Looking to the future— Convair's XFY-1 Navy fighter, the Pogo, takes off and lands vertically, is capable of high-speed horizontal flight.

THE FUTURE OF AIRCRAFT ENGINEERING

by A. L. KLEIN

POWERED FLIGHT will be one hundred and one years old on the one hundredeth anniversary of the Society of Automotive Engineers. Industries of this age are noted for their stodginess and lack of imagination. Let us hope that our industry will maintain its rate of progress and its freshness of approach.

We hope that the present crop of juvenile imbeciles will not undo our work in building our industry to its present size and usefulness. We often are tempted to take the classical attitude that the new generation cannot amount to anything, forgetting that our generation was one of the most harebrained that ever came along. We actually believed that flying machines would work and be useful. We can therefore hope that with the aid of the psychologists and "human engineers" the new generation of aircraft engineers will make our future vehicles safer, more efficient and useful, and may, by means of some as yet unknown powerplants, enable us to escape into space.

We in this Activity are in all our efforts constrained by the requirements and needs of our customers and the output and opinions of the producers of powerplants. We are continually in the position of a chef who is asked to prepare filet mignon from round steak for a customer who can only pay for a hamburger. Fortunately for us, our fairy godmother, namely, the Armed Forces, has waved her magic wand and provided us with enough resources to make the above-mentioned miracle occur. Whether the international tensions that presently exist will continue for the next fifty years or whether a relaxed peaceful civilization or a war will replace the present turmoil is anyone's guess. I could, therefore, take the simple (and perhaps too simple-minded) course that the present international and internal conditions will continue. I hope that our industry and the communication industry will continue to do as they have in making world-wide access and knowledge available to everyone.

Our principal achievement, not without its disadvantages, is to provide cheap and rapid transportation for the world. We have now made it possible to get anywhere in our country in one day. Surely in fifty years the whole world will be reachable in the same time. This implies an average speed of at least 1000 miles per hour, which will be attained long before fifty years elapse. To be practical commercially such speeds must be economical.

The threshold of the supersonic era is on us and as the knowledge of the phenomena that exist at these speeds continues to accumulate there is an indication

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that supersonic flight will be in some ways easier than subsonic. High speeds imply high altitudes and the studies that have been made indicate that altitudes up to nearly 100,000 feet present few unusual problems. Whether we stay with winged vehicles, nuclear engines, or some new and unknown powerplant, the key problem will still be, as now, that of landing and takeoff.

With airplanes the power needed for the desired (and economical) high speeds will automatically give a satisfactory takeoff. In the case of nuclear powerplants the landing problem becomes acute as the nuclear airplane is as heavy at landing as it is at takeoff and therefore the entire airframe, and in fact the entire proportions of the airplane, will be determined by the landing case. The nuclear aircraft will therefore have large and comparatively lightly loaded wings and will have its best performance at comparatively high altitudes.

Supersonic design

At the present time the major problems with supersonic aircraft are low speed and landing control. Maneuverable supersonic missiles of either the rocket type or the airplane type are not too difficult to design, but with them every landing is a crash. We have achieved a good deal of competency in supersonic design and are at last getting to have some feeling and intuition about this region. Up to now we have had to proceed either by inventorism, or by the elaborate procedure of calculation and testing to get a satisfactory vehicle.

Though difficulties have occurred, they have been superable and we are now at the point where supersonic design is becoming a matter of engineering judgment. The striking thing has been the small number of drawings that are made and the large number of calculations and discussions that are needed. Perhaps this is the way to the future.

Using true rockets (without wings and having thrust larger than their weight), the way to the future is less clear. The low speed control of these vehicles is difficult indeed and has only been solved by the science fiction writers. The true rocket, to be commercially useful, must achieve a landing reliability equal to that of other aircraft. If this is done by the use of reversed thrust we must also answer the problem of powerless landing.

As far as extra-terrestrial travel is concerned the vehicle designer is completely at the mercy of the powerplant industry. Financing for such an endeavor must be provided non-commercially as the only immediate uses are military and scientific.

