The B-29 launched Bell X-1A was first of USAF's series of supersonic research aircraft to attain prominence.

The Role of Research

By GROUP CAPTAIN H. R. FOOTTIT

"The next war, should there be one, may well be lost in the laboratories years before the storm clouds show on the horizon." — *U.S. Air Policy Commission*

THE DEEP BLUE sky was spotted with white puffy clouds that were piling up towards the horizon. Against this backdrop a lone B-29 bomber, with the name "The Great Artiste" emblazoned on its nose, droned its way slowly towards the target. As the ragged coastline broke into view over the surface of the sea, the crew stirred into action. In a short time the target crept into the cross-hairs of the bombsight. Second followed second. Then the *Great Artiste* leapt skyward. "Bomb away!" echoed in the earphones. And the large mysterious mass plunged earthward, headed for the sleepy Japanese city of Nagasaki.

Later the crew were to report of the "giant flash" of bluish-white light, the successive blasts that shook the bomber, the purple pillar of fire that shot upward, the seething white mushroom cloud that boiled up to 60,000 feet. Thus, on this pleasant summer day of August 8, 1945, the *Great Artiste* established the atomic age with the second and last A-bomb to be dropped in World War II. While the world sat back and wondered of the future, the press extolled the power of the bomb. Few realized, however, that this was a product of the past. It was an end point to the research of Pierre and Marie Curie, Ernest Rutherford, Albert Einstein, and literally hundreds of other scientists and mathematicians. For atomic energy had been generally known and evaluated as early as 1900, and the basic equation that made the bomb a reality, written in 1905.

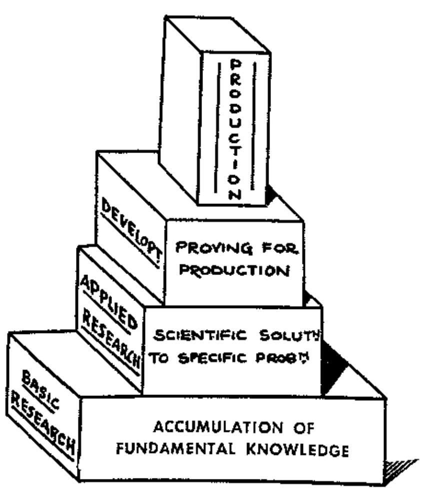


FIGURE 1

PILLAR OF AERONAUTICAL ADVANCET

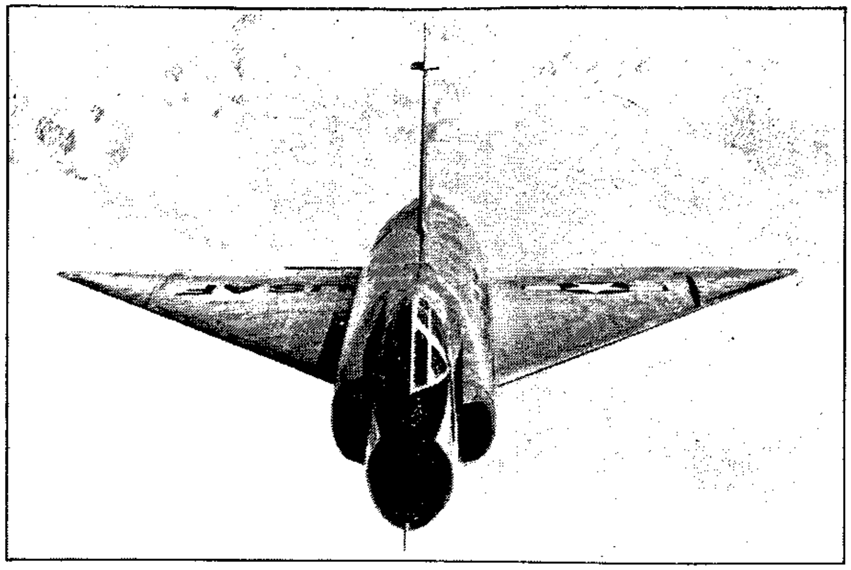
Same Heritage: We in aeronautics have a similar research heritage. What other scientific endeavour has built such churches of aeronautical theory, and spread the gospel of knowledge, as the U.K. Royal Aircraft Establishment, the U.S. National Advisory Committee for Aeronautics, Canada's National Research Council and National Aeronautical Establishment, and many others? In a brief 50 years, with such devotion to the cause, we have outstripped most other scientific endeavours. The practical results are proof positive of our work. Yet we are in grave danger today of letting our creed crumble to dust. For we have almost forgotten the real role of research — the quest for fundamental truths; the probing ever forward on the frontiers of the unknown, with no real goal except to let the light of knowledge pierce the shadows of ignorance.

