Information Coordination:

The Management of Information Models, Systems and Organizations

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Chapter 2: Concepts
Part a: General Concepts

2.1 Introduction

This document is one of a series of extracts from my 1994 book on Information Coordination.

This document contains the first half of chapter 2. It introduces the general concept of coordination, and describes some of the views and models of coordination to be developed further in later chapters.

After attempting to define what coordination is (and isn't), we consider three main theories of how coordination works: hierarchies, markets and networks.

2.2 What is coordination?

Like many concepts (including peace and freedom) it is easier to define coordination negatively rather than positively.

2.2.1 Lack of coordination – the symptoms

Coordination is often invisible, and we can only recognize it in its absence. Thus in an orchestral concert, we may wonder what role the conductor plays, and we could only discover this by trying to do without a conductor. Lack of coordination forces itself on our attention - when you have to wait nearly an hour to change trains because the timetables are not synchronized - when there is no date within the next three months on which all six members of a committee are available for a meeting - when you have to stay in all day because you don't know exactly what time the gasman is coming - when you find that you and your partner have both sent Christmas cards (from both of you) to the same people - when someone makes an arrangement on your behalf, causing you to be double-booked - when an exciting new venture is cancelled in the belief that a key resource is lacking, just as the required resource becomes available elsewhere in the organization - when the repairman brings the wrong replacement - when tactical voting results in the wrong candidate being elected - (the list is endless …). Many people are capable of organizing their lives in a chaotic way - double booking themselves and mislaying important documents - even without any help from anybody else.

> One of the most poignant and elegant examples of lack of coordination is in a story by O. Henry. An impoverished couple, desperate to find Christmas presents for one another. He sells his father's watch to buy combs for her hair; she sells her hair to buy a chain for his watch.

The three most common symptoms of the lack of coordination are waiting, duplication (or waste) of effort or demand, and confusion/misunderstanding. Further consequences may be felt as inefficiency

and lost opportunity. Where successful advancement or investment requires liaison, lack of liaison prevents real or lasting change. These symptoms are summarized in Box 1.

- ***Delay - waiting - work-in-progress***
- ***Duplication - redundancy - overlap***
- ***Confusion - cross purposes - incommensurate data - misunderstanding***
- ***Lost data - gaps - poor utilization of resources - missed opportunities***
- ***Inflexibility - prematurely frozen protocols - obsolete standards - stagnation***

Box 1 Symptoms of the lack of coordination

Although a good organization is robust enough to withstand imperfect coordination, there is a level of coordination below which the organization is no longer viable. This is particularly visible when a new organization is created through merger. A merger has a cost, which is justified in terms of expected synergies, economies of scale, economies of scope, or whatever. Achieving these benefits requires coordination between the merged organizations. If the expected synergy is not realised, this is usually because of unanticipated difficulties in coordination. Incompatible cultures, incompatible systems, incompatible business operations. In the 1980s, a merger between two of the largest building societies in the UK (equivalent to savings and loan institutions in the US) was called off, because the costs of aligning the computer information systems would have been prohibitive.

A romantic liaison between two people can only tolerate so much misunderstanding.

A lack of coordination is sometimes called a **contradiction**. This is not a logical contradiction, but an organizational or social or interpersonal contradiction. The process of coordination can then be thought of as the prevention or (more usually) the removal of contradictions.

2.2.2 Interaction between systems - a biological view

So what is coordination? Let us see if we can develop a positive definition of coordination, instead of a negative definition.

According to K.K. Smith[1], the important issue in the vitality of living systems is not control, as earlier versions of systems thinking emphasized, but dynamic connectedness. It is not an issue of adaption or nonadaption, as Parson [1949] argued. Rather it is the dynamic interplay between adaption and nonadaption. The future belongs to the symbiotic systems. Smith identifies five different levels of interaction:

Positive sum	Communication	Two systems make some inner adjustments to each other, so there is a greater alignment between elements in one and elements in the other. However, these realignments are carried out in such a way that they in no way diminish the total autonomy of each entity.
	Symbiosis	The exchange occurs in such a way that both systems sacrifice a part of their respective individual autonomies so that the superordinate system of which they are part may have greater autonomy in its relationship with other systems in its ecosystem.
	Fusion	The individual entities respond by treating their superordinate systems as all-important and surrender totally their individual autonomies so that the superordinate system will be maximally autonomous in its relationship with other entities of its kind in its larger ecosystem. By the entities giving up their autonomy in the interests of the superordinate system, they undermine their own capacity to continue as autonomous structures. Instead they become reduced to the status of elements in a larger autonomous system.
Zero sum	Parasitic	What one gains is another's loss.
Negative sum	Antibiosis	One, in its self-interest, actively harms the other.

Box 2 Biological coordination jargon: five levels of interaction between systems

We are only really interested in the first three levels, since we are after a positive coordination outcome. We shall see these three levels reappearing later in different guises: as blackbox, greybox and whitebox integration, or as market, network and hierarchical forms of organization; although these concepts are not exactly equivalent, there are useful parallels to be drawn.

The alliances between separate organizations can often be seen in biological terms. Some slime mould cells act independently when it's easy to get food. But when food is scarce, they attract each other and, in the process, develop a way of moving along the ground in search of more favourable feeding places. After arriving at new pastures, they unhook from each other and act individually again, until the next period of scarcity[2]. This is a form of temporary symbiosis. We might see certain strategic alliances between large computer manufacturers in this light.

With his usual whimsical abuse of Greek myth, Freud described these biological forces as a conflict between Eros (Love) and Thanatos (Death). "The goal of the first is to establish at any time larger unities and preserve them. The goal of the second is, on the contrary, to break connexions and destroy things. … In biological functions both basic instincts combine mutually or they act the one against the other."[3]

Kenwyn Smith sees symbiosis in two kinds of human organizations:

> *"One may be characterized by the existence of a central planning center where overall policy for the collectivity is formulated and then passed down to the parts in terms of specific actions for them to take in the service of both themselves and the collectivity. The alternative is a pooling process where the ideas of component groups are raised and then debated as mutual adjustments are made. The U.S. Congress is illustrative of the former while the SALT or START talks between the Soviet Union and the United States are like the latter."*[4]

From the point of view of general systems theory, both of these examples involve a two-level abstract hierarchy, involving the collectivity and the individual. However, we shall find it more useful to refer only to the former example as a proper hierarchy, since it involves control from above, and the latter as a network or confederation.

2.2.3 Coordination between activities

Malone and Crowston define coordination as "the act of working together harmoniously"[5]. They offer a conceptual framework for coordination as requiring four basic components: **actors** performing **activities** directed towards **goals**, with goal-relevant **interdependencies** between the activities.

"For example, an automobile manufacturing company might be thought of as having a set of goals (e.g. producing several different lines of automobiles) and a set of actors (e.g. people) who perform activities that achieve these goals. These activities may have various kinds of interdependencies such as using the same resources (e.g. an assembly line) or needing to be done in a certain order (e.g. a car must usually be designed before it is built)."[6]

They argue that interdependences can be analysed in terms of **common objects** that are involved in some way in both activities. Thus a resource may be a common object; a design blueprint that is communicated from a designing activity to a production activity may also be a common object.

We shall see the crucial importance of common objects in later chapters.

2.2.4 Scope of coordination

All organizations need both internal and external coordination. Internal coordination is between the parts of the organization itself, and the systems directly supporting the organization. External coordination is with other organizations.

For large organizations, the main problems of coordination are internal. As an organization gets larger, the need for internal coordination grows exponentially.

For smaller organizations, the main problems of coordination are external.

A merger between two or more organizations is not instantaneous. Although the legal formalities may be completed at a particular instant, it takes time to become one organization in a practical sense. There is a transition period, which may even start before the legal formalities are completed,

and may continue for a long time after. For months, if not years, the old organizations are still visible.

> British Airways was created in 1974 by a merger of British European Airways (BEA) and British Overseas Airways Corporation (BOAC).
> Two separate cultures are still visible, two decades later.