The vehicle except for the landing problem mentioned above, is fairly straightforward, there being only two other important problems. One of these, the auxiliary power problem, is apparently going to be solved by either the solar energy converter, some models of which were displayed lately by some highly reputable organizations, or by means of the direct partial conversion of the energy of radioactivity into electricity. The atmospheric re-entry problem seems to be of an engineering type and needs a great deal of effort but its difficulties are not fundamental.

To reiterate, something is required to replace chemical fuels if extra-terrestrial flight is to be achieved; there are no other serious difficulties other than the financial one.

In the next fifty years the helicopter will come into its own. I have never been a believer in aircraft for everyone and am still less a believer in helicopters as a personal vehicle. If our colleagues in the other Activities of the SAE cannot solve the automobile accident problem, we in this Activity have no chance of solving the problem of safe personal aircraft.

With helicopters the problem is even more aggravated as mere contact with another helicopter can be fatal. These infuriated windmills will destroy each other like creatures in a nightmare. Their present difficulties will be overcome when aircraft designers determine how to design high speed precision machinery. The convenience of the helicopter is so outstanding that its full utilization waits only on improvements in its reliability and safety with a consequent reduction in costs. Twenty years should see these problems solved.

Aircraft safety

The problem of safety for aircraft is largely psychological. It is notable that "safe" small aircraft do not sell. People do not buy small aircraft because they are safe; they buy them to inflate their egos and therefore the more dangerous, the better. The psychological attitude is similar to that of mountain climbers and hot rodders, and if everyone were properly adjusted none of these would exist. There is something to be said for teaching every young man to fly, if it is possible to do it without terrific carnage. Unfortunately the accidents don't always involve only the pilots.

This Activity is also concerned with aircraft accessories. It is safe to say that within another fifty years most of these devices should work. Some of our present accessories, such as capacitance fuel gages, being based on unsound physical principles, will be replaced. Fifty years from now most of these gadgets will be about as reliable as telephones are now.

Our present instrument flying system must be replaced by something less confusing. Twenty years of trying to get a satisfactory instrument arrangement should prove to anyone that our present system is unsound psychologically and physiologically. The pilot must be given a 3D television type of presentation in the windshield so that he will have a natural view of the situation. Anything less does violence to his instincts. In fifty years we can hope that the uniformity of design so typical of a mature industry will appear in these accessories and their functioning.

We can expect a great deal of progress in metallurgy. Duralumin as an alloy is not yet fifty years old. We can probably expect greater developments in this field than in many others since the metallurgists are just beginning to come out of the kitchen and to do their thinking at desks. Our structural alloys should be at least twice as strong as the ones we are now using; the non-metallic materials will also be improved in an even greater ratio. As a consequence of the improved materials, improved manufacturing, and assembly techniques, our aircraft fifty years from now will be as superior to our present best performance as today's aircraft are to those of the First War.

These aircraft may be made of metal or they may not. Some of the properties of long, fully saturated molecules are surprising. Who knows?—within fifty years perhaps someone will even come up with a non-destructive method for the measurement of incipient fatigue failure.

Engineering organization

We can expect engineering departments of the future to be differently organized. The problem of large engineering organizations operating on a small number of products is a new thing in human experience and as yet no standardization has developed. Let us consider the engineering organization of the future to be headed by a chief engineer and his immediate assistants: the sum of his detailed duties may be divided among several groups. A partial listing of these follows:

I. Internal Affairs
   1. Personnel
   3. Housekeeping
   3. Clerical services

II. External Affairs
   1. Customer contacts
   2. Project co-ordination
   3. Field service
   4. Licensing agency contacts

III. Engineering
   1. Intelligence
      a. Aerodynamics
      b. Structural
      c. Stress analysis
      d. Loads
      e. Weight
      f. Systems analysis
      g. Powerplants and thermodynamics
      h. Human engineering
         1. Acoustics
         2. Physiology
         3. Comfort and safety engineering
      i. Testing and Research
   2. Design
      a. General
      b. Specialists
         1. Structural
         2. Mechanical
         3. Electrical
         4. Thermodynamics
         5. Fluid Mechanics
         6. Controls
   3. Services
      a. Applied mathematics and computing
      b. Analog machines and simulation
      c. Metallurgical and Material services
      d. Production design
      e. Technical information
      f. Miscellaneous consultants

