**CYBERNETICS OF NATIONAL DEVELOPMENT
EVOLVED FROM WORK IN CHILE**

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I am deeply happy to be here with you, and to deliver this Zaheer Science Foundation inaugural lecture. You may well know the immortal words of the Aprocrypha, written in the book of Ecclesiasticus which says in part: 'Let us now praise famous men … giving counsel by their understanding, such as have brought tidings in prophecies: Leaders of the people by their counsels… wise were their words in their instructions… All these were honoured in their generations, and were a glory in their days.

These are very proper sentiments. The human mind has a deep need to focus its perceptions, its understandings and its aspirations if it is not to be lost in a welter of information, argumentation, and finally confusion. Our famous men help us do this even after their deaths. Thus, in the first place you and I would not be here today – to do some joint and serious thinking – if it were not that we have convened to honour a great man in this Zaheer Lecture.

The second famous man, who must be in our minds, is the founding father of cybernetics - the late ==Norbert Weiner. He defined cybernetics 'the science of control and communication, in the animal and the machine'. As you perhaps know the word cybernetics is the Greek name for 'Steersmanship'.== And in his definition, Norbert Wiener was pointing to the facts: firstly that pattern of information exclusively defines whatever regulation exists and secondly, that the laws that govern such regulation are general laws as, given in, nature that applies to living systems and to artefacts alike.

==This is a most important discovery for the western culture, since the dichotomy between the animate and the inanimate worlds has lasted from Aristotle till the present day - when it continues to pervert our insight into the nature of reality.== But if I have at all understood ==the Indian culture (which I have done my best to study for nearly 30 years) no such disharmony exists for you.== Then may I hope that India will not import philosophic rubbish from the West along with its material advance - so many of which alas turn into rubbish too.

The third of the famous men to whom I so proudly refer, is Salvador Allende, the last democratic president off Chile. I had the privilege - to serve him for two years, until his diabolical assassination, and the overthrow of the liberty of his beloved people. And here is a strange link which I embody between this room and Santiago half the world away. Night after night, at two or three o'clock in the, morning, I would walk out in Santiago to a special shrine dedicated to India. I would sit and meditate by a little pool where, sat in

stone Gandhiji, flanked by Nehru and Tagore? So that - along with famous men - I might indeed focus my mind.

THE CHILEAN PROCESS

Then now I ask you to join me in focusing on what everyone called, until a year ago, the Chilean Process. There is, in that expression, an acknowledgement that this society was - a SYSTEM a system moreover in continuous evolution, based on learning and adaptation, Put in such neutral, scientific language the idea sounds – banal. Yet it is not banal. For if we ask the question: are not all societies inevitably of this kind, the answer is no - even though we would like them to be and although they may not survive if they are not. The answer is 'no' today in Britain; the answer can be sought in today's Chile.

Here then is our focus, on the qualities of survival systems such as societies should be. And if society is a system, then let us recognize at once that those qualities conductive to survival is systematic, which is to say that they are intrinsic to the society's system. They cannot be imposed upon it by ruling elites or by dictators. If we look, at societies in which ruling classes have been dominant, it is not society itself that survives but the ruling classes themselves; and the people starve. If we look at societies run by dictators, it is not society itself that survives, but the dictators and their henchmen; and the people are oppressed

The insight emerges through a quotation of which I am very fond. It says: 'In reality, action is entirely the outcome of all the modes of nature's, attributes, moreover, only he whose intellect is deluded by egotism is so ignorant, that he presumes- 'I am doing this?' (*Main Karta Hoon* - Hindi). Of course that comes from the *Bhagvad Gita.* And if I have got the translation right, for I confess that it is my own. It tells us that the output of a complex probabilistic system (such as a society) is a function of a self-regulating, self organizing organization with high input variety, in which regulatory power is not vested in a 'controller' but in the structure of that organization itself. This pray, believe me is the key discovery of modern cybernetics. It is just because of the Gita, it comes roughly 5000 years to late to win a prize.

Salvador Allende knew this very well. He had come upon it through contemplation of the Marxist dialectic - which is it self a powerful if cybernetic device with which to think. At any rate, when I first displayed to him the basic model of —organisation that I use, he had the point rather more clear than I had myself. For this is a neuro-cybernetic model, and Allende was a physician. There are five sub-systems in my model and the one at the top is the cerebral cortex itself. Now although we think of the cortex as the cynosure of man's superiority over other animals, it is still very much part of the total bodily system. If we cut the ascending sensory pathways, the cortex does nothing at all. If we cut the collateral fibres arising from the ascending reticular formation of the brain stem, the cortex cannot wake up. And if the cortex looses its blood supply, it dies of lack of oxygen, in a few minutes.

Therefore I ought to have better than to say to Allende the fifth top subsystem represented the Companoro Presidente himself. But this I intended to do fortunately, he saved me from making such a fool of myself. As I drew in the top subsystem, number five, on the paper lying between us, he smiled with joy and said, 'At last: the people'.

I tell you this story for two reasons. I observe a monstrous campaign in the world's press, with a few honourable exceptions to rewrite even such History as this. The new mythology declares that Allende was a would-be dictator, intent on overthrowing a democracy and planning to establish a totalitarian state. I have a duty to say that such a mythology has no meaning within my own perception of the man or of his administration. It is a cover story: and you know whom it covers. The second reason concerns, with humility my own work for Allende - which has in turn been vilified as centralist, technocratic and totalitarian. I would ask you to remember this anecdote, which much affected me, as you listen to my explanation of the development of systems that were intended to be devolutionary, popular and pluralistic.

