try, do it a little at a time.

Evaluate yourself. If you want to become a better programmer, ask someone you admire how you

can become like them. You can also ask your boss, who will know less but have a greater impact

on your career.

Plan ways to learn new skills, both the trivial technical kind, like learning a new software system,

and the hard social kind, like writing well, by integrating them into your work.

**3.6. How to Evaluate Interviewees**

Evaluating potential employees is not given the energy it deserves. A bad hire, like a bad marriage,

is terrible. A significant portion of everyone's energy should be devoted to recruitment,

though this is rarely done.

There are different interviewing styles. Some are torturous, designed to put the candidate under a

great deal of stress. This serves a very valuable purpose of possibly revealing character flaws and

weaknesses under stress. Candidates are no more honest with interviewers than they are with

themselves, and the human capacity for self-deception is astonishing.

You should, at a minimum, give the candidate the equivalent of an oral examination on the technical

skills for two hours. With practice, you will be able to quickly cover what they know and

quickly retract from what they don't know to mark out the boundary. Interviewees will respect

this. I have several times heard interviewees say that the quality of the examination was one of

their motivations for choosing a company. Good people want to be hired for their skills, not where

they worked last or what school they went to or some other inessential characteristic.

In doing this, you should also evaluate their ability to learn, which is far more important than what

they know. You should also watch for the whiff of brimstone that is given off by difficult people.

You may be able to recognize it by comparing notes after the interview, but in the heat of the interview

it is hard to recognize. How well people communicate and work with people is more important

than being up on the latest programming language.

A reader has had good luck using a ‘take-home’ test for interviewees. This has the advantage that

can uncover the interviewee that can present themselves well but can't really code---and there are

many such people. I personally have not tried this technique, but it sounds sensible.

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3A number of readers have found this section arrogant and out of touch with their own experience. I value non-engineers

very highly; I am not being intentionally condescending. I do apologize if anyone is offended by these beliefs, but it would

be dishonest for me to retract them until experience gives me a counter-example. It is possible that I have been extraordinarily

lucky in the programmers that I have been able to work with, and that others will find the stereotype of the communication-

challenged programmer the norm.

Finally, interviewing is also a process of selling. You should be selling your company or project to

the candidate. However, you are talking to a programmer, so don't try to color the truth. Start off

with the bad stuff, then finish strong with the good stuff.

**3.7. How to Know When to Apply Fancy Computer**

**Science**

There is a body of knowledge about algorithms, data structures, mathematics, and other gee-whiz

stuff that most programmers know about but rarely use. In practice, this wonderful stuff is too

complicated and generally unnecessary. There is no point in improving an algorithm when most of

your time is spent making inefficient database calls, for instance. An unfortunate amount of programming

consists of getting systems to talk to each other and using very simple data structures to

build a nice user interface.

When is high technology the appropriate technology? When should you crack a book to get something

other than a run-of-the-mill algorithm? It is sometimes useful to do this but it should be evaluated

carefully.

The three most important considerations for the potential computer science technique are:

• Is it well encapsulated so that the risk to other systems is low and the overall increase in complexity

and maintenance cost is low?

• Is the benefit startling (for example, a factor of two in a mature system or a factor of ten in a

new system)?

• Will you be able to test and evaluate it effectively?

If a well-isolated algorithm that uses a slightly fancy algorithm can decrease hardware cost or increase

performance by a factor of two across an entire system, then it would be criminal not to

consider it. One of the keys to arguing for such an approach is to show that the risk is really quite

low, since the proposed technology has probably been well studied, the only issue is the risk of integration.

Here a programmer's experience and judgment can truly synergize with the fancy technology

to make integration easy.

**3.8. How to Talk to Non-Engineers**

Engineers and programmers in particular are generally recognized by popular culture as being different

from other people. This implies that other people are different from us. This is worth bearing

in mind when communicating with non-engineers; you should always understand the audience.

Non-engineers are smart, but not as grounded in creating technical things as we are. We make

things. They sell things and handle things and count things and manage things, but they are not experts

on making things. They are not as good at working together on teams as engineers are (there

are no doubt exceptions.)3 Their social skills are generally as good as or better than engineers in

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non-team environments, but their work does not always demand that they practice the kind of intimate,

precise communication and careful subdivisions of tasks that we do.

