Reprinted from

BULLETIN

of the Oxford University Institute of Economics & Statistics

Volume 29, No. 1, 1967

EDITORS: *E. F. Jackson and G. B. Richardson*
assisted by: *J. B. Knight*

BASIL BLACKWELL · OXFORD
PUBLISHER

For the Second time
Best wishes BdL

THE PROCESS OF INNOVATION: MAGNETIC RECORDING AND THE BROADCASTING INDUSTRY IN THE USA

By ROBERT HOULTON

Innovation has long been recognised as a complex process. 'The subject is not one to which economic analysis is easily applied. . . . And the descriptive Economist finds his way blocked by the complexity of the subject.'[1] Certainly, there are many difficulties. There is always a lack of data about innovation, and in certain cases the data that are available are of doubtful integrity. The economist is under pressure to produce a coherent account of what could be essentially incoherent or irrational. He is also faced with a tradition, maintained by his peers, that economic and technological data determine the emphasis of research into the process of innovation.

This prompts the question of whether we can deal adequately with complex matters with limited tools? Is some of the 'complexity' of our own creation, due to self-imposed blinkers? Is our prior determination of what constitutes relevant knowledge hampering the process of understanding which, after all, should be the primary goal of scholarship?

The purpose of this paper is to describe, with some detail, the process of innovation by dealing with two related innovations, and to introduce data, psychological, social and cultural, that would not normally be considered relevant. A secondary purpose is to emphasise the tortuous, and often incoherent, path of innovation, and to show that 'Progress—in the industrial as well as any other sector or social of cultural life—not only proceeds by jerks and rushes but also by one-sided rushes productive of consequences other than those which would ensue in the case of coordinated rushes.'[2]

To summarise the innovations: In April, 1948, the American Broadcasting Company became the first radio network in the United States to record and repeat programmes by magnetic tape. This enabled ABC to compensate for differences in the four time-zones across the North American continent. Variations in clock-time due to the uneven adoption of summer-time 'daylight-saving' schemes could also be adjusted, and the radio audience in 'prime-time' (7.30 to 11 p.m.) could be maximised. Magnetic tape made this possible without serious deterioration in broadcast quality. The second innovation occurred November, 1956, when Columbia Broadcasting System recorded and repeated a television programme through its network—again for time compensation. The equipment in both innovations was supplied by Ampex Corporation (called Ampex-Electric in 1948).

An observer might think that these innovations were part of normal technical progress. Yet, magnetic sound recording was a by-product of an intra-industry struggle in which the two most powerful networks were against innovation. The first innovation in ensuring the survival of Ampex helped to build the institutional

[1] J. Jewkes, D. Sawyers and R. Stillerman, The Sources of Invention, London, 1958, p. 3.
[2] J. Schumpter, Business Cycles (1939) Abridged Edition New York, 1964, p. 76.

framework for the second innovation. Strong anti-innovation forces were present within Ampex during the development of magnetic television recording which almost prevented the creation of a practical machine. Here the time-scale of innovation was important . When Ampex produced the first practical video-tape recorder (VTR) no other firm had solved the formidable technical problems.

Three years later, General Electric announced an alternative means of recording TV programmes, thermoplastic recording,[1] but this had not been developed into a marketable commodity. Video-tape recording had a three year lead, making it difficult to create an economically feasible alternative technology. If the VTR had been delayed until after 1959, probably it too would have found it difficult to challenge thermoplastic recording technology.

Development of Network Radio

Radio broadcasting was a spontaneous development in the USA after World War I. Radio stations were privately owned, situated in the larger towns and cities, and directed their signal at the surrounding community. Simultaneous broadcasting of high quality programmes by stations linked to form 'networks' was found to give economies of scale and larger audiences. As revenue came from advertisers concerned with reaching the largest possible audience for their expenditures, radio networks dominated broadcasting from the 1920's to early 1950's.

The American Telephone and Telegraph Co. created the first network by linking its radio stations in New York and Boston in January, 1923. The signal was carried on A.T. and T.'s own telephone lines. By 1925, the Telephone Company's network numbered 26 stations across the USA and attracted a gross annual revenue of $750,000 from advertisers.[2] In 1919, A.T. and T. had co-operated with General Electric, Westinghouse, the United Fruit Company and smaller firms, in setting up the Radio Corporation of America. Friction developed between A.T. and T. and the 'Radio Group' (R.C.A., Westinghouse, General Electric) when RCA organised a competing radio network in December, 1923. A.T. and T. would not allow the use of its telephone lines for radio networking and RCA was forced to use telegraph lines which lowered the broadcast quality. RCA was prevented by a contract with A.T. and T. from selling time to advertisers and was thus forced to allow advertisers the free use of its air-time. But RCA was deriving revenues from the sale of radio receivers.[3]

In 1926 the dispute was settled when A.T. and T. sold its network to RCA for $1,000,000 and agreed not to engage in broadcasting for a minimum of seven years. All restrictions on RCA's operations were removed and it was guaranteed that only A.T. and T.'s telephone lines would be used where possible.[4] RCA set up a subsidiary, National Broadcasting Company, to operate the two radio networks. By 1938, the annual profit earned by NBC amounted to 80 per cent of its investment in equipment and facilities.[5] In 1927, a third network was

[1] W. E. Glenn, Thermoplastic Recording, Jour. Society of Motion Picture and Television Engineers, v. 69; pp. 577–580, September 1960.
[2] Federal Communications Commission, Report on Chain Broadcasting, Order 37, Docket 5060, Washington May, 1941, pp. 5–6.
[3] FCC Order 37, op. cit., pp. 7–8. [4] Op. cit. pp. 7–8. [5] Op. cit. p. 33.

organised which, after financial difficulties and changes in ownership, became the Columbia Broadcasting System. A profit of $474,203 on a turnover of $4,453,181 was returned in 1929 and subsequently CBS proved to be as profitable as NCB.[1] The Mutual Broadcasting System was organised on a co-operative basis in 1934 and differed from the other networks in owning no studios, no stations and producing no programmes other than news broadcasts from Europe. All programmes originated from one or other of the participating stations.[2]

The Federal Communications Commission, in 1938, as the Federal Agency responsible for preserving the public interest in broadcasting, became concerned at the level of 'corporate honesty and sought to arrest certain monopoly trends related to network broadcasting'.[3] NBS and CBS owned and operated 18 radio stations. These were 'among the most powerful and desirable in the country. . . . They (were) located in the largest and richest markets and their station rates, time sales, and revenues (were) among the highest for all stations. . . . Ownership . . . renders such stations permanently inaccessible to competing networks.'[4]

In one of a series of new regulations covering network broadcasting, May 1941, the Commission called for the separation of NBC's two networks.[5] RCA complied with the order by gathering the least desirable stations and affiliates into one organisation, the 'Blue Network', and sold them to Mr. Edward Noble, a candy manufacturer. 'For his $8,000,000, Mr. Noble didn't receive very much—five transmitters, a title, some people, engineers and managers and that's all. The Blue Network did not own the inter-connecting lines, they belonged to A.T. and T.'[6] The Blue Network became the American Broadcasting Company.

