OVER THE HORIZON IN AIR TRANSPORTATION

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This article is an attempt at a broad forecast of the sorts of air transport vehicles that will follow the C-5A/747 subsonic jets and first-generation supersonic jets. The period covered will be roughly 1980-2000. Both civilian and military aircraft are considered. General aviation is not included.

In the course of its evolution, air transportation has grown steadily in scale, scope, and capability. One is tempted, in making this forecast, simply to extend the historical curves that for so long have climbed steadily upward, and to make a prediction based on extrapolation (see Fig. 1). But perhaps there has been too much of this sort of thing already and it is time to sound a note of caution. So the present article proposes to consider influences that may well tend to check the pace of past trends, though this risks the charge of lack of vision -- a conservatism common among observers of advanced years. We prefer to call it realism and facing facts.

Let's begin by talking about speed. This is, when all is said and done, the unique commodity that has sold air transport up to now, and it is only natural to assume that more and more of it will be a good thing. But during the past year there has been a most interesting

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and significant development; a fork in the road has appeared (Fig. 2). One path leads to the SST and its successors, with continued emphasis on speed, the other to the giant military and civil transports such as the C-5A and 747, where emphasis is on economy. This is indeed a major break with tradition, and one may well ask, where does it lead us in the next round?

These projects are extremely expensive. The C-5A, being a military vehicle, will of course be paid for by the government, except for its potential commercial version. It is generally accepted that the SST development will at least temporarily be paid for in large part by the government, the aircraft industry being unable to underwrite it by itself. The 747 is alone in being proposed for financing entirely through private channels, and it probably represents about the maximum that could be handled in this way.

This bifurcation of what has previously been a single market may be expected to be permanent. The economy market will not accept a sacrifice in speed below high subsonic values, nor will the speed market accept a sacrifice in economy below that consistent with the current fare structure; but the prime motivation will be, on the one hand, economy and, on the other, speed. This duality will require two distinctly different kinds of vehicles.

One may confidently expect evolutionary improvements in the original models as time goes on, but eventually a basic change will be justified. This may well come before the end of the 1980-2000 period. Will the next generation of economy vehicles be larger than the C-5A/747 transports? And will the next generation of speed vehicles be

faster than the first SST's?

The answer to both questions is "perhaps a little bit but not much." Why? Because in both cases we have, in the projects now on the boards, approached if not already in fact reached the point where diminishing returns (or cost/effectiveness considerations, if you will) make further increases profitless. (See Fig. 3.)

The giant economy transports will help to reduce growing congestion in the skies, but they will impose an enormous burden on ground facilities. The nearly simultaneous departure or arrival of several lots of 400 or more passengers during the popular periods of the day at major terminals is not a pretty picture to contemplate, considering the problems of ground transportation and parking, ticketing (and for international flights passport, health and currency control), baggage handling, and providing space for reasonable passenger mobility. And on those admittedly infrequent but nonetheless inevitable occasions when flights must be diverted to secondary airports, these problems will be compounded.

When the cost of modifying ground facilities to handle single-airplane passenger groups of this size has been assimilated and digested, there will be little stomach (let alone cash) for any substantial further increase.

It must be freely admitted that, while there will indeed be special problems associated with the introduction of large-capacity aircraft, the real problem will be how to handle the greatly increased traffic volume confidently anticipated for the period. This will exist regardless of the sizes of aircraft employed to carry that

traffic. The burden on ground facilities will be shared by passenger terminals and cargo terminals. In fact, the projected growth rate for cargo is much higher than for passenger traffic, and it will be compounded by the growth in the amount of military cargo carried by air as a result of the C-5A development.

As for the SST's, the generation of the 1970's will be deficient not in speed but in range. Comparing these jets with the subsonic jets that will be operating in that period, it is inconsistent from the standpoint of the traveller that the vehicle with superior speed should have inferior range. On the other hand, given the fact that the earth is fixed in size and the distance between major population centers is not going to change, even the longest flights, if made at Mach 2.5 to 3.0, will not be unduly boring or fatiguing. Nor will further reductions in time be of great significance to the businessman -- or to the cargo shipper.

So it may be expected that the second generation of SST's will concentrate on improvements in range rather than in speed. The goal will be to match the range of the subsonic jets as it is at that time. This goal in itself will be extremely difficult to attain at supersonic speeds, but substantial improvement could justify construction of aircraft.