Non-engineers may be too eager to please and they may be intimidated by you. Just like us, they

may say ‘yes’ without really meaning it to please you or because they are a little scared of you,

and then not stand behind their words.

Non-programmers can understand technical things but they do not have the thing that is so hard

even for us---technical judgment. They do understand how technology works, but they cannot understand

why a certain approach would take three months and another one three days. (After all,

programmers are anecdotally horrible at this kind of estimation as well.) This represents a great

opportunity to synergize with them.

When talking to your team you will, without thinking, use a sort of shorthand, an abbreviated language

that is effective because you will have much shared experience about technology in general

and your product in particular. It takes some effort not to use this shorthand with those that don't

have that shared experience, especially when members of your own team are present. This vocabulary

create a wall between you and those that do not share it, and, even worse, wastes their time.

With your team, the basic assumptions and goals do not need to be restated often, and most conversation

focuses on the details. With outsiders, it must be the other way around. They may not

understand things you take for granted. Since you take them for granted and don't repeat them, you

can leave a conversation with an outsider thinking that you understand each other when really

there is a large misunderstanding. You should assume that you will miscommunicate and watch

carefully to find this miscommunication. Try to get them to summarize or paraphrase what you are

saying to make sure they understand. If you have the opportunity to meet with them often, spend a

little bit of time asking if you you are communicating effectively, and how you can do it better. If

there is a problem in communication, seek to alter your own practices before becoming frustrated

with theirs.

I love working with non-engineers. It provides great opportunities to learn and to teach. You can

often lead by example, in terms of the clarity of your communication. Engineers are trained to

bring order out of chaos, to bring clarity out of confusion, and non-engineers like this about us.

Because we have technical judgment and can usually understand business issues, we can often

find a simple solution to a problem.

Often non-engineers propose solutions that they think will make it easier on us out of kindness and

a desire to do the right thing, when in fact a much better overall solution exists which can only be

seen by synergizing the outsiders view with your technical judgment. I personally like Extreme

Programming because it addresses this inefficiency; by marrying the estimation quickly to the

idea, it makes it easier to find the idea that is the best combination of cost and benefit.

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**Chapter 4. Advanced**

**1. Technological Judgment**

**1.1. How to Tell the Hard From the Impossible**

It is our job to do the hard and discern the impossible. From the point of view of most working

programmers, something is impossible if either it cannot be grown from a simple system or it cannot

be estimated. By this definition what is called research is impossible. A large volume of *mere*

*work* is hard, but not necessarily impossible.

The distinction is not facetious because you may very well be asked to do what is practically impossible,

either from a scientific point of view or a software engineering point of view. It then becomes

your job to help the entrepreneur find a reasonable solution which is merely hard and gets

most of what they wanted. A solution is merely hard when it can be confidently scheduled and the

risks are understood.

It is impossible to satisfy a vague requirement, such as ‘Build a system that will compute the most

attractive hair style and color for any person.’ If the requirement can be made more crisp, it will

often become merely hard, such as ‘Build a system to compute an attractive hair style and color

for a person, allow them to preview it and make changes, and have the customer satisfaction based

on the original styling be so great that we make a lot of money.’ If there is not crisp definition of

success, you will not succeed.

**1.2. How to Utilize Embedded Languages**

Embedding a programming language into a system has an almost erotic fascination to a programmer.

It is one of the most creative acts that can be performed. It makes the system tremendously

powerful. It allows you to exercise your most creative and Promethean skills. It makes the system

into your friend.

The best text editors in the world all have embedded languages. This can be used to the extent that

the intended audience can master the language. Of course, use of the language can be made optional,

as it is in text editors, so that initiates can use it and no one else has to.

I and many other programmers have fallen into the trap of creating special purpose embedded languages.

I fell into it twice. There already exist many languages designed specifically to be embedded

languages. You should think twice before creating a new one.