By organization, we shouldn't think only of traditional enterprises. A joint venture, or participation in a common business, itself creates an implied organization. A franchise operation may include one franchiser and many franchisees: this can be regarded as an organization whose marketing must be coordinated. Many industries have dealer networks, which can likewise be regarded as organizations. Various names have been used to denote different kinds of stable long-term relationships between independent exchange partners, including: cooperative arrangements, relational contracting, joint ventures, quasifirms, global coalitions, and dynamic networks[7].

> When Texas Instruments took ownership of JMA Information Engineering in 1991, the two companies had long since aligned their structures and working methods. Coordination had been prompted by the companies participating jointly in the same business, not by common ownership.

Thus the distinction between internal and external coordination can be blurred, since the boundaries of the organization itself are blurred. What is important is the need for coordination.

2.3 Three theories of coordination: hierarchies, markets and networks

There are three main theories of coordination. These are used by different writers both as descriptive and as prescriptive theories: they may explain how coordination actually happens, or they may recommend how it ought to happen.

In this section, we shall describe the theories in their most general form, without specific reference to information systems. In the following chapter, we shall see how the three theories lead to different approaches to information systems planning. The hierarchical theory leads to top-down planning; the market theory leads to protocol planning; the network theory leads to organic planning.

2.3.1 Hierarchical theory of coordination

A hierarchy is held together by administration, command and control. Each part is precisely defined to perform a specific function. Efficiency in a hierarchy is thought of in terms of the division of

labour. Ideally, each function is carried out by a single part, with no overlaps. Control functions are carried out by additional parts.

If a hierarchy is required to be fault-tolerant, or to allow for maintenance without halting operations, then some redundancy will be required, comprising back-up parts. This (known as **redundancy of parts**) is allowable although it compromises efficiency.

Hierarchies incur what economists refer to as **agency costs**, which has to do with the imperfections of delegation, and the fact that different levels and locations within a hierarchy have divergent goals. Although in theory each manager, at each level of the hierarchy, acts as conscientious and disinterested agent for the manager at the level above, and the top manager acts as agent for the shareholder, in practice each manager adds (or subtracts) something of her own objectives and values to the task, works partly for the organization and partly for herself. Even close supervision (which imposes a burden both on the person being supervised and on the person supervising) cannot entirely eliminate self-interest or occasional laziness.

There are therefore three kinds of agency costs: **monitoring costs**, incurred by each manager who doesn't entirely trust her hierarchical subordinates, **bonding costs**, incurred by each manager who is not entirely trusted by her hierarchical superiors, and **residual loss**, incurred by the organization from not getting full value from the manager, despite monitoring and bonding.

(Obviously there is a trade-off between these three: the more you spend on monitoring and bonding, the less the probable residual loss.)

In addition to agency costs, a hierarchy is subject to **decision costs**. These are the costs of making, communicating and documenting decisions, and the opportunity costs of making poor decisions. (In large organizations, it may take years before these costs come to light.) These costs are summarized in Box 3.

Agency costs:

- ***monitoring costs (incurred by supervisor)***
- ***bonding costs (incurred by supervised)***
- ***residual loss (incurred by organization)***

Decision costs:

- ***information processing costs (communication, documentation)***
- ***opportunity costs (due to poor decisions)***

Box 3 A hierarchy incurs internal coordination costs

In a hierarchical organization, decision-making authority can be centralized or decentralized. As authority is pushed down the organization, upward communication costs are reduced, but with a possible increase in agency costs resulting from the divergence of goals. For each organization, there is an optimal degree of decentralization, being the point at which the total internal coordination costs are minimized.

It is worth noting that effective use of IT can reduce both monitoring/bonding costs and decision processing costs, thus even-handedly favouring greater centralization in some situations and greater decentralization in others[8]. In organizations whose middle management has been entirely devoted to internal coordination, IT can significantly reduce the number of middle managers needed (However, politically adept middle management can usually prevent IT being excessively effective.)

2.3.2 Market theory of coordination

A market is a system of agents, providing products and services to one another. A market is held together by exchange, based on formal contracts.

