2
The Mythical Man-Month

Restaurant Antoine

Fondé En 1840

AVIS AU PUBLIC

Faire de la bonne cuisine demande un certain temps. Si on vous fait attendre, c'est pour mieux vous servir, et vous plaire.

ENTREES (SUITE)

Côtelettes d'agneau grillées 2.50
Côtelettes d'agneau aux champignons frais 2.75
Filet de boeuf aux champignons frais 4.75
Ris de veau à la financière 2.00
Filet de boeuf nature 3.75
Tournedos Médicis 3.25
Pigeonneaux sauce paradis 3.50
Tournedos sauce béarnaise 3.25
Entrecôte minute 2.75
Filet de boeuf béarnaise 4.00
Tripes à la mode de Caen (commander d'avance) 2.00
Entrecôte marchand de vin 4.00
Côtelettes d'agneau maison d'or 2.75
Côtelettes d'agneau à la parisienne 2.75
Fois de volaille à la brochette 1.50
Tournedos nature 2.75
Filet de boeuf à la hawaïenne 4.00
Tournedos à la hawaïenne 3.25
Tournedos marchand de vin 3.25
Pigeonneaux grillés 3.00
Entrecôte nature 3.75
Châteaubriand (30 minutes) 7.00

LÉGUMES

Epinards sauce crême .60
Chou-fleur au gratin .60
Broccoli sauce hollandaise .80
Asperges fraîches au beurre .90
Pommes de terre au gratin .60
Carottes à la crême .60
Haricots verts au berre .60
Pommes de terre soufflées .60
Petits pois à la française .75

SALADES

Salade Antoine .60
Salade Mirabeau .75
Salade laitue au roquefort .80
Salade de laitue aux tomates .60
Salade de légumes .60
Salade d'anchois 1.00
Fonds d'artichauts Bayard .90
Salade de laitue aux oeufs .60
Tomate frappée à la Jules César .60
Salade de coeur de palmier 1.00
Salade aux pointes d'asperges .60
Avocat à la vinaigrette .60

DESSERTS

Gâteau moka .50
Méringue glacée .60
Crêpes Suzette 1.25
Glace sauce chocolat .60
Fruits de saison à l'eau-de-vie .75
Omelette soufflée à la Jules César (2) 2.00
Omelette Alaska Antoine (2) 2.50
Cerises jubilé 1.25
Crêpes à la gelée .80
Crêpes nature .70
Omelette au rhum 1.10
Glace à la vanille .50
Fraises au kirsch .90
Pêche Melba .60

FROMAGES

Roquefort .50
Camembert .50
Liederkranz .50
Gruyère .50
Fromage à la crême Philadelphie .50

CAFÉ ET THÉ

Café .20
Café brulôt diabolique 1.00
Café au lait .20
Thé glacé .20
Thé .20
Demi-tasse .10

EAUX MINERALES—BIERE—CIGARES—CIGARETTES

White Rock
Vichy
Bière locale
Cliquot Club
Canada Dry
Cigares
Cigarettes

Roy L. Alciatore, Propriétaire

713-717 Rue St. Louis Nouvelle Orléans, Louisiane

2
The Mythical Man-Month

Good cooking takes time. If you are made to wait, it is to serve you better, and to please you.

MENU OF RESTAURANT ANTOINE, NEW ORLEANS

More software projects have gone awry for lack of calendar time than for all other causes combined. Why is this cause of disaster so common?

First, our techniques of estimating are poorly developed. More seriously, they reflect an unvoiced assumption which is quite untrue, i.e., that all will go well.

Second, our estimating techniques fallaciously confuse effort with progress, hiding the assumption that men and months are interchangeable.

Third, because we are uncertain of our estimates, software managers often lack the courteous stubbornness of Antoine's chef.

Fourth, schedule progress is poorly monitored. Techniques proven and routine in other engineering disciplines are considered radical innovations in software engineering.

Fifth, when schedule slippage is recognized, the natural (and traditional) response is to add manpower. Like dousing a fire with gasoline, this makes matters worse, much worse. More fire requires more gasoline, and thus begins a regenerative cycle which ends in disaster.

