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VISION BROADCASTING —THE ROLE OF SATELLITES

SINCE THE SPACE ERA was announced by the bleeps received from Sputnik I in October 1957, the progress made in the evolution of artificial earth satellites has been phenomenal. Long-distance communication performance and reliability have been revolutionized by their successful introduction to such an extent that television viewers on both sides of the Atlantic have come to accept relays via this medium as almost normal programme viewing. Such rapid strides make the task of forecasting the next five to ten years somewhat hazardous since the number of possible applications for satellite communications is multiplying fast. Already artificial earth satellites are being applied, either operationally or experimentally, for aviation and shipping communications, navigation, weather forecasting reconnaissance, geological surveys, data transmission and defence usage.

However, one of the most important areas foreseen for the application of satellites has been in broadcasting and, notably, television.

In this article, the current state of communication satellites is examined with particular reference to the plans for distribution and direct broadcast satellites. However, in order to give as complete and logical a picture as possible and to give a better appreciation of the problems which have to be solved to realize these new types of satellites, a brief review of the main historical milestones and current development work is given.

EVOLUTION AND DEVELOPMENT OF GLOBAL COMMUNICATION SATELLITES

Earth satellites can be considered to be of two main types; those which move asynchronously round our planet and those which are in synchronism with its rotation.

A well-known example of the former type of satellite was Telstar I, launched in 1962, which successfully relayed television pictures across the Atlantic between Andover (Maine), USA, and the European stations at Pleumeur Bodou (France), Raisting (Germany) and Goonhilly (UK). However, satellites of the Telstar type operated in a low-altitude orbit, not exceeding a few hundred miles above the earth, and thus moving relative to the earth's surface. Such a satellite could be seen for only a limited time during each 'pass' so in practice Telstar was visible to European and American stations simultaneously for only about 30 minutes—and not on every revolution of the satellite. For continuity of communication between two points using these types of satellites, a number would be required as well as dual aerial installations at any one point for tracking both the 'setting' and 'rising' satellites.

However, work initiated by the Hughes Aircraft Company in the USA was actively moving along the path first suggested by a British scientist Arthur C. Clarke. In an article 'Extraterrestrial Relays' in the October, 1945, edition of *Wireless World*, Clarke suggested that a satellite placed in an equatorial orbit 22,300 miles above the earth could provide a 24-hour communication service. At that altitude, the orbital speed acquired by the satellite permits it to keep pace with the earth's rotation, so as to appear stationary above the chosen point. He further postulated that three such satellites could provide coverage of the main populated areas of the world.

It should be noted, however, that due to the transmit and receive distances (a total of approximately 44,600 statute miles), geo-stationary satellite systems are subject to a long propagation delay of the order of 0·5 second (two way) which leads to objectionable echo effects. However, recent work on improved echo suppressors should minimize these undesirable effects.