Today we have become so material minded that we think almost solely of the number of electronic gadgets flowing from a production line, the stacks of jet engines piled in a supply depot, or the line-up of fighters on the tarmac. Begrudgingly the taxpayer will throw a few dollars into the pot for *applied* research, when he can see that there's a specific problem to be solved that might improve tomorrow's airplanes. But he balks almost every foot of the way when the scientist wants to plod down a path that has no clear ending; a path that the research worker hopes will unveil some new, basic principle of aerodynamics, or reveal a new theory of structures.

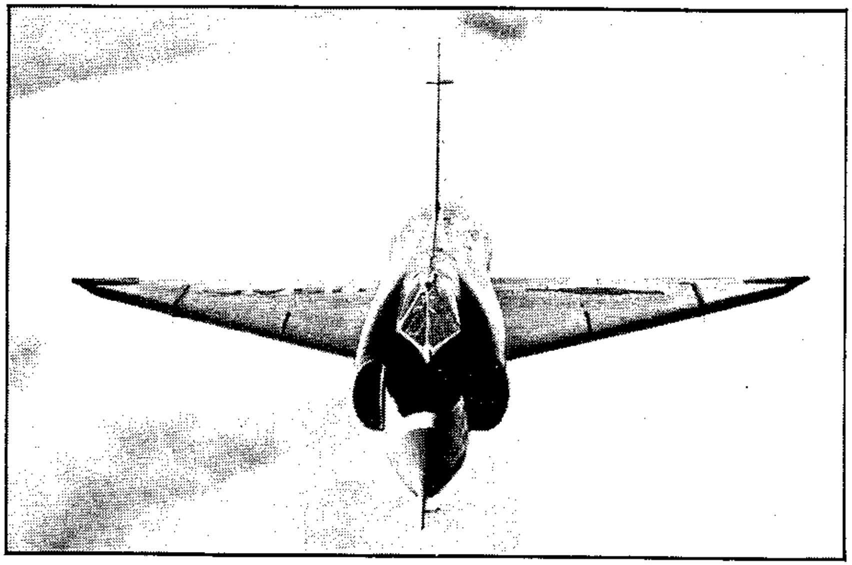
We don't have to look far afield for a typical public attitude to such ponderings. Recently Production Minister C. D. Howe and Defence Minister Ralph Campney announced that the Defence Research Board had spent $24 million on a Canadian designed missile, the Velvet Glove. Now the project was to be cancelled, and the U.S. Navy's Sparrow missile was to be built in Canada. The spending of such money on a project that misfired is certainly open to question. Did the DRB scientists engaged on the job prove themselves to be incompetent? Did they overspend and back an obvious failure? We have every right to ask such questions. But I have yet to see one newspaper account, or parliamentary enquiry, that asked the questions, "What basic knowledge did Canada accrue from this work? What scientific capital has now been deposited to our account?"

Understanding Needed: Part of this public apathy, even hostility, to basic research is probably rooted in a lack of understanding. There is really a fine line dividing basic research from applied research and what we usually call "development".

