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HOPES AND PLANS OF THE UNITED STATES AIR FORCE: A SUMMARY

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A. Y. Pope

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ABSTRACT

Data on future airplanes and operational procedures as given at an Air Force colloquium are summarized. Due to the sensitive nature of the material, only a limited distribution is authorized.

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Case No. 403.07

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SUMMARY

This paper is a summary of information given to a group of engineering executives by the United States Air Force at a secret meeting in Cleveland in late January 1956. The purpose of the meeting was to draw attention to new data and new problems that have resulted from substantial breakthroughs in aircraft fuels, aerodynamic theory and operational techniques such that very rapid progress in general aircraft performance is expected in the near future. This paper has been written to summarize the breakthroughs as they appear to affect the Sandia Corporation.

Two items should be clearly noted at the onset: The first is that while the figures are from a USAF report, the context is from notes and memory and may not entirely convey the original thought. The second is that a paper such as this is on a very sensitive subject and should not be discussed outside the Corporation.

The five most salient points resulting from the meeting are as follows:

1. Improvements in fuels, engines, and design indicate that a manned airplane flying at M = 7.0 and 250,000 feet is now technically possible, and it is expected one will be built within two years. Fighter operational speeds are expected to be 1200 knots by 1960 with altitudes up to 75,000 feet. Our weapons should be made compatible, especially as regards aerodynamic heating.

2. Modern jet engines can suck up rocks and dirt from a runway, and hence complete runway destruction is not necessary to deny the use of an airport on a temporary basis if debris can be liberally scattered over the runway by a bomb blast.

3. Bomber altitudes should reach 70,000 feet by 1960. Such altitudes may require special efforts to preserve bombing accuracy.

4. In view of the aerodynamic heating problems, external stores should phase out in favor of internally carried stores. Every effort should be made to make the stores small, with emphasis on size rather than weight.

5. The nuclear-powered airplane is running ahead of schedule, and design problems indicate that our products will necessarily be in areas of high radiation for extended periods of time. They should, accordingly, be proven unaffected by this radiation.

This paper contains reprints of 29 out of 200 slides actually presented. The others are on file in Division 5142 should anyone be interested.

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INTRODUCTION

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Progress in aircraft performance has been going along ever since the Wright Brothers, and no special attention need be drawn to it except when technical breakthroughs accelerate progress so that suppliers of aircraft parts, materials, and components need to be jogged into action. Such a breakthrough was the jet engine. A combination of new breakthroughs in fuels, engines, aerodynamics and operations now appears imminent such that aircraft performance is about to receive another jog.

In order that the suppliers to the Air Force might be made aware of the new developments, a meeting was set up by the Air Force for some three hundred engineering executives in late January 1956, at which a series of papers were presented explaining the hopes and problems of the Air Force, and soliciting immediate assistance from industry. Sandia Corporation was represented at the meeting by Alan Pope, 5142, and the attached pages were written by him using prints of some of the slides used at the meetings. Inasmuch as the meetings encompassed two full days and since many talks had either movies or no visual aids, the material furnished is pretty sketchy. It is, naturally, mostly relative to airplanes and aerodynamic theory.

DISCUSSION

The meeting started with a frank disclosure of Russian capabilities by members of the Air Force Technical Intelligence Office. A brief summary is presented below; specific information on landing and take-off distances has been forwarded to Department 5120 directly and is not included here.

The current situation as regards Russian aircraft and capabilities is as follows:

The Russians continue to follow slightly behind us in originality but output of aircraft and engineers has frankly startled and dismayed our observers. Repeated notice has been given in American newspapers to the effect that the Russians are pushing the production of engineers. At the present time, they are exceeding our college output by a factor of two and a half. Their 1954 output was 54,000 versus our 23,300. In 1956 they will graduate 1,440 aeronautical engineers compared to 645 in this country. There is no reason to believe that these engineers are inferior in any way. The impact of their training program--started many years ago--is now being felt by the quality and numbers of airplanes currently flying in Russia. Some of these worthy of comment are as follows:

The performance of the MIG-15 (approximately equivalent to our F-86) is well known. The airplane is, however, lighter than the F-86

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and capable of higher altitude performance. The one flyable MIG-15 graciously provided by the defector from the Russian Air Force has finished its second year of flight test without operational difficulties.

The MIG-17 (called "Fresco" by our people) corresponds roughly to our F-100 airplane. However, the Russians currently have 6,800 operational. The "Farmer" is a 22,000-pound two-engine fighter bomber of which approximately 600 are currently available.

For the first time, considerable emphasis is being given to an all-weather fighter in Russia. Approximately 200 of these 24,000-pound fighters (called "Flashlight") are currently available.

The IL-28 which corresponds to our B-45 and of which the Russians built about a thousand, is currently being phased out. There are about 310 Badgers which correspond to our B-47's and about 35 Bisons. The latter are comparable to our B-52's. A turboprop airplane in the 300,000-pound class (called the Bear) has no counterpart in the United States Air Force. It has four 12,000 hp engines and a range of 8,900

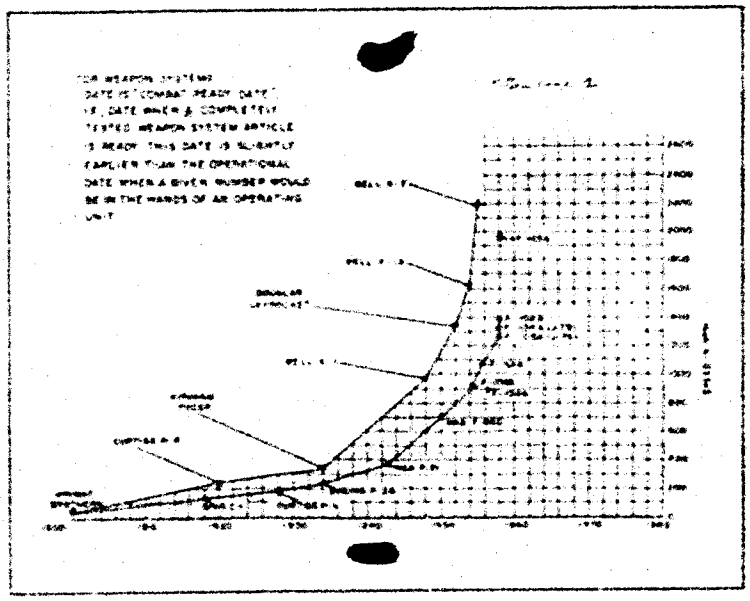

FIGURE 1

miles; 35 Bears have been built. As far as is known only one turbojet transport is now flying in Russian and it is quite a bit smaller than our Boeing 707. It is powered by two 19,000-pound-thrust jet engines.