The real question to ask oneself before embedding a language is: Does this work with or against

the culture of my audience? If you intended audience is exclusively non-programmers, how will it

help? If your intended audience is exclusively programmers, would they prefer an applications

programmers interface (API)? And what language will it be? Programmers don't want to learn a

new language that is narrowly used; but if it meshes with their culture they will not have to spend

much time learning it. It is a joy to create a new language. But we should not let that blind us to

the needs of the user. Unless you have some truly original needs and ideas, why not use an existing

language so that you can leverage the familiarity users already have with it?

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**1.3. Choosing Languages**

The solitary programmer that loves her work (a hacker) can choose the best language for the task.

Most working programmers have very little control of the language they will use. Generally, this

issue is dictated by pointy-haired bosses who are making a political decision, rather than a technological

decision, and lack the courage to promote an unconventional tool even when they know,

often with firsthand knowledge, that the less accepted tool is best. In other cases the very real benefit

of unity among the team, and to some extent with a larger community, precludes choice on the

part of the individual. Often managers are driven by the need to be able to hire programmers with

experience in a given language. No doubt they are serving what they perceive to be the best interests

of the project or company, and must be respected for that. However, I personally believe this

the most wasteful and erroneous common practice you are likely to encounter.

But of course, things are never one-dimensional. Even if a core language is mandated and beyond

your control, it is often the case that tools and other programs can and should be written in a different

language. If a language is to be embedded (and you should always consider it!) the choice

of language will depend a lot on the culture of the users. One should take advantage of this to

serve your company or project by using the best language for the job, and in so doing make work

more interesting.

Programming languages should really be called *notations* in that learning one is not at all as difficult

as learning a natural language. To beginners and to some outsiders ``learning a new language''

seems a daunting task; but after you have three under your belt it's really just a question of becoming

familiar with the available libraries. One tends to think of a large system that has components

in three or four languages as a messy hodgepodge; but I argue that such a system is in many cases

stronger than a one-language system in several ways:

• There is necessarily loose coupling between the components that are written in different notations

(though maybe not clean interfaces),

• You can evolve to a new language/platform easily by rewriting each component individually,

• Its possible that some of the modules are actually up-to-date.

Some of these effects may only be psychological; but psychology matters. In the end the costs of

language tyranny outweigh any advantage that it provides.

**2. Compromising Wisely**

**2.1. How to Fight Schedule Pressure**

Time-to-market pressure is the pressure to deliver a good product quickly. It is good because it reflects

a financial reality, and is healthy up to a point. Schedule pressure is the pressure to deliver

something faster than it can be delivered and it is wasteful, unhealthy, and all too common.

Schedule pressure exists for several reasons. The people who task programmers do not fully appreciate

what a strong work ethic we have and how much fun it is to be a programmer. Perhaps

because they project their own behavior onto us, they believe that asking for it sooner will make

us work harder to get it there sooner. This is probably actually true, but the effect is very small,

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and the damage is very great. Additionally, they have no visibility into what it really takes to produce

software. Not being able to see it, and not be able to create it themselves, the only thing they

can do is see time-to-market pressure and fuss at programmers about it.

The key to fighting schedule pressure is simply to turn it into time-to-market pressure. The way to

do this to give visibility into the relationship between the available labor and the product. Producing

an honest, detailed, and most of all, understandable estimate of all the labor involved is the

best way to do this. It has the added advantage of allowing good management decisions to be

made about possible functionality tradeoffs.

The key insight that the estimate must make plain is that labor is an almost incompressible fluid.

You can't pack more into a span of time anymore than you can pack more water into a container

over and above that container's volume. In a sense, a programmer should never say ‘no’, but rather

to say ‘What will you give up to get that thing you want?’ The effect of producing clear estimates

will be to increase the respect for programmers. This is how other professionals behave. Programmers'

hard work will be visible. Setting an unrealistic schedule will also be painfully obvious to

everyone. Programmers cannot be hoodwinked. It is disrespectful and demoralizing to ask them to

do something unrealistic. Extreme Programming amplifies this and builds a process around it; I

hope that every reader will be lucky enough to use it.

**2.2. How to Understand the User**

It is your duty to understand the user, and to help your boss understand the user. Because the user

is not as intimately involved in the creation of your product as you are, they behave a little differently:

• The user generally makes short pronouncements.

