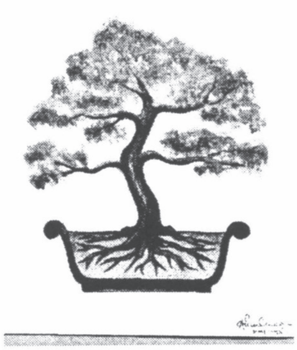
SEQUOIA SOURCING- DERIVING A TECHNOLOGY STRATEGY

Professor Chris Pearce FREng
Technical Director
INBIS Group plc

Getting the right product to market at the right time lies at the heart of an organisation's ability to compete and survive in today's environment. A fundamental pre-requisite for business is therefore the ability to find and link technologies key to its products. This implies understanding which technologies to use and where they are to be sourced, combined with the understanding and vision to track developing technologies, introducing them at the appropriate time and degree of maturity.

This is a very important strategic question for companies to answer and analogies can be helpful in thinking about how a company relates to its technology. One such model, the "Bonsai Tree" concept of a company and its product knowledge base, has been suggested in the past. This model proposes that the roots of the tree are founded in generic technologies, the trunk represents the core technologies of the business and the fruits the products of an organisation. The problem with this model is that the roots of the bonsai are constrained by the pot and deliberate pruning, with the result a beautiful, but stunted organism. This is the model of an organisation finding its technology only in known and comfortable traditional sources. In order to break away from this closed view of a business, it is more appropriate to consider the Californian Sequoia tree as a model for the sourcing of technology and the technology transfer process.



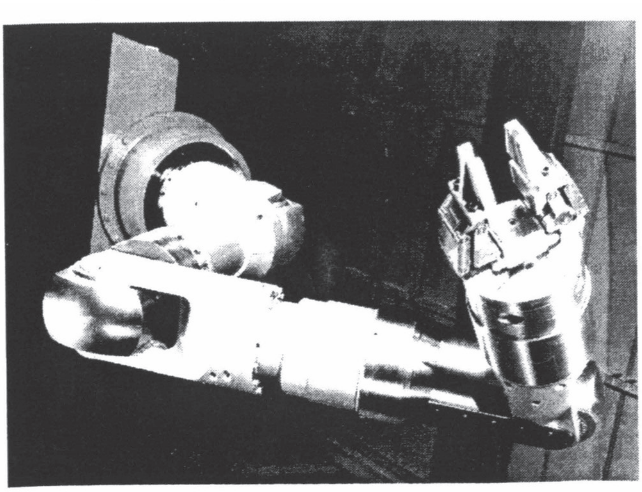
The natural history of the Sequoia is instructive and worth understanding to put the proposed representation of the business world into context. Each tree in the Sequoia grove is an individual, but whenever the roots come into contact with the roots of another, fusion occurs and the trees share the extended root system. Adjacent trees grow together where they touch resulting in two separate individual canopies with a single trunk. During the wet season, each root system will store large volumes of water, and this is released progressively during dry periods. What is interesting is that the interconnecting root system means that a tree in a drier area can in effect draw on a communal resource in times of need.

This observation leads to the view that perhaps the "Sequoia Model" is a better way to describe the relationships between companies and industries at the technological level. A company can grow its products in relative isolation, developing its generic skills, its core knowledge and its products. This model is the "Bonsai", a small world view. The development of technology outside a sector can have significant impact when transferred in, and the development of complex supplier chains suggests that today's environment requires the large world perspective of the Sequoia Model. In this model, the role of the individual responsible within an entity for the strategic development

of technology is to determine where and in which industries or supply bases the key technologies needed for future success can be found. The role is to act as a means to "touch" the roots of the next door tree and make the connection. In this way, the roots of the organisation are in the wider world knowledge network and can provide the support benefits needed for today's competitive environment. The Sequoia has no enemies other than man and heavy snowfall, and can live almost indefinitely. As the objective of strategic management of technology is the long term survival of the organisation, the model is a good one to consider given that increasingly, organisations cannot develop all their own technology and must perforce out-source skills and technology.