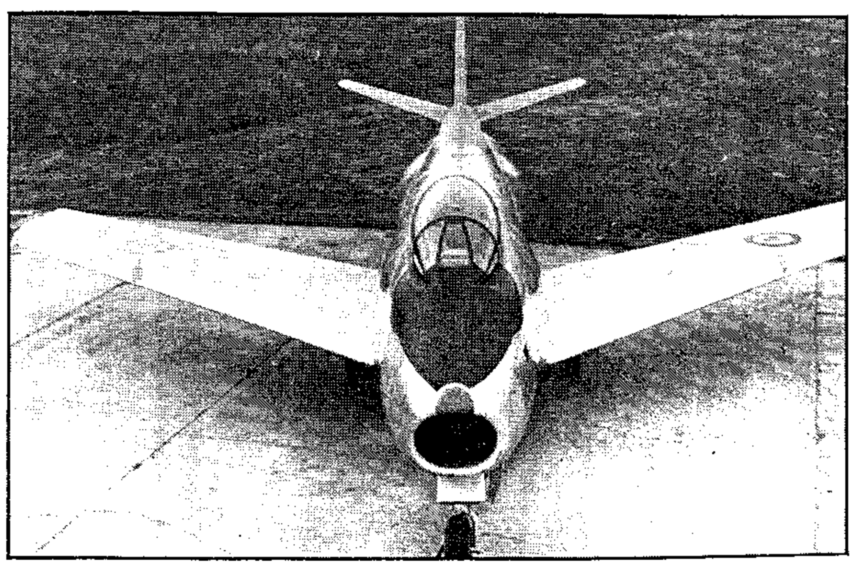
I went up to see John L. Orr, Director of Engineering Research for DRB, on these categories of aeronautical advancement. Between the two of us we decided that they are best defined by what they expect to achieve (Figure 1). Basic research is what John Orr calls "a reconnaisance into the future." It is a look behind the curtain that separates our present knowledge from what we will know in time to come. He also drew my attention to a statement by B. G. Ballard, Director of the Division of Radio and Electrical Engineering in our National Research Council. "In this field (of basic research)," Ballard told the Special Parliamentary Committee on Research this year, "it is rarely possible to foresee the ultimate benefit which may arise from a particular project. We do not, in general, attempt to channel or guide the direction which

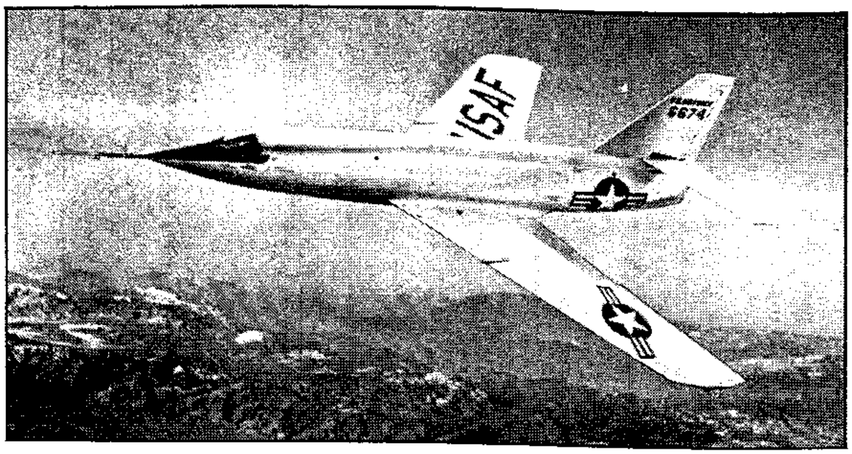


First application of the area rule to a production airplane was on the Convair F-102 all-weather delta fighter. Above is shown the YF-102, the fuselage of which did not have the characteristic area rule wasp waist, while below is the production F-102A, on which the pinched-in fuselage is clearly evident.



Below is a Canadair Sabre on which falsies have been experimentally installed at strategic locations to give an area rule effect. Although performance was not materially improved, neither did the ungainly bumps have any effect on Sabre's speed. Aircraft is still being flown by the NAE at Uplands.





Designed to take up the supersonic flight research program where the Bell X-1 series left off, the Bell X-2 has already flown at more than 1,900 mph.

research should follow, mainly because we feel that, by allowing complete freedom, better results will be achieved and because almost any information acquired in this manner is likely to lead ultimately to useful results."

Applied research, on the other hand, is research aimed at the solution of a specific scientific problem. It is John Orr, for example, when he was at NAE, digging out the basic principles of electro-thermal propeller de-icing; or M. Keuring, of the Engine Laboratory, sifting the results of his work on pre-turbine injection afterburners to sort out basic design data.

By taking information from basic and applied research sources, the design engineer can lay out a new airplane, or piece of equipment, and predict how it should perform. Of course it never does perform exactly as he predicted on the prototype model. Thus he plunges into the development phase. He designs and redesigns, correcting detail errors, with the sole idea of bringing out a workable piece of "hardware" that is suitable for production.