ON TECHNICAL AID AND THE CHILEAN SCENE

When the question of my going to Chile arose, I was already highly critical of the process known as - 'granting aid' to developing countries. With what condescension do visiting experts arrive to explain to the 'natives' what they ought to do, and then depart, leaving the local people to obey the bureaucratic rules - if they want the money. (This sort of thing is not aid: it is technocratic imperialism. And what is more, it does not work. The arrangements for Chile, finally agreed in London in September 1971, were quite different. They worked out very well.

During the summer of 1971, a team was formed in Santiago consisting of some dozen; scientists. All of thorn had studied cybernetics, and were doing so now the more intensively. I spent that summer in England, clearing other jobs out of the way, and studying Chile. Within an hour of my arrival in Santiago on 1^{st}November, we were at work. In two week's non stop activity we prepared our basic plans, which were approved; by the president on the final day. The business had begun.

As scientific director, I worked alongside a Chilean minister, with a budget approved by him. There were shortages of expertise of various kinds. Therefore, I subcontracted work to two teams of scientists in Britain, and subcontract the building of certain equipment to two firms in Britain. For the next two years I flew ten times from London to Santiago, and ten times back. But although the budget, which included my salary, had been settled, the Chilean Government decided to apply to the British Government for a grant of technical aid – in order, if possible, to reimburse itself. After all a substantial part of the budget was being spent in England on the four subcontracts, and on me. The application was filed early in 1972. A British official, eventually called on me to ascertain the facts. It was one week after the coupde'tat. Allende was dead the work was over.

Then how did it begin? We were faced with a situation in -which most of major industry had been taken under state owner ship. The old owners and managers had left. They had not, for the most part, trained their Chilean subordinates, and many Chilean - professionals (who wore trained) left too, for these were the days of the terror campaign which said that Allende intended to trans-shipment of Chilean babies to Cuba. Often these people had taken the entire documentation of their companies with them. Firms were in the hands of worker's committees, headed by an Interventor - that is - someone appointed by the government to sort things out. These committees knew nothing about modern management techniques, and nothing about theories of cost and prices, which

were in any case- irrelevant to them. Their Job was to keep the Chilean social - industrial economy moving, in terms of product flow, and this they were highly motivated to do.

Now Chile is a long, thin country. Although it is only about a hundred miles wide, it is- nearly three thousand miles long. Santiago is in the middle, and around it laid a great deal of the engineering industry. Due west on the coast, lies the second largest, city - the port of Valparaiso. South of this is the centre of iron and steel industry. The climate in the middle belt is idyllic, further south-still, it is extremely wet. Pine trees grow twenty times as fast as- they grow in Scandinavia, and this is the homo of the forest products industry: wood, wood pulp, paper. To the north of this middle belt is desert where nothing lives, until we reach the cluster of cities that evolved around the nitrate industry, and the largest copper mines in the world.

I had already made play with the cybernetic theorem that shows how regulation depends upon information. In any industrial economy such as this, government is faced with two main problems. What exactly is going on in all those plants? Secondly how quickly will we know about today's results? In heavily industrialized societies, a lot is known about what is going on, but the knowledge is of a highly complex nature. Moreover, this knowledge is vested partly in the bureaucracy, and partly in the business press, both of these customarily distort that knowledge for their own reasons. As to the speed with which government can be apprised of movements in the economy, it is notorious that such statistics are six months or more out of date. Therefore, a lot of effort, and therefore, a lot of   money going into the financing of econometric studios that try to offset the time lags implicit in the system. But they do not work and the governments of advanced industrial societies are forever reaching precisely the wrong decisions as to taking money out of the economy or putting it in, for instance.

Then surely this is where to apply our scientific knowledge and our technological skill. I was appalled, when I first arrived in Chile, to find the whole middle class of this beautiful country already hold tight in the grip of consumerism, so that the worth of life was already to be measured in terms of cars, television sots and refrigerators. The devastation wrought in the quality of life in the advanced industrial countries by such use of science and technology is plain to see. Do developing countries really wish to follow the same road? Only the people themselves are entitled to answer this question but they need the full facts. And certainly people everywhere are entitled to use the intellectual inheritance of mankind that includes science and technology, to whatever ends they wish.

The frightening aspects of technical aid lie in the bland assumption that good technical solutions to perennial human difficulties have already been found which is demonstrably untrue. That where some solutions do look satisfactory, they can be transplanted wholesale into alien cultures by the mere investment of money and that the rich world, because, it has made that investment is entitled to treat the poor world as a so called 'expanding market' to be ravaged in search of profits to food its concept of limitless growth on a finite planet. We have in honesty to note that the whole process as in the case of Chile incredibly turns the poor country into a net importer of wealth to the rich country. This must be wrong. Injustice in the form of gross inequalities across the world is already shameful enough.

PROJECT SYBERSEN

The main proportion of the effort we made in Chile was to install a regulatory system for the social economy. The project aimed to acquire the benefits of cybernetic synergy for the whole of industry, while devolving power to the workers at the same time. It is called Project Sybersyn.

Thanks to the way in which the whole world of government discusses those matters, there appears to be a straight conflict between centralization and decentralization. That is to say, people hold a model in their heads that has a single scalar variable called 'percentage centrality' on which a point must be fixed. I reject this model completely, because neurocybernetics - shows that so simplistic a concept is useless to account for viable behaviour. We need a model that is not a scale at all, but a structured space. In this, there is a horizontal dimensionality, listing (like the lines of print on a page) all sorts of activities that are in principle free to do anything they like. And there is a vertical dimensionality, representing authority that is in principle capable of stopping the horizontal activity from doing what it likes.

In this space we may precisely the nature of autonomy. We may measure variety (which is defined as a possible number of states of a system for any horizontal component in the space. We may then measure the variety subtracted from this first variety by interventions on the vertical plane. If, in a given case, almost the whole horizontal variety we're left intact, then this situation will correspond to the simplistic notion of decentralization; the simplistic notion of centralisation would correspond to the subtraction of most of the horizontal variety. Using this model, we are now able to define autonomy, whose social name is freedom.

