The Scientific Intelligencer

Some further bits of historical and philosophical wisdom from the father of British scientific intelligence.

R. V. Jones

The devices of Archimedes in the defence of Syracuse gave an earnest of what would happen in warfare as scientific knowledge expanded; and, although it has taken a long time to come, we have seen in this century a complete change in weapons brought about by the application of science. The classic principles of war still apply to the new weapons, of course, and one of the first of these principles dictates that you should establish the intentions of your enemy. In the modern situation, this principle has a new application: it is now vital that you should anticipate your opponent's use of science in warfare, and a need has thus arisen for scientific intelligence.

I have sketched elsewhere[2] some account of the service aspects of scientific intelligence in the 1939-45 war, and it may be of value if I give here my impression of scientific intelligence more from the point of view of the scientist. This form of intelligence has now become an important part of the defence system of all the major powers, and it is therefore desirable that its aim, scope, methods, and difficulties should be appreciated by everyone working in science in this country who may perhaps be able to help our own scientific intelligence organization or whose work may prove a target for the intelligence services of other powers.

Scientific intelligence is the foremost outpost of a defence system. Failure to appreciate the development of new weapons by enemies actual or potential may later mean a national disaster. Hitler's retaliation campaign with the V-1 and V-2 would, for example, have been much more damaging had we not been alerted to develop countermeasures months before the campaign started. Today, as science and technology take up an increasing proportion of a nation's total effort, scientific intelligence is even more important than it was fifteen years ago.

Intelligence Sources

The variety of intelligence sources is greater in war than in peace because war entails direct contact with the weapons and the personnel of the enemy. Thus in war there are at least three kinds of source not normally available in peace: captured equipment, documents, and prisoners. There is also an increased amount of radio communications in the field, with greater chances of insecurity. While modern codes are highly secure and centimetric transmissions hard to intercept, there are the chances from time to time of lucky breaks. Photographic reconnaissance by air is another source in war; we owed much to it from 1939 to 1945, and there is no reason to believe that we should find it any less valuable in the future, even though robots may replace the pilots whom it was our privilege to regard as colleagues during that period.

The traditional peacetime source is the human secret agent. In scientific intelligence good secret agents are rare, and part of the skill of the game is to be able to use agents who have no scientific training. Occasionally an agent is a trained scientist or engineer, and he is then of outstanding value. The source of the Oslo report of 1939, for example, was presumably in this category, and his timely warning of several of the new German weapons placed us permanently in his debt, if we had ever been able to find him. Klaus Fuchs, Alan Nunn May, and Bruno Pontecorvo must have been of even greater value to the Russians had a war broken out in the last few years.

There is another important source, peculiar to scientific intelligence. This is the body of experts in particular fields of science available in one's own country for consultation. The phenomena of nature are independent of political boundaries, and the experts are in the position of agents spying on these phenomena in so far as they throw light on the feasibility of a suspected enemy development. As with many other factors in applied science, Francis Bacon was the first to see this analogy:

> . . . and therefore as secretaries and spials of princes and states bring in bills for intelligence, so you must allow the spials and intelligencers of nature to bring in their bills; or else you shall be ill advertised.[3]

These words of Bacon exactly fit the function of specialists in relation to intelligence and, as we shall see later, one of the early difficulties in scientific intelligence was to make this understood.

The Task of Collation

Behind all the different sources there must be a centre coordinating their activities and collating their scraps of information. This centre may be alerted by information coming from any one of the sources, including the experts in its own country who may have found, for example, that a new kind of nuclear bomb is feasible; it then has to consider the import of this information and lay a plan of operation for all the other sources to throw light on what the enemy is doing in the new field. This is where it is particularly necessary to understand the capabilities of each kind of source and to have the imagination to see in addition that new kinds of source are perhaps possible. A new enemy development sometimes has an Achilles' heel, and one function of the coordinating centre is to foresee this and plan an intelligence attack on it.

Radar, for example, was a powerful aid to warfare, but it was also vulnerable from a security point of view, since it involved characteristic transmissions which could be intercepted and evaluated. Thus the 1939-45 war saw the establishment of new interception services for listening to enemy radar transmissions. More recently, trial atomic explosions are to some extent insecure in that they cause such large-scale interference with normal meteorological conditions that they can be detected fairly easily. One task of the coordinating centre, therefore, is to foresee such possibilities and to exploit them by setting up new forms of collecting agency.