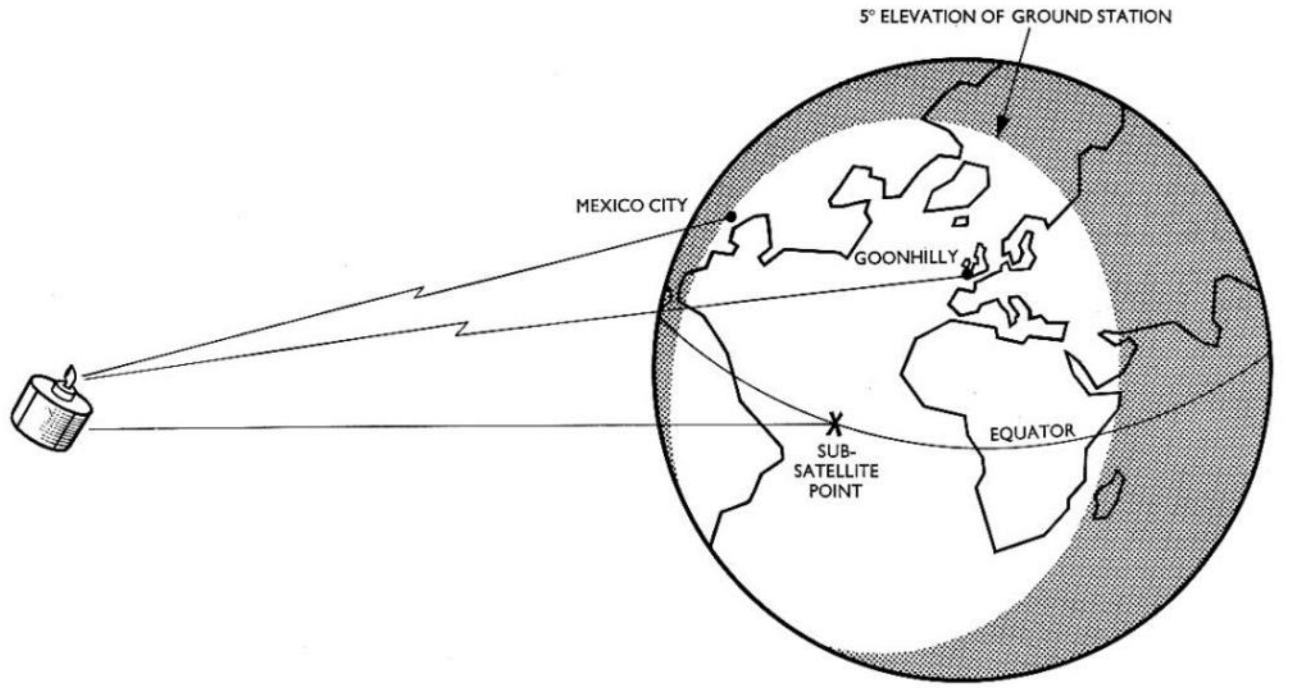

Fig. 1. INTELSAT III when stationed over the Atlantic can act as a relay point for any earth station within the ellipse.

EARLY BIRD

This concept was translated into reality by the National Aeronautics Space Administration (N.A.S.A) and the Hughes Aircraft Company, and a series of satellites termed SYNCOM was designed and built. Though the first of these, launched in July 1963, suffered a communication failure, the subsequent satellites went on to achieve a series of brilliant successes. Syncom III (still operational) was positioned over the Pacific in August 1964 and used to relay the television signals from the Tokyo Olympic Games to the west coast of America. Early Bird, ordered and operated by COMSAT (the Communications Satellite Corporation of America), was launched and positioned over the Atlantic in April 1965 to become the world's first commercial satellite, and is still giving excellent service.[1]

One of the aims of COMSAT had been to establish, in conjunction with overseas countries, a global communication system. An agreement was signed in August 1964 between a number of nations who formed INTELSAT. Since that time the number of signatories has risen to 62 and further countries are expected to join.

One of the initial tasks of INTELSAT was to decide on the type of satellite and its performance to establish the basic phase of the global plan. Following a series of studies, the synchronous orbit satellite was chosen and orders placed for six. Two of these satellites are to be positioned over the Atlantic, and one each over the Indian and Pacific Oceans, leaving two spares. The first of these satellites, INTELSAT III, with a communication capacity of 1200 two-way telephone channels or up to two television channels, was launched in September 1968. Unfortunately it failed to go into synchronous orbit due to a fault in the third stage of the launch vehicle. The first assignment planned for this satellite was to be the relaying of colour television pictures from the Olympic Games in Mexico. The games were ultimately relayed via one of the ATS (Application Technology Satellites) orbiting off Brazil—a solution which proved to be a satisfactory substitute.

In England, the signals from the satellite will be received by the new Goonhilly II station. Around the world, stations are being planned or are under construction, to operate with these new satellites to forge the first links in the INTELSTAT global network. However, satellite communications never mark time and already the next generation of even larger satellites, INTELSTAT IV is being planned with communication capacities of about 5,000 duplex telephony channels.

NETWORK PLANNING

Further, the organizational arrangements of INTELSAT are due to be reviewed in 1969 when the existing interim agreements are due for ratification. It is generally known that the present organization of INTELSAT is heavily influenced by the United States and there are feelings, particularly strong within Europe, for a change in the management agreements. Part of this general review is the consideration of the future plans for the global communication network. Certainly with the coming realization of a world-wide link-up of the telecommunication services via satellites the possibilities are enormous.

Mention should be made of the INTELSAT II satellites which were launched over the Atlantic and Pacific Oceans to provide special communication support facilities for the Apollo 'man on the moon' project. These satellites, which have a capacity of about 240 duplex telephony channels (or one t.v monochrome channel), have been available for commercial traffic, when not required for their prime role.

At this point it is considered appropriate to discuss a number of the technical problems which are currently being investigated in the USA and Europe concerning communication satellites, since the resolution of these directly affects their future application for distribution and direct broadcast, as well as for other purposes.

