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6.3 Nacelle Drag Reduction: An Analytically-Guided Experimental Program

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Standard estimation procedures as well as the NCSU "Body" Computer program (Ref. 1) predict that the drag of the two nacelles on the NASA ATLIT airplane will equal the drag of the fuselage. These estimates are based on computations of the drag of isolated nacelle-shaped bodies in uniform streams with no internal flow. Losses due to air motion through the cooling fins, to helical components in the flow over the nacelle, or to unusually high levels of streamwise turbulence are not accounted for in the analysis, nor are interference effects arising from the presence of the wing or fuselage. The analysis must therefore be regarded as qualitative at best.

Within these limitations, however, one finds that the high drag of the nacelles is due to their high form drag, this being about three times as large as their skin friction drag. Normally, for a streamlined body the skin friction drag is three times as large as the form drag! When one considers this result and the nacelle shape it seems apparent that the nose of the nacelle is too blunt. Thus the indicated course is to increase the dimensions of the nacelle forebody so that the nose (cooling intake) is relatively less blunt. A preliminary computer analysis following such an approach (using NCSU "Body") indicates that the reduction in form drag is much greater than the increase in skin friction drag which accompanies the increase in surface area. However, to validate this approach it would be necessary to conduct flight tests with modified nacelles during which the total aircraft drag could be determined. Comparison of the drag of the new configuration with that of the original would then yield the increment (plus or minus) due to the change in nacelle geometry.

What is needed, then, is a simple procedure, similar to what is done in the wind tunnel with clay and wax which permits one to make minor alterations in the nacelle surface contours quickly and inexpensively. A configuration which, on the basis of computer calculations, seem propitious can then be tested easily. The results of the tests can then be fed back to correct the estimation procedure. With such an iterative scheme it seems reasonable that one should not have to test more than three or four nacelle shapes before finding a practical optimum.

It seems reasonable to suppose that these nacelle modifications can be effected through the use of sprayed on polyurethane foam perhaps with bolts into the nacelle structure to provide additional wind shear resistance. This foam is easily shaped and smoothed after application. Or, it is conceivable, that fiberglass shells of appropriate contour could be appended to the normal nacelle for the duration of the test. Since the required recontouring of the nacelles is not expected to be very extensive so far as lift and moment characteristics of the airplane are concerned, it should not be necessary to investigate changes in handling qualities in a substantive fashion for each modification.

One would probably wish to do so, however, for the configuration finally selected for production, particularly its effect on handling qualities at high angles of attack.

The two figures below show the original nacelle as analyzed by the NCSU "Body" program and an alternate also analyzed by "Body". These results are the basis for believing that there is significant improvement to be gained by recontouring the nacelles. If the question of fuel economy becomes critical enough, it is to be expected that efforts will also be directed toward treating analytically the internal cooling flow, the propwash components, and the wing and fuselage interference effects.

A completely analytical treatment of the loss in total head experienced by the flow which is ingested at the front of the nacelle, proceeds over the cooling fins, and then leaves near the rear of the nacelle is difficult virtually to the point of impossibility. In addition to the three-dimensional nature of the multiplicity of tortuous flow passages, one has variable heat fluxes and temperatures at each of these boundaries. The indicated approach therefore is an integral analysis with the magnitudes of the various contributions to be determined experimentally. By placing a pitot rake and total temperature probe at the cooling air intake as well as at the cooling air exhaust and measuring the flow areas at these points one can determine the cooling mass flow, its total head loss (which appears as aircraft drag) and its heat gain. Comparison of the head loss with that for equal heat addition for flow between parallel plates will then give an indication of how efficient the cooling path is. A significant difference will indicate the need for redesign.

Proper analytical treatment of the propwash components and the interference effects must await both the development of accurate, three-dimensional turbulent boundary layer calculation routines and a computer of sufficient size and speed to perform the combined inviscid-viscous problem in a relatively short time, say 30 minutes.

This is probably some five years in the future. In the meantime, a very crude analytical model treating the situation on the basis of equivalent flat plate area, supplemented by flight measurements using tufts and/or skin friction gauges seems to be the approach most likely to yield tangible near-term results.