If the four major networks are ranked in order of their innovatory potential, in the immediate post-war years, the primary position must be given to NBC and its parent company.[7] Radio Corporation of America, by 1945, dominated the whole electronics industry as 'the leading patent holder and developer of radio and allied lines, and through RCA-Victor Division engages in the manufacture and sale of apparatus for radio purposes, television, and for recording and reproducing sound; and through subsidiaries engaged in . . . the operation of radio broadcasting stations and the supplying of programmes for radio broadcasting.'[8] RCA, a conglomeration of economic and technological power, was the most likely innovatory source. The second most likely source was Columbia Broadcasting System, which, during the war years, had built up its research and development department. A rivalry developed between the laboratories of RCA and CBS, which later took on the characteristics of a feud, and could be expected to produce innovations in radio broadcasting.[9] Little could be expected from the other two networks—Mutual lacked technical staff and ABC was

[1] Op. cit. pp. 21–23. [2] Op. cit. p. 27.
[3] L. White, The American Radio, Chicago, 1947, p. 127.
[4] FCC Order 37, p. 67.
[5] FCC Order 37, Regulation 3.107—'No license shall be issued to a standard broadcast station affiliated with a network organisation which maintains more than one network. . . .'
[6] Interview with Mr. W. Trevarthen, former Vice President Engineering American Broadcasting Company, New York 28th Oct., 1965.
[7] W. Rupert MacLaurin, Invention and Innovation in the Radio Industry, New York 1949, see Chapters VIII and IX.
[8] Moody's Manual of Investments, 1949.
[9] R. Gelatt, The Fabulous Phonograph, New York 1965, pp. 290–296.

Gross Network Billings[1] of the 4 US Radio Networks: Gross Revenue and Net Income for 3 Parent Companies, 1942–1948

Year	Radio Corporation of America			Columbia Broadcasting System			American Broadcasting Company			Mutual Broadcasting System[4]	
	NBC Gross Billings $'000[2]	Gross Revenue $'000	Net Income $'000	Gross Billings $'000[2]	Gross Revenue $'000	Net Income $'000	Gross Billings $'000[2]	Gross Revenue $'000	Net Income $'000	Gross Billings $'000[2]	
1942	47,400[3]	196,020	9,002	45,593	62,211	8,210	15,783	12,463	53	9,636	
1943	54,000	293,326	10,192	57,951	75,166	12,043	24,870	18,820	696	13,841	
1944	57,000[3]	324,754	10,263	66,791	84,905	12,714	40,945	30,342	466	19,533	
1945	64,500[3]	278,327	11,317	65,724	86,257	10,524	40,046	30,688	213	20,637	
1946	66,000	236,145	10,985	60,064	91,996	8,949	40,604	32,829	1,232	25,907	
1947	66,000	312,678	18,769	60,600[3]	101,045	9,086	43,548	35,955	1,520	22,372	
1948	69,700	356,864	24,022	66,100[3]	98,377	7,462	44,303	37,110	468	22,770	

[1] Moody's Manual of Investments, New York, 1942–1948. [2] Radio Annual, New York, 1943–1949.
[3] Estimated from FCC statistics and Radio Annual, 1943–1949, data.
[4] No estimates available for Revenue and Income of MBS co-operating firms.

Note. Gross Billings—the expenditures of advertisers in radio *before* discounts for the frequency of the advertisement and for promoting the programme associated with the commercial message. Advertising agency commissions are paid by the media (radio) which makes for a further reduction of the 'net'. Normally agencies charge 15 per cent commission, but the field is complicated by split commissions, negotiated fees and services which are provided free. Therefore Gross Billings are the only consistent measure of advertising expenditures but suffer from being an exaggeration of actual expenditures.

struggling to survive (Table 1). Yet ABC's vulnerable situation became a more favourable environment for innovation than the technological 'muscle-bound' security of its two major competitors.

Threats to Stability of Network Radio

Three developments threatened the stability of network radio post-1945: television, Frequency Modulated radio (usually termed VHF in Europe) and Electrical Transcriptions. Several television stations had been broadcasting when the entry of the USA into the war brought development to a standstill. In the post-war period it was evident that TV would develop into an important broadcasting medium and would seriously affect the radio industry. Several factors suggested that networking would be a feature of TV broadcasting. First, there was a technical limit on the number of television frequencies available, ensuring limited access to major markets. Secondly, because of increased technical and labour inputs, TV programming would be expensive. Finally, if the new medium was to be advertiser-supported it required a mass audience. Both CBS and NBC were determined to dominate TV networking as they had in radio. Therefore, they had a powerful reason for protecting their position, and the technological and institutional status quo within radio networking, until they had completed 'colonising' the new medium.

Frequency Modulated (FM) radio was invented by Major Edwin Armstrong, a Columbia University Professor, in the 1930's, and offered substantial advantages over standard, Amplitude Modulated (AM) radio. FM gave exceptional clarity of reception with freedom from interference, allowed for a larger number of radio stations than AM, and promised the creation of new radio networks linked by micro-wave transmitters instead of telephone lines. It gave substantial cost reductions and posed a threat to the radio networks and the telephone companies. A Congressional Committee heard that: 'there are some AM broadcasters who shudder to think of FM coming in (because) . . . no station will be able to cover more area than its competitors . . . they are all on an equal basis.'[1] The powerful clear channel radio stations (AM) owned by or affiliated with the major networks were the backbone of the networking system.

Both major networks attempted to hinder the full development of FM broadcasting, with some assistance from the Federal Communications Commission. In 1945, the FFC moved FM broadcasting from the wave-band it had previously occupied to another, higher wave-band. Subsequent evidence suggests the possibility of a conspiracy, involving FCC staff members, in connection with this decision.[2] Columbia Broadcasting System, the same year, submitted a series of proposals to the FCC apparently designed to hinder the growth of micro-wave FM radio networks. The FCC made these 'impartial' suggestions the basis for further FM regulations. By two decisions the FCC rendered existing FM radio receivers obsolete, forced FM broadcasters to rebuild their equipment, and tied

[1] House of Representatives Committee on Education and Labour, 80th Congress, 2nd Session, Hearings in Washington, D.C., Jan. 13, 14, 15, 16, 19, 21 and 22, 1948: testimony of J. N. Bailey, Executive Director of the FM Association, p. 91.