• The user has their own job; they will mainly think of small improvements in your product, not

big improvements.

• The user can't have a vision that represents the complete body of your product users.

It is your duty to give them what they really want, not what they say they want. It is however, better

to propose it to them and get them to agree that your proposal is what they really want before

you begin, but they may not have the vision to do this. Your confidence in your own ideas about

this should vary. You must guard against both arrogance and false modesty in terms of knowing

what the customer really wants. Programmers are trained to design and create. Market researchers

are trained to figure out what people want. These two kinds of people, or two modes of thought in

the same person, working harmoniously together give the best chance of formulating the correct

vision.

The more time you spend with users the better you will be able to understand what will really be

successful. You should try to test your ideas against them as much as you can. You should eat and

drink with them if you can.

Guy Kawasaki[Rules] has emphasized the importance of watching what your users do in addition

to listening to them.

I believe contractors and consultants often have tremendous problems getting their clients to clarify

in their own minds what they really want. If you intend to be a consultant, I suggest you choose

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your clients based on their clear-headedness as well as their pocketbooks.

**2.3. How to Get a Promotion**

To be promoted to a role, act out that role first.

To get promoted to a title, find out what is expected of that title and do that.

To get a pay raise, negotiate armed with information.

If you feel like you are past due for a promotion, talk to your boss about it. Ask them explicitly

what you need to do to get promoted, and try to do it. This sounds trite, but often times your perception

of what you need to do will differ considerably from your boss's. Also this will pin your

boss down in some ways.

Most programmers probably have an exaggerated sense of their relative abilities in some ways-

--after all, we can't all be in the top 10%! However, I have seem some people who were seriously

unappreciated. One cannot expect everyone's evaluation to perfectly match reality at all times, but

I think people are generally moderately fair, with one caveat: you cannot be appreciated without

visibility into your work. Sometimes, do to happenstance or personal habits, someone will not be

noticed much. Working from home a lot or being geographically separated from your team and

boss makes this especially difficult.

**3. Serving Your Team**

**3.1. How to Develop Talent**

Nietschze exaggerated when he said[Stronger]:

What does not destroy me, makes me stronger.

Your greatest responsibility is to your team. You should know each of them well. You should

challenge your team, but not overburden them. You should usually talk to them about the way

they are being stretched. If they buy in to it, they will be well motivated. On each project, or every

other project, try to stretch them in both a way that they suggest and a way that you think will be

good for them. Stretch them not by giving them more work, but by giving them a new skill or better

yet a new role to play on the team.

You should allow people (including yourself) to fail occasionally and should plan for some failure

in your schedule. If there is never any failure, there can be no sense of adventure. If there are not

occasional failures, you are not taking enough risks. When someone fails, you should be as gentle

as you can with them while not treating them as though they had succeeded.

Try to get each team member to buy in and be well motivated. Ask each of them explicitly what

they need to be well-motivated if they are not. You may have to leave them dissatisfied, but you

should know what everybody desires.

You can't give up on someone who is intentionally not carrying their share of the load because of

low morale or dissatisfaction and just let them be slack. You must try to get them well-motivated

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and productive. As long as you have the patience, keep this up. When your patience is exhausted,

fire them. You cannot allow someone who is intentionally working below their level to remain on

the team, since it is not fair to the team.

Make it clear to the strong members of your team that you think they are strong by saying so in

public. Praise should be public and criticism private.

The strong members of the team will naturally have more difficult tasks than the weak members of

the team. This is perfectly natural and nobody will be bothered by it as long as everyone works

hard.

It is an odd fact that is not reflected in salaries that a good programmer is more productive than 10

bad programmers. This creates a strange situation. It will often be true that you could move faster

if your weak programmers would just get out of the way. If you did this you would in fact make

more progress in the short term. However, your tribe would lose some important benefits, namely

the training of the weaker members, the spreading of tribal knowledge, and the ability to recover

from the loss of the strong members. The strong must be gentle in this regard and consider the issue

from all angles.

You can often give the stronger team members challenging, but carefully delineated, tasks.

