ADVANCING TECHNOLOGY

BY

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Advances are being made in many areas of technology, both within the Ministry of Defence, by intramural research, and by industry. Many are candidates for application by our ships, submarines, and weapon systems. Some of these advances are being harnessed in support of the trend towards stealth in maritime warfare—with ships and submarines being required to remain covert and yet retain the initiative. New technologies are being—or possibly might be—applied to three elements which contribute towards our ability for stealth. These are:

(*a*) Communications.
(*b*) Signature reduction.
(*c*) Detection capability

Stealth and Communications

The benefits of assuming a posture of stealth in our maritime operations are well known. To maintain the initiative is one of NATO's fundamental concepts of operations in the North Atlantic and this will require the maximum use of tactics which surprise and confuse. Certainly if we are to put the capability of our ships and submarines to effective use, we need to be supremely cunning.

To achieve stealth, it is necessary to deny to the enemy information which will in any way assist him to establish our characteristics, movements, or intentions. EMCON—Emission Control—is vital. We already conduct strategic shore-to-ship communications on a broadcast basis so that the Fleet can receive messages without the need to transmit. But as far as sensors are concerned, we need to investigate their roles to decide in what way we might compensate when they are silent.

There is no potential in the foreseeable future for passive sensors controlling tactical weapons. Active sensors for surveillance are designed primarily to build up the information base on which the Command makes its decisions. Clearly, the Command cannot function without this information, and so if it is not available from on-board sources, we need to provide it from elsewhere.

An associated requirement has arisen with the advent of weapons with an over-the-horizon range. The submarine-launched Harpoon is one example and its surface-launched derivative is another. These weapons need information to direct them to their targets—a requirement known as Over the Horizon Targeting (OTHT). Until there is an alternative available, this requirement will be covered by so-called third party targeting. However, the presence of the third party limits the employment of such a system and consequently there is, again, a need for information to be provided from a source outside the operating area.

The requirement may be met by many sources of information—for example wide area sensors, visual sightings, or assessments from headquarters—and each source contributes to our ability to maintain in accurate picture of our own forces, hostile forces, or neutral shipping. The raw inputs to the picture need validating. The data also varies in its timeliness; a contact's position received from an AEW aircraft may be a few seconds old but a sailing report from a merchantman may be many hours or even days out of date.

There is a thus a need:

(*a*) to process raw data from the sensors in order to extract information;

(*b*) to correlate the information from different sources;

(*c*) to transfer the product to support the user.

This process must be conducted in such a way as to maintain the timeliness and accuracy of information, particularly for OTHT. Security implications must be considered also.

There are two particular areas of emerging technology which are having a major impact on our ability to cope with the twin requirements of stealth and OTHT:

(*a*) impressive developments in micro-electronics.

(*b*) the exploitation of space.

Certainly the major development in micro-electronics has been the advent of Very Large Scale Integration (VLSI). The result of this revolution is primarily that large amounts of logic and memory are available at low cost, occupying a small space and consuming and dissipating relatively low power.

One aspect of this technology in support of maritime operations which has quickly become apparent, is that of survivability. ADP support to Command, Control and Communications and Information Systems (known as C3I) was originally introduced as a helpful aid without which we could manage when it failed. However, it is now firmly in position as a fundamental tool and one essential to normal operations. As our dependence upon it has grown, so have the risks involved if it fails. ARM—Availability, Reliability and Maintainability—is only a partial solution because of the threat to C3I facilities ashore. The requirement therefore is for survivability of the system even when elements of it are out of action, and for any system function failure to be by graceful degradation.

The second area of emerging technology to be considered is that of the exploitation of space. Satellites are becoming ever more prominent information gatherers—that is for those countries that can afford them.

Space-based sensors take both active and passive forms. Various types of active radar and passive electronic intelligence sensors as well as meteorological and oceanographic satellites are currently under development or in operation. But in all cases, not least because of their wide area of coverage, a vast amount of raw data is produced which needs involved processing before it becomes a useful product.

For our part it is unlikely that the Royal Navy would move into this area of space sensors on its own, because of cost. However, satellite communications is the one area of space exploitation in which we are fully involved and have been increasingly over the last 15 years. Our dependence on SATCOMMS has arisen to overcome the vagaries of the ionosphere and to give us a high data rate capability 24 hours a day over a wide geographical area. As with ADP support, this is another example of technology driving the requirement: technology gave us the potential, the potential highlighted the requirement, and our dependence on the requirement in turn calls for a high level of reliability and survivability.

A large level of redundancy is built into modern satellites, with almost all components being duplicated except for aerials. The software has to be simple and 100% bug-free. Remember that the geostationary orbit is over 22 000 miles high whereas the Shuttle flies at 160 miles. The successful repair to Solar Max does not mean that Commander Longhurst or his successors will be able to service Skynet 4.