In economics, a market is defined as **efficient** if no agent has the power to distort the market. Various forms of monopoly are regarded as inefficient, since the monopolist may exact higher prices or degrade the quality of service without redress.

For an engineer, a system of automated agents providing products and services to one another is **robust** if no agent has the power to interrupt or destroy the functioning of the system, and is **efficient** if no agent has the power to distort the system. If an agent has a monopoly on providing a particular essential service, then its failure causes the system to fail, and its inefficiency causes bottle-necks in the system as a whole. Fault-tolerant systems are designed to ensure that no agent has such a monopoly. (This also makes maintenance much easier, because each part is able to be disconnected and replaced, without halting the operating of the system as a whole.)

Markets incur what economists refer to as **transaction costs**, as shown in Box 4. These apply to the operational and contractual costs of supplying and purchasing products and services between independent organizations. (The terms ‘transportation’ and ‘inventory’ need to be understood metaphorically with respect to services.)

Operational costs:

- ***search***
- ***transportation***
- ***inventory holding***
- ***communication***

Contractual costs:

- ***writing contracts***
- ***enforcing contracts***

Box 4 A market incurs external coordination costs

2.3.3 Network theory of coordination

In the broadest sense, a network can be regarded as any system of interconnected parts. In this sense, hierarchies and markets can be regarded as forms of network. However, there is a third form, which is how we intend to use the term 'network' in this book.

Sociologists use the term 'network' to denote a system held together by informal communication, based on trust. It is a 'flat' organizational form, in contrast to the 'vertical' organizational form of the hierarchical form. Fashion in management theory favours network over hierarchical forms, at least for human organizations.

You might think that machines cannot communicate informally. Computerized information systems are formal by definition, and so the idea of informal links between systems would be nonsense. How can a machine trust another machine?

But if a machine leans on another machine, relies on its robustness and integrity, depends on the internal structure of another machine, this could be regarded (metaphorically) as a form of trust. When we say that machine A 'trusts' machine B, this is perhaps just a shorthand way of saying that the designers of machine A trusted machine B (or its designers). Trust is 'inherited' by the machine from the designers.

Membership costs:

- ***establishing trust***
- ***breaches of trust (failure)***

Exclusion costs:

- ***lost opportunities***

Box 5 A network incurs both internal and external coordination costs

So for the purposes of this book, we shall use the term 'network' to refer to a tightly linked flat structure, in contrast to a 'market', which is an open structure.

Nearly coordinated networks

In parts of the City of London, as in many other cities, there are overhead walkways that cross over roads, pass through buildings, and enable pedestrians to get quickly and safely from A to B.

These walkways have been extended over the years; starting from the Barbican development, each new adjacent building has added to the walkway network.

If all the walkways in a network had to be at exactly the same level, this would place extreme restrictions on the architects, and make it impossible to link two networks together. To overcome this, the network includes some gentle slopes, and the occasional stair. But if the network is riddled with stairs, so that a person walking from A to B is constantly having to ascend and descend, this will greatly reduce the advantage of the walkways over walking at street level. And of course, people in wheelchairs need at least one route - not necessarily the shortest - that doesn't include stairs at all.

To achieve this, it is necessary to ensure that each walkway, if not at exactly the same level as the walkways on all other buildings, is at least at a similar level to its neighbours. This allows for gradual gradients, which may be necessary if the ground itself slopes. This is **near coordination**, as opposed to total coordination. It is clearly a network solution, since it is not centrally planned, and extends itself through piecemeal activity in a complex and unpredictable manner.

2.3.4 Comparison of the three theories of coordination

As we have seen, hierarchies and markets incur different kinds of costs: agency costs and transaction costs. IT can be used to reduce both[9]. Sometimes a hierarchy will be the more cost-effective form of coordination; sometimes a market will be more cost-effective; sometimes IT will tilt the balance

one way, sometimes the other. Networks can be highly efficient, but because they are not open, they can be vulnerable to corruption.

The transaction costs associated with markets are those of writing, executing and enforcing contracts. Williamson[10] identified three factors that influence these costs: (i) uncertainty, (ii) asset specificity, and (iii) frequency. These factors translate into 'make-or-buy' decisions: whether it is better to provide a service from within the organization, with hierarchical coordination, or from outside the organization, with market coordination.

