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COMPUTER PREDICTION OF AIRCRAFT NOISE

by P.J. Dickinson
I.S.V.R., University of Southampton

The I.S.V.R.'s Operational Acoustic Unit's first major project, financed by the Ministry of Aviation Supply through the British Aircraft Corporation, was to design and develop a mathematical computer model able to predict the economic impact of achieving reduced noise levels from aircraft. The model had to be able to consider the noise characteristics of all the different aeroplane types, including future advanced-technology engined aircraft, using all the major British airports, and be able to play off the cost of retrofitting noise-suppression devices to existing types, and introducing new aircraft types (including the inherent increased operating costs), against the alleviation of noise dis-benefit resulting by so doing, at some predetermined future date. A particular requirement was the ability to incorporate a delimitation of land usage (in five categories) and population density counts into predicted noise exposure bands, thus enabling the effect of land usage strategies to be considered in conjunction with aircraft routeing and (in a vertical plane) various take-off and approach noise abatement procedures. It was a requirement also that the model should be able to calculate the installation costs of any retrofitting device, and the increased operating costs introduced in any airline, based on some standard method of costing. It was recommended that the model should be designed to calculate the noise exposure levels in any of the units in use in the world.

A unique situation was set up by involving in the project a steering committee, composed of leading noise engineers in the British aircraft industries. The committee contained, under Professor J.B. Large as Chairman,

Mr. J. Hay, Head of Acoustics, British Aircraft Corp. Weybridge,
Mr. W. Reid, Head of Acoustics, Hawker Siddeley, Hatfield,
Mr. M. Smith, Chief Engineer, Noise Division, Rolls Royce, Derby,
Mr. J. Nivison, Operations and Engineering Manager, BOAC,
Mr. R.M. Chowns, Principal Noise Engineer, BEA,

Mr. M. Hale, Chief Project and Development Engineer, British Caledonian,

together with representatives of the Ministry of Aviation Supply and the Ministry of Defence and an observer for the Scientific Adviser's Division of the Department of Trade and Industry.

In a project of such magnitude, the Committee's help was invaluable, especially in the production of the most up-to-date aircraft noise, performance and cost input data.

The program suite designed is shown in block form in Figure 1 and is composed of ten main programs fed by input data from three storage files. The first of these contains all the data relating to each aeroplane type. This included not only its performance, but also the cost of its operation with and without silencing devices. For the modified aircraft the increased operating cost is also linked with its possible loss in performance. Noise data is filed as Equivalent Perceived Noise Level (EPNdB), and Perceived Noise Level (PNdB), at various distances from the aeroplane. Also included are details of the ground absorption likely at low angles of elevation from the observing point in relation to the type and make of the engines fitted, and an indication of the magnitude of the noise shielding by the fuselage. For aircraft with rear-mounted engines, some noise attenuation on the sideline at some angles of elevation is possible by wing-tip vortex shedding, and allowance, when known, is made for this. Also documented are the various vertical flight profiles possible with the relevant engine thrust settings.

The second file contains all the flight data at the airports under investigation: geographical positions of the approach and departure routings, the flight densities of each aeroplane model using each flight route average per day, evening and night for the four seasons of the year under consideration, the vertical flight profile (numbered to relate with the first file) used on each route by each aeroplane model, and at present the altitude of each grid reference point (although this latter by rights should be included in the third file, and perhaps later will be so).

The third file has been built by the University's Cartographic Unit and includes a delimitation of each airport environ into five land usage categories, with the population (for each square kilometre of the National Grid) and, if required, the average number of persons per household and average (1969) house price.

Programs 1 and 5 calculate the installation and increased operating costs of retrofitting the aircraft for each airline: 1 in terms of data produced by the computer models used by the main airlines, and 5 by the A.T.A. Standard Method of Costing 1967, for those airlines who do not have use of a computerized standard costing procedure.