Detection Capabilities

We must expect our potential enemies to devote just as much energy to stealth as we do ourselves. Thus we must make advances in our own detection capabilities not only to provide the local Command with the complete up-to-date tactical picture but also to contribute to the data base used by fleetwide systems.

Many exciting new possibilities and developments are being considered. Above water these are associated with new types of radar phased array, over-the-horizon, and synthetic aperture techniques for example—together with ESM and visual aids. Below water new technologies are being considered to improve the performance of towed arrays and submarine hull-mounted sonars.

One technique which has received some publicity and which has been credited with a quite remarkable performance is Synthetic Aperture Radar (SAR).

Synthetic Aperture Radar

The use of synthetic aperture radar, arises from its capability to provide a better azimuth resolution than can be provided by conventional radars, as a result of the continuing improvements in digital processing techniques. A synthetic aperture radar is mounted on a moving platform, such as an aircraft or spacecraft, and it transmits at right angles to the platform motion. It provides the improved resolution by processing data within its real radar beam over a period of time.

The angular resolution of any antenna is approximately proportional to its beam width, and this depends on the radiated frequency and the linear dimensions of the antenna. It is roughly true to say that:

$$\theta_B = \frac{\lambda}{L}$$

where θ_B is the beam width
λ is the wavelength
L is the antenna length

For example, an antenna of length 1 metre and a frequency of 3 cm gives a beam width of 0·03 radians, or 1·7 degrees. This means that, at a range of 40 km, targets must normally be spaced in azimuth by at least 1·2 km if they are to be individually detected. If we want to resolve targets say 3 metres in size it is evident that we would require an impossibly large antenna, or a ridiculously high frequency. SAR however achieves this high resolution by taking advantage of the platform's motion.

Imagine a spacecraft moving through space in the along-track direction, sending out pulses of microwave energy just like a normal radar, in the across-track direction. The radar beam fans out from the real antenna on the spacecraft like light from a torch. Resolution in the across-track direction depends on the length of radar pulse, as in standard radars where the shorter the pulse the better the resolution. In the along-track direction the resolution

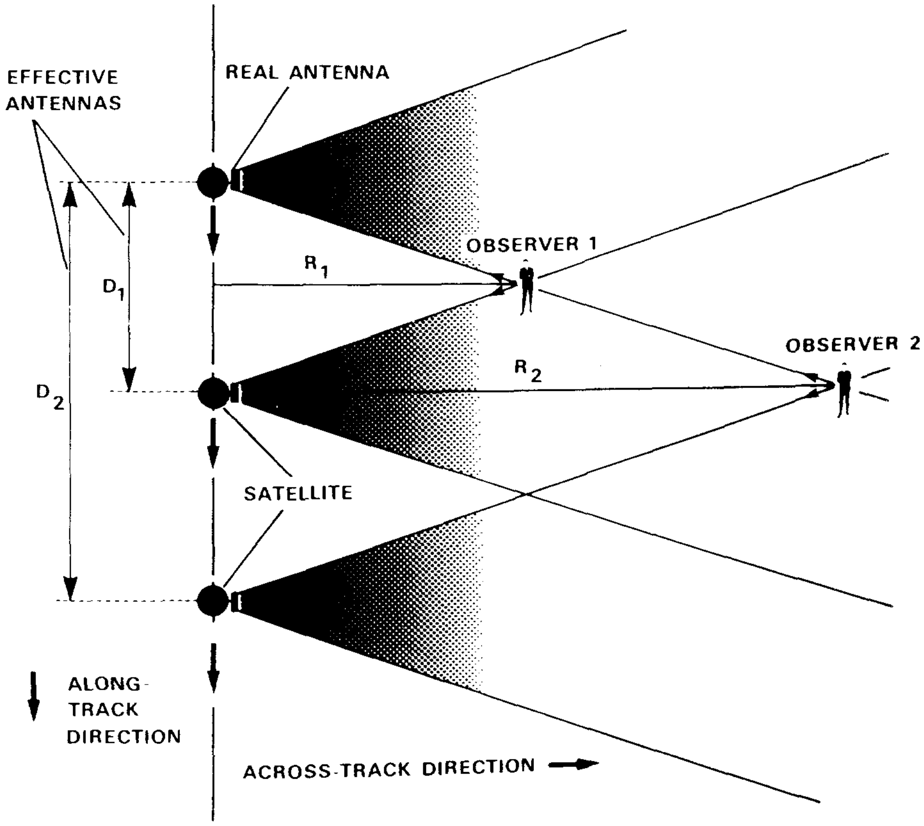

FIG. 1—PRINCIPLE OF SYNTHETIC APERTURE RADAR (SAR)

depends on the length of the antenna. Referring to FIG. 1, Observer 1 at range R1 from the spacecraft can see the radiation from the spacecraft whilst it moves through distance D1, and D1 is known as the effective antenna diameter for Observer 1. Observer 2 at range R2 from the spacecraft can see the radiation whilst the spacecraft moves through distance D2, and D2 is larger than D1 because the observer is further away and because the radar beam fans out. Resolution normally increases with antenna diameter and decreases with range, but with SAR the effective antenna size increases with range. The net result is that for SAR, resolution is indepedent of range and independent of wavelength. Therefore a SAR on a spacecraft hundreds of kilometres into space can have the same resolution as a SAR on an aircraft a few thousand feet high. However, an enormous amount of signal processing is required.

