

Fourth, in addition to the crew costs, estimates of many other D.O.C. elements seem low when compared with airplane experience, particularly maintenance. The operating costs of potential civil long-haul airships are critically discussed in Refs. 3 and 4.

Finally, there are some discrepancies in the paper. Table 2 states that the net lift of the helium was assumed to be  $.063 \text{ lb/ft}^3$  while the discussion indicates that  $.072 \text{ lb/ft}^3$  was actually used in the computation. Figure 11 shows that costs per ton-mile increase as size increases for the hybrid, in contradiction to past experience, one's intuition, and the discussion in the text.

Figure 11 of Ref. 1 shows that even with the apparent errors and optimistic assumptions just discussed, the hybrid airship has an operating cost per available ton of payload per mile roughly equivalent to the 747F. It therefore seems clear that a correct analysis would show the hybrid concept to be uncompetitive. Further, in the vehicle size class being considered (1000 tons gross weight) there are airplane concepts which promise to have significantly lower operating costs per ton-mile than does the 747F (Ref. 5).

### References

- <sup>1</sup> Calkins, D. E., "Feasibility Study of a Hybrid Airship Operating in Ground Effect," *Journal of Aircraft*, Vol. 14, Aug. 1977, pp. 809-815.
- <sup>2</sup> Lancaster, J. W., "Feasibility Study of Modern Airships, Phase I—Final Report, Volume IV—Appendices," NASA CR-137692, Aug. 1975.
- <sup>3</sup> Ardema, M. D., "Economics of Modern Long-Haul Cargo Airships," AIAA Paper 77-1192, presented at the AIAA Lighter Than Air Systems Technology Conference, Melbourne, Fla., Aug. 11-12, 1977.
- <sup>4</sup> Vittek, J. F., "The Economic Realities of Air Transport," presented at the Symposium on the Future of the Airship—A Technical Appraisal, London, England, Nov. 20, 1975.
- <sup>5</sup> Whitehead, A. H., "The Promise of Air Cargo-System Aspects and Vehicle Design," *Acta Astronautica*, Vol. 4, Jan.-Feb. 1977, pp. 77.

## Reply by Author to M.D. Ardema

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I WOULD like to thank Dr. Ardema for his careful critique of my paper. However I would like to take exception to some of the comments which were made, and to his basic definition of the phrase "many errors." He claims that the conclusion concerning the discussed type of hybrid airship is rendered invalid by "many errors." The type of paper that is presented, i.e. a concept presentation, may be regarded as one which is based, to a large extent, on opinion. In other words, since there is not a large technical data base upon which to draw to verify the concept's validity, the author must rely on his judgment and opinion. It is possible, therefore, to have a difference of opinion, among technical people, on the assumptions that are made in the paper. However, for one person, whose opinions differ from those of another, to state that his are correct, while those of the other are "errors," is incorrect. Therefore, I cannot agree that my paper contains "many errors," because Dr. Ardema's opinions differ.

Further, the study was done as an unfunded project during 1975, making use of the limited amount of research material that was available to the author at the time. This data base should be compared to Dr. Ardema's airship program at NASA Ames which involves two large aerospace corporations, The Boeing Company and Goodyear Aircraft. I believe that Dr. Ardema's comments are based on the voluminous studies which have been the result of this program. I would like to point out that at the time that I did the study, I did not have the resources that were available to both Boeing and Goodyear, including the computer time. It should also be pointed out that, as a basic part of both of the Goodyear and Boeing studies, comprehensive computer-aided design programs were developed which were used to do vehicle parametric studies. These computer programs are discussed in Ref. 1. It is interesting to note in this reference, which discusses the hybrid type of airship, that agreement between the results of the contractors was not reached as to whether or not the hybrid airship was a good concept, nor were they able to define an optimum design. Are these differences in results, which obviously arise because of different design assumptions, to be regarded as "errors" on the part of either contractor?

Dr. Ardema's first comment concerns the structural weight of the hybrid. The particular expressions for the structural weight were developed based on data available to me at that time, Ref. 2. While it is true that the technically correct way to do it would be a detailed structural design, such as the approach that was used by both Boeing and Goodyear, it was beyond the scope of my paper.