The above airplanes have been designed and put into production in very short time periods.

Following the data on Russian capabilities, the military problem was introduced by considering data on the performance of past American airplanes projected into the future. Figure 1 shows the close correlation...

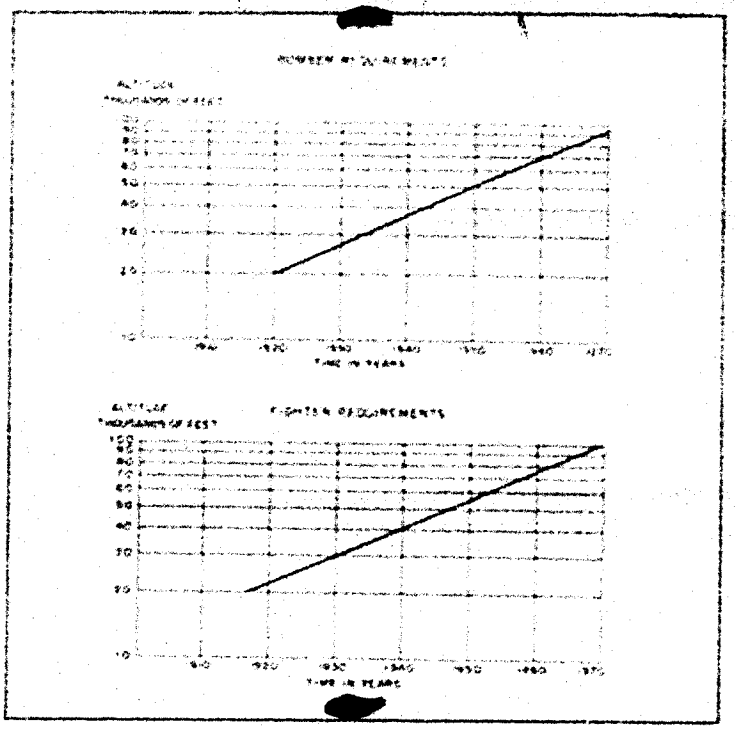

FIGURE 2

between the experimental aircraft and those in actual service. Plotted on semilog paper the curves straighten out so that Figures 2, 3 and 4 can be constructed, which show the expected increases in performance