Definition: If a system regulates itself by subtracting at all times as little horizontal variety as is necessary to maintain the cohesion of the total 'system' then the condition of autonomy prevails.

Now we can see why the scalar centralisation-decentralization model does not work. Our definition entails two features that cannot be represented on the scales. Firstly, intervention will prove to be selective as between horizontal components, and secondly both its selections and the amount of variety abstracted will continually change. In both cases this is because intervention is responding to a criterion of overall cohesions which is itself a variable responding fro the degree of pressure exerted on the total system to blow it apart. In times of great stress, there will be more net intervention; this is the 'self - organising property of the system.

In the Chilean situation, the basic horizontal components were all the enterprises of the social economy. But the enterprises wore grouped into industries. Now all industry, such as textiles, encompasses many textile firms. The relationship of an industry to its component firms is of course, a vertical component of our model. And yet there are many industries, and they are: horizontal components of the economy. Thus we reach the important cybernetic concept of definition by recursion. (I use the word in the exact sense defined by Recursive Number Theory).

Enterprises are horizontal components of an industry itself conceived as a vertical component. Now advance a level of recursion. Here there are industries- as horizontal components, and something called a branch of industry (such as 'light' or 'heavy') is the vertical component. Advance to the next level of recursion. The branches are now horizontal components, and the vertical component is total industry itself. (At a further

level of recursion, industry joins agriculture, transportation, health, education, and so on, as a horizontal component of something called the economy).

The conceptual modelling is not just fun and games. I mentioned earlier that I went to Chile armed with a basic model of organisation, based on neurocybernetics. Then the point of definition by recursion is this. We can apply exactly the same model at every level of recursion, to each of the four industrial branches; at the next level of recursion, to each of the enterprises in each industry. That adds up to a huge number of models. But they are all the same. They nest inside each other; and they are linked "by" the definition of autonomy, which is guaranteed for each level of recursion by the one above.

Those concepts have to be understood before anyone could possibly believe what was accomplished in Chile in less than two years. Because we used the same neurocybernetic model everywhere, we could standardise our procedures of communications, menstruation, filtration, exposition. Above all, we were able to prepare a single, vast, expensive computer programme to operate everywhere, at every level of recursion. I shall discuss that later.

Then let me return now to the two problems identified as critical just now. What exactly is going on? How quickly shall we know today's results?

We trained, a number of operational research teams in the use of the neurocybernetic model, and sent them right through industry. Guided by the model and constrained by its conventions, their task was to discover the detailed content of operations at all levels of recursions. This meant making a new sort of model, in order to express this content uniquely for each enterprise, each industry. Remember that we were dealing, except in the ease of primary industries such as steel and energy with worker's committees; and that, in any case, we adhered to a political decision to transfer power to the workers. Then the standard techniques - would not help. Workers do not understand input-output analysis, or linear programming. Instead, we developed the notion of a quantified flow chart. This depicts the operations under review as a systems diagram, in which the operations themselves are boxes whoso relative size quantifies their relative roles and in width of the lines of flow quantifies; the amount of flow. Such diagrams portray quite vividly the nature of the plant, and no one is more qualified than the worker himself to join in the task of preparing them. He works there, he knows what really happens. As these quantified flow charts begin to come in we set our design team the task of fixing the artistic rules for such iconic representation. The use of colour, the radius of bends in the flow lines, and so on, were standardised on ergonomic principles, so that any such chart, whatever its source, has a familiar and readily understood appearance.

The further task of the operational research teams was to identify a primary set of critical variables in each system under study. For example we needed to identify the size of stocks, input, output, and inter-process; we needed to identify bottleneck operations, in all cases we identified the level of absenteeism as a critical variable, since there is at least some evidence that this is a-measure of social unease. But I must emphasise that this was the preliminary picture that we sought to create. Plans were Well advanced to provide cursory to make films, to publishing booklets, that would make the techniques we were using readily accessible to the workers themselves We wanted them to enrich our preliminary model and to add anything, they liked to the list of measured variables for which (as you shall see) we wore providing them with huge computer power to monitor.

This programme was beginning, with the participation of the President himself when the end came.

So, the second question: the speed or response. Why do the overdeveloped nations tolerate a statistical system that embodies time lags of six months or more, since this is the age of telecommunications? Having been deeply into the question, in one such country, I think the answer is that they are frightened. Businessmen do not want an effective and especially a, transparent economy, too many profit opportunities would be exposed as fraudulent - or at the least, not in the national interest. Bureaucrats are terrified to set up such a system, lest they are accused of trying to bring about exactly that result. But this was Chile. We saw no reason why the economy should not move into a mode of regulation operating in real time. This was the first time that any such thing has ever been attempted. There was no problem at all, because we had the models, and the theoretical cybernetic underpinnings.

Of course Chile could not afford to buy modern teleprocessing electronics. You know, I am sure, that the country was under economic siege and worse whereby another country firmly intended to bring down the government of the Unidad Popular. Meanwhile, therefore, we used the Telex. Now there is a wasted facility. Telex is used all over the world to convert news, to make purchase enquiries and quotations, and, to send birthday greetings to meet in the outposts of commercial empires. We used it in Chile to provide the economy with a nervous system, nerves to activate the sinews of the government.

Within four months of the start of our work our telecommunications team had established Cybernet. This was a network of Telex communication extending by some means or other, to every enterprise. The big firms had Telex already; small ones had never heard of it of course. But Telex machines were moved around so that every enterprise could transmit the state of its critical variables, as identified by the models, to the switching centre in Santiago every day even if they had to be taken to the machine by telephone or by messenger.