Dr. Ardema indicates that the problems and weight penalties associated with attaching a heavily loaded wing structure to a lightly loaded body structure, were ignored. They were not ignored; I had an insufficient data base upon which to rationally include the effect. In addition, he states that bodies with noncircular cross sections were assumed to weight the same as bodies with circular cross sections, implying that this is incorrect. Does he have a detailed structural analysis to prove this?

He states that "the effects of the severe near-sea environment were neglected." It is discussed on page 810 of my original paper. While he may argue the validity of flight in ground effect, as done in Ref. 3, this is again a difference in opinion as may be seen by comparing it to the noted reference.

Dr. Ardema states that a more realistic empty weight would be 50% higher than that shown in my paper. Why 50%? Why not 45% or even 60%? I would be interested in knowing how Dr. Ardema arrived at this figure.

Dr. Ardema then discusses the "major errors" made in the accounting procedures used in the paper. If Dr. Ardema is at all familiar with accounting practices, he is aware that there are many different types which are used in business. I would appreciate the particular reference that he uses as the basis for his economic analysis. The economic analysis used in the paper was based on Ref. 4. It is also interesting to note that he points out that other economic studies have made the same mistakes as have I. Again, I think he means that other people have different opinions as to how to conduct economic analyses, which just happen to be different from his. Dr. Ardema states that the estimates of other D.O.C. elements seem low when compared with airplane experience. I am sure that this comment is based on data which is available to him. Again, I would appreciate his reference.

Dr. Ardema talks about discrepancies in the paper. Table 2 states that the net lift of the helium was assumed to be  $.063 \text{ lb/ft}^3$  and the discussion indicates a value of  $.072$ . The figure that was used in my calculations is  $.063$ . I am unable to locate in the discussion the implication of the value  $.072$ .

He states that Fig. 11 shows that the cost per ton-mile increases for the hybrid, which is in contradiction to his experience. I assure Dr. Ardema that I have rechecked my calculations, and the figure is correct as drawn.

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He states that the hybrid airship has an operating cost per available ton of payload per mile roughly equivalent to a 747F. I find nowhere in my paper, nor on Fig. 11, where this is indicated. At the time that I did the paper, I did not have sufficient data on the 747F which would allow me to plot this data point.

He further states, "it therefore seems clear that a correct analysis would show the hybrid concept to be uncompetitive." I believe what he really means is that if I were to re-do the study, using either the Goodyear or the Boeing computer-aided design programs, the results would be different. I agree that they would be. I am sure that the data base that exists now, in 1977, is much more complete than it was in 1975. I would welcome the opportunity to re-do the study for Dr. Ardema, using either one of his computer programs.

He concludes that there are airplane concepts which promise to have significantly lower operating costs per ton-mile than the 747F. Again, these come under the category of design concepts, subject to the same constraints as I have

mentioned earlier in my comments. Until these concepts are designed, built, thoroughly tested, and evaluated, the statement may or may not be true.

Dr. Ardema talks about the fact that in the hybrid I assumed a crew of three and he believes there should be a crew of six. This is a difference of opinion, and I am sure that I could find pilots who would disagree with his number. For example, note the crew number controversy for the Boeing 737.

### References

- <sup>1</sup>Ardema, M. D., "The Feasibility of Modern Airships—Preliminary Assessment," *Journal of Aircraft*, Vol. 14, Nov. 1977, pp. 1140-1148.
- <sup>2</sup>Cleveland, F. A., "Size Effects in Conventional Aircraft Design," *Journal of Aircraft*, Vol. 7, Nov.-Dec. 1970, pp. 483-512.
- <sup>3</sup>Handler, E., "Practical Considerations of Wings in Ground Effect," *Journal of Hydronautics*, Vol. 11, April 1977, pp. 35-41.
- <sup>4</sup>Harthoorn, R., "The Airship, the Missing Link in Transport Chain," *Holland Shipbuilding*, March-April 1971, Parts 1 and 2.

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