Examples from civil applications show the clarity that can be obtained. FIG. 2 is an image of an island near Bali, clearly showing volcanic craters and radial drainage patterns. FIG. 3 shows the ready distinction between arable fields and the surrounding semi-arid region. It shows rows of crop cultivation as well as grain. The circular shapes at the centre bottom of the picture are created by rotating water sprinklers. FIG. 4 has three images of the same area taken at different times of the year, with the December picture showing ice covering the water areas. Seasonal differences in the field patterns are also evident.

Turning now to SAR capabilities for surveillance of maritime units. FIG. 5 was taken from a satellite-borne SAR called SEASAT in 1978, and shows Devonport Dockyard and ships in the Hamoaze. The large blob at the centre bottom is H.M.S. *Eagle*. FIG. 6 shows a large commercial container ship. It must be emphasized that a very significant signal processing load is required

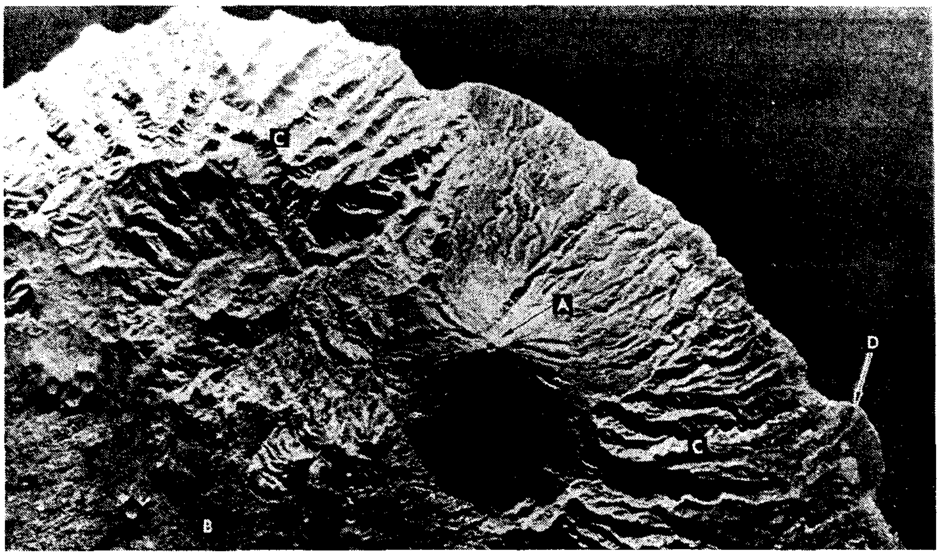

FIG. 2—PART OF AN ISLAND NEAR BALI (SAR IMAGE)
A: large volcano
B: other volcanic craters
C: radial drainage pattern
D: edge of lava flow

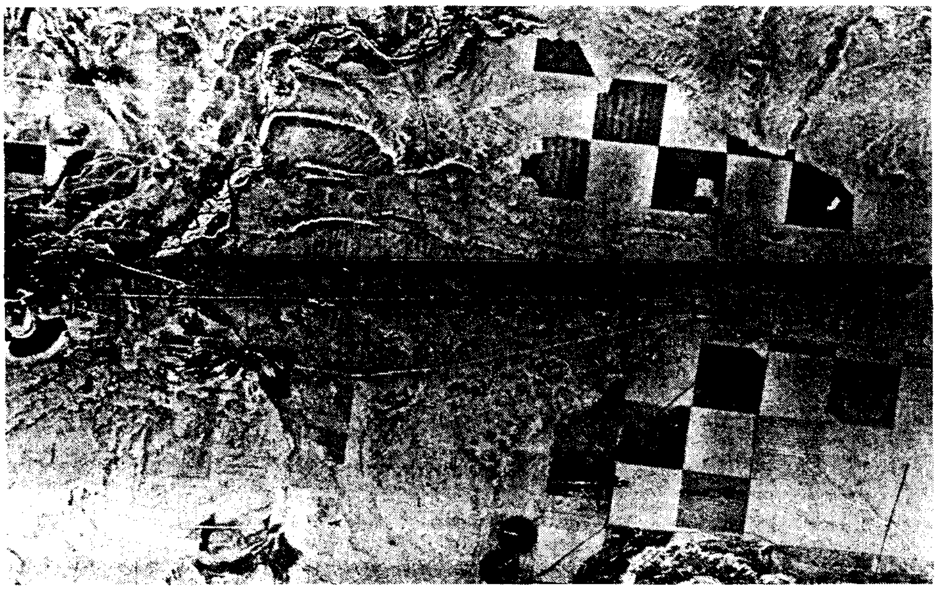

FIG. 3—ARABLE FIELDS IN A SEMI-ARID REGION (SAR IMAGE)

to present images like this and at present they take a considerable time to produce.