It is clear why I was accused of centralising the economy. Yet still I was not. We had only two computers at our disposal, and both were in Santiago. That is all there is to it. There are much better ways of doing the job, using a disseminated network of mini computers, but the facilities were not available. At any rate, we soon had Cybernet live extending from Africa a in the far north down to Punto Arenas the southernmost city in the world. The linkages were by microwave, already installed excerpt, for the last lap from Puerto-Montt southward which: were by protected RF transmission.

QUANTIFICATION AND THE CYBERSTRIDE PROGRAM

We are now confronting the situation in which Cybernet is alive with critical economic data flowing on a daily basis. Of course the figures themselves represent all manner of different things, thousands of tons, hundred of people, millions of escudos. Writing computer programs to accommodate such a variety is a daunting prospect.

The answer is to reduce every input datum to a triple index in which all numbers range simply between 0 and 1. When the operational research teams touring the plants had made their models and identified the critical variables, they were asked to agree two

values relating to each variable with the management. The first value was capability. This means: how should this variable perform under existing conditions, when the whole system is running in the smoothest way we have every experienced or; can envisage? So capability is not same thing as traditional since many processes work below their 'theoretical limits - because they are embedded in a productive system. Capability takes account of the Systematic reality using the quantified flow chart to understand it. The second value to be agreed for each critical, variable was potentiality. This stands for a, better performance than capability, based on the realization that if only we had a better lubricant, or if could install a conveyor bolt, and so on, then we could do this much better.

It is evident that the values for capability and potentiality will not change frequently. They can be stored in the computer, and their ratio provides an index called latency: the latent performance that that could be released by new investment. The datum arriving dally over cybernet is called actuality. The ratio between this actuality and the capability yields the classic index of productivity, while the ratio between actuality and potentiality yields the overall performance index. Performance can also be computed by multiplying together the indices for latency and productivity.

This computer programme called Cyberstride operates on the following way. On arrival, the actuality figure is examined for plausibility. This is done by statistical tests to ensure that it belongs to the population of which it is supposedly a sample. When the datum has been accepted, the capability and potentiality associated with this variable are drawn from the store and the three indices are computed. Insetting up the system, we created statistical system distribution of a hundred day's input for each index, and studied their characteristics. Since, any ratio has a finite upper bound such distributions are usually badly skewed; whereas it is convenient in a system of this kind if Gaussian distributions are available, so that whatever one later decides to do will be statistically robust. This is accomplished by making a trigonometric transformation, such as the inverse sine, to the index, which has the effect of moving the distribution towards the centre of its scale, thereby simulating a Gaussian curve.

On the strength of a hundred day's sample, each enterprise was informed of the mean level of productivity, and the latency, associated with each critical variable in its quantified flow chart. These values were then used to quantify the charts developed at the next level of recursion, and so on to the total industry level. Please note that this is the form of aggregation of economic statistics that has a lot more to commend it than aggregation by totals in the customary way. For each level of aggregation of economic statistics is related to a system, and the critical variables being measured combine information according to the systematic characteristic revealed by the model at that level of recursion.

Now we have a static picture of the state of productivity, latency and overall performance for the whole of industry – or, to be accurate we had the picture for about 75% of nationalised industry by the time of the government's fall. Let us return to the computer programme Cyberstride, and its daily operations. An actuality figure for a critical variable has arrived, and has been accepted by the programme as plausible. The triple indices have been calculated and normalized by the trigonometric transformation. Now this value is the latest in a time series of the values that have been computed for this

variable day by day. The question that the program must now answer is does this new result matter at all, or is it to be understood as a chance variation in the ordinary course of events?

Answering this question is the heart of the Cyberstride program. We did it by the use of Bayesian probability theory, building on the truly elegant and powerful work of Harrison and Stevens. For each new point computed, the programme calculates four probabilities that it is a chance variation in the time series, that it is a transient that it indicates a change of slope, that it indicates a change by a step; function. The first two outcomes are important: nothing happens. But either of the indications of change matter very much, and therefore the enterprise is immediately and automatically informed. A truly cybernetic feature of this complicated programme is that it uses more or less of the time series, and undertakes more or less statistical work, depending on whether its assessment of these probabilities suggests that they are likely to be important or not.

In this way we sought to endow the humblest Chilean enterprise with computer power - not to calculate its payroll or update its order books on which and similar trivialities most of the world's computer power is frittered away - but to be a new lobe of the management's own brain. We found that Cyberstride could track the course of the critical variables, and sound alarms about potential trends far more reliably than can the brain itself. There were many practical difficulties. The greatest was the need to tune Cyberstride so that it would not overreact. A special tuning programme had to be prepared for the purpose. But the effort involved in this is predictable from the neurocybernetic model we were designing the very filtration system that will not overload the cortex, and yet will make the cortex aware of everything it should know. No wonder the task was difficult.

Reports back to the enterprises from this monitoring facility were not available to anyone else. In this lay the devolution of power. When we came to the higher level of recursion, the daily data were aggregated through their systemic models. Then at each higher level of recursion there would be a new (Set of critical variables, newly activated every day by systematically aggregated statistics, and producing a new stream of indexed responses appropriate to each level concerned. Of course these streams of data could be monitored in real time, using sets of nested models quantified flow charts appropriate to every level of recursion, and a single ingenious computer program for filtration and short-term forecasting. May I remind you again of the provision that the worker's committees would be entitled to add any variable that they liked to our basic few. They would not even have to declare what they were. Cyberstride would monitor them.

Anyway this total picture was incomplete: it was within the five year, not the two-year time horizon. What is much more interesting is that the facts about timing are the experience gained in using these tools as they developed.

The conceptual framework we were using changed the way that both the government and industry looked at their problems. As the practice tools became available that enabled both to deal with the tasks of allocation and distribution, and to face up to emergencies by local shortages and even widespread strikes, the people found that the basic model made sense in active service. The process of innovation became a dynamic drive.