In systems, the same principles apply: is it easier to perform a function internally, or to call an external (reusable) module.

In practice, most organizations combine all three modes of coordination in complex ways. Thus for example, a regulated market consists of a basic market with an administrative (i.e. hierarchical) superstructure to impose controls. Most commercial organizations are divided into cost centres or profit centres, allowing certain limited market transactions between them. Complex market transactions may need to be based on trust as well as formal contracts, since the cost of agreeing a complete and legally watertight specification of a complex product or service can often be prohibitive.

Quality management systems (including those following the international standard ISO 9000) recognize that the quality of software products & services delivered by a systems development project cannot always be determined by inspection or functional check alone; verification may be required throughout the development process. This means that the relationship between the purchaser and supplier of software needs to involve some level of trust and mutual collaboration, and cannot be simply a market-driven commodity transaction.

2.4 Limits to coordination

This book adopts the pragmatic view that total coordination is neither possible nor desirable.

This view is not universally accepted. Ultra-liberals such as von Hayek believe that a perfect market is possible. Stalinists used to believe that a perfect hierarchy was possible, allowing total coordination by central planning; Hitler tried to implement the teutonic concept of Gleichschaltung, which implied total synchronization of German society through technology, metaphorically linking all society to the same grid, the same source of electricity.

> That Hitler and Stalin were in favour of total coordination is not itself an argument against it. After all, Hitler was a vegetarian, but that is not a good reason to eat meat.

The idea that technology will enable or impose coordination that had not been possible by political action alone is a surprisingly popular one. Many thinkers fall into the category of **hedgehog**, derived by Isaiah Berlin from a fragment of ancient poetry (a hedgehog is a person who knows one big thing, contrasted with a fox who knows many small things). Hedgehogs "relate everything to a

single central vision, one system less or more coherent or articulate, in terms of which they understand, think and feel - a single, universal, organizing principle in terms of which alone all that they are and say has significance"[11]. For the hedgehog, everything can and should be managed and coordinated by this principle, which is elevated to religious or ideological status

> "Fox knows many
> Hedgehog one
> Solid Trick"
> Archilochus (7th Century BCE)

The hedgehog also knows that we all have the same basic goals. All people and organizations want to survive, although they may adopt different strategies. We all need the same things, and we all have the same underlying values, although there may be superficial differences in how these manifest themselves in behaviour.

However the pragmatic view, that total coordination is neither possible nor desirable, seems to be gaining ground, as evidenced by the collapse of central planning in the communist block, and by the move away from 'ivory-tower' strategic planning in large capitalist enterprises. The Catholic doctrine of 'subsidiarity' has been extended to fix the principle of decentralized planning and decision-making into international agreements.

There are four main reasons why total coordination is not practically possible:

1 An organization is made up of parts with different (although overlapping) purposes and objectives.

2 Parts of an organization may deploy different, and perhaps even competing methods and conceptual apparatuses to calculate, rank and measure their objectives, and to undertake their activities. Indeed, some parts of the same organization may be locally structured as hierarchies, others as networks.

3 Coordination mechanisms incur some cost; there is a level of coordination at which the additional cost of further coordination outweighs the additional benefits.

4 Stable evolution of a system or organization often requires the possibility of one part to change in advance of other parts. Even if it were possible, total coordination may degrade and fragment over time, thanks to external forces.

5 Although coordination is supposed to be an antidote to chaos, there are circumstances where excessive coordination itself actually causes turbulence and chaos.

2.4.1 Different objectives

In a market, each of the actors is presumed to be acting out of self-interest. Their goals therefore conflict.

Even in a hierarchy, there will often be different opinions and interpretations about the corporate goals. Two designers on a project may have strongly opposed opinions about the design priorities.