**3.2. How to Choose What to Work On**

You balance your personal needs against the needs of the team in choosing what aspect of a

project to work on. You should do what you are best at, but try to find a way to stretch yourself

not by taking on more work but by exercising a new skill. Leadership and communication skills

are more important than technical skills. If you are very strong, take on the hardest or riskiest task,

and do it as early as possible in the project to decrease risk.

**3.3. How to Get the Most From Your Teammates**

To get the most from your teammates, develop a good team spirit and try to keep every individual

both personally challenged and personally engaged.

To develop team spirit, corny stuff like logoized clothing and parties are good, but not as good as

personal respect. If everyone respects everyone else, nobody will want to let anybody down. Team

spirit is created when people make sacrifices for the team and think in terms of the good of the

team before their own personal good. As a leader, you can't ask for more than you give yourself in

this respect.

One of the keys to team leadership is to facilitate consensus so that everyone has buy in. This occasionally

means allowing your teammates to be wrong. That is, if it does not harm the project too

much, you must let some of your team do things their own way, based on consensus, even if you

believe with great confidence it is the wrong thing to do. When this happens, don't agree, simply

disagree openly and accept the consensus. Don't sound hurt, or like you're being forced into it,

simply state that you disagree but think the consensus of the team is more important. This will often

cause them to backtrack. Don't insist that they go through with their initial plan if they do

backtrack.

If there is an individual who will not consent after you have discussed the issues from all appropriate

sides, simply assert that you have to make a decision and that is what your decision is. If there

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is a way to judge if your decision will be wrong or if it is later shown to be wrong, switch as

quickly as you can and recognize the persons who were right.

Ask your team, both as a group and individually, what they think would create team spirit and

make for an effective team.

Praise frequently rather than lavishly. Especially praise those who disagree with you when they

are praiseworthy. Praise in public and criticize in private; with one exception: sometimes growth

or the correction of a fault can't be praised without drawing embarrassing attention to the original

fault, so that growth should be praised in private.

**3.4. How to Divide Problems**

It's fun to take a software project and divide it up into tasks that will be performed by individuals.

This should be done early. Sometimes managers like to think that an estimate can be made without

consideration of the individuals that will perform the work. This is impossible since the productivity

of individuals varies so widely. Who has particular knowledge about a component also constantly

changes and can have an order of magnitude effect on performance.

Just as a composer considers the timbre of the instrument that will play a part or the coach of an

athletic team considers the strengths of each player, the experienced team leader will not usually

be able to separate the division of the project into tasks from the team members to which they will

be assigned. This is part of the reason that a high-performing team should not be broken up.

There is a certain danger in this given that people will become bored as they build upon their

strengths and never improve their weaknesses or learn new skills. However, specialization is a

very useful productivity tool when not overused.

**3.5. How to Handle Boring Tasks**

Sometimes it is not possible to avoid boring tasks that are critical to the success of the company or

the project. These tasks can really hurt the morale of those that have to do them. The best technique

for dealing with this is to invoke or promote Larry Wall's programmer's virtue of Laziness.

Try to find some way to get the computer to do the task for you or to help your teammates do this.

Working for a week on a program to do a task that will take a week to do by hand has the great advantage

of being more educational and sometimes more repeatable.

If all else fails, apologize to those who have to do the boring task, but under no circumstances allow

them to do it alone. At a minimum assign a team of two to do the work and promote healthy

teamwork to get the task done.

**3.6. How to Gather Support for a Project**

To gather support for a project, create and communicate a vision that demonstrates real value to

the organization as a whole. Attempt to let others share in your vision creation. This gives them a

reason to support you and gives you the benefit of their ideas. Individually recruit key supporters

for your project. Wherever possible, show, don't tell. If possible, construct a prototype or a

mockup to demonstrate your ideas. A prototype is always powerful but in software it is far superior

to any written description.

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**3.7. How to Grow a System**

The seed of a tree contains the idea of the adult but does not fully realize the form and potency of

the adult. The embryo grows. It becomes larger. It looks more like the adult and has more of the

uses. Eventually it bears fruit. Later, it dies and its body feeds other organisms.

We have the luxury of treating software like that. A bridge is not like that; there is never a baby

bridge, but merely an unfinished bridge. Bridges are a lot simpler than software.