The Area Rule: About the best example I know of, to illustrate this march of events from basic research through to production, is the aerodynamic procedure called "area rule". The results of this work are popularly known as the "Marilyn Monroe", "coke bottle", or "wasp waist" fuselage. It is one branch of a tree of basic research that started out to find out something about airflow in the transonic region. And it has since been heralded as one of the greatest aerodynamic advancements in our age.

Like all new things, the achievements of the area rule tend to get exaggerated. We mistake the branch for the tree trunk. However, it has brought to the fore the basic idea that the wings, fuselage, and tail of a modern supersonic airplane must be designed as a single entity. Before the area rule advent, designers laid out each separately, then worried about cleaning up the interference drag. Now they try to design the airplane as a complete unit.

However, there is still a lot to learn from basic research on transonic and supersonic airflow. For example, we are still not sure, in the design stage, whether we have the right combination of wings, tail, and fuselage, to produce the best possible airplane for the mission, in spite of the area rule concept.

The basic research, that led to one branch called area rule, really got started during the last war. Spitfire and Thunderbolt fighters had been dived close to the speed of sound during air combat. Strange things happened to them. Pilots lost control for a period, the airplanes shook like a leaf. And some plunged to earth, never to fly again. Information was sorely needed on this sonic barrier — this transonic speed range around Mach 1.0 where shock waves buffet the airplane until smooth sonic flow is established.

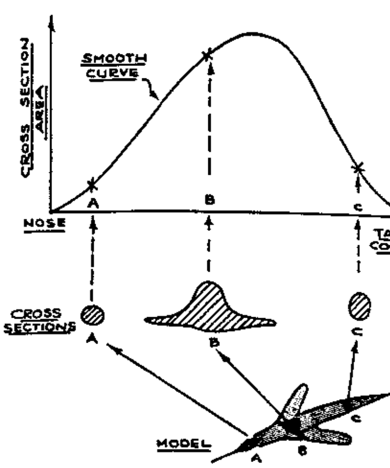


FIGURE 2
SIMPLIFIED AREA RULE: M=1.0

First Steps: As early as 1943 the U.S. National Advisory Committee for Aeronautics had suggested a research airplane for this job, since the standard wind tunnel "chokes" at transonic speeds, and is useless for exacting measurements. By late 1944 the final decisions were made. A contract was then let with Bell Aircraft for the rocket-powered X-1 airplane, and with Douglas for the jet-engined D-558-I. These two record breakers were the first of a series of research aircraft whose major role was to break into and analyze the turbulent air of the transonic regime.

By 1947 the airplanes were finally delivered to the NACA. As the years followed this series of research aircraft, with their speeds of 1,650 mph. and over, and their altitudes of 80,000 feet and more, so caught the imagination of the flying world that their real role was completely masked by their front page performance feats.

In the meantime the NACA was busily concocting other schemes to probe the sonic wall. Free fall models were dropped from aircraft at 35,000 feet; a bump was built on the wing of a Mustang fighter to induce transonic flow and test a model in it (our NAE made a similar installation on an RCAF Mustang); models were also attached to rocket projectiles and fired from the ground. But the aerodynamicist had not forgotten his favourite tool, the wind tunnel. Porous walls, bumps, and slotted walls were put into the working section of the tunnel to try and stop the "choking" phenomona, and restore the tunnel to the usefulness it enjoyed in subsonic days.

Success at Last: Finally the NACA was successful. In early 1951 they started up the first of two truly transonic tunnels. So important was this development that for three years they kept the existence of the tunnels a closely guarded secret.

No sooner was the first tunnel operating than scientist Richard T. Whitcomb was assigned the job of penetrating the secrets of the transonic zone. This was basic research, since its primary aim was to log data, analyze it, and add it to our small storehouse of knowledge on transonic airflow. Part of what Whitcomb discovered has now become aerodynamic history. He noted that there was an interfering pressure field built up at the intersection of wing and fuselage. This caused large increases in drag at sonic speeds. By designing the wing and body as a unit, to achieve a smooth plot of their cross sectional areas from nose to tail (Figure 2), the drag could be drastically reduced.