The other main task of the coordinating centre is to collate the information coming from the various collecting agencies and to construct from it as objective and full an assessment as possible of what the enemy is going to do. The method here is precisely that to which scientists are normally trained, one of observation and deduction-with due regard to Occam's razor-followed if possible by prediction and confirmation. Because, however, of the fallibility of individual observations-either on account of inexperience or stress in the agent making them or of deliberately false information planted by the opponent-the scientific method has to take also into account those parts of legal and historical method which apply to the consideration of evidence. It should not be forgotten here that it was E. F. F. Chladni,[4] following his training as a lawyer, who finally demolished the disbelief of the French Academy of Science in meteorites. As F. A. Paneth has said, by the eighteenth century men of science had become far too enlightened to believe such a ridiculous tale as that of stones falling from the sky; but Chladni went and talked to eyewitnesses of the fall of meteors and became convinced that they were giving a truthful account of their observations. It took ten years for the French Academy to admit that he was right.[5]

Occam's Razor

The principle of Occam's razor-that observations should be explained with the fewest hypotheses-is the surest guide to a sound appreciation of evidence; but in intelligence, as in pure research, it can sometimes produce the wrong result. One of the few examples which I encountered occurred when we noticed, both from aerial photographs and from plans of a flying bomb launching site which were stolen for us, that there was a single fuel store on each site. This building was divided into two completely separate parts, and the only way from one part to the other involved going outside and round an elaborate blast wall. It was obvious that the two materials had to be kept apart. We were aware of two fuel components the Germans had used in another application that satisfied the necessary condition: hydrogen peroxide and a solution of sodium or potassium permanganate. These could be used in a rocket motor, the permanganate decomposing the peroxide to steam and oxygen. Following this possibility, we found that some servicing personnel accustomed to handling these two materials had been drafted to the flying bomb regiment.

All other buildings on the site were checked and it was found that there was no other fuel store. We measured the capacity of the fuel store and found that it could hold enough peroxide to carry twenty flying bombs (the number usually stored on the site) the necessary range to London. We therefore tentatively concluded that the flying bombs would be driven by hydrogen peroxide rocket motors, and we were rather pleased with ourselves for seizing the clues, particularly when the fuels concerned had never been used by our own side.

In the upshot, the conclusion was wrong. Hydrogen peroxide and the permanganate were used, but only as the propellent in the launching catapult. The flying bomb motor was of a new and ingenious type, running on a low-grade hydrocarbon. Although the final assembly of the bombs was carried out at the launching sites, the bomb bodies arrived with full fuel tanks. To have assumed this on the facts available would have been a more elaborate hypothesis than the one used, but it was what in fact happened. Fortunately, our incorrect conclusion made no difference to our operational action, but it showed that, quite understandably, Occam's razor is a guiding rather than a rigorous principle. For this one failure, however, we could point to many successes where scares based on more elaborate hypotheses were dispelled by the intelligent application of the razor.

Expert Opinion

Chladni's experience in part exemplifies a key point in scientific intelligence, the function of experts. It has often been plausibly but erroneously argued that the best authority for assessing what an opponent is' doing in a particular field of science applied to warfare is the scientist most concerned with the same development in one's own country. This argument was our worst obstacle in the development of scientific intelligence in Britain, but the fallacy in it is quite simple. As Bacon said, the true function of one's own expert is that of a spy on the laws of nature and, the limits which they impose on a particular line of development. Usually, since he is a trained observer, much weight should be given to his opinion; but if this opinion disagrees with the evidence available from other sources, the coordinating centre should be able to go back both on the expert's opinion and on the evidence from the other sources. If the contradiction persists, then the coordinating centre must make a final judgment as to what is the truth about what the enemy is doing. In my own experience, while there have been times when the experts alone were right, there have been important occasions when the other forms of intelligence have been right and the experts wrong.

Two examples will suffice. The first concerns the German nightfighter radar control stations of 1942. Photographic reconnaissance showed that each of these stations had two 25foot paraboloids. One of these paraboloids always had three searchlights around it, the other none. The inference was that the paraboloids were functionally different, and it was reasonable to conclude that the one with the searchlights was intended to follow the raiding bomber, which the German station would try to illuminate, while the one without searchlights was intended to follow another aircraft which it was not intended to illuminate, and this would obviously be the defending fighter.

Our own radar experts, however, disagreed with this conclusion, saying that the second paraboloid, following British practice, would be a standby if the first one broke down. They further pointed to the extreme difficulty they experienced themselves in marrying the plots from two different radar equipments following different aircraft with sufficient accuracy to bring about an interception. They were, of course, quite right that it is easier to observe both aircraft on one equipment because observations of the relative position of one aircraft with respect to the other are all that are necessary for interception purposes and any absolute error in the equipment can be ignored, whereas the use of two separate radar equipments entails each of them producing absolute measurements to a higher accuracy.