Schedule monitoring will be the subject of a separate essay. Let us consider other aspects of the problem in more detail.

Optimism

All programmers are optimists. Perhaps this modern sorcery especially attracts those who believe in happy endings and fairy godmothers. Perhaps the hundreds of nitty frustrations drive away all but those who habitually focus on the end goal. Perhaps it is merely that computers are young, programmers are younger, and the young are always optimists. But however the selection process works, the result is indisputable: "This time it will surely run," or "I just found the last bug."

So the first false assumption that underlies the scheduling of systems programming is that *all will go well,* i.e., that *each task will take only as long as it "ought" to take.*

The pervasiveness of optimism among programmers deserves more than a flip analysis. Dorothy Sayers, in her excellent book, *The Mind of the Maker,* divides creative activity into three stages: the idea, the implementation, and the interaction. A book, then, or a computer, or a program comes into existence first as an ideal construct, built outside time and space, but complete in the mind of the author. It is realized in time and space, by pen, ink, and paper, or by wire, silicon, and ferrite. The creation is complete when someone reads the book, uses the computer, or runs the program, thereby interacting with the mind of the maker.

This description, which Miss Sayers uses to illuminate not only human creative activity but also the Christian doctrine of the Trinity, will help us in our present task. For the human makers of things, the incompletenesses and inconsistencies of our ideas become clear only during implementation. Thus it is that writing, experimentation, "working out" are essential disciplines for the theoretician.

In many creative activities the medium of execution is intractable. Lumber splits; paints smear; electrical circuits ring. These physical limitations of the medium constrain the ideas that may be expressed, and they also create unexpected difficulties in the implementation.

Implementation, then, takes time and sweat both because of the physical media and because of the inadequacies of the underlying ideas. We tend to blame the physical media for most of our implementation difficulties; for the media are not "ours" in the way the ideas are, and our pride colors our judgment.

Computer programming, however, creates with an exceedingly tractable medium. The programmer builds from pure thought-stuff: concepts and very flexible representations thereof. Because the medium is tractable, we expect few difficulties in implementation; hence our pervasive optimism. Because our ideas are faulty, we have bugs; hence our optimism is unjustified.

In a single task, the assumption that all will go well has a probabilistic effect on the schedule. It might indeed go as planned, for there is a probability distribution for the delay that will be encountered, and "no delay" has a finite probability. A large programming effort, however, consists of many tasks, some chained end-to-end. The probability that each will go well becomes vanishingly small.

The Man-Month

The second fallacious thought mode is expressed in the very unit of effort used in estimating and scheduling: the man-month. Cost does indeed vary as the product of the number of men and the number of months. Progress does not. *Hence the man-month as a unit for measuring the size of a job is a dangerous and deceptive myth.* It implies that men and months are interchangeable.

Men and months are interchangeable commodities only when a task can be partitioned among many workers *with no communication among them* (Fig. 2.1). This is true of reaping wheat or picking cotton; it is not even approximately true of systems programming.

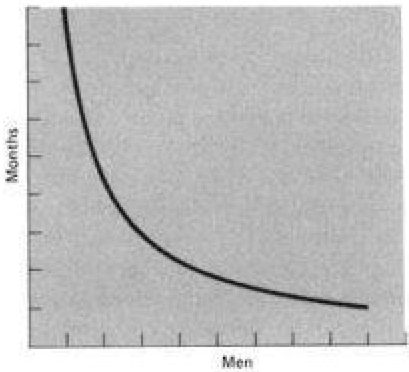

Fig. 2.1 Time versus number of workers—perfectly partitionable task

When a task cannot be partitioned because of sequential constraints, the application of more effort has no effect on the schedule (Fig. 2.2). The bearing of a child takes nine months, no matter how many women are assigned. Many software tasks have this characteristic because of the sequential nature of debugging.