One of the most important features of current satellites, which has the effect of greatly complicating the design of the receiving earth stations, is the limitation in radiated power. At present, power supplies for the active elements in the satellite are derived from solar cells fitted around the periphery. It is now possible to produce 8–10W per sq.ft of total surface area of solar cells—provided the panels are fully orientated to solar radiation (three axes). The number decreases to 1·25–1·75W per sq.ft of total area for an unorientated (non-spin) system; semi-orientated (spin-stabilized) systems give 2·5–3·2W per sq.ft of total area. It is considered that further development of the solar cell system can produce total powers for satellites of the order of 2kW, which will be necessary for the distribution satellite systems if the ground station design is to be simplified. Study has also been undertaken into nuclear sources as a method of developing the higher powers of 10–20kW which will be required for the multi-programme direct broadcast satellites.

Another aspect which has a fundamental effect on satellite design is the present capability of launchers. For the realization of a high-power, multi-programme direct 'into-the-home' synchronous satellite, the weight could well be up to 5,000lb which is beyond the present capability of available launchers (understood to be some 4,000lb) but work is proceeding in the USA to develop launchers with higher lift-off performance specifically for the advanced communication satellites.

A further important feature of current satellite design is the multiple-access facility. To realize the establishment of a global communication network it is essential that a number of earth stations should be able to communicate with others via the satellite (assuming they are within its coverage). This, however, raises problems in that the already limited power of the satellite has to be shared among the earth stations and also the wanted to unwanted signal to noise ratio of the communication system decreases, on account of inter-modulation effects between the various carriers passing through the common travelling wave tube in the satellite repeater.

Other areas of study being undertaken in communication satellites include digital modulation techniques, improving the accuracy of station keeping and orientation of the satellite (permitting narrower beam

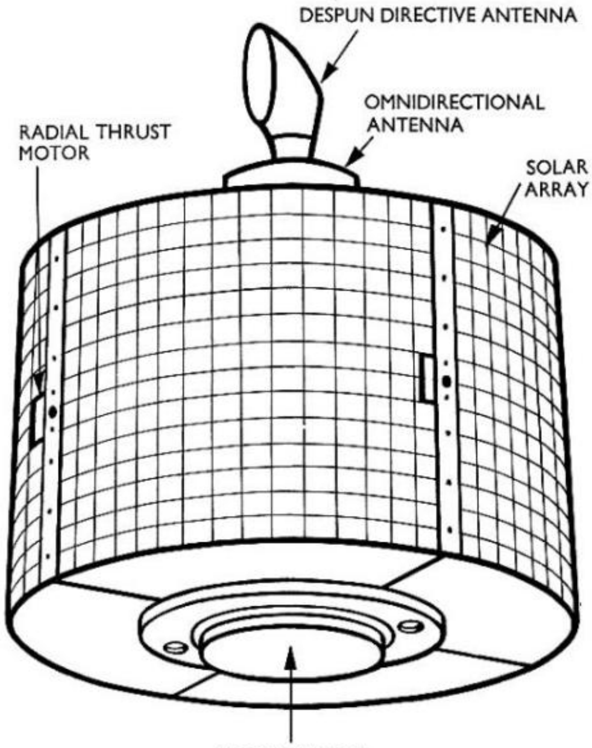

Fig. 2. With a capacity of 1,200 channels INTELSAT III is the most advanced civil communications satellite in the present series. Thought is already being given to INTELSAT IV with a capacity of 5,000 channels.