References

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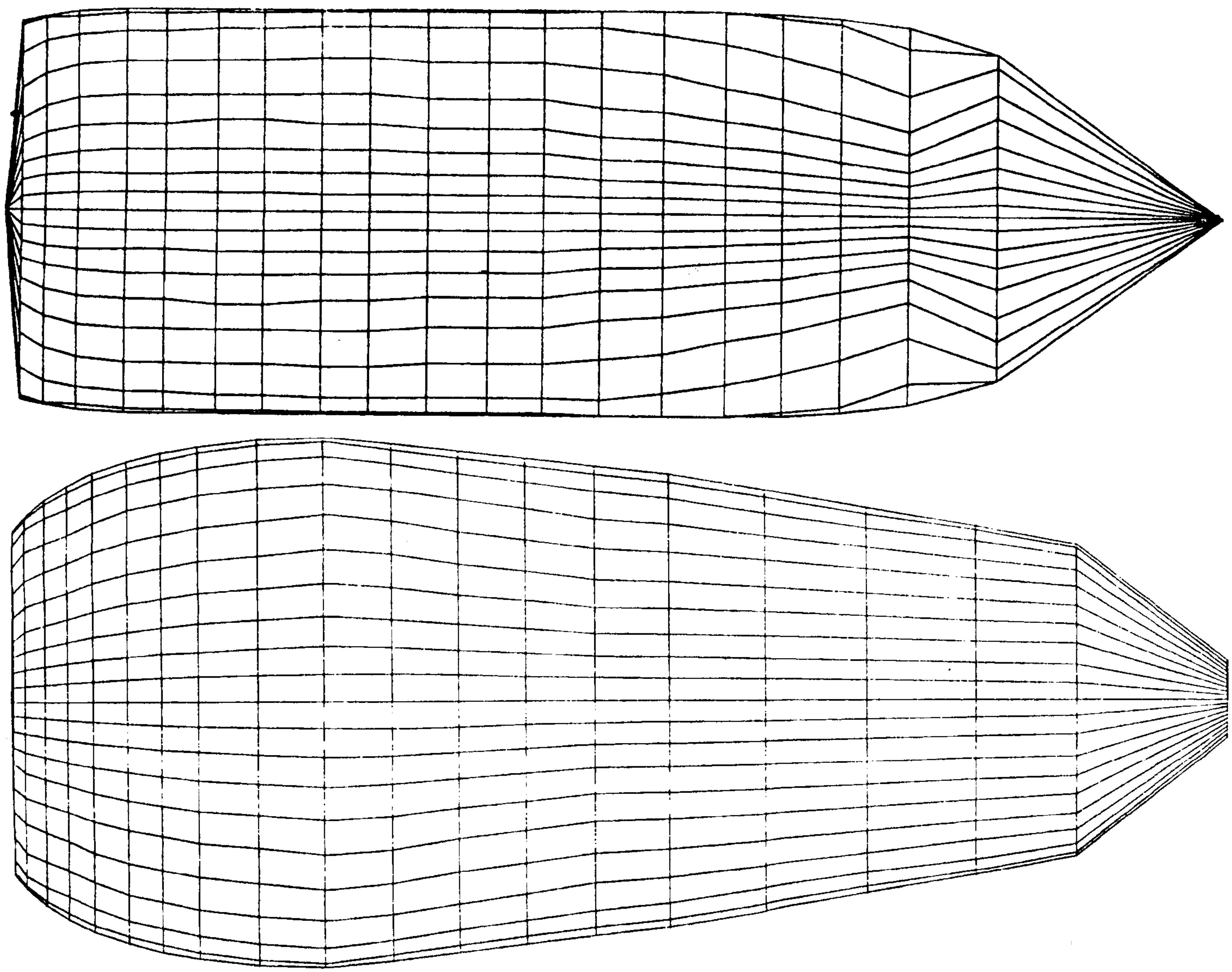
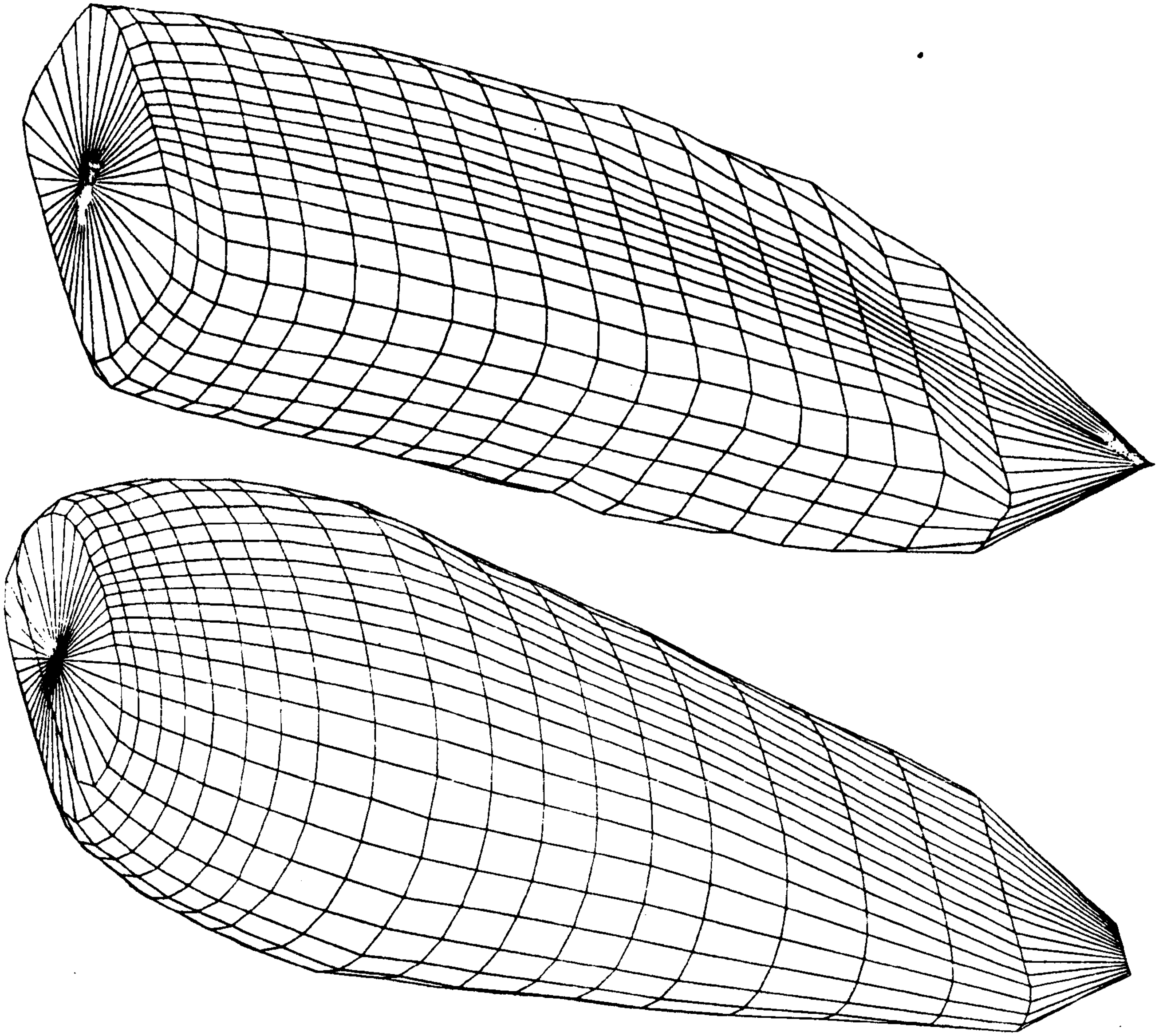


ORTHOGRAPHIC PROJECTION OF THE ORIGINAL ATLIT NACELLE AND THE MODIFIED LOW-DRAG NACELLE.



PLANFORM VIEW OF THE ORIGINAL ATLIT NACELLE AND THE MODIFIED LOW-DRAG NACELLE.