It is good to think of software as growing, because it allows us to make useful progress before we

have a perfect mental image. We can get feedback from users and use that to correct the growth.

Pruning off weak limbs is healthful.

The programmer must design a finished system that can be delivered and used. But the advanced

programmer must do more. You must design a growth path that ends in the finished system. It is

your job to take a germ of an idea and build a path that takes it as smoothly as possible into a useful

artifact.

To do this, you must visualize the end result and communicate it in a way that the engineering

team can get excited about. But you must also communicate to them a path that goes from wherever

they are now to where they want to be with no large leaps. The tree must stay alive the whole

time; it cannot be dead at one point and resurrected later.

This approach is captured in spiral development. Milestones that are never too far apart are used to

mark progress along the path. In the ultra-competitive environment of business, it is best if the

milestones can be released and make money as early as possible, even if they are far away from a

well-designed endpoint. One of the programmer's jobs is to balance the immediate payoff against

future payoff by wisely choosing a growth path expressed in milestones.

The advanced programmer has the triple responsibility of growing software, teams, and persons.

A reader, Rob Hafernik, sent in this comment on this section that I can do no better than to quote

in full:

I think you under-emphasize the importance here. It's not just systems, but algorithms,

user interfaces, data models, and so on. It's absolutely vital as you work

on a large system to have measurable progress toward intermediate goals. Nothing

is as bad as the special horror of getting down to the end and discovering

that the whole thing just isn't going to work (look at the recent debacle of the

Voter News System). I would even go further and state it as a law of nature: no

large, complex system can be implemented from scratch, it can only be evolved

from a simple system to a complex system in a series of intentional steps.

To which one can only reply *Fiat lux*!

**3.8. How to Communicate Well**

To communicate well, you have to recognize how hard it is. It is a skill unto itself. It is made

harder by the fact that the persons with whom you have to communicate are flawed. They do not

work hard at understanding you. They speak poorly and write poorly. They are often overworked

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or bored, and, at a minimum, somewhat focused on their own work rather than the larger issues

you may be addressing. One of the advantages of taking classes and practicing writing, public

speaking, and listening is that if you become good at it you can more readily see where problems

lie and how to correct them.

The programmer is a social animal whose survival depends on communication with her team. The

advanced programmer is a social animal whose satisfaction depends on communication with people

outside her team.

The programmer brings order out of chaos. One interesting way to do this is to initiate a proposal

of some kind outside the team. This can be done in a *strawman* or *white-paper* format or just verbally.

This leadership has the tremendous advantage of setting the terms of the debate. It also exposes

you to criticism, and worse, rejection and neglect. The advanced programmer must be prepared

to accept this, because she has a unique power and therefore a unique responsibility. Entrepreneurs

who are not programmers need programmers to provide leadership in some ways. Programmers

are the part of the bridge between ideas and reality that rests on reality.

I haven't mastered communicating well, but what I'm currently trying is what I think of as a fourpronged

approach: After I have my ideas in order and am fully prepared, I try to speak verbally,

hand people a white-paper (on real paper, as well as electronically) show them a demo, and then

patiently repeat this process. I think a lot of times we are not patient enough in this kind of difficult

communication. You should not be disheartened if your ideas are not immediately accepted. If

you have invested energy in there preparation, no one will think poorly of you for it.

**3.9. How to Tell People Things They Don't Want**

**to Hear**

You will often have to tell people things that will make them uncomfortable. Remember that you

are doing this for a reason. Even if nothing can be done about the problem, you are telling them as

early as possible so they will be well-informed.

The best way to tell someone about a problem is to offer a solution at the same time. The second

best way is to appeal to them for help with the problem. If there is a danger that you won't be believed,

you should gather some support for your assertion.

One of the most unpleasant and common things you will have to say is, ‘The schedule will have to

slip.’ The conscientious programmer hates to say this, but must say it as early as possible. There is

nothing worse than postponing action when a milestone slips, even if the only action is to inform

everyone. In doing this, it is better to do it as a team, at least in spirit, if not physically. You will

want your team's input on both where you stand and what can be done about it, and the team will

have to face the consequences with you.