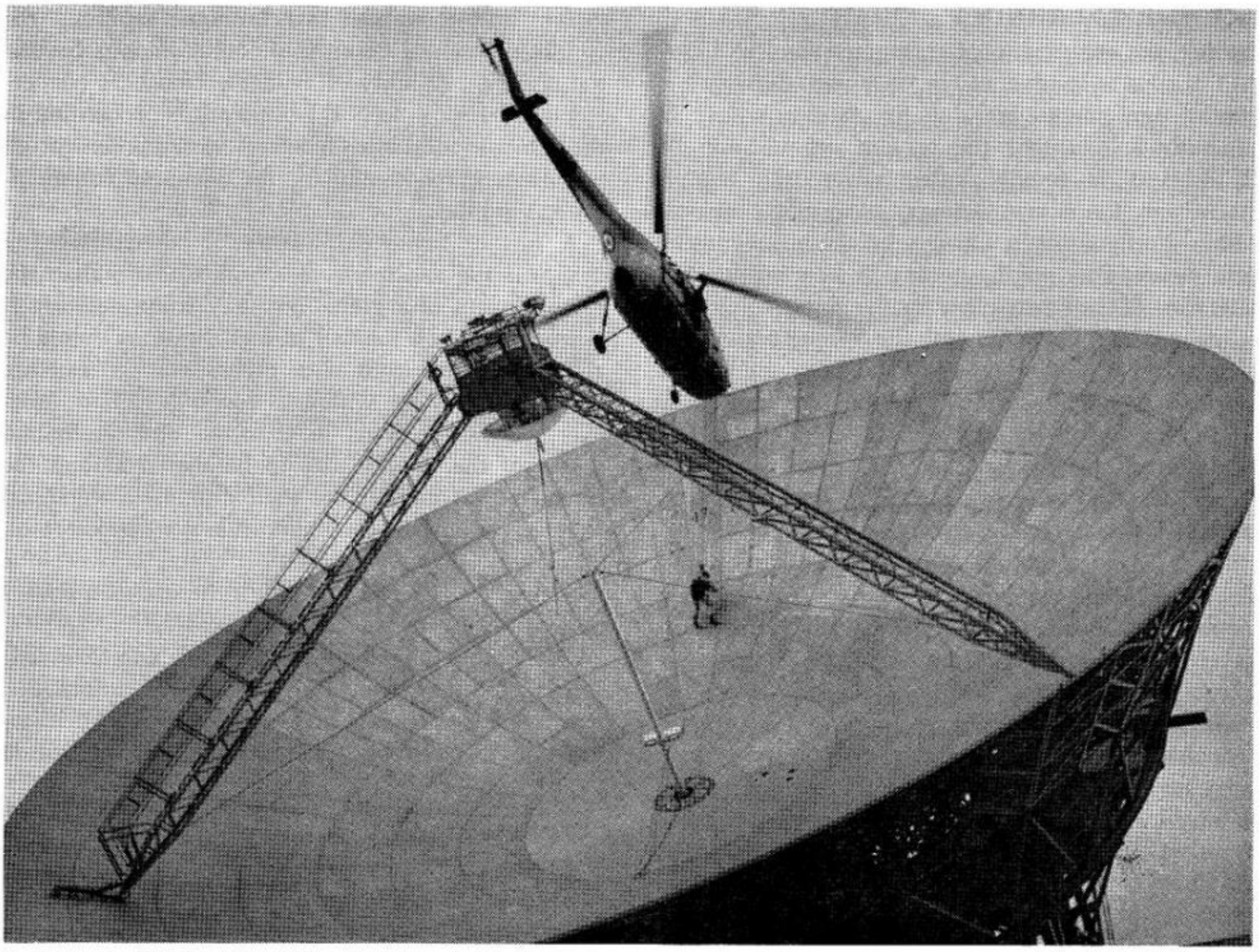

Fig. 3. The Goonhilly II aerial with 90ft reflector.

antennae to be used), and also despun antennae. The later types of synchronous satellites are utilizing despun antennae which mechanically rotate at a speed in the opposite direction to the natural spin rate of the satellite (in the range 120/150 r.p.m), enabling the radiated coverage to be shaped to that desired. However, study is also well advanced on achieving this effect by electronic means which should lead to higher reliability. This feature of shaping the coverage to within reasonably precise limits (coupled with improved station keeping) will be essential for broadcasting satellites where technical and legal problems exist.

As is generally known, the synchronous satellite is placed in its 24-hour equatorial orbit at a height of 22,300 miles above the earth and manœuvred to its chosen position by the operation of gas jets fitted to the satellite. External forces operating on the satellite, however, gives it a drift (relative to the earth's surface) which can be corrected by the operation of the gas jets. This has to be done sparingly to conserve 'the on-board' supply and it is this which principally determines the useful life of the satellite. Investigation into the control system for the satellite is aimed at extending its life from the present capability of five years to up to ten and more years.