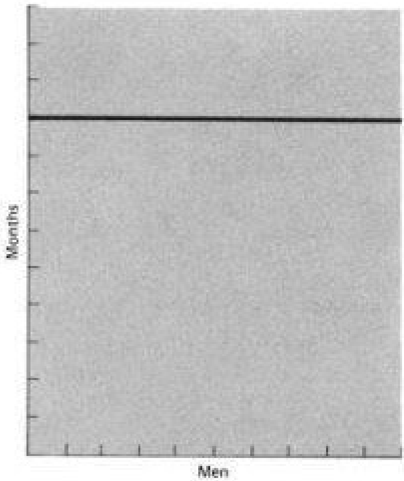

Fig. 2.2 Time versus number of workers—unpartitionable task

In tasks that can be partitioned but which require communication among the subtasks, the effort of communication must be added to the amount of work to be done. Therefore the best that can be done is somewhat poorer than an even trade of men for months (Fig. 2.3).

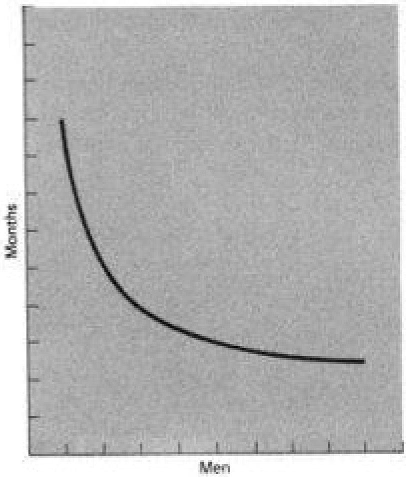

Fig. 2.3 Time versus number of workers—partitionable task requiring communication

The added burden of communication is made up of two parts, training and intercommunication. Each worker must be trained in the technology, the goals of the effort, the overall strategy, and the plan of work. This training cannot be partitioned, so this part of the added effort varies linearly with the number of workers.[1]

Intercommunication is worse. If each part of the task must be separately coordinated with each other part, the effort increases as $n(n-1)/2$. Three workers require three times as much pairwise intercommunication as two; four require six times as much as two. If, moreover, there need to be conferences among three, four, etc., workers to resolve things jointly, matters get worse yet. The added effort of communicating may fully counteract the division of the original task and bring us to the situation of Fig. 2.4.

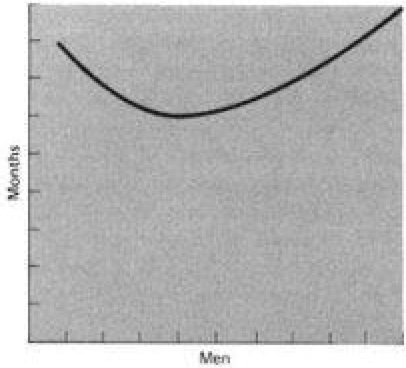

Fig. 2.4 Time versus number of workers—task with complex interrelationships

Since software construction is inherently a systems effort—an exercise in complex interrelationships—communication effort is great, and it quickly dominates the decrease in individual task time brought about by partitioning. Adding more men then lengthens, not shortens, the schedule.

Systems Test

No parts of the schedule are so thoroughly affected by sequential constraints as component debugging and system test. Furthermore, the time required depends on the number and subtlety of the errors encountered. Theoretically this number should be zero. Because of optimism, we usually expect the number of bugs to be smaller than it turns out to be. Therefore testing is usually the most mis-scheduled part of programming.

For some years I have been successfully using the following rule of thumb for scheduling a software task:

⅓ planning
⅙ coding
¼ component test and early system test
¼ system test, all components in hand.

This differs from conventional scheduling in several important ways:

1. The fraction devoted to planning is larger than normal. Even so, it is barely enough to produce a detailed and solid specification, and not enough to include research or exploration of totally new techniques.
2. The *half* of the schedule devoted to debugging of completed code is much larger than normal.
3. The part that is easy to estimate, i.e., coding, is given only one-sixth of the schedule.

In examining conventionally scheduled projects, I have found that few allowed one-half of the projected schedule for testing, but that most did indeed spend half of the actual schedule for that purpose. Many of these were on schedule until and except in system testing.[2]

Failure to allow enough time for system test, in particular, is peculiarly disastrous. Since the delay comes at the end of the schedule, no one is aware of schedule trouble until almost the delivery date. Bad news, late and without warning, is unsettling to customers and to managers.