More powerful processors will make it possible to reduce this processing period to minutes instead of hours but there still remains the problem of knowing which area of ocean to process images from. If we want to achieve near real-time surveillance, assuming instant signal processing but a staleness of 30 minutes, then for the 100 minute orbit we would need nearly 1000 satellites up at the same time. Hence, although the capability of SAR to detect and perhaps identify surface ships has been demonstrated, there is still much work to be done to see how this capability can best be exploited.

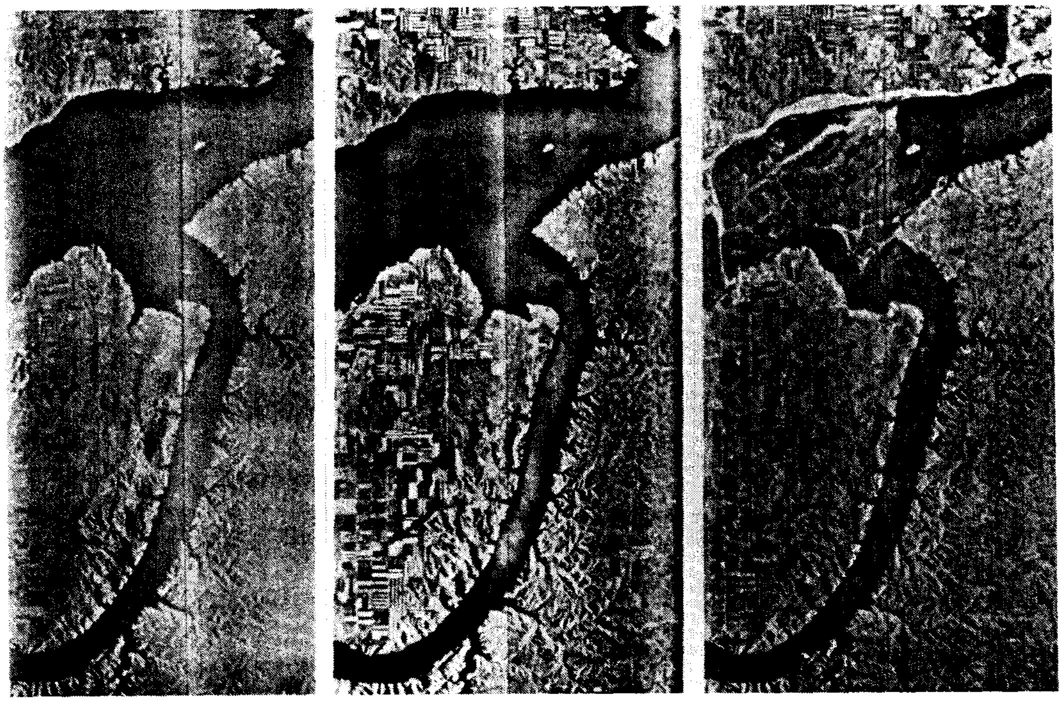

FIG. 4—SEASONAL DIFFERENCES IN VEGETATION, ETC. (SAR IMAGE)
left: June
centre: September
right: December (showing ice)

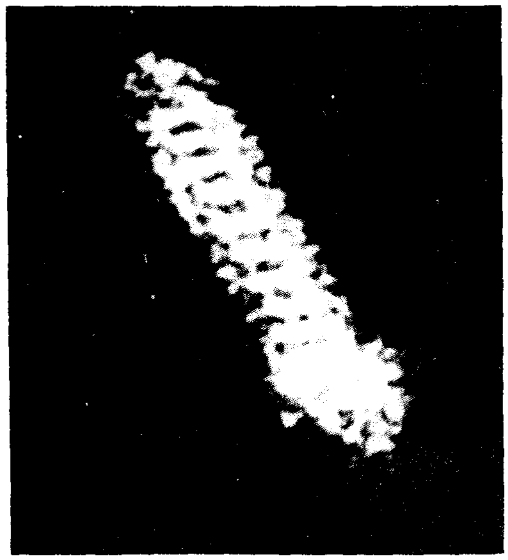

FIG. 6—A LARGE CONTAINER SHIP (SAR IMAGE)

FIG. 5—DEVONPORT DOCKYARD (SAR IMAGE)