[2] H. of R. Cttee., op. cit., testimony of Major Edwin H. Armstrong, pp. 159–160. Also L. Lessing, Man of High Fidelity: Edwin Howard Armstrong, New York 1956, pp. 269–270.

future FM radio networks to the telephone companies.[1] The networks thus effectively contained the FM threat.[2]

Electrical transcriptions were similar to phonograph records, only larger and turning at a much slower speed than the 78 r.p.m. of then-current records.[3] Each ET held 12–15 minutes of programming and threatened the radio networks at the most basic level. A 'canned' ET radio show could be distributed across the USA by post, making the radio networks, with their telephone lines, redundant. Either the big corporate advertisers or the large advertising agencies could, if they so desired, set up their own transcription networks.[4] In 1940, the Keystone Broadcasting System was organised as an ET network supplying programmes to radio stations in non-metropolitan areas. By 1944, Keystone had 200 affiliates which were being supplied with programmes lasting 4 hours a day, seven days a week.[5]

The reaction of the major networks to ET's took several forms. In 1935, NBC went into the transcription business, followed by CBS in 1940.[6] RCA had merged with the largest US recording company, Victor Talking Machine Co., in 1929 and CBS purchased the other two major recording firms, American Record Company and Columbia Phonograph Company, in 1938.[7] The major potential sources of high quality ET's were firmly in the hands of the networks.[8]

Both networks had a 'stranglehold'[9] on the supply of radio talent. Up to the 1940's this was manifested in the talent agencies operated by the networks, with a clear conflict of interest being present.[10] Under pressure from the FCC these monopolitic restraints on the supply of performers, writers and producers, were removed, but the networks were successful in discouraging 'top' personalities from working for the independent ET companies. By 1946, the ET companies were making virtue out of necessity—'Many slick shows without . . . "big names" have pulled greater results per dollar of expenditure for time and programme than some of the more costly shows with the so-called "stars". The pay-off isn't always in the "big-name", or even in the ratings. It's in the jingle of the sponsor's cash register.'[11] The lack of adequate talent must have seriously hampered the growth of the ET industry.

[1] The tendency for Federal Agencies to identify themselves with the industry they are supposed to be regulating has often been noted.

[2] Armstrong was involved in litigation with RCA over FM patents. MacLaurin (op. cit., p. 257) states that Armstrong sold the patent rights to an earlier invention because—'I (Armstrong) was in danger of being litigated to death'. When Armstrong committed suicide in January, 1954, the FM litigation was still unsettled after a decade in the courts.

[3] ET's were a development of the Vitaphone disk-system invented by Bell Laboratories and used by Warner Bros. in the early 'talkies'. Motion pictures later adopted the technically superior 'optical-sound' system.

[4] White, op. cit., pp. 56–57. There was considerable tension between broadcasters and the advertising industry.

[5] Radio Annual, New York, 1944.

[6] FCC Order 37, op. cit., pp. 17–18 and p. 25.

[7] O. Read and W. L. Welch, From Tinfoil to Stereo, New York, 1959, pp. 486–498.

[8] A personal suspicion is that the poor quality of records made in the USA in the 1930's and '40's is connected with the reluctance of the recording companies (controlled by the networks) to provide free musical programming for small radio stations. Unlike most other countries, the broadcasting industry in the USA pays no royalties to the recording companies. (R.H.)

[9] White, op. cit., p. 40.

[10] FCC Order 37, op. cit., p. 17 and pp. 24–25.

[11] Radio Annual, New York 1946, p. 71.

The final line of defence of CBS and NBC was a strict rule that major network broadcasts be 'live'. An event had to be exceptional to beat the ban. In May, 1937, two Chicago broadcasters took portable recording equipment to Lakehurst, NJ, to interview celebrities arriving from Europe on the airship, the Hindenburg, and recorded a dramatic eye-witness account of the disaster. 'The recordings were flown to the National Broadcasting Company in New York for transmission over the wire lines to WLS (Chicago). Officials of NBC were so impressed by the account that a *rule of ten years' standing was set aside* and the recordings broadcast through all of the stations of the NBC network.'[1] However, the rule against ET network broadcasts was to be successfully challenged by the singer and actor, Bing Crosby, and by the American Broadcasting Company.

Bing Crosby—the Catalyst of Innovation

Bing Crosby, over a twenty year period beginning in the early 1930's, was the most popular entertainer in the USA.[2] He had a direct effect on the whole development of the mass-entertainment industry in these years. 'At times it has been asserted that in our larger cities during certain hours of the day, there have been times when it has been impossible to get out of the reach of Bing Crosby's voice! Crosby was so unbelievably popular that many of the so-called record stations, those which depended almost entirely upon records for broadcasting, found it expedient to feature programs of Crosby's records twice a day and sometimes even more often.'[3] Crosby's career at certain junctures is distinguished by a number of shrewd business decisions by Crosby himself, by Everett Crosby—his manager and brother—and by Jack Kapp, who first recorded Crosby when he was General Manager of the Brunswick recording company and who later helped to organise the Decca Record Co. (USA) and induced Crosby to record for that label. But to understand Crosby's success it is necessary to note the inter-relationship of his career in radio, records and motion pictures.

Through the mass-entertainment media the Crosby persona was broken down into three commodities, Crosby-records, Crosby-radio and Crosby-films. Part of Crosby's uniqueness was that he could be 'marketed' successfully through the three media. The 'consumption' of one Crosby-commodity while satisfying one particular demand would also have the effect of increasing the demand for the other two commodities. Thus, when Bing Crosby made a radio broadcast it stimulated the sales of his records and attracted an audience for his films. This effect, being a process analogous to creating resonance in physical structures, had a tendency to increase over time, and finally to decline as the basic ingredients of the Crosby-persona, the voice and the appearance, deteriorated.

At the end of World War II, Bing Crosby was at the height of his popularity. Total sales of his records were in excess of 75,000,000 and had brought him an

[1] Radio Annual, New York 1945, p. 909, italics added.

[2] All the books about Crosby have been written for his 'fans'. D. Boorstin states, with some justice, a that study of popular figures 'would teach us more about ourselves than many of the more conventionally "important" figures in our political, literary, and academic life' (D. Boorstin, The Image, New York, 1962, p. 274.)