To achieve this smooth plot, it is necessary to waist in the fuselage opposite the wing. The cross sections are taken at right angles to the longitudinal axis of the airplane at Mach 1.0, and at different angles at speeds above this. The net result is a deep "wasp waist" at Mach 1.0, with less waisting effect as the airplane's design speed exceeds the speed of sound. A similar necking in of the fuselage of course is necessary at other protuberances such as the canopy or tail. The effect of all this is called the area rule in formal circles. But informally Marilyn Monroe suddenly had a different meaning to the aerodynamicist than it did to the movie magnate.

Before Monroe: Like all things, it was soon discovered that others had suggested this approach from incomplete experiments and mathematical considerations. Both British and U.S. researchers had suggested this solution as early as 1947. And few know, even today, that the Supermarine "Swift" fighter of the RAF has a slightly waisted fuselage that was designed before the days of area rule, as a result of some incomplete work.

With this branch of the basic transonic research now building, it was time to move into the applied research stage. Other organizations picked up the trail that the NACA had blazed. In Canada we got started with an RCAF Sabre whose fuselage was altered by Canadair Ltd., to the area rule design of our National Aeronautical Establishment. This particular project got underway when R. J. Templin and Phillip Pocock of NAE talked it over with R. D. Richmond of Canadair. The result was a proposal to the RCAF to try the coke bottle fuselage on a Sabre 5. The project was approved late in 1954, and about a year later the modified airplane took off on its first flight from

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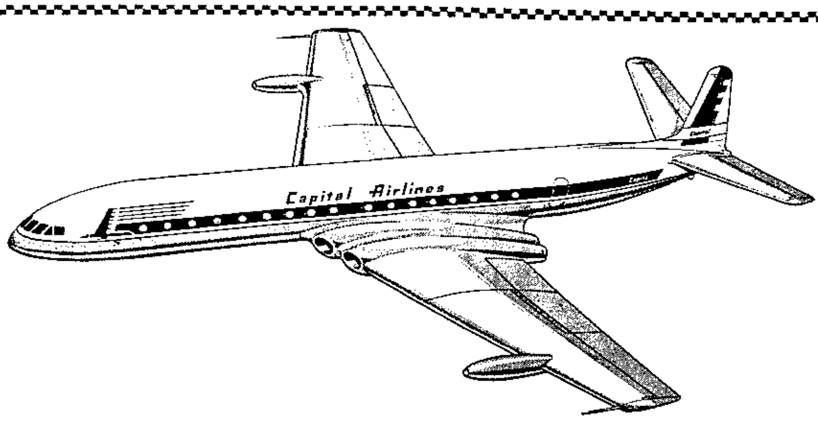


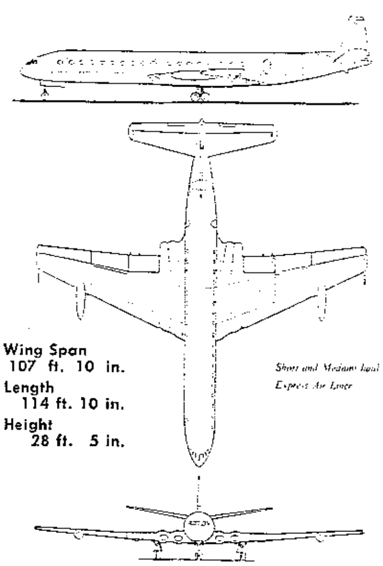
The Comet 4A

The latest Comet variant, the 4A (unveiled coincident with the recent announcement that Capital Airlines had ordered ten Comet 4's and four 4A's), is described by The de Havilland Aircraft Co. as being intended for short and medium-range operations. Its role, therefore, differs from the one in which the 4 has been cast in that the latter has been designed for long range services. The 4, of course, will continue to be available to operators who need an airliner in this category.

The more important design changes which distinguishes the Comet 4A from the Comet 4, are as follows:

- The fuselage has been lengthened by 40 ins.

- The wing span has been reduced from 115 ft. to 108 ft. and this, coupled with some structural reinforcement of the rear fuselage and tail makes possible a higher cruising speed at lower altitudes.



Wing Span
107 ft. 10 in.
Length
114 ft. 10 in.
Height
28 ft. 5 in.

All-up weight of both airliners is 152,000 lbs.