Here is a very extraordinary truth. We may sit here together and understand – deeply, and in full – what is the meaning of modelling, and of linking together models at several levels of recursion. But when it comes to doing those things to practising cybernetics, the quality of our enlightenment changes utterly. It is not easy to acquire skill in the use of sophisticated tools, even when they are properly understood, that much is obvious. But it was not obvious that the use of the tools imparts new dimensions to the management process.

I think that it ought to be obvious, because it is clearly true of Physical Tools. The equipment that men hold in their hands governs their whole perception of the task they confront. It is true of management too, as we discovered in Chile. And if this was not our expectation in advance, it shows how little genuine innovation ever penetrates management – else the truth would be obvious to all. How many managers have ever felt that, as a result of a computer innovation for instance, their perceptions and purposes were totally changed? Very few I believe? Because we use computers and indeed cybernetics, to do silly things.

ALGEDONIC REGULATION

There is now something more to be learned from the brain and it is of critical importance. Clearly all this filtration is vitally necessary, or we should be in a perpetual condition of epileptic seizure with great tides of electrical activity sleeping over the cortex with management   inundated with great piles of irrelevant computer output (an all too familiar situation: (modern management is epileptic). But when, the filtration system is really working smoothly, and eliminating a great deal of this irrelevant input, we run the risk of simply falling asleep.

Neurocybernetics has penetrated the mechanism whereby, as I mentioned before, the organism is alerted to danger. I call this the Algedonic system, meaning the apparatus whereby pain and pleasureprovide a qualitatively different set of filters from those that monitor sensory-input. We copied the brain's tricks for algedonic response in the Chilean system in the following way.

So far as you have heard each level of recursion has its own set of critical variables, monitored at its own level. None has any direct information about imminent crisis - at the level below, because the alarms have been sent back at their lower level, and only the raw data have been transmitted upward,   in order to quantify the higher-level systematic models. Now we use the vertical dimension of our original phase-space to make an algedonic, and not an authoritarian linkage.

For the last time, I refer back to the work of the operational research teams. They made the preliminary quantified flow charts, theyselected the critical variables, and they obtained agreement on the capability and potentiality values. But they were also asked to agree with the worker's management on two things more. For every critical variable a weight had to be assigned because some critical variables are more critical than others. And for each critical variable they were asked to assess how long it would take, given the type of technology involved, to restore productivity to normal - if it   showed a statistically significant decline. This time interval, duly weighted by the importance of the variable, was then set up within the Cyberstride program as a kind of clock.

When a signal forewarning a change for the worse was sent out, at any level of recursion, the clock for that variable was started. Cyberstride would then look out for a recovery of this indicated variable. If the recovery did not appear before the clock ran out, then an algedonic cry of pain would automatically pass up to the next higher level of recursion – announcing a need for help. In this way, it is possible in theory that the President's economic committee would eventually hear of the ineffectiveness of a limestone crusher's somewhere in the north. It would hear of this if the clock ran out in the plant, then in the cement industry, then in the materials branch, because the algedonic signal would have passed on.

This facility belongs to any industrial system, although it is usually informal. Algedonic signals are passed by word of mouth. But they become distorted in the process, and often result in hasty adverse judgements being passed on the human beings involved. By building these algedonics into the electronic system, I believe, that we made another big advance. Some critics have called this mechanism oppressive; it depends on the motivation behind it. I think that the Chilean worker's were not in the least concerned about being 'found out'; rather they were anxious to have their problems brought to the attention of those who might be able to solve them as soon as possible. The system was set to do just this as an objective, clear cut ways, and a way that from its inception was in any case under their own control.

THE OPERATION'S ROOM

The next questions concerns just how all this information ought to be presented? For a long time I had been anxious to create an environment of decisions, a place where a creative group of people really could undertake creative thinking – with all the aids to that process that science could give them. Our boardrooms, committee rooms, and cabinet rooms are shrines to institutional pomp and circumstances; and the latest and greatest scientific aid that they can boast is the ball point pen.

We built in Santiago an operations room, conceived as a decision environment for a creative group that would certainly include workers. There are no tables, and no paperwork in here. The people in the room (who might be the key people at any level of recursion) constitute the brainpower. And they are served, as the brain itself is served, by a nervous system innervating the whole of the relevant body – in this case the whole of the Chilean industry. You know how that was done. So to this room come the daily, filtered, sensory inputs from Cyberstride; to this room come the algedonic signals, and from this room went the questions and ultimately the decisions. The room I describe was built and was working. But it was simply a prototype, and the economy of Chile was never actually commanded from there.

Instead smaller and less pretentious rooms were constructed at other levels of recursion, to act as foci for information and regulatory activity.   .

On the first wall is an illuminated, animated, screen eight feet high depicting the neurocybernetic model. The content of this model can be changed by the Room Manager, so as to depict the correct components for the level of recursion that the meeting has to consider.

Into this screen are slotted iconic representations of the mean triple indices - so that one can see at a glance how low the productivity, here, how high is the latency there is. The flow lines do not bear the conventional arrow: they actually move, and each can be set at one of three different speeds. This screen provides the back-cloth to the meeting, reminding those present (and they certainly do need reminding) of the level of recursion with which they are supposed to deal. If an algedonic signal is present this is shown flashing.

On the second wall are two screens. The first carries today's Cyberstride output, as appropriate to this level of recursion; the second carries details of the algedonic signals, if any are present, from lower levels of recursion. In this actual room, those signals had to be hand posted; but it is obvious that, if we had proper interface equipment such as is perfectly available the screens would have been activated directly by the computer.