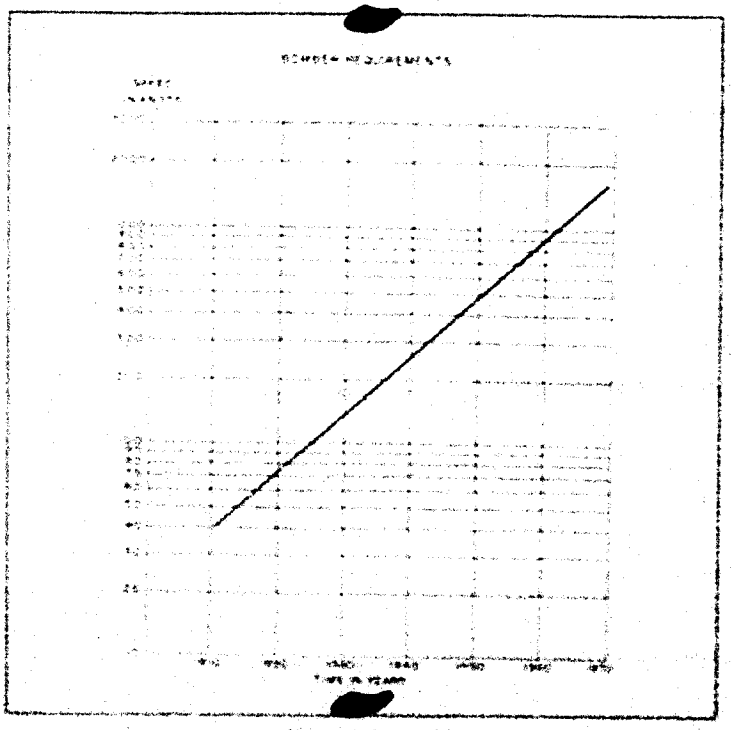

FIGURE 3

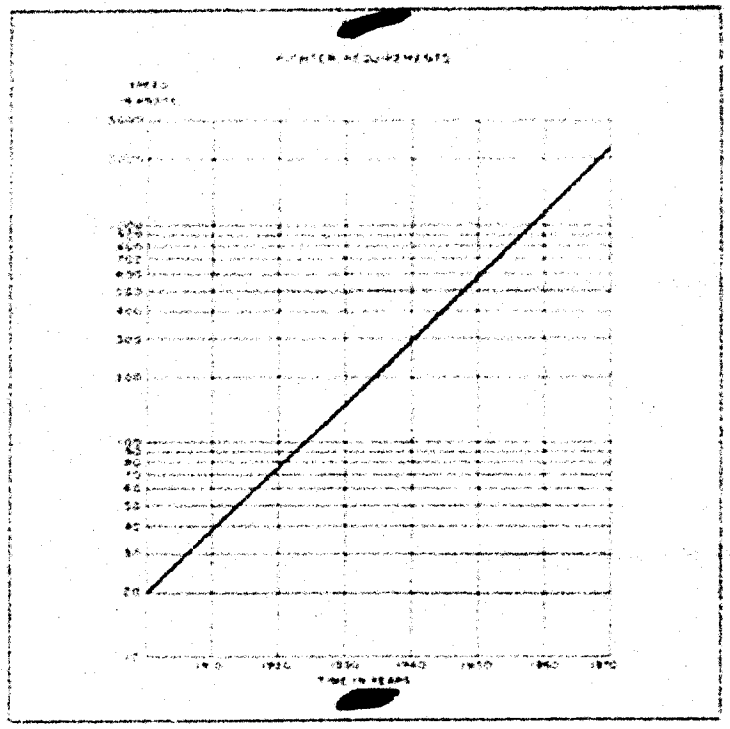

FIGURE 4

in the next 10 to 15 years. The interesting fact to be derived from these figures is that the curves do not seem to be falling off either in altitude performance or in speed as one would normally expect. Prominent among the new problems is that of obtaining a fuel which has more BTU's per pound and is exceedingly dense as well, so that tankage is small. Figure 5 shows the heats of combustion of a number of substances which have been

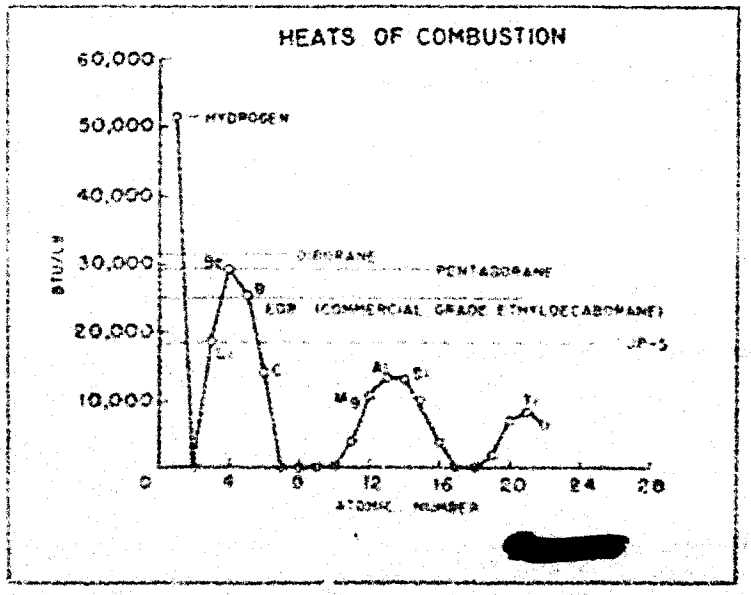

FIGURE 5

PROPERTIES OF SPECIAL FUELS

	JP-4*	B_5H_9	EDB
HEATING VALUE, BTU/LB	18,600	29,100	26,000
SPECIFIC GRAVITY	0.78	0.63	0.82
VAPOR PRESSURE, PSI	2 - 3	7.5	0.2
BOILING RANGE, DEG F	130-490	137	270-400
TOXICITY	MILD	EXTREME	MILD
COMBUSTION PRODUCTS	-	B_2O_3	B_2O_3
REACTION WITH WATER	NONE	IGNITES	NEGLIG

* FOR COMPARISON

[redacted]

FIGURE 6

considered as possible fuels. Hydrogen, as is well known, has the maximum heating value per pound, but has so little density that fuel tankage is an exceedingly difficult problem to lick. Moderate success has been obtained with a compound known as ethyldecaborane. Ethyldecaborane has approximately 40 per cent more heat per pound than does JP-4 and is at the same time more dense than JP-4. Other characteristics of fuels considered are in Figures 6 and 7 and their comparative

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PROPERTIES OF HYDROGEN VS JP-4

	H_2	JP-4
HEATING VALUE, BTU/LB	51,570	18,600
HEATING VALUE, BTU/CF	225,400	913,700
SPECIFIC GRAVITY	0.07	0.78
BOILING POINT, DEG F	-423	130-480
LB/GALLON	0.58	6.55
LB/CU FT	4.37	49.0
FLAME SPEED, FT/SEC	8.76	1 - 2

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FIGURE 7

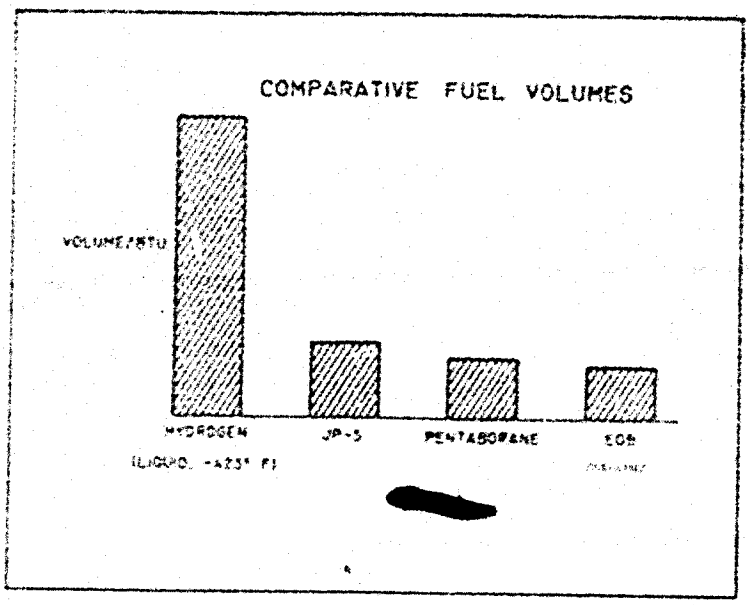

FIGURE 8

volumes are shown in Figure 8. The effect of specific heat on range is essentially linear; that is, an increase of 40 per cent in BTU's per pound yields a 40 per cent increase in range. A pilot plant for the manufacturer of ethyldecaborane is now in operation and its capacity is expected to be 25 tons a day in three years. Much has to be learned about the handling of this new fuel, but it is much easier to handle than a number of other fuels considered and discarded. Its cost is thirty times that of gasoline. The magnesium slurries which are capable of increasing the thrust of a jet engine by 100 per cent and seemed so promising a few years ago have worn out fuel pumps so rapidly that their use now seems improbable.