The point was a matter of some importance to our countermeasure programme, and of course we were concerned not with establishing the best way to do the job, but with discovering the way the Germans actually did it. Our experts had not realized the accuracy with which all German radar equipment was made to work as a matter of course. The German engineers had achieved the absolute accuracy required, perhaps unnecessarily, and the radar equipment was in fact used in the way deduced from the aerial photographs.

Another example was the opinions of the experts in the rocket threat of 1943-44. We found in photographs of Peenemunde what seemed to be a rocket about 45 feet long and nearly 6 feet in diameter. Our own experts assessed the weight at 80 tons, on the argument that the only practicable rockets known to them were those burning cordite in a steel case. A 50:50 charge-weight ratio was all that could then be achieved, since the whole steel carcase had to be thick enough to stand the full pressure of the exhaust gases. A simple calculation showed that a steel-cordite rocket of such dimensions would weigh about 80 tons. Then, with such a large carcase weight, it would obviously be a futile missile unless it carried a warhead of about 10 tons, and the War Cabinet was consequently faced with the threat of missiles the weight of railway engines crashing on London and exploding.

The way in which the threat was correctly evaluated may be of some interest because it shows the value of knowledge of elementary science unbiased by too much expertise. A trial rocket fell in Sweden in June 1944. Air intelligence engineer officers who saw the fragments reported to us that two fuels were fed into the jet chamber and one of the fuels was pumped by a pump which appeared to be lubricated by the fuel itself. This immediately recalled to us the details of the Claude process for liquefying gases as described in elementary textbooks and convinced us that liquid oxygen was one of the fuels.

From that point, it was a simple matter to sort out all those intelligence reports from agents or prisoners which had mentioned liquid oxygen as one of the fuels. For we had hundreds of reports, many of them bogus, and this fact of liquid oxygen could be used as a touchstone of truth to test the good faith and authority of the sources. This method of selection left only five reports, and they were all remarkable for the light weights which they attributed to the rocket and its warhead. As a result we in scientific intelligence were able to inform the War Cabinet that the rocket would weigh 12 tons with a 1-ton warhead, while the experts were still saying that such a light weight was impossible.

Principles of Impotence

I have mentioned the above examples in some detail because the general point is of much importance. Why is it that experts can sometimes be so entirely wrong, and yet so emphatic in their convictions? My own belief is that some of the reason lies in the success of "principles of impotence," particularly in modern physics. Somehow it seems part of the scientific approach to postulate impotence; even the ancients, for example, had their "Nature abhors a vacuum." More recently, the acceptance of such postulates has led physics to great advances: Albert Einstein's impossibility of signalling faster than light, Max Planck's inability to discriminate inside quanta, W. Heisenberg's indeterminacy, the second law of thermodynamics, and the unattainability of absolute zero, are all examples of outstanding success.

There is therefore a strong temptation, after one has failed in a particular experiment or line of development, to believe that one is up against a principle of impotence, and with a little ingenuity such a principle can usually be postulated to explain one's failure. Before 1939, for example, it was widely believed that centimetre waves could not be generated in thermionic valves because of transit time difficulties. Here it was our own experts who broke through the budding postulate, while the Germans remained bound by it until they were astonished by recovering centimetric radar equipment from a British aircraft.

In a different field, that of infra-red detectors, we in this country in 1939 were despairing of finding photoconductive materials sensitive beyond a wavelength of 2 microns. We were told that Service laboratories had tried all likely materials, including lead sulphide, over a period of eighteen years, and had found nothing going beyond about 1.8 microns. Yet in 1944 scientific intelligence managed to prove that the Germans had lead sulphide cells going to 3.5 microns, with the prospect of lead selenide and telluride going further.

Having the privileged position in scientific intelligence of, as it were, sitting on the fence and watching laboratories on both sides in the war, I was repeatedly struck by two opposite phenomena. Sometimes both sides would in great secrecy develop precisely the same weapon. The "hollow charge," for example, was developed almost simultaneously by the Germans and ourselves. The Munro effect, on which it is based, had been known for some forty years without anyone taking any notice, and suddenly both sides started work on it. The jet engine and radar were other examples.

At other times, as indicated above, there were completely blind spots in the development on one side or the other. We failed to develop bulletproof petrol tanks in our pre-war aircraft; the Germans failed to develop the plan-position indicator and, above all, the atomic bomb. At the basis of all these examples and of many others there was usually the fact that someone had done a bad experiment or a bad calculation and, having apologized to himself that he was up against a new principle of impotence, he went around discouraging any of his countrymen whom he found trying to do the same thing.