On the third wall is an equipment called DATAFEED. It is obvious that once the creative group has checked up on its general position, using the first screen, and noted the alerting signals emanating from Cyberstride on the second wall, it will want supportive information. Now I do not believe in the concept of computer data banks, which says that providing one stuffs every iota of relevant information into a computer, somehow or another the answer you need will always be there. There is a little problem in the way and it is and it is called retrieval. Millions of dollars have been spent on the problem of selective retrieval. It has not been solved. I think there are good cybernetic reasons for judging that it cannot be solved. Therefore, adhering to our belief in iconic representation as being fully acceptable to the human brain, DATAFEED is a visual data bank.

DATAFEED incorporates three active information screens surmounted by huge index screens. Each of the three active screens is supplied, by back projection, with five carousel projectors each containing eighty slides. Thus the three screens between them command twelve hundred different pieces of visual information. These carousels are selected; from store by the Room Manager, ready to servo the meeting at its appropriate level of recursion. All the relevant quantified flow charts are available here. Photographs of plants are available (and how much information the experienced brain can gain simply from looking at a photograph of a works) Investment plans and projections are also available, also in iconic form. And so on.

In the room are seven swivel chairs. The fact of seven is drawn from experimental psychology. It appears that this is about the largest number for a creative group. After seven, the interpersonal reactions break down, and formal procedures have to be devised. In the arms of the seven chairs are fixed a set of buttons. Anyone can slam home a button, and gain control of datafeed. Then by using the index screen and another set of buttons he may display to the group any information that he wants to call up. The digital logic for doing this is quite complicated, but it certainly worked.

Well, the room is octagonal: it is a room, ten metres wide, inside a larger room - the annular space being filled technical apparatus, such as the sixteen projectors and the digital logic racks required for Datafeed. The fourth wall is an access door to all this. The fifth wall is set aside to contain an algedonic meter to which I shall refer later. The sixth wall is the main entrance.

On the seventh wall a huge animated model of the whole economy. Now I must emphasise that in the two years that we had, this was never made to work. It certainly worked visually but the Computer drive behind it was experimental and fragmentary. We used the Dynamo II compiler emanating from Forrestor's work because it was so free, of programming defects - it had been thoroughly 'debugged'.

That idea is that the creative group aware of their situation as they are from the equipment so far discussed, should be able to simulate the effects' of alternative decisions, They are able to change the animated model of the economy, and to obtain ten year projections of the likely effects on the screen built into the eight, and final, wall.

As I said, we did not achieve this result. This is the moment to say that the President had five years left to run when I arrived, and this was our time horizon. Constitutionally, he could not be re-elected; constitutionally he could not be evicted. We had two of our planned five years and we were ahead of schedule.

You now have a total, albeit but not fully detailed, account of Project Cybersyn. Even within its short life, it had its uses to the government. So much so that the last instruction that we received from- the President - just a week before his death – was to move the whole operations room from its experimental location right into the palace 'La-Moneda. That was a strong decision. It meant ripping out some historic rooms, because the total area required was large. By the 11th September 1973, the plans were nearly ready. Instead, La Moneda itself was reduced to a smoking ruin.

ON THE PROBLEM OF NATIONAL MODELS

I have just mentioned briefly the technical difficulties that we encountered in the overall Modelling process using the Dynamo II compiler. But I consider this lecture an appropriate occasion on which to ventilate much more profound issues than such technicalities.

Many countries attempt national economic planning at various levels of rigour and I will remember that India herself was early in this development. Today, there are various whole world models being canvassed, and these deeply affect the interests of the Third World. Most of these models choose GNP per capita as the maximising functional on the understanding. that can stand for 'the greatest good of the greatest number,' as Bontham put it," But of course it was noticed that GNP per capita is a poor proxy, if you happen to live in a small, rich state where the ruler holds all the wealth. The GNP per capita may be very high, but the mass of the people is starving.

Accordingly, the Club of Rome enables the Foundacion Barukoche of Argentina to develop a different kind of a model; and they decided that the proxy variable that they would use as a maximising functional was life expectancy at birth. They have compounded this concept from the availability of shelter, food, health and education. I think that this is an advance because it does not build into the model, as does "Limits of Growth" the wholesale assumption of the capitalist ethic. Even so, we are not there yet. I want to offer you a brief personal reflection, based on my Chilean thoughts.

I see myself standing on the road to Portillo in the High Andes, looking down thousands of feet on the city of Santiago, where several millions of people live in the

direst poverty. Laid over the city is an enormous blanket of smog – quite as bad as anything that I have seen from the aeroplane over Los Angeles in California. And I ask myself driving from the coast near Los Vilos back to the capital. It is growing dark, and as I am passing a settlement of shacks. Through an open doorway in the dusk, appears the familiar rectangular glow of the television screen, carrying programmes made in the United States, and a mass of consumer advertising. I ask myself again: Is it really GNP per capita? And then I think of the Bariloche criterion of life expectancy. This time I ask myself: Were 43% of Chileans, when they voted for Allende in March 1973, really after life expectancy? Most of them it seems to me were quite consciously not maximising anything of the kind.

In short, I am saying that developing countries still have the opportunity to ask themselves what kind of civilization they wish to become in the age of advanced technology. I do not think that there is any sense in eschewing technology if the terrible crisis provoked by famine and disease are to be overcome. But this does not mean to say that we cannot eschew consumerism; or that we cannot retain this dignity and joy of philosophic and aesthetic values that belonged to the national soul before the steam engine was ever invented.

There should be totally new studies of such problems as transportation, education, and health that do not lean on the value system of the west – because they do not work. There are many fine scientist, belonging to the Third World, wasting their talent in the alien culture of the West because (so they tell me) there are no opportunities at home. I beg you to bring than back, and to create the opportunities. The idea would be to design the nation that the people want and not just to let the nation emerge as a confused and corrupts copy of the over-developed nations who demonstrate the path only to cultural decay and institutional collapse.