The main noise prediction part of the model is arranged in three block options, each of which can be run independently. The programs were designed, on recommendation, so that existing D.T.I. aircraft-noise footprints could be input instead of manufacturers' data. In the first option, consisting of Programs 2, 3 and 6, noise footprints at runway level are computed for each aeroplane model using each flight profile, by using Program 2. A rectangular grid 20 km long by 16 km wide is used and at each grid point the noise calculated for each aeroplane model, an allowance being made for ground absorption and for noise shielding by the fuselage, and where known for noise attenuation by wing-tip vortex shedding where a rear-engine configuration is used. Very little data is at present available on this latter subject, and where no data is yet available a standard allowance of $\gamma = 3$ is used in the shielding equation (based on empirical data) of

$$\text{shielding attenuation} = \gamma(1 - \sqrt{\sin\beta}),$$

for an angle of elevation β. The equation was derived from measurements of the noise from an aeroplane with "podded" engines, in which case γ was found to be equal to 3.

The footprints produced by Program 2 are then superimposed on Program 3, which calculates the minimum distance and distance from brake release point (or landing threshold) for each grid reference point. Program 6 then calculates the noise exposure for each of these grid reference points in whatever noise exposure units are chosen: e.g., N.E., NNI, WECPNL, CNEL, etc.

The second block option uses D.T.I. input data in place of Program 2 and proceeds in the same way.

A third block option (Programs 3, 7 and 8) considers the airport in three dimensions. Program 7 plots the noise footprints at 50 m intervals in height from a level 50 m below runway level. These are combined in Program 8 with the results of Program 3 to give the noise exposure at any reference point at any altitude. This is beneficial when investigating the noise experienced in high-rise dwellings situated near the airport. However, the program is very long and expensive to run and is recommended for noise-critical areas only. Around Britain's major airports the largest change in NNI when making an allowance for ground altitude is probably only 1½ NNI, for a small community situated 450 ft above runway level, at Glasgow. This sort of change in practice would be unnoticed over a period of time, representing a change in noise level of 1½ PNdB or a change in number of aircraft heard of ¼. The operator of the model obviously has to consider whether such accuracy is justified.

The noise-exposure contours thus produced are superimposed in Program 9 onto the output of a land usage sorting program - Program 4 - and the land usage in five categories: residential, commercial, institutions and schools, industrial and white land, delimited for each of the noise exposure bands chosen.

A noise disbenefit figure for each area is also calculated by this program, based on the Roskill research team's formula involving house prices.

Finally, a comparison is made in Program 10 between the costs of retrofit involved and the possible change in noise disbenefit by so doing.

During the summer of 1972, at Gatwick Airport, studies at M.Sc. level [1, 2] verified, in the near field up to 3 km sideline and up to 7 km along the track, the footprints predicted for British aircraft from data supplied by the British Aircraft Corporation and Hawker Siddeley. However, the noise predicted for American aircraft from American data was found to be on average at least 10 dB below that measured! It would appear that the flight profiles used by American aircraft at British airports do not follow those used in American literature to predict the resulting noise exposure.

The unit is at present working on this subject, under a small contract from the Civil Aviation Authority. Part of this work consists of collecting data from all the airlines using British airports so that an up-to-date aircraft category noise and flight profile system can be set up, for use by the Authority in future noise predictions.

A simplified version of the model is complete. This is designed to work fifty times faster and be suitable for use on a small computer - the main model requires 48k storage. The model has been applied to the noise situation around some British airports. The results of these applications (compared to measured values), and some procedural strategies attempted, will be discussed.

References

1. R.C. Lam. Aircraft Noise Exposure at London (Gatwick) Airport. A comparison between measured and predicted values. M.Sc. dissertation University of Southampton 1972.
2. T. Wagstaff. The measurement and propagation of aircraft take-off noise at Gatwick Airport. M.Sc. dissertation University of Southampton 1972.