[3] Read and Welch, op. cit., p. 297.

income estimated variously from $8,000,000 to $12,000,000. His salary from the Kraft Music Hall radio show was $5,000 a week.[1] His performance in 'Going My Way' had been awarded an 'Oscar' and at the end of 1945 RKO Studios released 'The Bells of St. Mary's' which earned $8,000,000 in gross rentals in the USA and Canada alone, making it one of the four top-grossing films made up to that time.[2]

Crosby had surrounded himself with a number of interesting corporate institutions: the Crosby Investment Coporation, a trust fund for his four sons, Bing Crosby Enterprises to produce, manage, and direct Bing Crosby and other related ventures;[3] the Crosby Research Foundation, founded in 1940 to finance promising inventions and market *new innovations*.[4] Bing Crosby has to be seen in three different rôles—the entertainer, the businessman, and the entrepreneur actively seeking out new innovations.

In June, 1945, Bing Crosby quit his radio show, and as Kraft had an exclusive contract until 1950 they sued for performance rights. Under a California statute that limited personal contracts to seven years, the courts sustained Crosby.[5] Once he was free, large advertisers vied for his services. 'With the possible exception of Franklin Roosevelt, Crosby was perhaps subjected to the greatest combined pressure that American big business ever put on one individual. The entire big board of the Stock Exchange seemed to be after him.'[6] Crosby wanted his own terms. He insisted that he control his own show and that production be handled by Bing Crosby Enterprises. If his corporation grew, he stood to make a capital gain by selling part of his investment. Capital gains tax was lower than the 91 per cent that Crosby was then paying on personal income. The second condition was that the programmes be recorded by Electrical Transcription to be broadcast over the radio network. NBC, which had broadcast the Kraft Music Hall, informed Crosby that it would not allow ET's to be used over its network. CBS followed suit. American Broadcasting Company said it would welcome Crosby, who would be an asset to the whole network. ABC also pointed out that it was planning to use ET's in the summer of 1946 to compensate for daylight-saving schemes.[7] Finally, Crosby signed a contract for three years with ABC and a large electrical appliance manufacturing firm, Philco, which specified that ET's could be used. But Philco inserted a clause in the contract that would enable it to insist on 'live' broadcasts if the audience rating fell below a certain point (a Hooper rating of 12).[8]

Why did Bing Crosby insist on ET's? He disliked the 'weekly nagging deadline'[9] of a radio show, the ridigity of a radio script and the inability to exert the kind of control over his broadcasts that was commonplace in films and records. Several 'takes' would often be required in films and records before a satisfactory performance would be achieved. But Crosby was also facing serious domestic problems. He had tried to recreate for his four sons some of the stringency of his own childhood, believing that this would be to their benefit.

[1] Fortune, January 1947, pp. 129–135.
[2] Variety, Diamond Jubilee Edition, January 1966, p. 6.
[3] Fortune, Jan. 1947, op. cit.
[4] *New York Times* Magazine, June 6, 1948.
[5] Fortune, Jan. 1947, op. cit.
[6] Fortune, op. cit., p. 132.
[7] The Billboard, Feb. 21, 1948, p. 6.
[8] Fortune, op. cit.
[9] Photoplay, June 1950, p. 96.

Crosby's strict regimen in the midst of luxury created tensions and resentment within the family group.[1] Crosby's own close relationship with his parents and brothers only served to highlight his difficulties. Most of the evidence suggests that these tensions were at their peak 1944–48. Electrical transcriptions offered Crosby a means of re-adjusting his work-load so as to be able to spend more time with his family. He could, by working continuously for several weeks, build up a stock of transcriptions which could be broadcast later at weekly intervals.

The programme was first broadcast in October, 1946, with an audience rating double that specified in the Philco contract, but then the ratings began to fall. The competing networks 'crammed their Wednesday night shows with flashy programmes designed to be heard *en bloc* in an effort to keep listeners from tuning in on Bing, thus cutting down Crosby's Hooper rating.'[2] Another cause of declining ratings was due to the interaction of technical and cultural factors. At that time, many radio shows relied heavily on a genre of low comedy known as the 'wise-crack', an art form that Crosby, and Bob Hope, had helped to develop.[3] But the 'wise-crack' presented production problems. If rehearsed, it created a poor audience response the second time round, and many 'wise-cracks' were an impromptu response adding greatly to the broadcast. Crosby, by using ET's, could record an *ad lib* performance lasting up to one hour. The final programme would then be produced by the laborious process of editing from the first disk to a second, third, fourth or fifth as necessary. As the ratings dropped lower, Crosby's staff resorted to more and more editing to 'polish' the programme.

The multiple editing of ET disks created a high frequency modulation which, when broadcast through an AM network, produced a barely audible interference which caused a strain on the listener.[4] By editing and re-editing the programme, Crosby's staff were in a vicious circle—the more they edited the more the ratings fell, and the more they edited. Philco warned that they would invoke the 'ratings clause' if it became necessary.

Magnetic Recording—Research and Development

The first magnetic recording machine was invented by a Danish engineer, Valdemar Poulsen, in 1898. Attempts to market the machine on a commercial basis failed. Magnetic recording required advances in the methods of modulating the recording signal and amplifying the recording before it was a marketable commodity.[5] However, over the following decades development became concentrated in three different recording media—steel wire, steel tape, and plastic or paper coated with a substance sensitive to magnetism.

[1] This analysis is based on a study of the ephemeral literature in Bing Crosby's file in the Library of the Academy of Motion Picture Arts and Sciences, Hollywood, Calif.

[2] Fortune, op. cit. p. 129.

[3] An example is the following exchange.

HOPE. How long do you take getting up in the morning?

CROSBY. Twenty-five minutes.

HOPE. You're getting old, it takes me five minutes.

CROSBY. But I wash in a morning.

HOPE. You do? I'd sooner send mine to a laundry.

[4] Interview with Mr. H. Lindsay, Vice-President Ampex Corp., Redwood City, Calif. June 7, 1966. Technicians at that time were unaware of this effect.

[5] S. J. Begun, Magnetic Recording, New York, 1949, pp. 2–5.

Wire recorders were manufactured in quanity in Germany in the 1930's as dictating machines and for recording telephone conversations.[1] Wire recording technology advanced substantially in the USA during World War II.[2] In the years following the war, efforts were made to develop and market wire recorders as a consumer commodity in the USA. 1948 was expected to be 'the year of great progress in the wire-recording field which would open up new facets in the music-record biz (sic).'[3] Many firms were ready to meet the demand that failed to materialise—RCA, Webster-Electric, Lear Inc., and Sears-Roebuck.[4] The wire recorder had disadvantages—the quality of reproduction, with the exception of one high-priced professional model, the Magnecord, was poor. It was also an inflexible system because editing required two machines plus a high level of technical skill.

