MODELLING COMPLEX SYSTEMS
IN AN AGE OF COMPLEX SYSTEMS

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We live now in an age of complexity, especially since the rise of microprocessors. It is very important to understand how the complete system will and can behave and how it might fail.

Two British air to air missiles had preceded Bloodhound at the Woomera Rocket Establishment (WRE), and they had shown a problem unique to missiles. While aircraft can be flown in mock battle, missiles have to be evaluated theoretically. The British had set up Evaluation Simulation while staff at the WRE did the same. Thus from 1957, under Alex Biggs, Australia developed the model for Bloodhound. The modelling was complex; it had to include target radar characteristics, radome aberration, tracking errors, and the full dynamic characteristics of the missile and its control systems. First analogue, and later digital computers were barely able to cope with the complexity and needs for accuracy. Yet, without it, the Royal Air Force would not know how effective its missiles would be as the threat evolved. Comparison with the missile trials would evaluate the model. Bristol staff joined in on the modelling, and they stayed in Australia. We found the modelling of great value in improving weapon performance, and it was essential for potential customers for the weapon.

ENGINEERING COMPLEX SYSTEMS
The skills for engineering complex systems are best learned by experience. The fundamentals are:

- Identify every element of the system
- Identify every interaction in the system
- Identify and use the technology which should be used in each problem area

It was the third of these which led to the World's first operational use of the digital computer in the Bloodhound 2 system.

A complicating factor is human beings who participate in the functioning of the system. As an example, the Generals who sought information from a 1950s battlefield control system made so many demands that the fighting soldiers could get nothing from the system! For this reason system simulation has to be added so that such problems can be spotted early, and for military systems war-gaming makes further demands on simulation.

MORE COMPLEXITY
The complexity of defence has recently increased greatly; nations divided, suicide bombers, unmanned and remotely controlled air, land and sea devices. The days of one disciplined Service attacking another are gone, and the political reactions to military operations can be unpredictable and incapable of simulation. Opinions on all this vary greatly, and the complexity lies beyond what conventional simulation can achieve.

New thinking is needed.

ON TIME, ON BUDGET
The British Defence budget is hopelessly overspent. Too many projects are late and overspent. The road back started with the Bloodhound 1 missile, whose development was faster and cheaper than its competitors.

Bloodhound 1
A Government Working Party found that the main factor was continuous mutual criticism by the Bristol and Ferranti teams throughout the project. There were other factors. Despite top National Priority, at Bristol the aircraft team grabbed all the structure and aeronautics graduates. As a result the G.W. team was built from physicists and mathematicians. I arranged that all staff would have an annual interview in which their skills needs were examined and acted on. Many of the staff regarded this as the cause of successful subsequent careers. The annual interview was also important in controlling staff wastage. Quite simply, we showed that we cared about them. The result is that qualified designers stay with you and do things fast and well. A recent survey shows that 40% of qualified designers in most companies have left design.

Bloodhound 2 Onwards
Few people know that a series of Bristol projects was completed on time and on budget, or of the methods which led to those achievements. The methods can be summarized as:

- Learn from experience
- Train engineers and designers
- Make information for design available at the right time
- Establish technology base
- Criticise design effectively

RESCUING COMPLEX PROJECTS FROM OVERSPEND AND DELAY

Early History
The Ministry of Defence had noted that Bloodhound 1 was developed more quickly and for less money than its competitors, and considered that this was mainly due to the project review methods. It was deployed as planned to defend the British nuclear deterrent at V-bomber squadrons. Their life was extended by carrying standoff missiles, but it gradually became clear that they would be vulnerable to ballistic missile attack and the nuclear deterrent was switched to submarines. This freed the Bloodhound 2 system, which was air and land transportable, for service in trouble areas including West Germany, Singapore and Cyprus. I visited it at the last of these and saw the big contribution it made to deterrence and knowledge of the tactical situation.

The nuclear deterrent soon ran into trouble in the two projects illustrated below:
The Polaris Submarine
It became clear that traditional shipbuilding methods were failing in the Polaris submarines, with cost blowouts, programme delays and no view of completion. The Government, recognizing the Bristol G.W. expertise in complex systems, asked the team to sort it out. To start with it was essential to have a complete definition of the system, which had to be created. It turned out that different submarines were differently wired, so discipline had to be introduced. The fire control system was complex and many problems existed. Once the system was defined the problems could be tackled so that the programme was completed and the installations passed test.

The British Nuclear Warhead
The credibility of the submarine based deterrent rested on the invulnerability of the nuclear warhead to enemy defence systems which were deployed at many target areas and were continuously improving. An improved warhead delivery system was ordered from British contractors. It had multiple decoys whose trajectories had to be controlled, while the nuclear targeting was unobservable until a late stage. The programme went out of control because contractors could not master the complexity needed with their knowledge of technologies, so the Bristol team was again asked to come in and sort it out. Once again they found an inadequate description of the complete system plus a failure to master its complexity and the demands on

technology. And once again the problems were solved, the programme completed and the system passes test. Members of he Bristol Guided Weapons team which achieved this were honoured, being highly decorated by the Queen. This story must be illustrated at the Bristol Aerospace Centre for the public to understand and prevent in the future.

A CURRENT NEED

Because of limited experience in Australian industry, the Australian Navy's nuclear submarine failed to meet its specification in several ways. The contract for the next generation submarine has become a political issue in which ability to achieve full performance is obscured. Study of the Bristol experience would be well rewarded.

WHAT MADE IT POSSIBLE?

Every member of the Bristol Weapons team had benefited from acquisition of skills in the many technical areas needed in guided weapons. The Bristol -Ferranti sale of complete weapon systems to neutral countries had greatly broadened that knowledge to a level of system engineering which the Government knew was unmatched elsewhere.

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