There is an unmistakable and complete trend toward turbine-powered aircraft for every duty. The long-range bombers, transports and training airplanes which now use piston engines are being replaced as rapidly as possible by turboprop airplanes while turbojet aircraft will maintain their

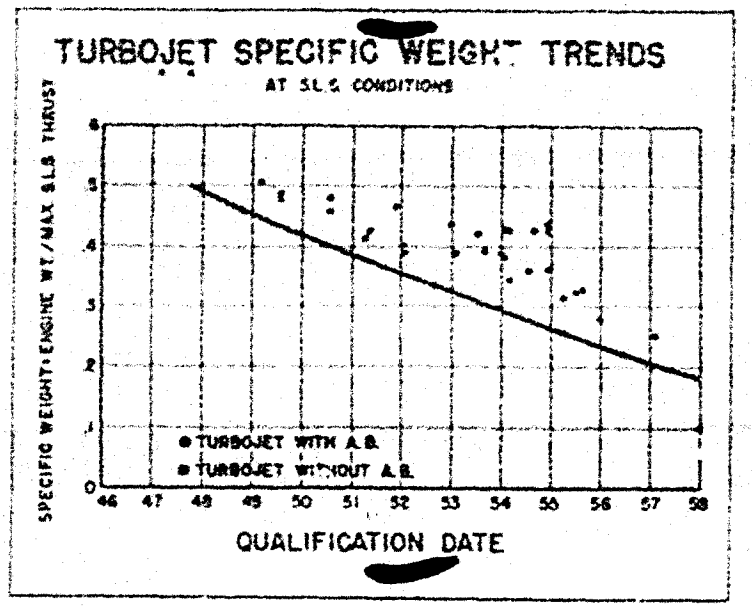

FIGURE 9

position with or without special boost arrangements. Figure 9 shows the remarkable progress in reducing the weight of turbojet engines that has taken place in the last 10 years. Figure 10 shows the shape of typical thrust drag curves and how a comparatively small increase in thrust at high Mach numbers can yield a large increase in top speed as the thrust available-thrust required curves are then nearly parallel. The present

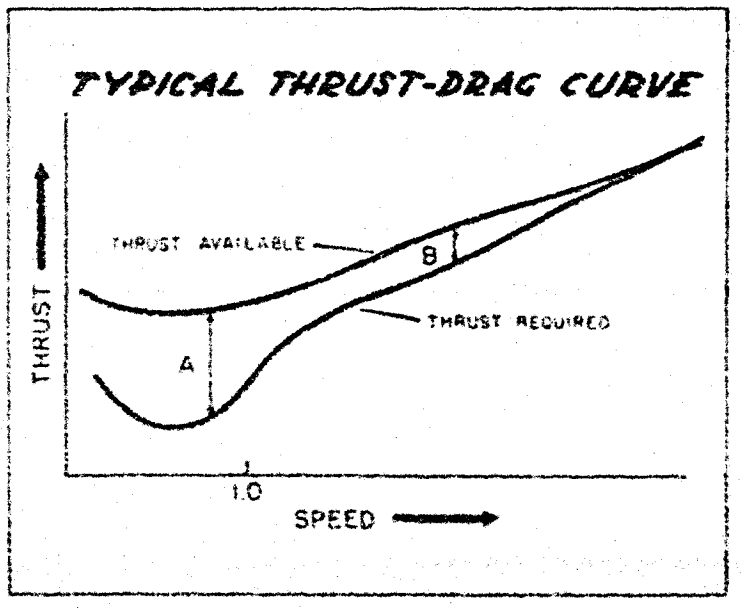

FIGURE 10

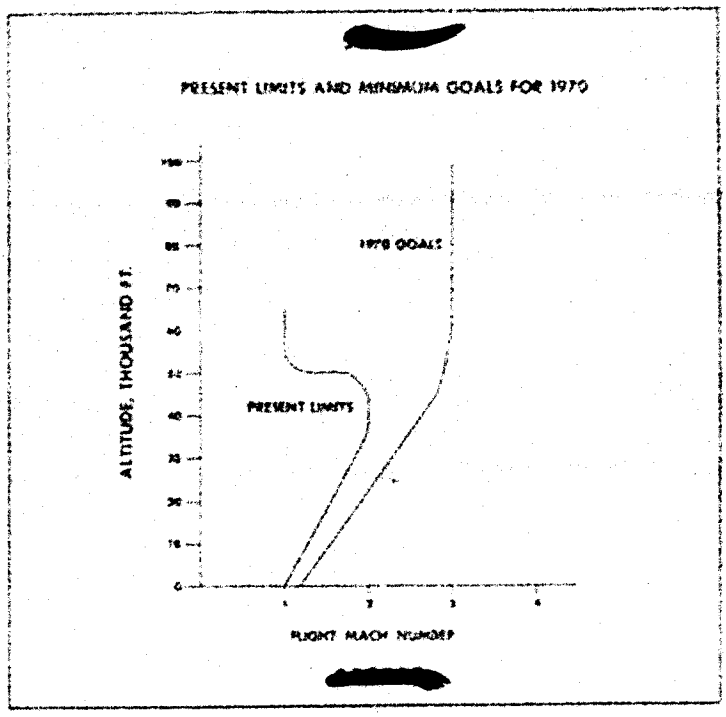

FIGURE 11

limits and minimum goals for 1970 are shown in Figure 11 where it may be seen that altitudes of 100,000 feet at Mach No. 3 are expected at that time. Present technology, it was pointed out, is adequate and sufficient for the construction of a rocket-powered research airplane capable of M = 7 at 250,000 feet. Contracts for such an airplane are being let and the craft should be flying in a little over two years. The 1970 goal for bombers (not shown in Figure 11) is M = 3 at 95,000 feet minimum and a 5,500 nautical mile radius. It is not anticipated that either fighters or bombers will be capable of much over sonic speed at sea level. In order to satisfy the above performance goals, engines of 33,000 pounds unaugmented thrust will be necessary.

