From a business point of view, the most crucial linkage is between the overall costs/benefits analysis — the 'global view' — and the business value 'at a local level' along the transition path. Some changes might be very advantageous in the long run but would bankrupt airlines on the way, for example by them having to purchase expensive kit but then only getting worthwhile operational gains at a much later date.

The ideal metaphor is the human eye, which is seen as the result of evolution from a photosensitive cell in primitive life. During this evolution, the advantages in competition with other organisms have been sufficient to keep the evolutionary process going, ie even intermediate stages offered increasing advantages over competitors and protection against predators. Technology does not always work like that: investments in change may not 'pay off' until changes have accumulated and the environment itself is suitable. An investment that would yield huge benefits in the long term may not come to fruition because the step by step decisions on its introduction require two or three year paybacks.

## 10.0 CONCLUDING COMMENTS

The aim has been to identify and explore a group of five tests that ideas for the future air traffic management system will have to pass. There is nothing very unusual about the nature of the tests, or even the questions that they pose, but setting them out together in a structured fashion shows clearly the importance of 'systems thinking'.

The illustrations of examples of past innovatory successes and failures show that the tests are not just simple static questions: the tests have to evolve over time to pick up lessons from practical experience. Over time, the 'ideal' versions of the tests will no doubt evolve, akin to the wood carver's progressive refinements. Not all ATM development flaws are obvious the first time around, but aviation is an industry that continues to demonstrate its willingness to learn lessons from safety incidents such as airproxes and mandatory occurrence reports, and it must adopt the same approach for ATM systems development generally.

The discussion here does display how challenging it is to make major changes to the present system — and hence how vital it is to have a long-term commitment to such changes.

It must be emphasised that new ideas for ATM R&D do not have to pass the tests immediately — it would be foolish to cut off promising avenues prematurely. However, when significant amounts of spending are contemplated for development work, then the tests start to need to be applied, otherwise expenditure could well be nugatory.

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# Letter

You asked for comments on Dennis Bushnell's paper 'On (civil) aircraft future(s)' published in *The Aeronautical Journal*, October 2001, **105,** (1052), pp 603-606.

I enjoyed Dr Bushnell's paper and agreed with it. One in particular of his forecasts, the displacement of the aerospace kerosene powered gas turbine engine, I commend to aerospace practitioners. Not much more than 25 years ago the present gas turbine powerplant more or less totally displaced the until then dominant aero piston engine industry, and did so only 25 years after the gas turbine's first practical implementation. Twenty five years before that, at the time Alcock and Brown were flying the Atlantic, and ten years before Whittle's first patent, few incumbent aeronautical engineers would have given much credence to the idea that such a development was likely. My own expectation of the form of aerospace propulsion that will ultimately replace the gas turbine is what Dr Bushnell calls electrostatic propulsion. If I knew the details of how it will work, of course, I would patent it and become the next Whittle. The only surprising omission from Dr Bushnell's paper is the potential in the interim for present upper atmosphere water producing powerplants to be used through appropriate routing to favourably control the world's weather.

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https://doi.org/10.1017/S0001924000013063 Published online by Cambridge University Press