We referred above to the concept of a **fox** as a person who knows many little things. Foxes are "those who pursue many ends, often unrelated and even contradictory, connected, if at all, only in some *de facto* way, for some psychological or physiological cause, related by no moral or æsthetic principle. [They] lead lives, perform acts, and entertain ideas that are centrifugal rather than centripetal, their thought is scattered or diffused, moving on many levels, seizing upon the essence of a vast variety of experiences and objects for what they are in themselves, without, consciously or unconsciously, seeking to fit them into, or exclude them from, any one unchanging, all-embracing, sometimes self-contradictory and incomplete, at times fanatical, unitary inner vision."[12]

The fox knows that we all have different motives and goals. Some organizations may want to increase profit, to replace human workers with machines; other organizations may want to grow, to create employment for human workers; other organizations may want to survive, or contribute to broader social goals. Indeed, many organizations set conflicting objectives at the highest level: e.g. growth and profit, in situations where long-term growth can only be achieved by sacrificing short-term profit.

In a large public utility company, operating in different regions, each region had differing requirements from the customer accounting system. One region had a rapidly shifting population and needed facilities within the system to track customers and support debt control. This was of no benefit to other regions, who wanted to minimize workload of customer record maintenance.

2.4.2 Different concepts and methods

Different specializations

Within an organization, there will necessarily be some division of intellectual labour. Not everyone needs to be familiar with the details of accounting practice, or with employment legislation; not everyone needs to know the detailed engineering design of a product, or the exact readership profiles of the magazines in which the company advertises.

Different specializations usually deploy different jargons, and different measurement principles. For communication across specializations, one of the following is required:

1 Overlap between jargons

2 Specialists in more than one area, who speak two or more jargons and can translate between them

3 Ability of specialists to communicate in plain language when talking outside their specialist domain.

However, it would be a serious constraint on specialists if the occasional need to communicate outside their specialist domain prevented them from using jargon at all. Specialist jargon is

developed not just for elitist secrecy and ego, but also for accuracy and reliability. Would you want to fly in an aeroplane that had been designed in language so simple that even the non-executive directors of the aerospace company could understand the blueprints?

Therefore, there will sometimes be a need to communicate between members of the same specialization, or for specialists to store and retrieve information in a form that is perhaps incomprehensible or uninteresting to members of other specializations.

> Two descriptions are better than one

Integration and consistency means you only have a single unified view of the world. This is of course dangerous when this view is wrong. But even when it is correct, it may be limiting. Multiple descriptions aid calibration, allow cross-checking and learning, bring new patterns into the fore.

> Two loudspeakers are needed to hear stereo. Two eyes are needed to see in three dimensions. Mystics claim to see with the 'third eye', hear with the 'third ear'.

Example: the Zeta Corporation used three or four different distribution channels. Given identical data, each division calculated which channel was the cheapest, and all came to the same conclusion. The other channels were therefore closed down. This may have been the most efficient solution for the Zeta Corporation in the short term, but led to inflexibility and vulnerability in the longer term. When the chosen channel became more expensive, it proved hard to reestablish the others.

2.4.3 Cost of coordination

We have already seen that the different forms of organization, the different coordination mechanisms, all incur costs and risks of one kind or another.

It follows that, at some point, the benefits of coordination are outweighed by the costs and risks.

One of the paradoxes of bureaucracy is that, although each separate attempt at coordination may appear to be rationally justified, the benefits are not additive. If this is ignored, an organization can easily extend its attempts at coordination beyond what can be rationally justified. For each person doing real work, there are several others trying to coordinate her. It would be unfair to name any of the many many organizations, both public and private sector, which commit this collective error.

Of course, the costs and benefits of coordination change over time. Consider the different patterns of television viewing in affluent families during the past few decades. In the 1960s, a lucky family might have one television set, and was therefore required to coordinate its viewing. Everybody had to watch the same programme at the same time; if two viewing requirements conflicted, a choice had to be made.

By 1990, it has become common in the OECD countries for a middle-class household to possess several television sets, and one or two video recorders. Advances in technology have made it

unnecessary for these affluent households to make difficult choices. This is not an unusual pattern: although technology can sometimes make coordination easier, at other times it can make coordination irrelevant or unnecessary.