IV. Research and Testing
   Facilities
   1. Aerodynamics
   2. Structural
   3. Electronic
   4. Electrical
   5. Mechanical
      a. Hydraulic
      b. Pneumatic
      c. Power Plant
      d. Miscellaneous
   6. Simulation
   7. Flight Research

It will be noticed that all the information for the shop originates in Section III, 2—the only part of the entire department that makes drawings and transmits other information to the manufacturing organization. This group, which must weigh the information given to it by the other parts of the engineering department and must make the basic decisions which determine the general and specific nature of the product, is now inadequately educated, staffed and supported. In order for such a group to work at all, and for an organization to come up with sensible results, the members of this group must have an adequate training in evaluating the opinions of specialists. This means that this group requires a more complete, and broader education and training than that of the specialists groups.

Basically these people need the scientific background of a physicist with the practical approach of a mechanic. They need knowledge and skill capable of determining the optimum design in a multidimensional field. These men are frequently in the position of a family physician who can, according to the advice of specialists, have his patient's teeth pulled, operate on him for appendicitis, have him given psychiatric treatments, or put him on a special diet. The future education for these people will be discussed later.

Fifty years from now

Fifty years from now the designer will be much more of a mathematician than his present counterpart. He will be used to large calculating machines, and familiar with the characteristics and capabilities of analogs. He may work at his desk with a miniaturized multidimensional analog and solve some of his polydimensional and non-linear problems directly.

It is difficult for us in the kindergarten epoch of the art to realize what fifty years will bring. The designer will think in terms of rates, not of magnitudes; problems will not be approached by sampling but will be optimized. Problems will be formulated in terms of physically independent variables and not in terms of meaningless parameters.* These aircraft design problems will contain from fifty to a hundred independent variables; the solution in terms of the desired operating characteristics, such as takeoff run, high speed, cost per ton mile, etc., will determine the values of wing thickness, sweep back angle, wing area, span, etc.

A further investigation will be made to determine the sensitivity of the results to variations in the excellence of manufacture and the quality of the detail design. A further study of the effects of powerplant growth and of changing economic conditions will permit an ade-

*The writer has come to the conclusion that a parameter is something that is used by a specialist to confuse his readers.

quate evaluation of the probable economic success or failure of the design. This method can be applied to any products, the characteristics of which can be expressed by mathematical relations. At the present time it can only be used where comparatively simple functional relations can be found. Let us give the mathematicians the next fifty years to produce better methods.

The engineer of the future will be much better educated than his present-day counterparts. He will have a solid foundation in the basic sciences, and will, in addition, be given a background in economics, industrial management, and psychology. He will be trained in the conveying of ideas, both upward and downward in his organization. He will know that the number of geniuses available in the industry is effectually zero.

He will know that materials do not maintain fixed dimensions. He will know that neither mechanics nor pilots can be expected to give continuous and unfailing attention. He will know that all devices fail and what failure rate to expect from different kinds of equipment. He will be immune to false objectives such as "do it electrically."

He will recognize from his psychological studies when he, himself, is prejudiced and in important cases will accept good suggestions even if they come from disagreeable individuals. He will know the fields in which he is competent and will not hesitate to ask for help in others. He will be trained to recognize the cycles in human optimism and pessimism so that he can evaluate his performance properly. He will not be pressured into making impossible commitments, and he hopes that his customers will have reached the state where they do not need to be bolstered up by false expectations.

Education to prepare the designing engineer for his job will consist of an academic training roughly equivalent to that for a present-day PhD, plus an interneship under careful supervision.

The men who are to exercise judgment and to compromise the differences between the specialists must be carefully trained. They not only must understand the basic facts involved in each specialty but also must understand the personalities of the individuals concerned, and how far to believe them. In order to get the time to train these people a new synthesis of the scientific background will occur and the old breakdown into specialities will be avoided.