The limitation in radiated power from the satellite (as mentioned earlier) has its repercussions on the design of the co-operating earth stations in the INTELSAT global network and necessitates the use of large steerable antenna of at least 85ft in diameter, and an extremely efficient low noise, wideband (500MHz) receiver to amplify the minute signals. Further, the antenna has to point at the satellite with an accuracy of 1 minute of arc in order to capture the maximum available signal. It will be recognized that once power supplies in the satellite become larger the earth station can be simplified and for the broadcast

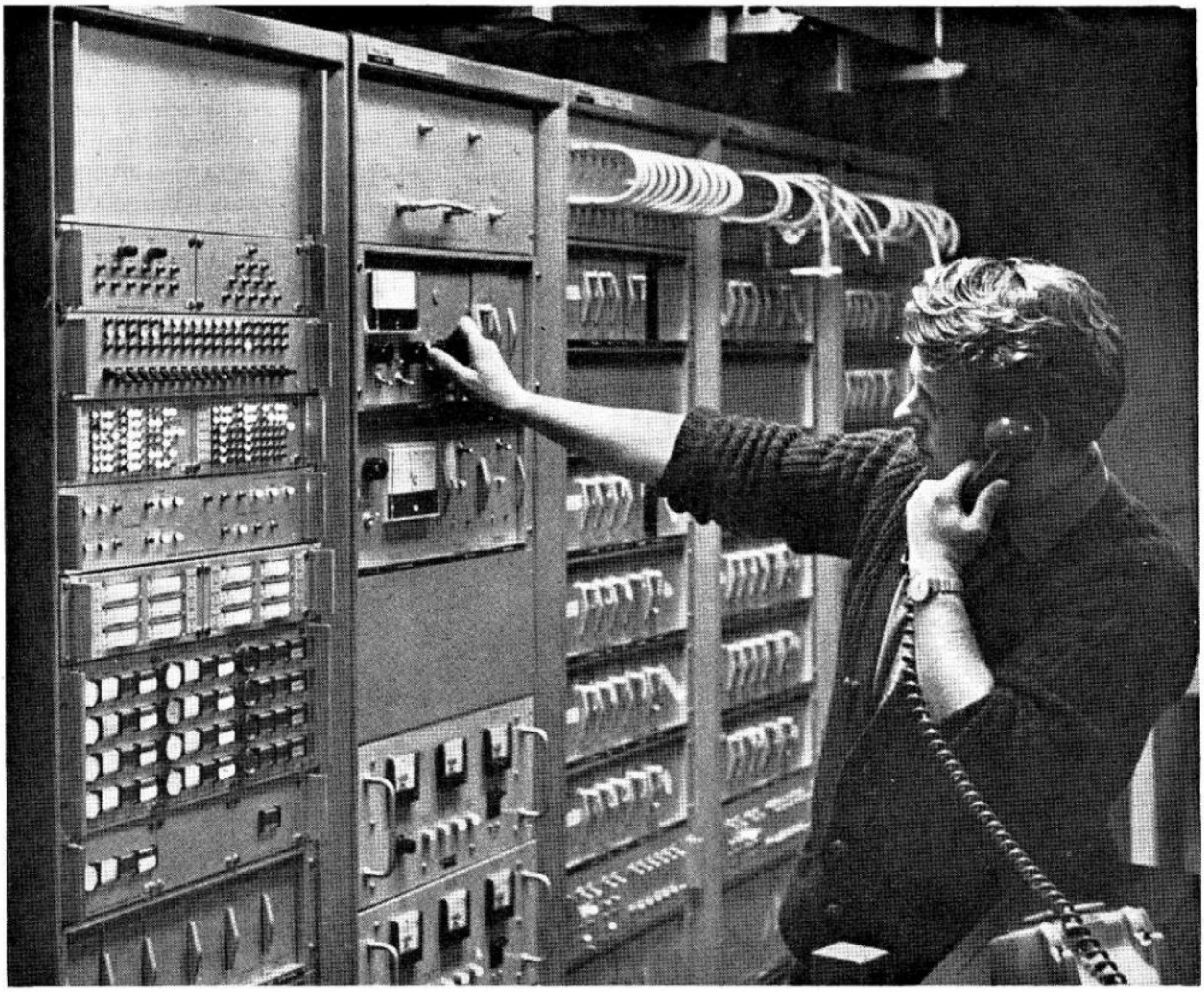

Fig. 4. Receiving equipment recently installed at Goonhilly II.

distribution receiving station, antenna sizes of 30–40ft will be possible.