Will the period under discussion see anything new in long-range air transport? Two possibilities are presently over the horizon: hydrogen-powered and nuclear-powered aircraft (Fig. 4).

Hydrogen fuel is compatible with hypersonic speed, the value of which, as has been said, is questionable for air transportation. More-

over, much must be learned regarding the handling of hydrogen -- and assuredly will be as the missile and space program advances -- before it can be considered safe enough for air transport use. Considering the advanced technology required for hypersonic flight and its marginal utility in transport applications, we would rule it out in the 1980-2000 period.

Nuclear-powered aircraft would greatly relieve logistic support by carrying their own virtually inexhaustible supply of fuel -- a characteristic of considerable value for military transport. But the problem of crash safety in connection with the possible release of nuclear products has not as yet found any real solution, even on paper, and once again we would not expect this form of propulsion to become operational during the subject period.

Ballistic and orbital transports, if they come, are even farther in the future. One may perhaps be pardoned for doubting their usefulness for point-to-point transportation on this small earth of ours.

The current crop of subsonic jets is proving to be highly versatile and practical (Fig. 5). These aircraft are setting an amazing record of dependable, comfortable, trouble-free transportation and they are making money. The match between them and ground facilities is being constantly improved so that door-to-door delivery time of passengers and cargo is shrinking even though air time remains substantially constant. The manufacturers are showing great ingenuity in exploiting the usefulness of these vehicles by stretching or shrinking them and making technological improvements. In spite of the introduction of the new low-cost and high-speed classes of aircraft, which

will begin in the next decade, there is no reason to believe that modifications of the current subsonic jet fleet will cease or that this genus of aircraft will not continue to carry a very substantial share of the expanding travel market 'way past 1980.

We are now witnessing the introduction of smaller and smaller subsonic jets as well as larger and larger ones, as jet engines take over the jobs previously handled by piston engines and make new jobs possible. This trend will surely continue to its logical full potential.

Already the jet transport is demonstrating its ability to compete on shorter ranges than was thought possible a few years ago. But inevitably there are limits, which brings us to the feeder aircraft that will serve the considerable market at the lower end of the range and field-length spectrum after 1980 (Fig. 6).

In the interests of clarity, it is well to discuss vertical- and short-takeoff and landing vehicles separately. Although a VTOL vehicle will have STOL capability also, the reverse is not necessarily true. The ability to hover costs money and should not be called for except in types of service which definitely require it.

Speaking then first of VTOL, the usefulness of the helicopter in military airlift operations has been so thoroughly demonstrated in Vietnam that this device, or its future variants, has already proven itself an essential part of our general-purpose forces. One may expect future improvements in VTOL vehicles to take several different directions. First will probably come lowered maintenance and service costs as experience accumulates and weaknesses are corrected. Lower

vibration and noise levels and greater stability will follow. And ultimately the marriage of high performance with hovering capability will bring about a completely successful combination of vertical-lifting devices and efficient devices for horizontal flight. By 1980 the VTOL will have been sufficiently perfected and advanced to invade the commercial transport field to a much greater extent than at present, and this without subsidy.

As ground transportation, particularly in and near urban centers, becomes more congested with the increase in population, and as these centers diffuse into "megalopolises," the need will grow for more rapid and comfortable transport between airports and satellite urban concentrations. Frequency of service to numerous, widely dispersed points will be an essential element of this kind of transport. It may be expected that VTOL vehicles will grow in number to meet this need, but not particularly in size except for specialized tasks.

Winged technology is already quite capable of producing STOL vehicles and in fact has already done so. What is lacking at present is adequate ground facilities, both in number and design, to produce a fully integrated system. A growing need will ultimately create these, a need that will be very evident long before 1980. We are referring to the market for STOL that will fall between the one requiring VTOL capability and the one that can be filled by conventional small jets -- that is, transportation between small but separated communities, where there are adequate land and resources to make short landing fields practicable, where landing pads are therefore unnecessary, and where long fields are too expensive.

The major carriers are already alert to the potential value of VTOL and STOL collecting and distributing systems for their payloads, whether passenger or cargo. A couple of decades hence, these two elements of the transportation system should be much better integrated than now.