De Havilland notes that in order to achieve competitive economy on the short and medium stages with the Comet 4A, a special operating technique has been evolved and this may be summarized as follows: by cruising at a lower altitude the true air speed is increased relative to the limiting Mach number. This increase in speed goes far to compensate for the increased fuel consumption due to the reduced cruising altitude. In addition, both the rate of climb and descent are increased, resulting in the maximum possible distance for high-speed level cruise so block time is further reduced.

This operating procedure is said to enable the 4A to cruise at an air speed which varies between 520 mph and 545 mph, according to the ambient temperature, when flying at 23,500 ft. De Havilland reports that because of the resulting improvement in block time the 4A achieves good operating economy on stage lengths of 500 statute miles or less. At the upper end of the scale the high-speed cruise procedure shows advantages up to some 2,000 statute miles.

This high speed cruise technique can also be applied to Comet 4 operation, though with some loss in maximum range. In addition, for structural reasons the fastest cruising altitude in the case of the 4 will be higher by some 5,000 ft. and the cruising speed somewhat lower as compared with the 4A. Similarly, the 4A could be operated using the normal long-range technique, but its longest practical stage length would be somewhat less than that of the 4.

The 4A provides seating for up to 92 passengers. The maximum payload for the 70-seat version is 19,070 lbs., and that for the 92 seat arrangement is 22,690 lbs. With these payloads, the 4A, using the high speed procedure, is capable of maximum stage lengths, in still air with full reserves, of 2,040 statute miles and 1,880 statute miles respectively.

Both the 4 and 4A are powered by Rolls-Royce RA-29 Avons of 10,500 lbs. take-off thrust. The Comet 3 is now about to have its RA-26's exchanged for RA-29's and will begin certification flight testing later this year specifically for the 4 and the 4A. It will incorporate all the significant features of the new aircraft, including the shorter wing span of the 4A. Detachable wing tips will enable quick conversion from the 4A to the 4 shape for flight testing.

part of the central fuselage, with the jet pipe beneath the fuselage between the wing trailing edge and the tailplane. Fuel is normally carried internally, but there is provision for additional fuel to be carried in detachable wingtip tanks. The aircraft is fitted with complete dual controls, including full blind-flying instruments.

Principal Data — Span, 26 ft. 4 ins.; Length, 22 ft.; Height, 8 ft. 5 ins.; Empty weight, 1,283 lbs.; Loaded weight, 2,024 lbs.; Max. speed, 224 mph; Max. cruising speed, 194 mph; Rate of climb, 886 fpm; Range, 280 miles; Landing speed, 56 mph; T/O run, 400 yds.

•**Temco Model 51:** The Temco Model 51 is, perhaps, almost the "baby" of jet training aircraft, since first details have only just been released by its designers and producers, Temco Aircraft Corp. of Texas. The protoype aircraft first flew on March 26, 1956.

The Model 51, for training of *ab initio* pilots, is a two-place, tandem seat, mid-wing, all-metal monoplane, with retractable tricycle landing gear. It is powered by the French-designed, Continental-produced YJ-69-T-9 turbojet engine, which produces 920 lbs. of static thrust at sea level. The landing gear is stressed for an ultimate sinking speed of 20.4 ft./sec., a high figure providing for student error in landing practice.

In performance, its manufacturers claim stall speeds low enough for first solo, combined with a dive speed in the high subsonic range. Although unspecified, this would be a Mach number close to .85.

The aircraft is fitted with two ejection seats. The instructor's seat at the rear is raised in reference to the student's position, to provide better vision.

All primary flight controls are mechanically operated by push-rod linkages. Trim tabs are electrically-actuated and flaps, landing gear and air brakes are operated hydraulically. In the event of hydraulic system failure, the landing gear will extend and lock by gravity and air forces.

Principal Data — Span, 29.33 ft.; Length, 30.6 ft.; Height, 10.82 ft.; Gross weight, 4,137 lbs.; Training fuel load, 119 U.S. gals.; Max. fuel load, 165 U.S. gals.; Ultimate load factor, 11.25 G; Max. level speed at SL, 285 kts.; Max. level speed at 15,000 ft.; 300 kts.; Cruising speed at 25,000 ft., 215 kts.; Service ceiling, 35,000 ft.; Endurance at SL, 1½ hrs.; Stall speed at gross weight, 66 kts.; Stall speed at normal landing weight, 60 kts.; Max. dive speed, 450 kts.; Rate of climb at SL, 1,900 fpm.