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These considerations made us realize that scientific intelligence is likely to be confronted in any particular problem with one of three situations. The first is where both sides have developed a particular new weapon. This is the normal case, where the scientific intelligence organization can rely on its own national experts for briefing and for help in assessing the information about the enemy weapon. The second situation is where our own research laboratories have produced a weapon and the enemy has failed to do so. This is more difficult, since intelligence has then to prove a negative case, which involves a complete cover of all places in which the enemy might conceivably develop such a weapon. The third situation, which is both the most dangerous and the most difficult from an intelligence point of view, is where our own experts have failed for one reason or the other to develop a particular weapon and the enemy has succeeded. Intelligence has then to be entirely self-reliant and to overcome the disbelief of the experts in its own country.

Scientific intelligence is a specialist task, almost as much so as research, and it requires its own coordinating and collating staff who are competent to take the ultimate responsibility in the light of both expert opinion and of the available intelligence. For this reason particularly, scientific intelligence needs to be staffed by men who can hold their own with the best experts available in their own country, who have a wide understanding of elementary science, and who are duly critical of principles of impotence. They must act as judges in conflicts between expert opinion and information received from other sources. More than this, they must be able to express their requirements to their sources in the way that these sources can best understand, and they must express their conclusions to policy officers in a way these officers can both accept and act on.

Returning for a moment to the matter of the failure of a country to develop a particular weapon, I would remark the tremendous value of knowing that the weapon can work if it is made. This is not particularly a matter of scientific intelligence, but it has some bearing on security. When a radically new weapon is conceived, such as the long-range rocket or the atomic bomb, there are often more disbelievers in its feasibility than otherwise. Even the strongest protagonist may then feel qualms of conscience in asking for more money and effort for development in the light of general disbelief, and he is certainly less likely to get what he needs. This nearly always slows up development. Such a brake is completely absent, however, when it has been demonstrated that the weapon will work: it is then known that there are no hidden principles of impotence, and bad experiments can be immediately rejected. Thus it was very much easier in principle for the Russians to make an atomic bomb than it was for the Americans, and from this point of view the explosion at Hiroshima (perhaps even the one at Alamogordo) was an act of value to the Russians not incomparable in magnitude with anything that an agent could have told them.

There may well be some scientists who consider that intelligence is a degrading activity for their talent, and that at best it is a "dirty business," prying into other people's secrets. It is true, of course, that some intelligence has its unsavoury side, but I would emphatically say that from my own experience the best intelligence is produced by "clean" methods. The professional spy is often a charlatan, and the good information comes not from him but from men who are actuated by idealistic motives to take great risks, or from the sheerly hard and painstaking work of officers who plough through an enormous amount of published detail to gather a few clues about what is going on abroad.

The idealist may be a patriot, risking everything to get vital information for his countrymen. He may also be someone who thinks his own country in the wrong, and who has either the courage or the presumption to hand over its secrets to foreign powers. Much as we may deprecate this, and indeed it must always be very doubtful whether any one man ever has the right to act in such an arbitrary manner, it is not the same as a traitor selling his country for personal gain, although its consequences may be more disastrous. I therefore count the idealist informer as "clean" from an intelligence point of view; we ourselves have from time to time been thankful for such services.

It would of course be silly to pretend that rackets do not exist in intelligence organizations. Such organizations always have a special claim-which must be granted-to be free from public investigation, and it is inevitable that this privilege is sometimes abused in that security is made the cloak for inefficiency. It will in fact add a good deal to any scientist's experience of human nature, -both good and bad, to work for a time in intelligence, but there is no need to imitate the bad, and there is much to admire in the good.

I do not pretend that scientific intelligence is as fundamentally satisfying a pursuit as either pure science or applied science. All intelligence has an element of the parasitic: you can only find out about a weapon if someone has done the more fundamental job of bringing it into existence. The service you may thereby render may be extreme, and the excitement of the intelligence chase may exceed almost any experience in normal life, but at the end of it all you cannot claim to have made a constructive step comparable with, say, a discovery in pure science or an invention in engineering. Moreover, it cannot be pretended that a spell in intelligence will enhance a scientist's reputation in his own field. If anything, the reverse is likely to happen, and it should be realized that any scientist working in intelligence may well be making a deliberate sacrifice of his personal interests partly because he believes that our way of life is worth defending.

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1 Excerpted from Research, Vol. 9 (September 1956), pp. 347-352.

2 See Studies VI 3, p. 55 ff.

3 The Advancement of Learning, Second Book.

4 Chladni, E.F.F. fber den Ursprung der von Pallas gefundenen and anderen ihr dhnlichen Eisenmassen and fiber einige damit in Verbindung

stehenden Naturerscheinungen. Riga, 1794.

5 Biot, J. B. Relation d'un voyage fait dans le department de t'Orne pour constater la realite d'un meteore observe d l'Aigle le 26 floreal au 11. Paris, 1803.

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