The Commander Robot

Working closely with a major client, a niche requirement for very high power manipulators was identified. In responding to this requirement INBIS developed the underlying technology and worked with BNFL to develop a machine to meet the need. The INBIS/BNFL Commander robot is a very highly loaded, seven degrees of freedom, remotely operated machine used for materials handling in the nuclear decommissioning sector. The challenge was to develop a machine capable of being deployed through a 270 mm diameter access port, capable of manipulating a 120kg payload at 2.3m arm extension and modular in design to allow easy reconfiguration up to 4.6 metres extension.



Fundamental to the requirement was the ability to design hydraulic rotary actuators subject to enormous loading, with clean lines for decontamination reasons, having the ability to be deployed and recovered through small access ports and with the reliability necessary for application in a nuclear environment.

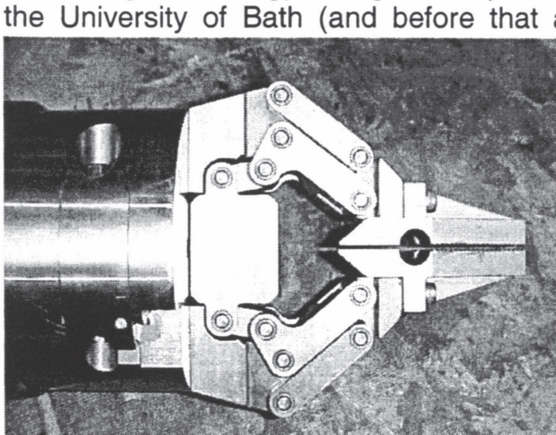
It is interesting to consider this challenge in the light of the Sequoia Tree model proposed earlier. The need was identified through the customer link. If you like, a water shortage was detected in the customer tree. The means to partially satisfy the need was available within INBIS Nuclear division (its experience of manipulator design within a nuclear environment), but the total means was not. There was insufficient knowledge of exotic materials and advanced analytical techniques within the nuclear robot design team to prove whether the design brief could be achieved. In this context, the role of the Technology Manager was to recognise the nature of the shortfall in knowledge and to establish access to the relevant technology.

The "missing technologies" in this case were to be found in several key areas, in particular in the aerospace sector. In the case of the Commander project, the Technology Manager had a strong aerospace background, as well as exposure to ceramic bearing technology and was able to make the necessary connections. It was the establishment of these connections within other technology sectors that enabled the innovation needed to be realised. This deliberate decision on technology sourcing resulted in an actuator concept using aerospace and waste pumping materials (titanium, maraging steels and ceramics), aerospace analytical techniques (FE modelling for stress, strain and life sourced in INBIS' aerospace division) to supplement the INBIS nuclear robotic design knowledge. This combination of technologies, commonplace in their own fields, but not applied together before in the recipient sector, achieved the breakthrough represented by the Commander Robot.

As an example of the impact of aerospace techniques, it is worth briefly examining the role that aerospace analytical skills had in project realisation. The design problem with such a machine is to keep self-weight to a minimum whilst maximising payload. The peculiar nature of the limited access available to the robot meant that bending moments at the shoulder joint were very high, well beyond known machine capabilities. The need for sophisticated weight control, stress analysis and deflection management were similar to requirements commonly found in aerospace, and a combined team of aerostructure and gas turbine analysts supported the nuclear design team. The aerospace sourced analysis enabled confidence to be gained that the stress concentrations resulting from the splines in the maraging steel would not result in premature failure or unacceptable deflections. The modelling methodology benefited from an approach developed in gas turbine applications to model the behaviour of features such as splines with high finite element density whilst reducing the massive computing time normally resulting. The validation of the method had already been done in a gas turbine context so high confidence could be expected in the outcome of the analysis.