There is no doubt whatever that the need for air transport will continue to grow at, or nearly at, its present rate of increase well into the 1980's. Another, related field of technology, however, may tend to inhibit this growth more than is generally appreciated: the field of communications. It is easier to transmit ideas and information while sitting in one place than while moving about, and the rapidly advancing arts of ground and satellite transmission are bound to revolutionize many social habits in the next decade or so. Sight, sound, and the written word will be instantaneously transported over virtually unlimited ranges without requiring the movement of weighty physical objects, animate or inanimate.

The air transport world of post-1980 that we have been describing is, then, not a simple extension of past trends, for almost all of these trends have a practical limit and some of these limits are already in sight (Fig. 7). The cost of vehicles cannot rise indefinitely. It is already reaching beyond the capabilities of private financing, and government financing also has its limits. Earthbound transportation clearly does not make sense as a practical matter much beyond ranges of 6000 miles, for only a small fraction of the market could use more. Hypersonic or orbital speeds are not called for at such ranges. Air space, enormous as it is, is finite and can contain

only a certain number of vehicles travelling at the same time over established routes. Materials, no matter how exotic, all have thermal limits. The populace will accept only a certain amount of noise without revolt. There is an economic limit to the size of airfields and the thickness of their paving. Congestion in and around air terminals can only go so far before complete immobility and frustration set in.

There's a long-standing phrase which we suspect antedates even aviation: "The sky's the limit." It used to imply that there is no limit. But there is a limit, in fact many of them. In spite of this, we are confident that the current SST and C-5A/747 designs are not the end of the road. Generations of vehicles will succeed them, and air transportation will continue to have, as always, "a great future."