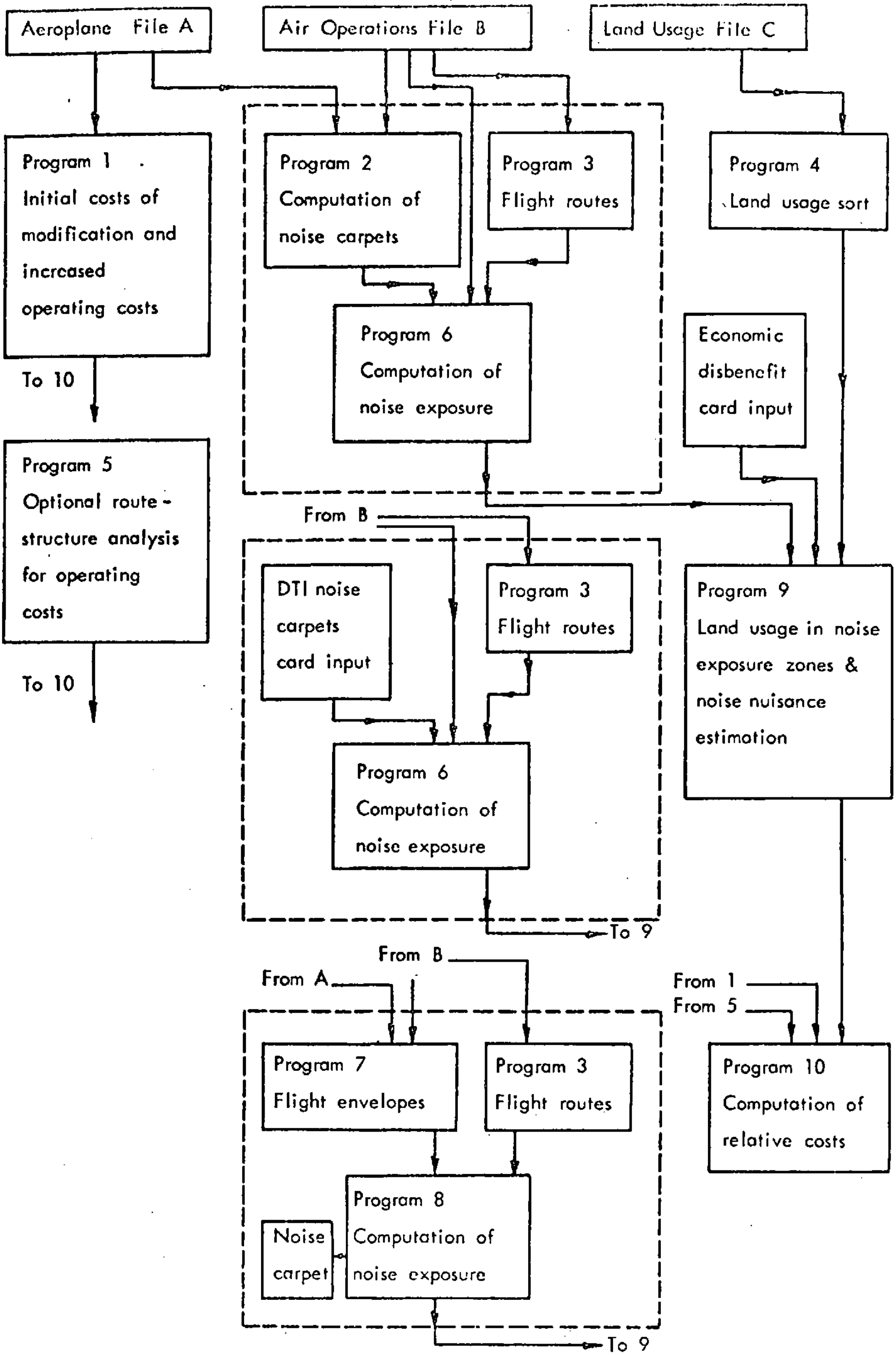

FIG. 1 FLOW CHART OF MATHEMATICAL MODEL.