Steel tape recorders were produced in Germany and England in the late 1920's and early 1930's. The British Broadcasting Corporation bought several machines from a German motion picture promoter in the early '30's.[5] These were eventually replaced by ET machines. Steel tape recorders were also developed in the USA by Bell Laboratories, but appear to have suffered from the disadvantages of all steel-tape recording—expense, difficulty of operation, and inflexibility.[6]

Only through the medium of plastic tape did magnetic recording develop its full potential. Dr. Pfleumer, an Austrian scientist, developed the first tape machine. In 1931, Allgemeine Electrizitäts Gesellschaft (AEG) took over the development of the machine; Dr. Pfleumer moved to I. G. Farben to continue working on magnetic tapes. AEG exhibited an improved tape recorder, the Magnetophone, in Berlin 1935.[7] The development work after this was surrounded by a security curtain. Dramatic improvements in the quality of recording were made by two employees of the German State Broadcasting Service, in 1940, when high frequency a.c. biasing was applied to the tape.[8]

When the Allies advanced into Europe, portable Magnetophones were captured and usually transported to a U.S. Signals Corps post in Paris. Three Magnetophones were shipped to Signal Corps HQ, Fort Monmouth, NJ and orders were given that subsequent Magnetophones should be inspected for design modifications and then smashed to prevent them falling into German hands. Some members of the Signal Corps, including one Jack Mullin, were reluctant to smash such valuable equipment.[9] Mullin was a partner in a San Francisco firm which made industrial motion pictures and he realised that the Magnetophone would be invaluable after the war. Taking advantage of a regulation that stated

[1] Op. cit., pp. 7–8. [2] Jewkes, etc., op. cit., p. 328.
[3] The Billboard, Jan. 24, 1948, p. 28.
[4] Mark Mooney, Jr., The History of Magnetic Recording, Tape Recording, Feb. 1958, p. 26.
[5] Asa Briggs, The History of Broadcasting in the United Kingdom, Vol. II, The Golden Age of Wireless, London, 1965—'. . . the Blattnerphone was an awkward piece of apparatus and the cutting of steel tapes was a hazardous procedure, requiring "battleship"-driving machinery,' p. 99.
[6] Mooney, op. cit., p. 24; also Begun, op. cit., pp. 156–161.
[7] Begun, op. cit., pp. 9–10. [8] Jewkes, etc., op. cit., p. 328.
[9] These details and much of the subsequent data are the product of several interviews with officers and employees of the Ampex Corporation, Redwood City, Calif., June 7–9, 1966. I am most grateful for the kindness and help given me by everyone concerned.

a 'souvenir' could be sent back to the USA providing it weighed less than 70 lbs., Mullin stripped down two Magnetophones and posted them, together with a number of reels of tape, to his home in San Francisco. When Mullin returned home he rebuilt the machines and in May, 1946, was asked to demonstrate them to the Institute of Radio Engineers and later to the Institute of Electrical Engineers, in San Francisco. A scientist, Harold Lindsay, attended the meeting and made Mullin's acquaintance.

Lindsay had been given a thorough musical training as a child and was aware of the 'difference between the subtleties of a "live" performance and then-current recordings.'[1] He realised that magnetic recording rendered all existing methods obsolete. Lindsay, at that time, was working for an electronics and instrumentation firm, Dalmo-Victor, in San Carlos, 40 miles south of San Francisco. It was a fortuity that he joined this firm—he had worked on the Manhattan Project and at the end of the war became concerned about his future and took a job as head of the high vacuum department with Charles V. Litton Laboratories in San Carlos.[2] He bought a house in Redwood City. After three months, a fire gutted the Litton plant and Lindsay was forced to take a job with Dalmo-Victor as an electronic designer—with a drastic cut in salary and status.

In 1944 Dalmo-Victor had been responsible for producing air-borne radar antennae for the Sperry Gyroscope Company under a war contract. Critical components included high-precision motors which no supplier would guarantee to supply to specifications. Finally, the head of Dalmo-Victor set up a separate company, Ampex-Electric, in partnership with one of his top engineers, A. M. Poniatoff, to manufacture the motors. It is possible that the firm was also a device to avoid the high incidence of war-time taxation. With the end of the war the contract for the supply of motors was sharply reduced. Poniatoff and the other executives began searching for a post-war product for the firm to manufacture, and Lindsay, Dalmo-Victor's bright young scientist, was invited to take part in the 'Brainstorming' sessions. Lindsay, impressed with the Magnetophone, tried to interest Ampex's management in magnetic recording. Poniatoff was eventually persuaded that he should see the machine demonstrated, but when Mullin was contacted it was discovered that he was in the process of taking his equipment down to Hollywood to demonstrate it to a joint meeting of the Institute of Radio Engineers and the Society of Motion Picture Engineers. Mullin suggested that Poniatoff should fly down to Hollywood to see the demonstration. Poniatoff acted on this suggestion and returned to San Carlos convinced of the future of magnetic recording; the enthusiasm of the Hollywood engineers had impressed him with a force greater than any normal argument. Lindsay joined Ampex-Electric as leader of the magnetic recording project.[3]

The Hollywood demonstration also attracted the attention of the staff of Bing Crosby Enterprises. 'Mullin was introduced to Frank Healy of Bing Crosby Enterprises and to Mordo McKenzie, the technical director of the Bing Crosby

[1] Interview, Mr. H. Lindsay.

[2] Lindsay—'I left the Manhattan Project like a rat leaving a sinking ship. Little did I realise then that the atomic programme would develop at an even faster rate once the war was over.'

[3] Ampex interviews.

Show. Mullin demonstrated the Magnetophone and the men realised they never could do on disks what Mullin was so easily doing on tape.'[1] Mullin was editing the tape with scissors and adhesive; this ease of editing made magnetic tape superior to other forms of magnetic recording. Healy wanted to sign Mullin immediately to a contract for recording and editing the Crosby show, but McKenzie was for delay. A magnetic recorder had been demonstrated in New York and McKenzie wanted to explore an alternative avenue.

In fact, the New York demonstration had been by Colonel Richard Ranger who, serving alongside Mullin in the Signal Corps, had also secured a Magnetophone. Crosby's staff contacted Ranger and arranged a definitive test between the current recording techniques. In the summer of 1947, Bing Crosby travelled to New York and recorded one of his shows by Electrical Transcription. RCA was hired to make a simultaneous recording by the 'optical-sound' system used in motion pictures. Ranger also made a recording on the Magnetophone. It took three weeks to edit the ET disks into a completed programme which the other systems then duplicated from their 'takes'. This took one day for tape. A panel of people connected with the broadcasting industry then met at ABC's studios and listened to unidentified 'play-backs' from the three recordings, and then voted. Six votes were cast for tape, five for ET's, and one for 'optical-sound'. All the radio engineers voted for disk and all the lay men voted for tape.[2] The engineers, evidently, had grown so used to listening to 'broadcast' sound that they rated ET's as a more authentic reproduction than the high fidelity of magnetic-tape.