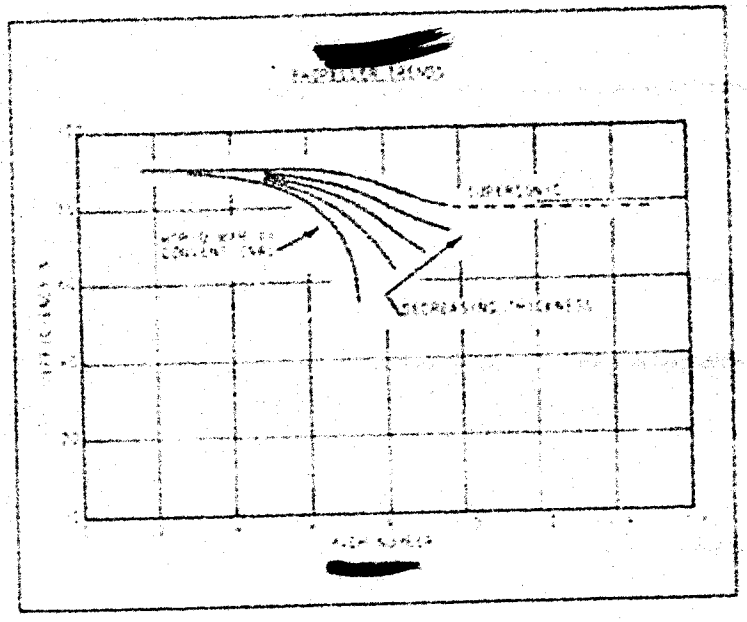

FIGURE 12

The propeller, while suffering difficulties in the high-speed range, is by no means dead and thin propellers of very high efficiencies are currently being developed. Their high efficiency (see Figure 12) seems to indicate a place for the high speed turboprop-powered transport for the foreseeable future when range is a major consideration. Some new and odd-looking propellers are being considered, but have not yet reached the flight stage.

There is expected to be widespread use of the ram-jet engine. These engines have now made many hundreds of successful flights and while their fuel consumption at the present time is approximately four times that of a turbojet engine, a theoretical capacity of only double jet engine consumption is possible at M = 3. One of the surprises of engineering performance is that the turbojet has shown itself to be highly efficient in the supersonic speed range where a few years ago it was believed that ram-jet would reign supreme. Figure 13 shows the contribution to thrust due to the compressor in a turbojet and that due to the inlet, and it is seen that as the speed increases, the inlet takes over an ever-increasing importance.

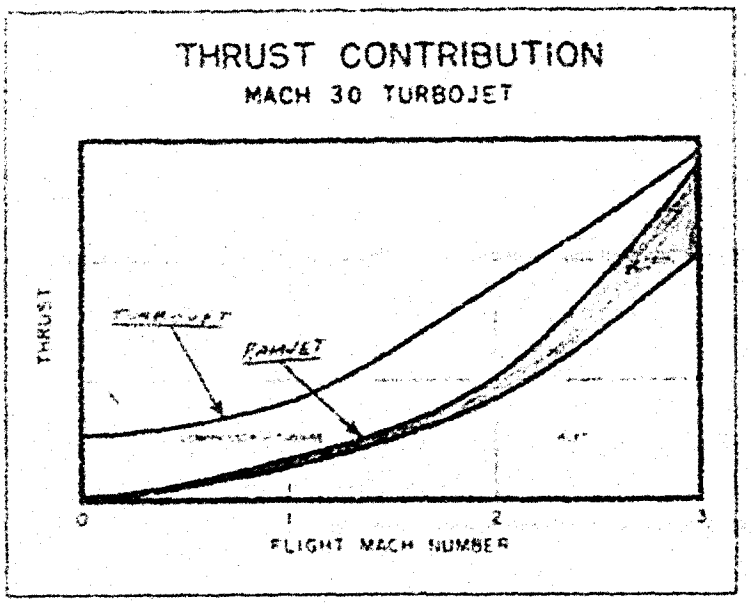

FIGURE 13

As range increases, the proportionate amount of the total weight taken by the fuel increases substantially. Figure 14 shows the distribution of engine and fuel weights for the Navaho long-range missile and Figure 15 shows how range is hurt by increasing flight speeds. The flight