Fig.1
TYPICAL MATURITY CURVE

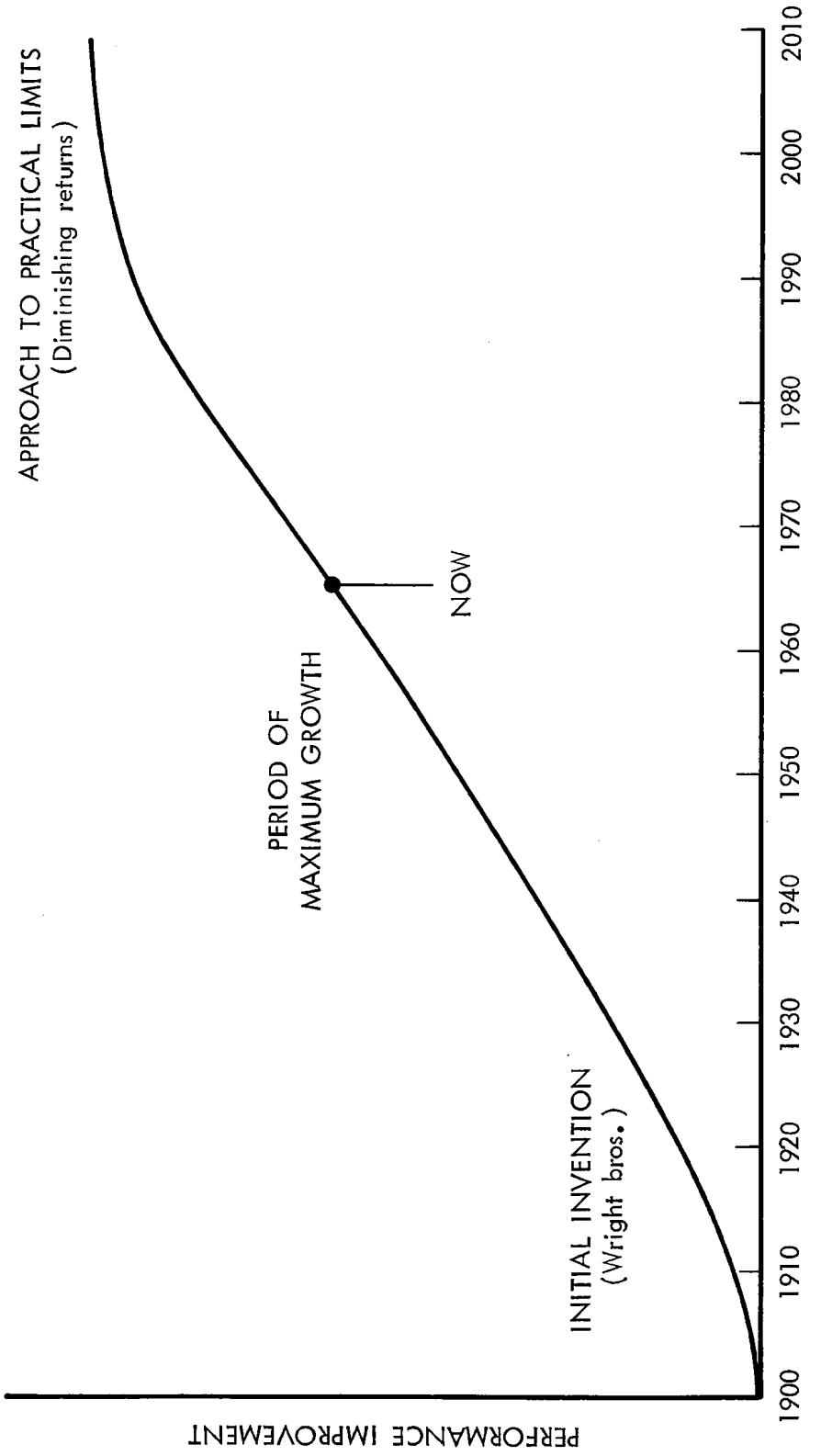

Fig. 2

LONG-RANGE TRANSPORTS

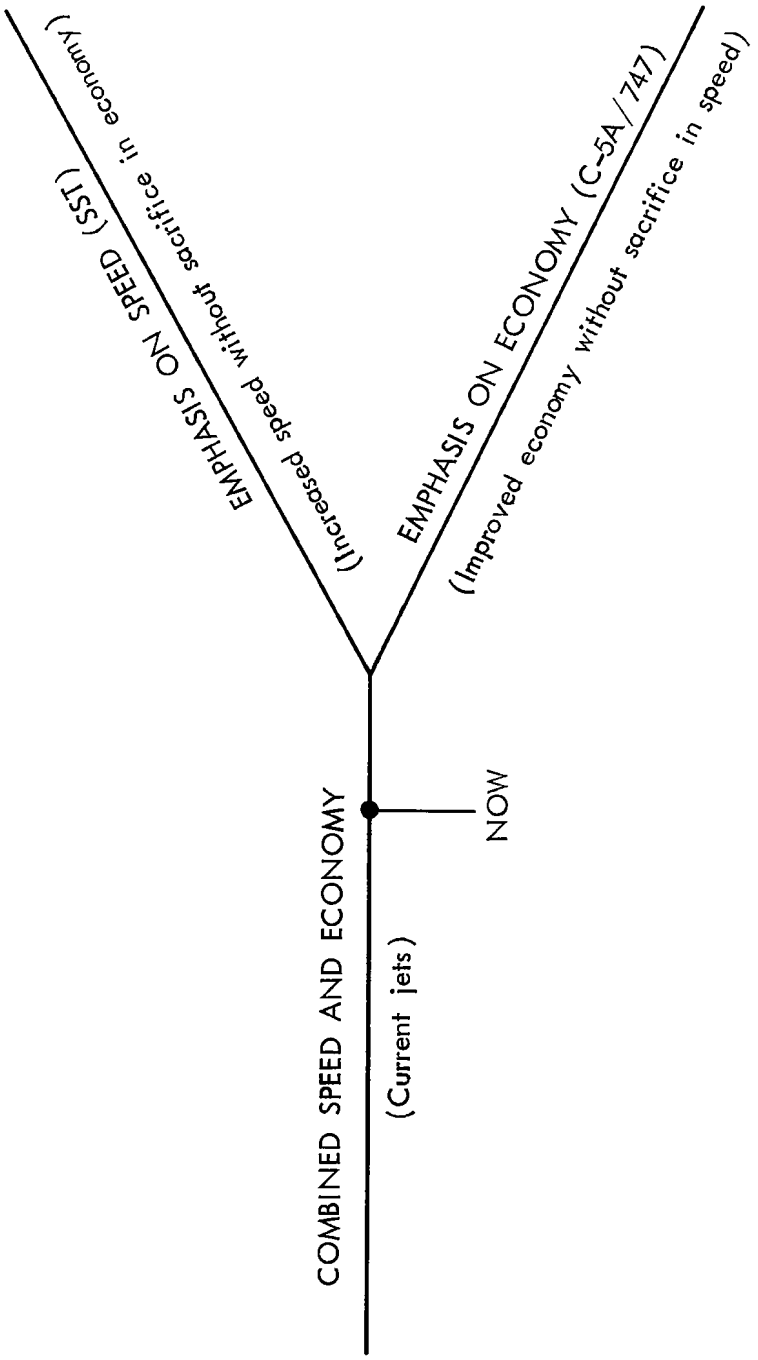

Fig.3

PROBABLE DIRECTION OF IMPROVEMENT— SECOND-GENERATION LONG-RANGE TRANSPORTS

GIANT ECONOMY SUBSONIC JETS	GREATER ECONOMY THROUGH INTRODUCTION OF ADVANCED ENGINES, MATERIALS, ETC.—FURTHER GROWTH IN SIZE UNREWARDING
SUPERSONIC JETS	GREATER RANGE TO MATCH THAT OF SUBSONIC JETS—FURTHER INCREASE IN SPEED UNREWARDING

Fig. 4

POSSIBLE PROJECTS FOR A LATER PERIOD

PROJECT	QUESTION
HYDROGEN - POWERED HYPERSONIC TRANSPORTS	HOW TO MAKE THE USE OF HYDROGEN AS A FUEL ACCEPTABLY SAFE.
NUCLEAR - POWERED MILITARY TRANSPORTS	HOW TO PREVENT POSSIBLE RELEASE OF NUCLEAR PRODUCTS IN A CRASH.
BALLISTIC OR ORBITAL TRANSPORTS	WILL THEY BE WORTH THEIR COST?

Fig.5

SUBSONIC JETS

- EVOLUTIONARY IMPROVEMENT
- STRETCHED VERSIONS
- AVAILABLE IN WIDE RANGE OF SIZES AND CAPACITIES
- HIGHLY REFINED AND TROUBLE-FREE
- WELL-MATCHED GROUND FACILITIES

Fig.6

V/STOL

VTOL

IMPROVEMENTS

- LOWER MAINTENANCE AND SERVICE COSTS
- IMPROVED INHERENT STABILITY AND ALL-WEATHER OPERATION