Crosby's staff, and executives of ABC, were convinced by the test that magnetic-tape would eventually replace all other methods of making original recordings. But neither Crosby nor ABC had the know-how to undertake the manufacture of machines. Colonel Ranger was in the process of organising a company to manufacture machines based on the Magnetophone. As a stop-gap measure Crosby hired Mullin to record his shows and then spliced them together on the Magnetophone. Crosby was determined to play a rôle in this new technology, it was the kind of innovation he had set up the Crosby Research Foundation to exploit. Through Mullin, Crosby heard of Ampex-Electric and sent one of his staff to San Carlos to investigate the progress of the firm.

Lindsay had succeeded in producing the most crucial component of the tape recorder; the magnetic head, after studying the German blueprints held by the US Alien Property Custodian. He had made several substantial design improvements in the head when the project was dropped for several months. Ampex were depending on two reels of magnetic-tape borrowed from Jack Mullin. Production of tape at I. G. Farden had ceased with the end of the war. There appeared to be no alternative sources of supply. After some months it was discovered that Audio-Devices Inc. and Minnesota Mining and Manufacturing Co., were both developing tape. The project was resumed and it was decided that Ampex-Electric should concentrate on producing the best possible design, as good as existing technology would allow, easy to service, and long-lasting.

[1] Mooney, op. cit., p. 29.
[2] Statement by Colonel R. Ranger, reprinted by Mooney, op. cit., pp. 29–30.

The market was defined as the broadcasting industry primarily, and the machine was designed to run for 30 minutes to match the half-hour stations breaks required by the FCC, and as a console unit rather than a portable machine.

But the company was plagued by financial difficulties. Poniatoff's partner, doubting the feasibility of the magnetic recorder, had hired six prominent San Francisco engineers to examine the project and pass judgment on it. The engineers unanimously agreed that the magnetic recorder was a very poor venture and was unlikely to be a commercial proposition. After this report Poniatoff's partner withdrew. Ampex-Electric was on the brink of failure. Poniatoff's savings were rapidly being exhausted. All the manufacturing workers, numbering 45–50 at the peak of electric motor production, had been dismissed. The banks refused to supply funds and suppliers would send essential components only on a cash-on-delivery basis. Often the staff of eight went without their pay-cheques. But the machine was almost completed when Crosby's representative called at the plant and induced them to promise to make the first demonstration to Bing Crosby Enterprises.

In the Autumn of 1947, Ampex demonstrated the prototype tape recorder to Bing Crosby Enterprises and invited representatives of the ABC radio network. Following the demonstration Crosby agreed to make a loan of $50,000 to set up a production line in exchange for being made the exclusive distributor for the Ampex machine.[1] He made an initial order for 24 machines to be supplied at a price of $4,000[2] each which were then resold to the American Broadcasting Company for $5,200.[3] They were to be delivered to ABC studios in New York, Chicago, and Los Angeles, on or before April 24th, 1948, so as to be operative when summer-time went into operation the following day.

Early in 1948, the National Broadcasting Company and the Columbia Broadcasting System formally, though not specifically, conceded defeat in their battle against Crosby and Electrical Transcriptions.[4] As from April 25th, 1948, they too would delay their broadcasts, to iron out variations in the broadcast time of their evening shows, by ET's.[5] On that date, the weakest of the three networks put into operation one of the most important innovations to occur in broadcasting. Three years later *Fortune* was to comment: 'It would be difficult to name another technological innovation that has spread so far so fast.'[6] In the first summer of operation ABC found that tape recorders could give substantial savings in cost. ET's were usually destroyed the day after they were made, a constant waste of material. Magnetic tape, however, could be used and re-used again. In Chicago alone, ABC saved in excess of the $56,000 it had cost to purchase 12 Ampex machines. And out of a total of 2,816 hours of magnetic tape broadcasting, ABC lost only three minutes of air-time because of technical

[1] Fortune, April 1960, Robert Lubar, The Five Little Ampexes and How they Grew, pp. 116–121.

[2] Ampex interviews.

[3] Mooney, op. cit., p. 31.

[4] The Billboard, Feb. 21, 1948, p. 6. With characteristic shrewdness, the two major networks petitioned the FCC to drop its regulation requiring a transcription to be identified as such by an announcement before and after a broadcast. The FCC granted this request, thus the networks never announced to their public that they were dropping a rule of 20 years standing.

[5] The Billboard, op. cit., p. 6.

[6] Fortune, January 1951, p. 104.

malfunctioning.[1] Simultaneously, ABC's powerful competitors, backed by powerful research laboratories and technical staff, were using the technically obsolete Electrical Transcriptions that gave a much poorer reproduction at a much higher cost.

Video-tape Recording—Innovation and Development

In comparison with the sound tape recorder, the process of innovation with the video-tape recorder (VTR) was straightforward. The need was obvious and there were no unwritten rules against using such a machine. There *were* substantial technical problems to be solved. The cause of the problems was the immense amount of information contained in the 6 megacycle TV signal—about 2,000 times that contained in a good quality sound recording.

An early solution to time-delay in TV networking was the kinescope, developed by the Eastman-Kodak company in conjunction with Allen B. Du Mont Studios and the National Broadcasting Company, in 1948. Television images were exposed to 35 mm. film which was then automatically developed. Kinescopes were widely used in the USA until displaced by VTR's but were less than satisfactory. Scientists responsible for developing the kinescope, while claiming that 'excellent recordings are possible', had to admit that 'such results are not obtained with consistency and the quality of the poorer recordings is so far inferior to studio origination as to cause severe criticism. This picture quality suffers in the loss of detail, the distortion of the grey-scale rendition and the increase of noise or graininess.'[2] Many of the losses in quality were due to chemical developing and to the optical lenses. The images taken from the face of a cathode-ray tube were usually distorted. Film negative was expensive, and there was an inevitable delay with developing. Magnetic recording, by using the electrical TV signals directly, promised to cut out distortion, degradation and optical losses. Once a practical machine was developed, innovation would follow almost automatically—the question was which company would develop it first.

Radio Corporation of America laboratories demonstrated an experimental VTR in the early 1950's that used 17 inch reels of magnetic tape, the tape passed the recording heads at a speed of 360 inches per second. The signal was divided between two recording heads for black-and-white TV, and five heads for colour TV. The machine held four minutes of programming—clearly inadequate. Observers noted a deterioration in the recorded TV image. 'There was a slight smearing, streaking and halo effect, as well as a high frequency noise level hiss. Occasionally there was some jitter due to non-uniform speed control.'[3]

Another machine was demonstrated by Bing Crosby Enterprises. Crosby's close relationship with Ampex had been broken at the end of 1949. Ampex was undercapitalised and Crosby was unable or unwilling to supply funds for expansion. Ampex was dissatisfied with Crosby as their distributor. First, they

[1] Copy of a letter from ABC to the Minnesota Mining and Manufacturing Co., in the possession of Mr. H. Lindsay.