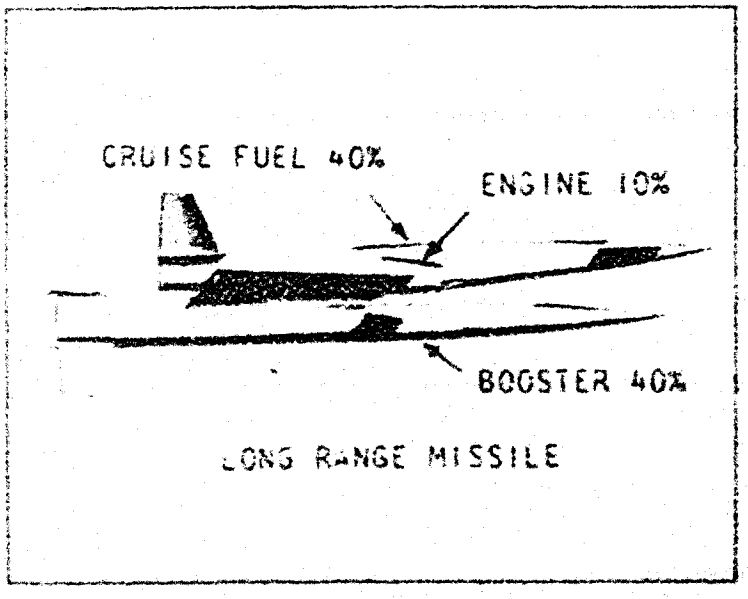

FIGURE 14

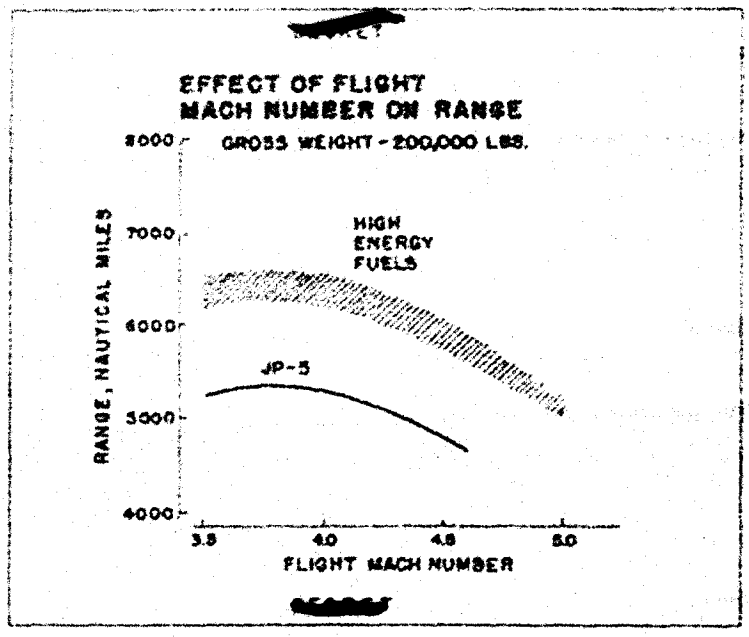

FIGURE 15

speeds shown are substantially higher than anything currently possible. While, as mentioned previously, range is directly dependent upon the BTU's per pound of fuel employed, it is also directly dependent upon the lift-to-drag ratio of the airplane. Maximum missile life-to-drag ratios are shown in Figure 16. Figure 17 shows the configuration of the Republic XF-103. The pilot flies this airplane by means of

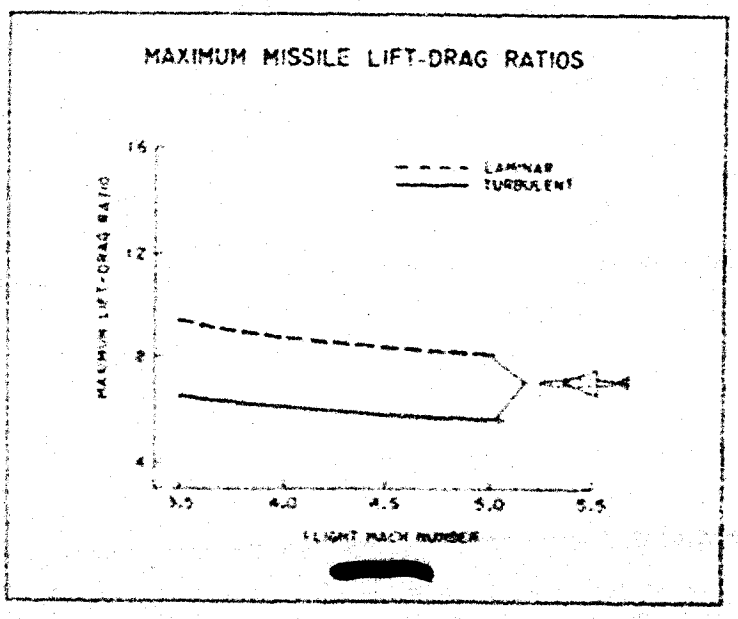

FIGURE 16

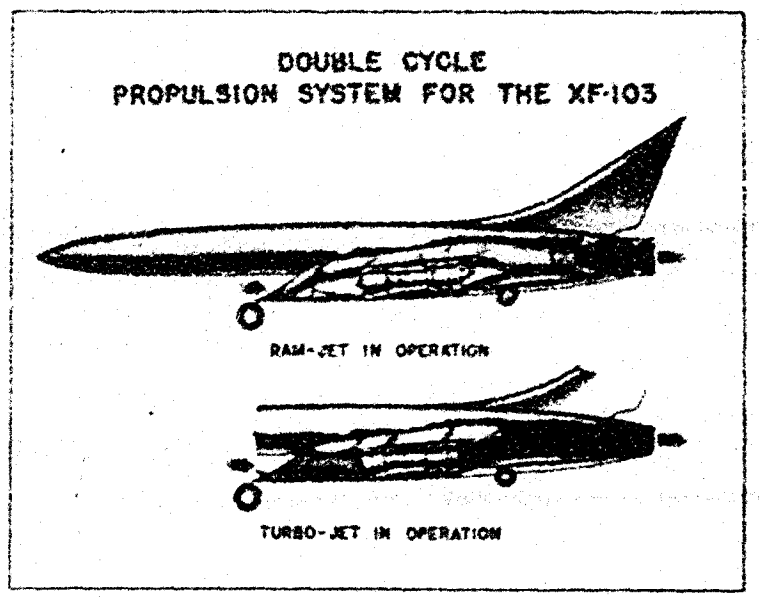

FIGURE 17

a periscope in order to reduce the over-all drag of the typical cockpit hood. At high speeds, the jet engine is shut off and the air bypassed to activate a ram-jet. It is assumed that pilots get time and a half for flying this aircraft.

Significant progress in rocket engine performance has been achieved in recent months. On exhibition at the meeting was a rocket engine of 175,000-pound thrust, while installations of as much as 240,000 pounds are being considered. The rocket, as always, presents a serious fuel problem since it carries its own oxidizer, but it is the only engine presently conceivable for operating well above 100,000 feet.