Furthermore, delay at this point has unusually severe financial, as well as psychological, repercussions. The project is fully staffed, and cost-per-day is maximum. More seriously, the software is to support other business effort (shipping of computers, operation of new facilities, etc.) and the secondary costs of delaying these are very high, for it is almost time for software shipment.

Indeed, these secondary costs may far outweigh all others. It is therefore very important to allow enough system test time in the original schedule.

Gutless Estimating

Observe that for the programmer, as for the chef, the urgency of the patron may govern the scheduled completion of the task, but it cannot govern the actual completion. An omelette, promised in two minutes, may appear to be progressing nicely. But when it has not set in two minutes, the customer has two choices—wait or eat it raw. Software customers have had the same choices.

The cook has another choice; he can turn up the heat. The result is often an omelette nothing can save—burned in one part, raw in another.

Now I do not think software managers have less inherent courage and firmness than chefs, nor than other engineering managers. But false scheduling to match the patron's desired date is much more common in our discipline than elsewhere in engineering. It is very difficult to make a vigorous, plausible, and job-risking defense of an estimate that is derived by no quantitative method, supported by little data, and certified chiefly by the hunches of the managers.

Clearly two solutions are needed. We need to develop and publicize productivity figures, bug-incidence figures, estimating rules, and so on. The whole profession can only profit from sharing such data.

Until estimating is on a sounder basis, individual managers will need to stiffen their backbones and defend their estimates with the assurance that their poor hunches are better than wish-derived estimates.

Regenerative Schedule Disaster

What does one do when an essential software project is behind schedule? Add manpower, naturally. As Figs. 2.1 through 2.4 suggest, this may or may not help.

Let us consider an example.[3] Suppose a task is estimated at 12 man-months and assigned to three men for four months, and that there are measurable mileposts A, B, C, D, which are scheduled to fall at the end of each month (Fig. 2.5).

Now suppose the first milepost is not reached until two months have elapsed (Fig. 2.6). What are the alternatives facing the manager?

1. Assume that the task must be done on time. Assume that only the first part of the task was misestimated, so Fig. 2.6 tells the story accurately. Then 9 man-months of effort remain, and two months, so 4½ men will be needed. Add 2 men to the 3 assigned.
2. Assume that the task must be done on time. Assume that the whole estimate was uniformly low, so that Fig. 2.7 really describes the situation. Then 18 man-months of effort remain, and two months, so 9 men will be needed. Add 6 men to the 3 assigned.