- GREATER SPEED AND RANGE, AND IMPROVED GENERAL PERFORMANCE
- BETTER ECONOMY

MISSIONS

- MILITARY AIRLIFT
- TRANSPORTATION BETWEEN AIRPORTS AND INTRACITY POINTS NOT SUITABLE FOR RUNWAYS

STOL

IMPROVEMENTS

- EVOLUTIONARY IMPROVEMENT OF VEHICLE
- BETTER AND MORE NUMEROUS GROUND FACILITY COMPLEXES

MISSION

- TRANSPORTATION OVER SHORT RANGES BETWEEN POINTS WHERE:
  1. SHORT RUNWAYS ARE PRACTICABLE
  2. PADS ARE UNNECESSARY
  3. LONG RUNWAYS ARE IMPRACTICABLE

GENERAL: VALUABLE AS FEEDING AND DISTRIBUTION SYSTEMS SERVING MAJOR TRUNK LINES

Fig.7

OPPORTUNITIES AND LIMITATIONS

OPPORTUNITIES

- INEVITABLE, GREATLY EXPANDED REQUIREMENT FOR AIRLIFT
    1. PASSENGERS
       (Population increase and air travel acceptance)
    2. CARGO—COMMERCIAL AND MILITARY
       (Even greater rate of growth than passenger seat-miles)
- NEW MARKETS

LIMITATIONS

- COMPETITION OF ADVANCING TECHNOLOGY IN FIELD OF COMMUNICATIONS
- ENORMOUS DEVELOPMENT COSTS
- LIMITS OF AIR SPACE—PROBLEMS OF AIR TRAFFIC CONTROL
- THERMAL LIMITS ON MATERIALS
- ACCEPTABLE LIMITS ON NOISE
- ECONOMIC LIMITS ON AIRFIELD LENGTHS AND RUNWAY THICKNESSES
- TERMINAL CONGESTION