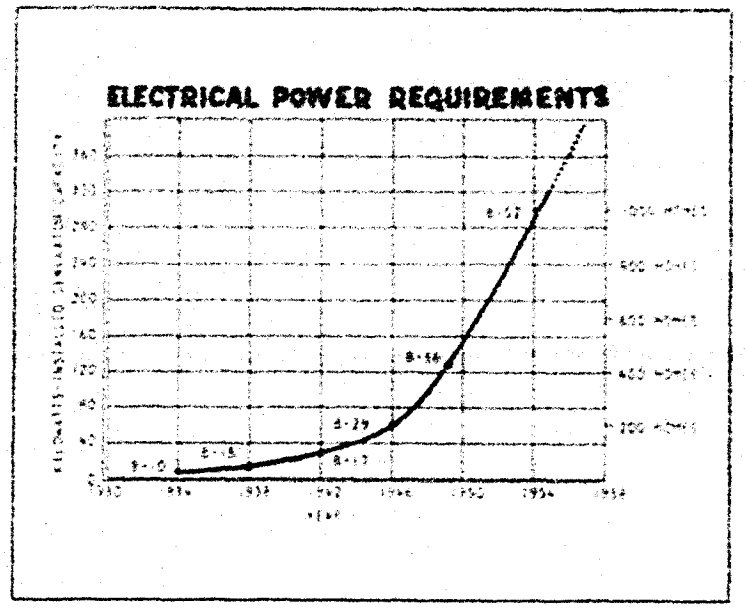

FIGURE 18

The new engines and aircraft performance figures discussed above led to rather striking requirements for secondary power. This power is used for operating the landing flaps, spoilers, ailerons, brakes, elevators, rudders, radios, radar, landing gear and fire control apparatus, and in the B-52 equals the electrical requirements of 1000 typical suburban homes. There will be a continued effort to reduce the secondary power requirements of all apparatus carried in high speed airplanes. Figure 18 illustrates the electrical power requirements of past airplanes and shows the indicated trend for the future.

Great difficulty is being encountered with hydraulic fluids and lubricants needed to operate the extremely high temperatures. New gasket materials are needed as well.

The problems associated with landing fields seem to pass through alternate phases as the years go by. Towards the end of World War II very great runway lengths were needed by airplanes underpowered by modern standards. At that time take-off was much longer than landing run. The increase of power which in turn yielded great increases in speed reduced the take-off run to the point where modern fighters take-off and land in about the same distance although bombers require twice the take-off run they need for landing. Operational take-off and landing

	Take-Off	Landing
F-84F	7500 feet	3000 feet
F-100C	3500 feet	3200 feet
B-57B	5000 feet	1500 feet
C-123B	1500 feet	1000 feet
C-119B	3000 feet	2500 feet

Table I. Operational aircraft landing and take-off distances.

	Take-Off	Landing
YF-105B	3500 feet	3500 feet
F-104A	3000 feet	2400 feet
B-66A	6500 feet	3400 feet
C-130A	2000 feet	1500 feet

Table II. New generation of aircraft, landing and take-off distances.

distances are given in Table I for current aircraft and in Table II for aircraft available in the near future. Efforts that have received wide publicity towards reducing take-off distances are not yet operational. Movies of one of the most promising take-off devices were shown. This system consisted of an F-84 fighter on an inclined zero-length launcher. The aircraft with pilot was boosted directly into the sky by a very large jato unit. This system is simple, direct and effective and permits wide dispersion of fighter aircraft. Landing is not as completely under control. Movies were shown of a tremendous mattress intended to accept an airplane without landing gear. The mattress appeared to be inflated neoprene about 100 feet wide, 400 feet long and 4 feet thick. It had a hook landing apparatus similar to that employed on aircraft carriers. Landing attempts shown in the movie were not successful as the aircraft was unable to engage the cables and slid off the end of the mattress and continued on out in the desert.

Icing of high-speed airplanes does not appear to be a problem except for slow-moving aircraft such as helicopters and transports. It is not anticipated that high-speed, high-altitude aircraft will have de-icing equipment.

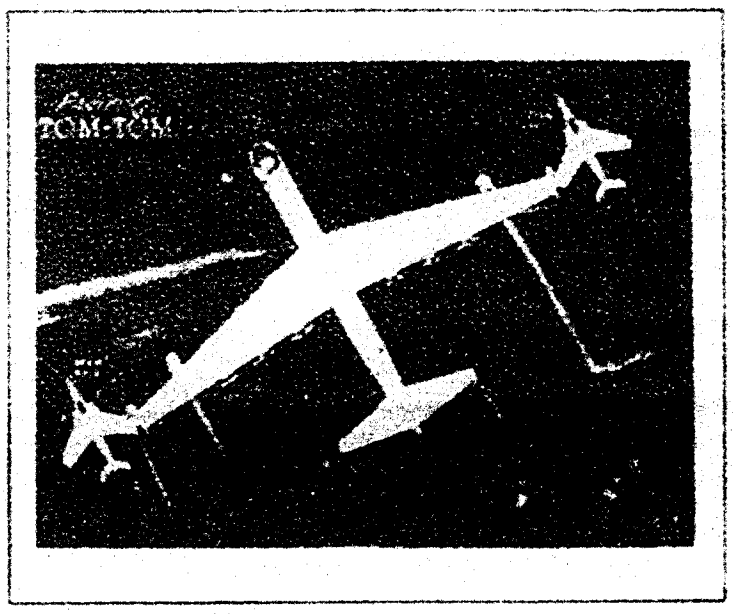

FIGURE 19

The increase of range by improvements in fuel and direct aircraft L/D ratios have already been mentioned. A new system now being used with apparent success is to attach fighters to the wing tips of bombers to increase their span and hence their L/D. The engines of the fighters are not employed during cruise out. A second system is to attach fuel tanks having their own wings to the wind tips of airplanes. The two systems are shown in Figures 19 and 20. Fighters on the wing tips are released