ROLE OF RESEARCH

(Continued from page 18)

Canadair's field at Cartierville.

This was true applied research. To change the shape of the Sabre's fuselage, metal pads were rivetted to the outside of the existing body. Thus, this was a "bumping out", instead of a waisting in". The object of the research was to see if the drag of the airplane would be reduced in Mach 1.0 dives, so it would pick up speed faster, and still react in the normal way to the controls. This, of course, could be a combat advantage. But the flight results were not impressive. The only thing that amazed Canadair and

RCAF test pilots was the fact that the area rule Sabre, with all its ungainly bumps, was still as fast as the normal fighter. The aircraft is still being flown at the NAE's Flight Research Station at Uplands.

Stillborn Seven: If the results of these tests had shown that a marked improvement to the Sabre was possible, then, all other things being equal, Canadair would have been given a contract to develop this modification. Proper production drawings would have been made, tooling changed, and eventually a Sabre area rule Mark 7 would have appeared on the flight line.

The Sabre story, and the basic research from which it sprung, is typical of the path that leads from fundamental studies to production in quantity. But as we look back down the avenue of the area rule concept, the view is startling and scaring. It is startling to think that the NACA started its work in 1944, and it wasn't until 1951 that they even had the right research tool, the transonic wind tunnel, to really probe the problem. Moreover, it wasn't until last year that really practical results were achieved with the area rule on the Convair F-102A delta wing fighter, after the straight fuselaged prototype, the F-102, had been a sorry failure.

It is scaring to imagine what might have happened if the Russians, for example, had started this transonic research and we hadn't. The NACA say that a 25% performance gain is possible with certain area rule designs. Suppose the Russians had pushed out area rule, supersonic fighters during the Korean War. We might have been completely out-matched and completely in the dark. What would the Western World have done? Would it have taken us seven years even to develop the research tool, the transonic wind tunnel? And a further three years to get results and apply them to our airplanes? The conclusion of Korea might have been vastly different if it had.

Canada Lagging: In spite of this vital necessity for basic research we do very little of this work in Canada. Outside of some experiments at such places as Dr. Gordon Patterson's Institute of Aerophysics, at the University of Toronto, the average Canadian's production-mindedness frowns on this approach. We don't even have enough wind tunnels to take care of normal development, and Canadian companies must lean heavily on U.S. facilities. Yet we love to play in the big leagues, with such advanced projects as the Avro Aircraft CF-105 supersonic fighter, and Orenda Engines Ltd., *Iroquois* jet engine.

We are just now building a wind tunnel for the Defence Research Board at Uplands, Ontario. It will be far advanced over anything we now have, covering a speed range from 200 to 3,000 mph. "It will take at least three years to build this tunnel," says John Orr, "and a further six months to a year before its calibrated." Until it's fully operational it has limited use. Is this another case of too little and too late?

Undoubtedly we have much research work to catch up on. And we can't duck the decision by leaving it to our Western allies. As Orr points out, "Even if we do no development at all, it is still necessary to carry on some research. Only by having scientists work in this field can we build up some knowledge of the future 'state of the art'." And this knowledge is basic and vital to our selection of tomorrow's fighter or transport — if we are to get the best for the least.

Achilles Heel? Moreover, it is only fair and just that we Canadians should do our share in shoring up a sagging interest in basic research that is prevalent throughout the Western World. How critical is this situation? I don't honestly know. But thinking men everywhere are pondering the statement of Elisha Gray, President of the Whirlpool-Seeger organization, when he exclained that our niggardly support of basic research "could be our Achilles' heel!"

If we are going to advance aeronautics in Canada, as we have atomic energy in a few short years, then we must get into this basic research game. And we must get into it as a pooled effort with out Western neighbors, so we don't overlap and fritter away our facilities. We must commit our scientific forces to it on a shared basis, as we have committed our fighting forces to do their part with NATO. We must not hold back. Time is vital. We can, as the Truman Air Policy Commission said, lose the next war in the laboratories. "The first essential of air power is a pre-eminence in research," U.S. General Ira C. Eaker once stated.

How long is it going to take Canada to realize this fundamental fact?