Of course, all this— represents (as I am trying to say with my Chilean experiences) a totally new outlook on national planning. I am afraid that so much of this is bureaucratic? and unreal. In the work so fat described, we did not work through the, bureaucracy at all. We had the authority to set up the new system, and we went out and did it. If it had not been organised in this way, I am sure that we should still have been writing - papers for submission to committees, at the time of the coup de'tat. So here again, in the matter of national planning itself, I beg you to think afresh about the best approaches to use in order to get something done.

Now that may sound aggressive and technocratic. Do we not have proper machinery of government, to see that these advances are made in an orderly and a democratic way? But perhaps the machinery is not working well either, and perhaps the ordinary citizens' perspective is that there is nothing particularly democratic about the state bureaucracy which for him, may look merely oppressive, however good may be the intentions that it embodies. Then we ought to ask, how can the pursuit of democracy at all be aided by science and technology, and how can they be harnessed to ensure the participation of the people in national decisions? I would like to say something now about the Chilean work that has not been made, public before. It is tentative, and we did not get very far with, it, but the story I am telling would be grossly incomplete if I were to stop now.

THE PEOPLE PROJECT

While La Moneda was being shelled and bombed the President of Chile made a last broadcast to his people. One of his invocations said: 'I address myself to the youth, to those who sang, who gave their joy and spirit to the struggle."

It is possible to convey to you any more directly than that either the enthusiasm with which young people, with poets, artists, and musicians, sought to mobilise the spirit of the people in their adversity, or the President's own awareness of the need that they should do so. I joined in with them to the best of my ability and it was a joy. But what could the professional cybernetician do on this font? I tried to evolve some new ideas working with other sets of people that the teams involved in Cybersen.

In the first place, I reapplied the neurocybernetic model at a far higher level of recursion: that of the whole nation. Working diagnostically, I identified five aspects of the national life that seemed to cause ordinary people trouble, and which (the model suggested) slowed down the national metabolism. Five essays were written in cybernetic terminology discussing those five issues; and these were debated at the professional level. When it seemed that these matters were scientifically sound and properly understood, the essays went through a succession of transformations. Each transformation shortened the essay; each transformation removed another chunk of cybernetic jargon. In the end, the hope was that the issues had been reduced to their kernels. I finished with a little booklet bearing one of the five issues on each page. There the issue was described in about three lines of simple, ordinary language, illustrated by a drawing – a cartoon.

I handed over the booklet, suggesting that it should be printed and widely distributed, and the separate pages turned into posters. The idea was received, but nothing had come of it by the end of the day. We needed more time. I mentioned it now, because this was certainly a novel use of cybernetic analysis. We also tried to turn the booklet into songs. One of them was written and sung, but we could not get it recorded because of a strike, which you may find ironic. The second tentative research was more far reaching.

President Allende talked often about his concept of a National Assembly. Within the theory of a representative democracy, a parliament or a congress is a national assembly. But once again, the rate of technological development is eroding the traditional system. The mass media disseminates information continuously, whereas the elections occur at long intervals. Therefore, a great deal of power has fallen into the hands of the media, and of public opinion pollsters, because there is a gross mismatch between the time scales of public awareness and the electoral process. This threatens democracy itself.

But the media are not slow fro cash in on this situation. All over the Western world there are radio programmes in which people telephone in with their reactions to the state of current news. In particular a number of experiments have been made with television that, in the face of it, approximate to an electronic national assembly. I believe that these are fraught with danger, and will describe the sort of thing that is going on, and give you my objections.

It is easy enough to recruit a representative sample of the public by good statistical criterion to watch a television programme. Thanks to technological capacity, samples of the order of 20,000 have proven possible to handle. At various stages of the political debate in the studio, these people are asked to cast a vote. This they do by telephoning a number where their opinions on a selection of questions are received by punched card operators. The cards then go into a compute. A very short time after calling for the vote,

the television commentator is able to announce to the studio panel, and to the nation, 'what the nation thinks'. You can see why I say that the tradition of representative democracy may be eroded; this kind of technological development could soon make elections irrelevant. Now I come to the objections, which are similar to my objections of all kinds of national referenda.

In order to pose a set of questions in this form, the problems that face the nation have to be structured. The objections are that if we knew how to structure the problems properly, we could probably solve them, but we do not. Secondly, lists of questions are drawn up to fit the structure. The objections are that they may not be appropriate questions; they may be posed in an ambiguous or even tendentious ways. Thirdly, answers have to be given to these structured and may be slanted questions in binary form, to make things easier for he computer. But very often people do not want to say yes or no; they want to take up a third position; and their role is worse than negated if this attitude is represented as 'not knowing'.

This indictment of the system is brief but insufficiently damaging. When discussed it with one of its protagonists in North America, he said: 'But the computer equipment and operating system was originally designed for home teaching purposes. Don't you see that if the people cannot understand the problem of structures, the question forms, or the way to answer we can teach them. Heaven forbid. It seems that we may be talking about more than the end of democracy, but the end of freedom as well.

Here, then, is a new approach to the issue. People may not have either the learning or the wish to accept an inquisition of this form. What they certainly do have are brains, personal perceptions and purposes. I have great confidence in this arrangement, on which it seems to me that the whole nation of liberty is founded. And I have noticed that people, though uneducated, though inarticulate in an intellectual context are well able to express themselves in terms of their happiness or unhappiness with a given state of affairs. For this kind of social happiness which is quite different from inward spiritual joy, I use Aristotle's word eudemony.

Then how could one measure eudemony? The ballot box is a representative democracy tries to measure just this. It has the problem that what it really measures is negative eudemony: What is 'the least bad'. But in any case, if the state of our technology in communications calls for something more frequent than an election, something almost continuous, then it might yet be done. To use the terminology developed earlier, we may need an algedonic meter. It has to be simple and cheap.