BROADCASTING SATELLITES

The possibilities of utilizing satellites for distribution of television programmes and ultimately for direct broadcast have been under intense study in various parts of the world. The prospects, both socially and economically, are exciting since a whole new field of opportunity is opened up for regional, national and international entertainment, and more important still the possibilities for education services for the under-developed regions of the world.

Regional distribution of television and radio programmes is a subject which has attracted much attention on both sides of the Atlantic with Canada currently considering such a scheme using one to two synchronous satellites for covering the entire nation. Similar systems have also been considered in the United States and Australia. The economics are extremely attractive when it is related to the number of conventional terrestrial television transmitting stations required to provide equivalent coverage.

The U.S.S.R, who declined invitations to join INTELSAT, established their own domestic *Molniya* television satellite system operating telephony and colour television relays.

A most important application of distribution satellites will be in the field of education. With the possibilities of covering vast areas with higher power, receiving terminals can be small, simple and economic in cost. Such systems will undoubtedly be of great importance, especially in the under-developed regions of the world. Many problems of course have to be solved, notably language, but the prospects are so great that UNESCO is studying a pilot scheme for India, Indonesia and Brazil, while in America the Ford Foundation and other users are proposing the use of satellites for providing similar services.

In Europe a study of providing television regional distribution systems has been made by various bodies and providing governmental agreement and support can be found, a network could be established, largely using European technology. The question of the launcher, however, remains and it would appear that reliance would have to be placed on an American launch.

A fundamental problem still to be solved is possible co-channel interference with other satellites or ground stations within its coverage. With land-based stations, a common frequency can be used a large number of times with few problems, but a broadcast satellite serving, say, Europe would have to be allocated a discrete frequency since the high satellite signal level would cause excessive interference to established users in a band-shared system. The solution would appear to be offered by the design of highly directional satellite antennae and control of radiated power. Clearly international control is imperative if the frequency band is not to become chaotic.

INTERNATIONAL STANDARDS

A basic point which concerns all types of communication satellite systems is the need for international agreement on television standards. On the present global links, complex standards conversion equipment is required for international exchange of programmes. In the case of transmitting television from the United Kingdom to the United States it is usually necessary to convert to the 525-line standard before transmission to the satellite as USA internal radio relay links generally have insufficient bandwidth to carry the 625-line standard.

SATELLITE DIRECTIVITY

The next step in broadcasting satellites is the design of significantly larger and more powerful satellites which could weigh several tons. These could radiate beams of 5° to cover Europe and 2° for the UK to enable domestic receivers to pick-up direct transmissions. It is hoped that broadcasting from satellites of this type will necessitate the minimum number of modifications to the domestic receiver, possibly the addition of a low-noise front end and an improved antenna. However, since the received signal will be more uniform over the area of the satellite's coverage, multiple path effects should be largely overcome and the dynamic range of receivers limited accordingly. From the receiving viewpoint, a much wider choice of programmes could be made available to an extremely large number of homes in many countries (with the proviso, mentioned earlier, that agreement is reached on t.v standards). The question of propaganda broadcasting raises important political and legal issues, since receiving countries, to a great extent, could have no influence over its control.

It has been estimated that the full direct broadcast satellite could be up to ten years away, but the distribution satellites could be in service within five years.

FUTURE TRENDS

So far the synchronous satellite has been considered for its role in acting as a relay or as a direct transmitter to the user. The satellite can also be an important tool for the broadcasting authority as a means for relaying back to the transmitting centre, outside broadcast 'actualities'. Such flexibility would permit television outside broadcast units to become highly mobile, ranging all over the world. Such facilities would be particularly appropriate for relaying 'on the spot' programmes of special news value such as an earthquake or major incident. In this form the outside broadcast unit would be extended to cover a satellite transmitting station having a 20–30ft diameter antenna. The use of such equipment would of course have to be matched to a new series of satellites which would be made available for broadcasting authorities as well as for other purposes. At present the INTELSAT agreement stipulates minimum performance specifications for participating earth stations on the global system, and as previously mentioned this calls for antennae of at least 85ft in diameter.

This article has restricted its view to the role of satellites for broadcasting purposes. Beyond this, however, the coming of synchronous satellites has opened up a whole new world of possibilities which are as exciting for the potential users as to those engaged in planning the future systems.

ACKNOWLEDGEMENT

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REFERENCE

1 A. T. Owens: Early Bird Television Transmissions; *Sound and Vision broadcasting*, Vol. 7, No. 1, Spring 1966, p. 34.