**3.10. How to Deal with Managerial Myths**

The word myth sometimes means fiction. But it has a deeper connotation. It also means a story of

religious significance that explains the universe and mankind's relationship to it. Managers tend to

forget what they learned as programmers and believe in certain myths. It would be as rude and unsuccessful

to try to convince them these myths are false as to try to disillusion a devoutly religious

person of their beliefs. For that reason, you should recognize these beliefs as myths:

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• More documentation is always better. (They want it, but they don't want you to spend any time

on it.)

• Programmers can be equated. (Programmers vary by an order of magnitude.)

• Resources can be added to a late project to speed it. (The cost of communication with the new

persons is almost always more taxing than helpful.)

• It is possible to estimate software development reliably. (It is not even theoretically possible.)

• Programmers' productivity can be measured in terms of some simple metric, like lines of code.

(If succinctness is power, lines of code are bad, not good.)

If you have an opportunity, you can try to explain these things, but don't feel bad if you have no

success and don't damage your reputation by confronting these myths belligerently. Each of these

myths reinforces the manager's idea that they have some actual control over what is going on. The

truth is that managers facilitate if they are good, and impede if they are bad.

**3.11. How to Deal with Temporary Organizational**

**Chaos**

There are often brief periods of great organizational chaos, such as layoffs, buyouts, ipos, firings,

new hirings, and so on. These are unsettling to everyone, but perhaps a little less unsettling to the

programmer whose personal self-esteem is founded in capacity rather than in position. Organizational

chaos is a great opportunity for programmers to exercise their magic power. I've saved this

for last because it is a deep tribal secret. If you are not a programmer, please stop reading now.

Engineers have the power to create and sustain.

Non-engineers can order people around but, in a typical software company, can create and sustain

nothing without engineers, just as engineers typically cannot sell a product or manage a business

effectively. This power is proof against almost all of the problems associated with temporary organizational

mayhem. When you have it you should ignore the chaos completely and carry on as if

nothing is happening. You may, of course, get fired, but if that happens you can probably get a

new job because of the magic power. More commonly, some stressed-out person who does not

have the magic power will come into your cube and tell you to do something stupid. If you are really

sure that it is stupid, it is best to smile and nod until they go away and then carry on doing

what you know is best for the company.

If you are a leader, tell your people to do the same thing and tell them to ignore what anybody else

tells them. This course of action is the best for you personally, and is the best for your company or

project.

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**Glossary**

This is a glossary of terms as used in this essay. These do not necessarily have a standardized

meaning to other people. Eric S. Raymond has compiled a massive and informative glossary[

HackerDict] that rather surprisingly can pleasurably be read cover-to-cover once you can appreciate

a fraction of it.

boss

The person or entity that gives you tasks. In some cases this

may be the public at large.

bottleneck

The most important limitation in the performance of a system.

A constriction that limits performance.

boxes and arrows

A loose, informal style of making diagrams consiting of boxes

and arrows drawn between those boxes to show the relationships.

This contrast with formal diagram methodologies, such

as UML.

busines

A group of people organized for making money.

buy vs. build

An adjective describing a choice between spending money for

software or writing it your self.

communication languages

A language designed primarily for standardization rather than

execution.

company

A group of people organized reflecting the modern workspace.

divide and conquer

A technique of top-down design and, importantly, of debugging

that is the subdivision of a problem or a mystery into progressively

smaller problems or mysteries.

garbage

Allocated memory that no longer has any useful meaning.

garbage collector

A system for recycling garbage.

entrepreneur

The initiator of projects.

Extreme Programming

A style of programming emphasizing communication with the

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customer and automated testing.

heap allocated

Memory can be said to be heap allocated whenever the mechanism

for freeing it is complicated.

hitting the wall

To run out of a specific resource causing performance to degrade

sharply rather than gradually.

information hiding

A design principle that seeks to keep things independent and

decoupled by using interfaces that expose as little information

as possible.

lingua franca

A language so popular as to be a de facto standard for its field,

as French was for international diplomacy at one time.

logging

The practice of writing a program so that it can produce a configurable

output log describing its execution.

low-hanging fruit

Big improvements that cost little.

master

A unique piece of information from which all cached copies

are derived that serves as the official definition of that data.