An interesting technology sub root system has also been identified in this model. A key technology in manipulator design is the development of the end effectors, particularly the grippers. These have a heavy duty, requiring parallel motion of the jaws, whilst maintaining sufficient force across the full range of jaw openings to ensure that the load is always safely carried with no danger of falling out in transit.

Over five years ago, INBIS identified an interesting technology being developed at the University of Bath (and before that at



Brunel University) in the field of constraints modelling of high speed machines. Working in partnership with Bath, INBIS has developed a software suite from the results of this research known as INca® (INBIS Constraints Analyser) which allows designers to explore the constraints within a design process and optimise solutions in complex multi-variate situations. Gripper design has been a key skill at INBIS for over twenty years, and initially the gripper design for Commander followed normal practice. In this approach, the designer concentrates on three key variables and aims at achieving a design solution at a minimum of three positions during the jaw opening cycle. This is typical of complex constraints in design problems, where designers may be faced with many variables, but concentrate on those experience tells them can be manipulated most easily to move towards a solution. Many possible solutions are inevitably not evaluated due to the time constraints.

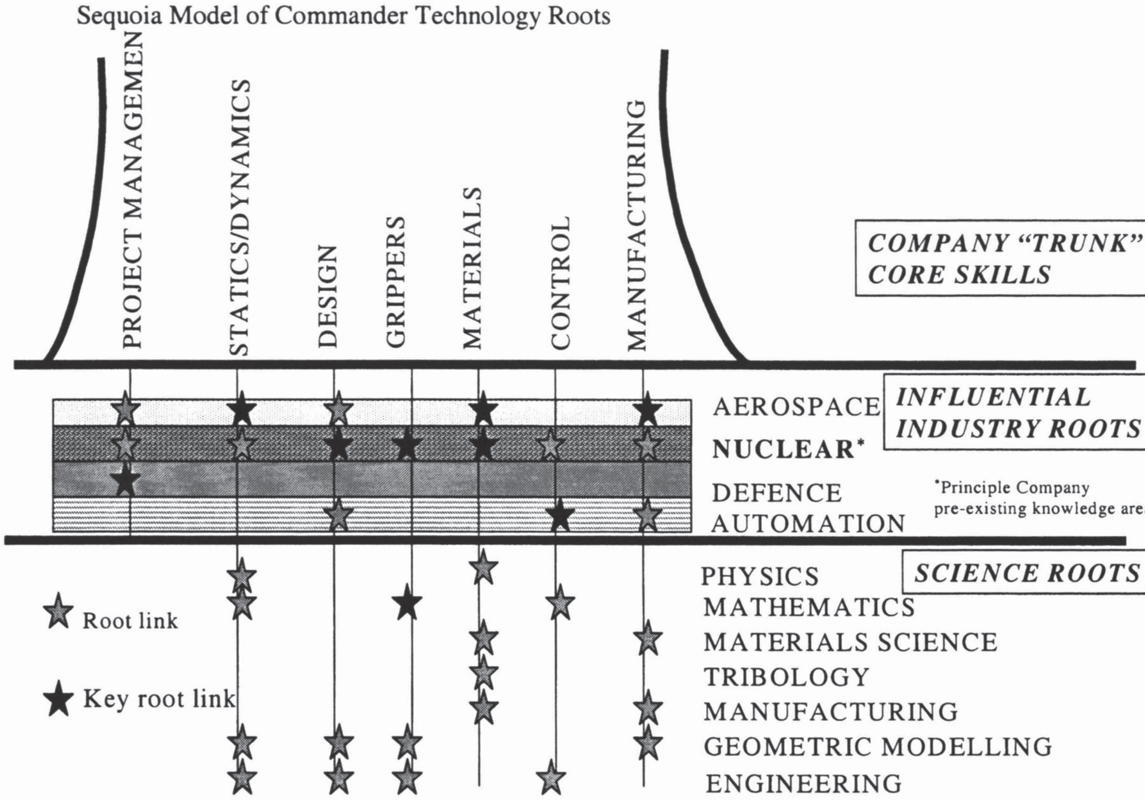
The use of the Constraints Analysis approach showed that the designer was really working with eleven variables and that the existing design could be further improved and sensitivity to manufacturing tolerances reduced. A new solution was developed using INca® technology that resulted in changes to a number of variables The changes were small. This is not surprisingly given the pre-existing experience of such designs, (joint pivot positions were changed by fractions of a millimetre, crank angles by 1 to 3 degrees), but the changes resulted in a radical improvement in joint performance. The resulting gripper has greatly improved efficiency, being both lighter and with very good performance under load, with excellent manufacturablity and has been proven in operation to be extremely reliable.