Note that this change also required a change in social attitudes. In the 1960s, though some families could easily have afforded another television set, it was thought that viewing ought to be a shared experience, and that even when clashes of programme caused arguments, this was an essential and healthy part of the family bonding process. By 1990, this thought had been abandoned, and the family had transformed into the household: an uncoordinated set of consumers occupying the same house. Some people might moralize and generalize from this example, to argue that the process of coordination itself has human value, in addition to the direct benefits from coordination. However, the same argument can be applied in reverse, since the process of liberation from coordination is also thought to be valuable in its own right. Within industry, the dilemma of liberation or coordination (alias solidarity) generates bitter arguments for and against syndicalism and trades unions: since many old-fashioned syndicalists believe that worker solidarity is a good thing in itself. Collective wage bargaining is a form of coordination (either hierarchical or networked) that has attracted orchestrated political criticism from those who believe it conflicts with the requirements of market coordination.

2.4.4 Stability and progress

Robust systems survive by absorbing fluctuations. The tighter the structure, the less permissible are fluctuations within the systems, therefore the greater the probability that fluctuation will provide a threat to that structure.

Furthermore, productive change is inhibited. If hundreds of small pieces have to be altered simultaneously, in order to make progress, such progress may never happen, or may be postponed until it is too late.

Organizational change and renewal therefore thrive on a tension between order and disorder. In a classic paper, Hedberg, Nystrom & Starbuck propose several aphorisms for the Learning Company, of which two are particularly relevant here[13]:

- Cooperation requires minimum consensus.

- Improvement depends upon minimum consistency.

2.4.5 Turbulence

Turbulence is a phenomenon that has been studied since Leonardo da Vinci, and is only now starting to be understood. Turbulence means unpredictable fluctuations in the behaviour of a system. We see the chaos in fast-flowing streams, and we feel the bumps when we fly through storms. A storm is a piece of turbulence in the global weather system. Turbulence can also be found in commodity or stock market prices, or in complex ecological systems.

Large highly interconnected networks of systems are found to be vulnerable to intermittent and unpredictable bursts of chaos. This effect has been found by both TRW and Xerox in different computer configurations. The effect has also been produced by Japanese scientists within superconducting switches. There appears to be nothing wrong with the design of these systems; the problem appears to be something inherent in the complexity of networks when they contain feedback loops of a certain kind; mathematicians refer to this property as **non-linearity**[14].

Although this effect is not fully understood, it seems that this turbulence can only be avoided by isolating subsystems from one another, rather than linking them all together. This therefore provides another argument against total coordination; the analysis of non-linearity giving us a mathematical explanation of the ancient Greek concept of **hubris** and the more recent concept of Murphy's Law.

Computer models for economic predictions are vulnerable to this turbulence. The more complex the models become, the more parameters and factors are added to increase accuracy, paradoxically the less reliable they seem to become.

2.4.6 Conclusions

This section has argued that total coordination is not feasible or desirable. The remainder of the book will assume that coordination is sometimes a good thing, but should not be elevated above all other goals, not taken to inappropriate extremes. One of the most difficult aspects of managing coordination is knowing where to stop coordinating.

(Technocrats may think this is not a problem; you just do as much as you are allowed to, since that will never be enough. But this is not a book solely for technocrats. It is a book for responsible managers as well.)

Notes

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[3] S. Freud, Abriß der Psychoanalyse (1938)

[4] K.K. Smith, op cit

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[10] O.E. Williamson, *Markets and Hierarchies: Analysis and Anti-Trust Implications* (New York: Free Press, 1975)

[11] I. Berlin, *The Hedgehog and the Fox* (London: Weidenfeld & Nicholson, 1953) His list of hedgehogs includes: Dante, Plato, Lucretius, Pascal, Hegel, Dostoevsky, Nietzsche, Ibsen and Proust.

[12] I. Berlin, *The Hedgehog and the Fox* (London: Weidenfeld & Nicholson, 1953) His list of foxes includes: Shakespeare, Herodotus, Aristotle, Montaigne, Erasmus, Molière, Goethe, Pushkin, Balzac and Joyce.

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