memory leak

The unwanted collection of references to objects that prevents

garbage collection (or a bug in the garbage collector or memory

management system!) that causes the program to gradually

increase its memory demands over time.

mere work

Work that requires little creativity and entails little risk. Mere

work can be estimated easily.

object-oriented programming

An programming style emphasizing the the management of

state inside objects.

printlining

The insertion of statements into a program on a strictly temporary

basis that output information about the execution of the

program for the purpose of debugging.

programming notation

A synonym for programming language that emphasizes the

mathematical nature of programming language and their rela-

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tive simplicity compared to natural languages.

scroll blindness

The effect of being unable to find information you need because

it is buried in too much other, less interesting information.

speculative programming

Producing a feature before it is really known if that feature

will be useful.

strawman

A document meant to be the starting point of a technical discussion.

A strawman may lead to a stickman, tinman, woodman,

ironman, etc.

tribe

A group of people you share cultural affinity and loyalty with.

unk-unk

Slang for unknown-unknown. Problems that cannot presently

even be conceptualized that will steal time away from the

project and wreck the schedule.

vapor

Illusory and often deceptive promises of software that is not

yet for sale and, as often as not, will never materialize into

anything solid.

wall-clock

Actual time as measured by a physical clock, such as one on a

wall, as opposed to CPU time.

white-paper

An informative document that is often meant to explain or sell

a product or idea to an audience different than the programmers

of that product or idea.

Glossary

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**Appendix B. History (As Of May,**

**2003)**

**B.1. Request for Feedback or Extension**

Please send me any comments you may have on this essay. I consider all suggestions, many of

which have already improved this essay.

I have placed this essay under the GNU Free Documentation License. This license is not specifically

designed for essays. Essays are usually intended to be coherent and convincing arguments

that are writtien from a single point of view in a single voice. I hope this essay is a short and pleasant

read.

I also hope that it is instructive. Although not a textbook, it is broken into many small sections to

which new sections can be freely added. If so inclined, you are encouraged to expand upon this essay

as you see fit, subject to the provisions of the License.

It may be arrogance to imagine that this document is worthy of extension; but hope springs eternal.

I would be joyous if it were extended in the following ways:

• The addition of a comprehensive reading list to each section,

• The addition of more and better sections,

• Translation into other languages, even if only on a subsection-by-subsection basis, and/or

• Criticism or commentary in-lined into the text.

• The ability to build into different formats, such as palm formats and better HTML.

If you inform me of your work, I will consider it and may include it in subsequent versions that I

produce, subject to the provisions of the License. You may of course produce your own versions

of this document without my knowledge, as explained in the License.

Thank you.

Robert L. Read

**B.2. Original Version**

The original version of this document was begun by Robert L. Read in the year 2000 and first published

electronically at Samizdat Press(http://Samizdat.mines.edu) in 2002. It is dedicated to the

programmers of Hire.com.

After this article was mentioned on Slashdot in 2003, about 75 people sent me email with suggestions

and errata. I appreciate them all. There was a lot of duplication, but the following people ei-

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ther made major suggestions or were the first to find a mistake that I fixed: Morgan McGuire,

David Mason, Tom Moertel, Ninja Programmer (145252) at Slashdot, Ben Vierck, Rob Hafernik,

Mark Howe, Pieter Pareit, Brian Grayson, Zed A. Shaw, Steve Benz, Maksim Ioffe, Andrew Wu,

David Jeschke, and Tom Corcoran.

Finally I would like to thank Christina Vallery, whose editing and proofreading greatly improved

the second draft, and Wayne Allen, who encouraged me to initiate this.

**B.3. Original Author's Bio**

Robert L. Read lives in Austin, Texas, with his wife and two children. He is currently a Principal

Engineer at Hire.com, where he has worked for four years. Prior to that he founded 4R Technology,

which made a scanner-based image analysis quality control tool for the paper industry.

Rob received a PhD from the University of Texas at Austin in 1995 in Computer Science related

to database theory. In 1987 he received a BA in Computer Science from Rice University. He has

been a paid programmer since the age of 16.

History (As Of May, 2003)

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**Appendix C. GNU Free**

**Documentation License**

Version 1.2, November 2002

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