As further illustration of the Sequoia Model, the concepts of constraints analysis and optimisation in the IN ca® methodology has now been cross-root connected by INBIS into other sectors. From its high speed machine design origins, it has now been successfully applied in fluid flow optimisation in aerospace, power steering system design in automotive, nuclear robotic control system optimisation, as well as its applications in packaging machine design and other high speed mechanism applications. Many variables can be managed simultaneously with resulting benefits to the designer in terms of insight into the way in which constraints impact his design, and allow better solutions to be achieved.

product meeting the specification requirements. The bringing together of differing sources of expertise was essential in this process.

The crucial role in enabling the Sequoia model is that of the Technology Manager who must actively look for opportunities to create the links at the roots of the organisation. Most innovations contain a

Sequoia Model of Commander Technology Roots



The Commander robot was taken through to realisation under a joint program between INBIS and BNFL Engineering Limited. The technology root diagram shows the sourcing routes for the technologies involved. In all, this is an interesting example of a Sequoia Tree model of linking and sharing to achieve the resulting growth of a new product. The linking was effected by aware, experienced personnel with a knowledge of, and readiness to consider, the benefits that can flow from crossing technology boundaries, without any compromise to the commercial acceptability or vulnerability of the programme to a "not invented here" mentality. What can be seen is that from a broad science base and experience generated from a broad industry base, innovation at the company has developed a breakthrough requiring knowledge from different fields of science or industrial sector. The proposed Sequoia analogy recognises this graphically.

IN CONCLUSION

The capture, analysis and recycling of knowledge will become ever more important, and need to be managed as a critical organisational resource. This cannot be dealt with purely as an information technology issue, as we are dealing with human beings interacting with the systems that we will evolve. Therefore it is essential that we design our management philosophies to satisfy basic human needs. People working in virtual teams will still have their social needs, they will still behave illogically from time to time, but it is they who will supply the intuitive leap. Our efforts should aim to provide a better environment in which the designer and manufacturing engineer can explore ideas, creating new, innovative products, recycling information, learning from the mistakes of the past and making the key connections across sectors which will provide the new products of the future. The role of the Technology Manager will be increasingly essential to the health of an organisation. Perhaps we can eventually stop "re-inventing the wheel" with each passing generation of engineer and plan to benefit from the technology developed elsewhere.

A further thought on the Sequoia model. The forest fire is an essential part of the regeneration of the forest and in particular creates the environment for new Sequoias to grow. The Sequoia is virtually immune to fire

because of the thick protective bark with high tannin levels its trunk carries. Fire is an essential part of its reproductive process. New Sequoia seedlings only germinate in the fertile tilth left after a forest fire when they have no competition from the undergrowth swept away in the conflagration. Seeds can lie dormant for fifty years awaiting the heat of a fire to initiate growth. When big enough they make their own root system connections. If we get our connections right, our own organisations will be better placed to withstand the vagaries, ill-winds and "forest fires" of the marketplace and to put on new growth in response. It is therefore imperative that we develop organisations with the agility to move technologies around and make innovative connections. Those who succeed will be the Sequoia organisations of the future and will have true longevity in the marketplace.