[2] P. J. Herbst, R. O. Drew, and J. M. Brumbaugh, Factors affecting the quality of Kinerecording, Jour. SMPTE, Feb. 1952, p. 86.

[3] A. Abramson, A short history of Television Recording, Jour. SMPTE, Feb. 1955, p. 75.

reduced his territory to west of the Rocky Mountains, making another company their Eastern distributor. Later they decided to set up their own marketing and distributive organisation. Two San Francisco financiers, Joseph and Henry McMicking, released Ampex from dependence on Crosby by buying an interest in the firm and supplying funds.[1]

Bing Crosby Enterprises entered the VTR development-race for several reasons. In 1949, as an inducement to get Crosby to return to its network (on a recorded show) the Columbia Broadcasting System bought a 25 per cent interest in Bing Crosby Enterprises for $1,000,000.[2] CBS needed a VTR machine; if Crosby's staff could develop one first it would give CBS a lead over its competitors. Crosby also had tape-recording engineers who had formerly been employed in installing and maintaining Ampex machines—he had a technical base to start from. Finally, it was a project compatible with Crosby's long-term interest in invention and innovation

Crosby's scientists developed a recorder with twelve recording heads in an attempt to reduce the speed of the tape and increase the amount of programming that could be recorded. The machine was demonstrated in October, 1952; it suffered from flickering, ghost images, and a diagonal pattern across the screen. The tape speed was 100 inches per second, sufficient for 16 minutes of recording, but it was evidence that the machine needed considerable development before it would be able to challenge the kinescope.[3]

The solution to the VTR bottle-neck was an invention by Charles P. Ginsburg of Ampex. Instead of recording the TV signal horizontally along the tape with fixed heads, Ginsburg recorded vertically across the tape with four heads rotating at high speed (100 m.p.h.).[4] By this elegant arrangement it was possible to reduce the speed of the tape to 15 inches per second, allowing the recording of most programmes on a single tape. The significance of the rotating head device is that it was widely felt to be impossible. One scientist working for CBS, a year before the Ampex VTR was announced, observed: '*Since the signal cannot be spread* . . . as it can in film recording, it *must* be spread along the length of the tape.'[5]

The manner in which Ginsburg was recruited to Ampex was as fortuitous as Harold Lindsay's recruitment in 1946. Ginsburg, a mathematician, had worked on transmitters for CBS's radio station on the San Mateo Peninsular, south of San Francisco. In 1951 CBS was awarded a 'clear-channel' frequency and decided to move the radio station to a more advantageous site. Ginsburg was, at that time, a compulsive golfer, and the move involved selling his house and buying another; it also meant moving to an area where the golfing facilities were inferior.[6] Because of this Ginsburg began searching for another job, and through a friend heard that Ampex were looking for an engineer with broadcasting experience—he had never heard of the firm. When told by Ampex management

[1] Fortune, April 1960, op. cit., contains inaccuracies on this point.
[2] Daily Variety, Jan. 21, 1949. [3] Abramson, op. cit., p. 75.
[4] C. P. Ginsburg, C. E. Anderson and R. M. Dolby, Comprehensive description of the Ampex Video Tape Recorder, Jour. SMPTE, April 1957, pp. 177–182.
[5] Abraham, op. cit., p. 75. italics added.
[6] Ginsburg, interview.

that the post was Project Leader for the VTR project Ginsburg protested that he knew nothing about this area of technology, but was offered the job. After considering the offer for some weeks in bewilderment, Ginsburg accepted. After a while, Ginsburg's obsession for golf became transferred to the development of the VTR machine.[1]

After two years development work, Ginsburg experienced a 'series of traumas' with Ampex management. His superior succeeded in shelving the VTR project. Ginsburg continued working on the VTR in his spare time from the summer of 1953 to summer 1954, in his garage at home. Planning meetings with his colleagues were held in a local bar over a beer. In mid-1954, the manager blocking the project was removed, for reasons unconnected with the VTR, and 'official' work was resumed. Even then there was little enthusiasm for the VTR. 'Although management would not like to be reminded of it now, they gave him very little encouragement,' said one of Ginsburg's associates. 'Charlie had to crawl every time he needed a few dollars for the project. But for him being a stubborn 'cuss the whole project would have died from lack of interest and funds.'[2]

By mid-1955 the project team had combined the rotating-head device with a system of Frequency Modulation—Armstrong's invention—to carry the recording signal. This produced a viable machine which, in turn, changed the attitude of management and funds were made available to develop reliable

TABLE 2

Gross Revenue, Net Income, and Research and Development Expenditures, Ampex Corporation, Redwood City, Calif., 1949–1960

Year	*Sales*	*Net Income*	*R. & D.*
	$	$	$
1949	366,299	3,723	—
1950	387,514	60,601	—
1951	968,472	114,931	38,855
1952	2,301,707	76,823	67,402
1953	3,548,593	88,520	119,092
1954	5,418,373	25,091	368,644
1955	8,163,663	365,736	502,712
1956	11,140,000	373,000	927,000
1957	20,568,000	993,000	1,469,000
1958	33,915,000	1,655,000	2,439,000
1959	49,167,000	2,914,000	3,857,000
1960	73,434,000	3,959,000	6,797,000

Sources: 1949–55, Moody's Manual of Investments, New York. 1956–60, Annual Report, Ampex Corporation, 1965.

components for the system. A market survey was commissioned to produce some indication of the potential demand for a VTR machine. The report, presented early in 1956, estimated the demand for VTR machines until 1960 to be for a *total* of between 25 and 35 and stated that under the best possible circumstances the demand would not exceed 50 machines. This report was considered very seriously by Ampex engineers and management who were concerned that VTR production should not disrupt the 'bread-and-butter' lines of audio and data recorders. The VTR was not expected to make a substantial contribution

[1] Ginsburg, interview.
[2] Interview, Jan. 5, 1967.

to the firm's profits. Ginsburg and his colleagues were disappointed. After solving, with limited funds, technical problems that the largest electronic laboratories in the USA had been unable to solve, they had produced a VTR that promised to be a commercial white-elephant.