The experimental equipment that I took to Chile was a low – voltage analogue device. A group of people, perhaps a whole village, would have one algedonic meter, which they would be entitled to set. It consisted of two inter twined discs, one orange and happy, the other grey could be varied. Obviously this setting could be picked up electrically and summed for districts, and for the nation itself. The equipment that I took had ten stations, and one summation machine. The intention was to make experiments, not at the level of national eudemony, but in a single factory first.

But now is the time to recall that, in my description of the operations room, I remarked on space set aside on the fifth wall to contain an algedonic meter. The tentative idea was that the Presidential Economic Committee might explain its policies to the nation by television for the operations room, while the nation registered its reactions on

algedonic meters summated on the fifth wall – which the audience could see. This was an attempted cybernetic answer to President Allende's interest in the concept of a National Assembly. Incidentally, it would have involved equipping villages with public television reception for the purpose. And strangely enough, I had first put that particular part of the suggestion forward to India – more than 10 years earlier. The costs of equipping the nation in this way for government purposes are not at all frightening these days. What is more frightening is the risk that the people, gathered in their village to reply, would doubtless be suborned by political parties. Such questions need much thought.

This whole scheme is simple enough to work and cheap enough to implement. At first hearing, it may sound too simple to be called, as I just called it, 'a cybernetic answer'. Then please allow me to explain why such a system is much more complex and subtle then you might at first think. It would be more convenient, perhaps, to use the example of the factory, where the experiment was planned, than to consider the whole nation. I am sure that you will make the necessary extrapolation.

Consider then a factory. In each section, where a group of a few people work, is an algedonic meter. The group is entitled to change the setting of its meter at any time. One can well imagine what can lead them to do so. Workers are loyal people; they also have machinery for voicing their views. But eudemony is another matter; it is inarticulate, unanalytic. Hence the idea to provide an algedonic signal. The algedonic meter setting throughout the factory is summed in two places: the main entrance to the factory, where all can see it, and in the office of the managing director. Here is the cybernetic analysis.

First of all, a group of workers which has set its mete will see, as it enters and leaves the factory that its own state of eudemony is or is not representative of the factory as a whole. Then this could prove a stabilising influence. On the contrary, this group might be outraged, and attempt to persuade other groups to change their settings. Whatever happens, a very complex chain of their – group is entitled – because eudemony exists and is discussed; but algedonic channels are use for exhibiting eudemony on a continuous and unemotive basis have not been provided before. The cybernetic complexity derives from the ramifications of feedback between groups that must arise.

Secondly, the case of the managing director is more interesting. Workers are never quite sure that the boss is aware of their state of eudemony. Under this scheme, he would be so aware; he would know that they know he was aware. Even more sensationally: he would know that they know he was aware; and they would know this, too. If one tries to think all this (and more) through, the complications are endless. We have installed algedonic feedbacks all through the system: I can see no way of predicting the outcome. Hence the wish to experiment.

If I may just refer to that television broadcast from the operations room a final time, I ask you to envisage what it would be like to be the Minister of Economics, who is explaining his benign policies to an expectant nation. As you do so, national eudemony as registered on the algedonic meter at your side steadily sinks. You can see it. The nation can see it. You know that the nation can see it. The nation knows that you know …

THE INCONCLUSIVE CONCLUSION

It is clear that I must conclude soon, although the experiences of two years have been so hard to condense into a lecture – even into of this inordinate length.

We have just been considering the will of the people, and how to make it known. We know what, under a democratic constitution, was the will of the Chilean people; and ==we know how that will was subjugated by tyrannical force, supported by money and decisions emanating from another government==. I have complete moral certainty that the situation would have been held if it had not been for that continuous external intervention; and surely I must be brave enough to say so. Fortunately, enough of the story is now public knowledge; to make that statement would seem less than wild.

No one can say that a country is not entitled to choose where it puts its money and its aid. Of course, it is; and that especially applies to private banks. But we were talking about the will of the people. And whether the people of the United States themselves approve of what happened in their name is open to doubt. I doubt, for instance, if the Americans I know are proud to hear that eight times the amount of credit for supplies of grain was released to Chile within a few days of the Coup d'tat, than had been released in the whole three years of Unidad Popular.

But a vicious government is one thing, and the perversion of especially international organizations in another. ==I am thinking especially of the Inter-American Development Bank and of the World Bank: so called 'multilateral' institutions. Neither would grant new loans to the Allende government (and this should be widely known) although that government, despite everything, did not default on its repayments of old loans==. In 1971 and 1972, Chile repaid around $ 16 million to the Inter-American Development Bank. In return, she was ==even denied emergency relief for her 1971 earthquake victims==. The world at large must renovate its multilateral machinery quickly, for it is at the mercy of financial power.

When the professional institutions of Chile finally became aware of project Cybersyn, they asked me to address them. I was open with my attitudes to them, as I am with you today. They were deeply shocked. They called me a partisan. Of course I am a partisan, because I am a human being, and to be a scientist is less than a castration. Perhaps this shocks you too. But if so, that is an intrinsic part of my message that you may accept or reject with all the rest. The time has passed when professionals can possibly disown the consequences of their work. The time came and went in 1945, when I myself was here in India, and two atom bombs were dropped upon Japan.

If I had not been proud and dedicated about the work in Chile, I ought not to have done it. If, given the nature of that work, I had not been aware of the foreign intent to bring the government down; I should have been a very poor operational research man and advisor. If, as I try now to report to you what happened, I were to leave out the most relevant facts of all, it would be most contemptible for us both.

I got the President a book which I inscribed with the words of a Spanish saying, 'Gran Victoria es in qua sin sangreae alcanza.' It means: (Great is the victory obtained without blood). Allende's victory was bloodless, until his own blood flowed – and that, as he well know was not defeat. Permit to salute his memory:

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