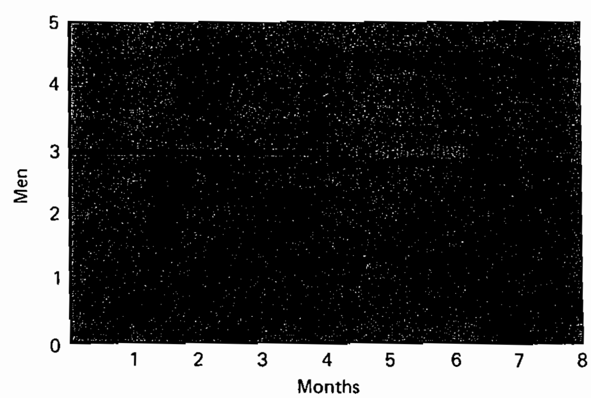

Figure 2.5

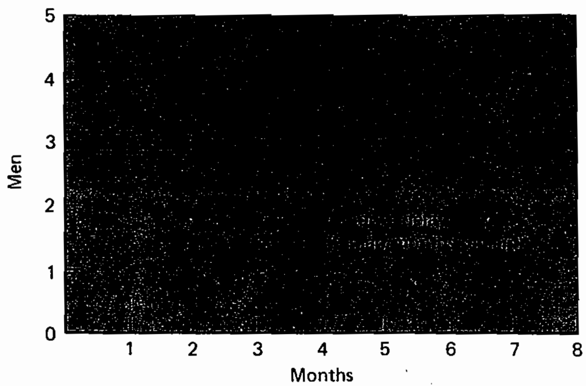

Figure 2.6

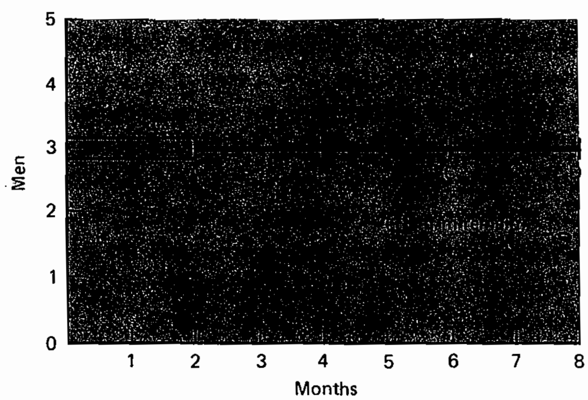

Figure 2.7

3. Reschedule. I like the advice given by P. Fagg, an experienced hardware engineer, "Take no small slips." That is, allow enough time in the new schedule to ensure that the work can be carefully and thoroughly done, and that rescheduling will not have to be done again.
4. Trim the task. In practice this tends to happen anyway, once the team observes schedule slippage. Where the secondary costs of delay are very high, this is the only feasible action. The manager's only alternatives are to trim it formally and carefully, to reschedule, or to watch the task get silently trimmed by hasty design and incomplete testing.

In the first two cases, insisting that the unaltered task be completed in four months is disastrous. Consider the regenerative effects, for example, for the first alternative (Fig. 2.8). The two new men, however competent and however quickly recruited, will require training in the task by one of the experienced men. If this takes a month, *3 man-months will have been devoted to work not in the original estimate.* Furthermore, the task, originally partitioned three ways, must be repartitioned into five parts; hence some work already done will be lost, and system testing must be lengthened. So at the end of the third month, substantially more than 7 man-months of effort remain, and 5 trained people and one month are available. As Fig. 2.8 suggests, the product is just as late as if no one had been added (Fig. 2.6).

To hope to get done in four months, considering only training time and not repartitioning and extra systems test, would require adding 4 men, not 2, at the end of the second month. To cover repartitioning and system test effects, one would have to add still other men. Now, however, one has at least a 7-man team, not a 3-man one; thus such aspects as team organization and task division are different in kind, not merely in degree.

Notice that by the end of the third month things look very black. The March 1 milestone has not been reached in spite of all

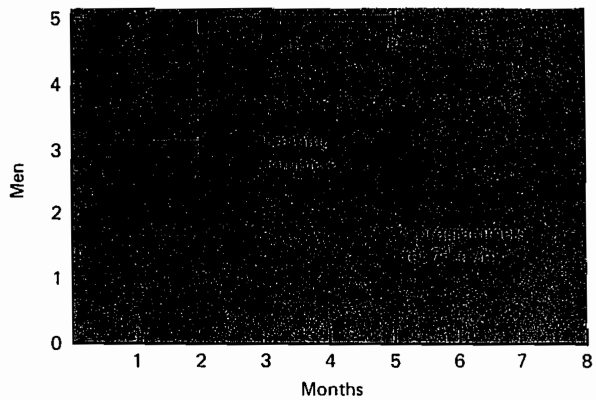

Figure 2.8

the managerial effort. The temptation is very strong to repeat the cycle, adding yet more manpower. Therein lies madness.

The foregoing assumed that only the first milestone was misestimated. If on March 1 one makes the conservative assumption that the whole schedule was optimistic, as Fig. 2.7 depicts, one wants to add 6 men just to the original task. Calculation of the training, repartitioning, system testing effects is left as an exercise for the reader. Without a doubt, the regenerative disaster will yield a poorer product, later, than would rescheduling with the original three men, unaugmented.

Oversimplifying outrageously, we state Brooks's Law:

Adding manpower to a late software project makes it later.

This then is the demythologizing of the man-month. The number of months of a project depends upon its sequential constraints. The maximum number of men depends upon the number of independent subtasks. From these two quantities one can derive schedules using fewer men and more months. (The only risk is product obsolescence.) One cannot, however, get workable schedules using more men and fewer months. More software projects have gone awry for lack of calendar time than for all other causes combined.