Despite the difficulties with management, the VTR project at Ampex had been a closely guarded secret, and when the prototype machine, the VR–1000, was exhibited in Chicago, April 1956, it 'dropped like a bombshell'[1] at the Convention of the National Association of Broadcasters meeting there. Some indication of the competitive psychological pressures that drove Ginsburg and his colleagues can be gauged from their behaviour at the Convention; in order to have a permanent record of their triumph they spent part of their time photographing the expressions of dismay and chagrin on the faces of RCA engineers examining the VR–1000.[2] At the convention they received orders for 13 prototype machines at a price of $75,000 each. By the end of 1956, Ampex had orders for over 100 production models at $45,000 each and held over $500,000 in deposits on the machine.[3] The problem was to meet the demand.

TABLE 3

Video Tape Recorders in Operation, 1956–61, By Location

Year	*1956*	*1957*	*1958*	*1959*	*1960*	*1961*
USA:						
Commercial TV Stations	—	—	—	221	346	433
Commercial TV Networks	—	—	—	76	101	102
Independent Producers	—	—	—	35	52	58
Educational Stations	—	—	—	31	63	115
Govt., Industrial, etc.	—	—	—	72	111	114
Foreign:						
TV Stations, etc.	—	—	—	159	278	445
Total	13	32	195	585	951	1,267

Sources: Society of Motion Picture and Television Engineers, Progress Committee Reports 1958 and 1961; Jour. SMPTE, May 1959, pp. 277–329, and Jour. SMPTE, May 1962, pp. 315–368.

When the first VTR went into operation with the CBS network it showed substantial savings over kinerecording which cost $65 in film alone for a half-hour programme. A reel of 2 inch-wide video-tape cost $80 and could be used and re-used up to 100 times, reducing the material cost of each recording to under $1.[4] VTR machines helped to quadruple the capacity of TV studios. Prior to 1957, NBC-TV was using five different studios in New York to supply the TV-network with 'live' programmes. By using VTR's it proved to be possible to use one central studio. Several half-hour programmes are recorded consecutively, usually in front of the same audience, and are then broadcast on different days. When one recording session is completed, the audience files out and another audience files in, and another programme-recording session starts.[5] There is no indication that these savings were envisaged before the VTR innovation took place. And certainly, they never figured in Ginsburg's calculations when he struggled with VTR development in his garage on the San Mateo Peninsula.

[1] Jour. SMPTE, May 1957, Progress Committee Report for 1956, p. 256.
[2] Ginsburg—'We were all a little juvenile in those days.'
[3] Jour. SMPTE, May 1957, op. cit., p. 256.
[4] Op cit., pp. 256–257.
[5] Interview, Mr. W. Trevarthen, op. cit.

Innovation—Image and Reality

The mosaic of events leading to the innovation of magnetic recording stands in contrast to the popular concept of the process of innovation. Several groups in modern industrial societies have a vested interest in the word 'innovation'. It is a key-word in the business of corporate image-building and often backward firms will retain public relations specialists to ensure that its true identity is hidden behind a façade of 'dynamism', 'progress', 'aggression', and 'innovation'. It is also a key-word with the marketing divisions of many firms which rely on a stream of innovations, or pseudo-innovations, to give them a succession of 'new', 'all new', and 'new and improved' products. Not only allowing them to write elevating advertising copy, it also provides them with a weapon in the battle to secure shelf-space in supermarkets and other outlets. The third group with a vested interest in innovation is, of course, the industry-supported research and development teams. Many technology-based industries spend up to 10 per cent, or more, of their gross income on R. & D., which creates a powerful lobby to upholding the myth that worthwhile innovations can only be the result of massive expenditures.

The net effect is that a popular conception of innovation has been created which is little more than a cluster of images. Innovation is presented as industry's commitment to progress and increased public welfare, carried out by Captains of Industry fearlessly advancing into the 'gale of creative destruction'. This is an attractive picture which may, in certain cases, approach the truth. But to allow it to be presented as the general pattern is to permit the creation and perpetuation of a powerful myth which becomes a barrier to understanding—making it necessary to 'resolve, as we must, that the purveyors of fiction bamboozlement will not get the better of us'.[1] But more than resolution is needed. There can be no substitute for comprehensive research into the process of innovation. And there will have to be a re-assessment of what constitutes relevant data. It seems unreasonable to say financial and labour inputs into R. & D. are important while denying the relevance of such factors as Bing Crosby's popularity and his domestic problems. It would seem evident that Harold Lindsay's musical training was an important element in the development of a sound tape recorder, and Charles Ginsburg's capacity for obsessions and his stubbornness were crucial in the development of the VTR. The relevance of various inputs must be judged in the light of their effectiveness, and not in terms of any prior classification.

The environment surrounding the process of innovation also needs to be examined carefully. Without understanding the extent of institutional opposition to changes in radio-network operations and without realising that in the case of FM radio 'the vast concentration of economic power that marked the field of mass communications . . . crushed it to a shape less threatening to the monopolistic pattern of operations',[2] it is impossible to appreciate the full significance of the magnetic-tape innovation. At the same time it is necessary to treat with a good deal of scepticism the information that might be provided

[1] J. K. Galbraith, The Liberal Hour (1960), Mentor Edition New York 1964, p. 119.
[2] Lessing, op. cit., p. 260.

by 'company chairmen, managing directors or other senior executives.'[1] While it may be valuable to persuade these people to outline the economic developments of their respective firms before a respectful audience of academics, it does not absolve the economist from the responsibility for digging beneath the surface of these events.

Finally, the interstices where technology and culture meet deserve more attention than they have received in the past. Cultural pressures can determine the way in which technology is used, while technology, in turn, shapes our culture. Certainly, Bing Crosby's need for a 'quick-fire' programme was a factor in his use of ET's, yet his requirements were in excess of what contemporary technology could cope with and provided some of the motive power behind the magnetic-tape innovation. Technology can affect cultural standards, as was demonstrated by the radio engineers who preferred ET recordings to magnetic tape. Scientists and technicians may be more imprisoned by the limitations of current technology than lay people—witness the CBS scientist who commented on the 'impossibility' of spreading the video signal across magnetic tape, and the panel of San Francisco engineers who decided that there was no future for magnetic recorders.

This is not to underestimate the difficulties in analysing and describing various examples of the process of innovation, There are few guide lines for the economist who moves outside the traditional conceptual framework of his discipline, but the techniques and concepts developed by related disciplines, psychology, sociology and anthropology, do provide some assistance. However, the reluctance to accept innovation is by no means confined to economic or technical situations. Academic innovations are rarely welcomed, except in providing an excuse for virtuoso arguments in favour of the status quo. But until changes are made in the direction and methodology of research into the process of innovation, the extent of our understanding of this complex activity must necessarily remain limited.

[1] R. S. Edwards and H. Townsend, Business Enterprise, London, 1962, p. vii.

University of California,
Los Angeles