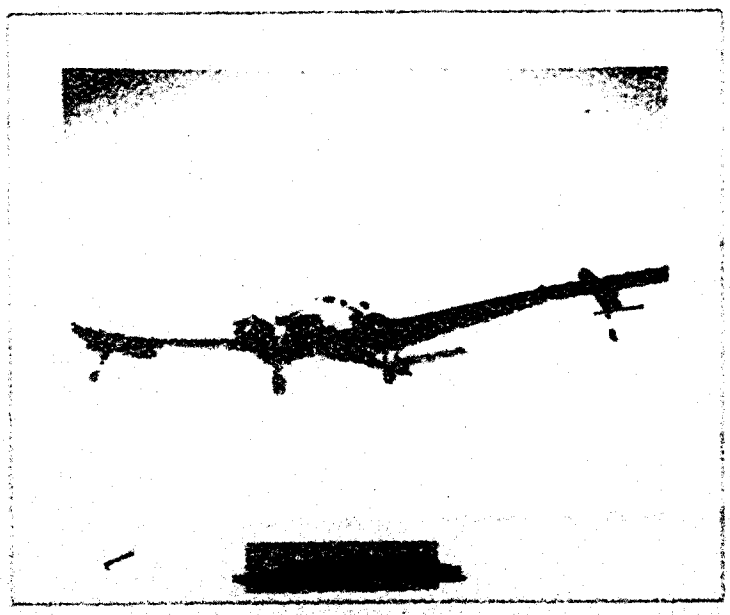

FIGURE 20

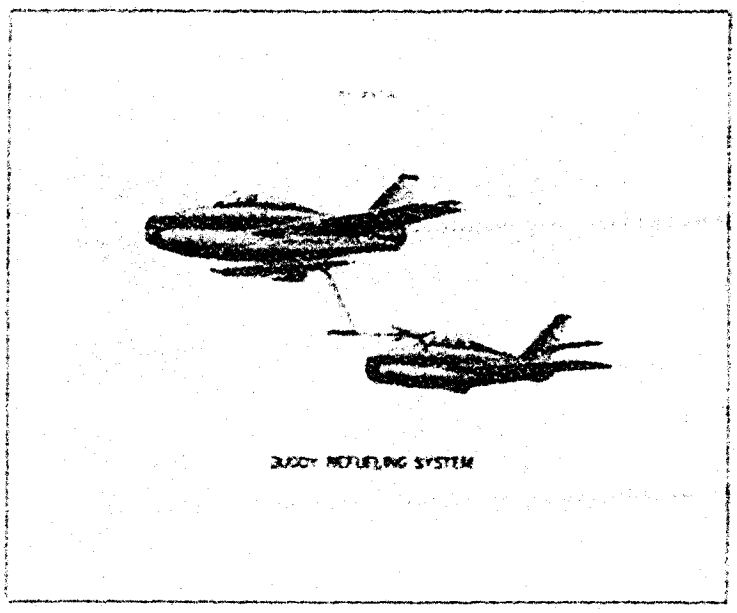

FIGURE 21

for high-speed run-in whereas the winged fuel tanks are for the direct increase of range. A third system is, of course, the well-known inflight refueling. Developments in this field include faster tankers and the buddy system shown in Figure 21. With the buddy system, an external fuel tank containing its own fuel probe is attached to one fighter and used to refuel a second fighter a few hundred miles from take-off. This system is simple and direct and can be applied to almost every type of airplane.

The high temperatures certain to be encountered will require new structural material capable of holding adequate strength at high temperatures. Figure 22 illustrates the comparison of aluminum, titanium and steel alloy as regards this effect. It will be noted that titanium is superior only in the range from M = 2.2 to 3.6. Since it is expected that this speed range will be bridged in a very short time period, the question was posed that perhaps titanium should be bypassed and the maximum effort directed towards steel.

Efforts to increase the performance of aircraft have led to the improvement of devices which blow air over the wings of airplanes or draw off

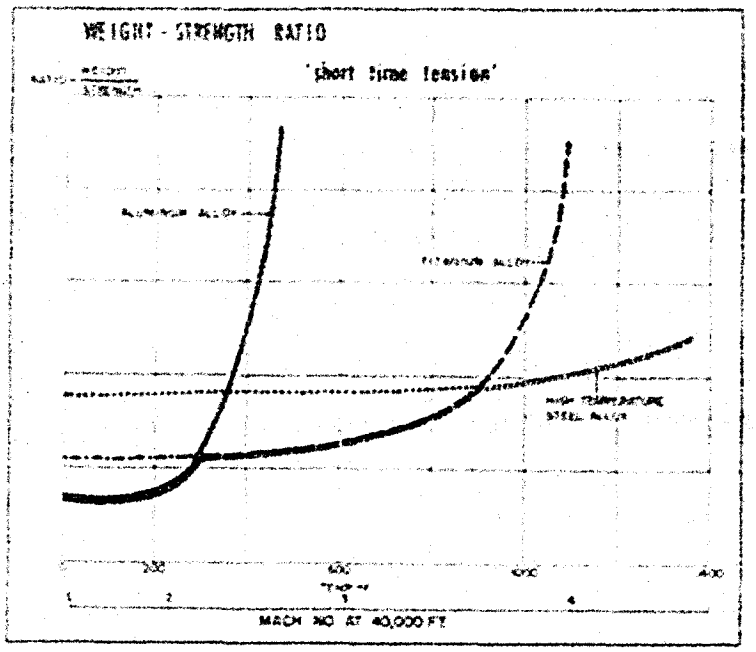

FIGURE 22

the boundary layer through vacuum systems. Some of these are shown in Figures 23 and 24 while the list of current airplanes employing such devices is shown in Figure 25. The lift of a wing may approximately be doubled by a boundary layer control system.

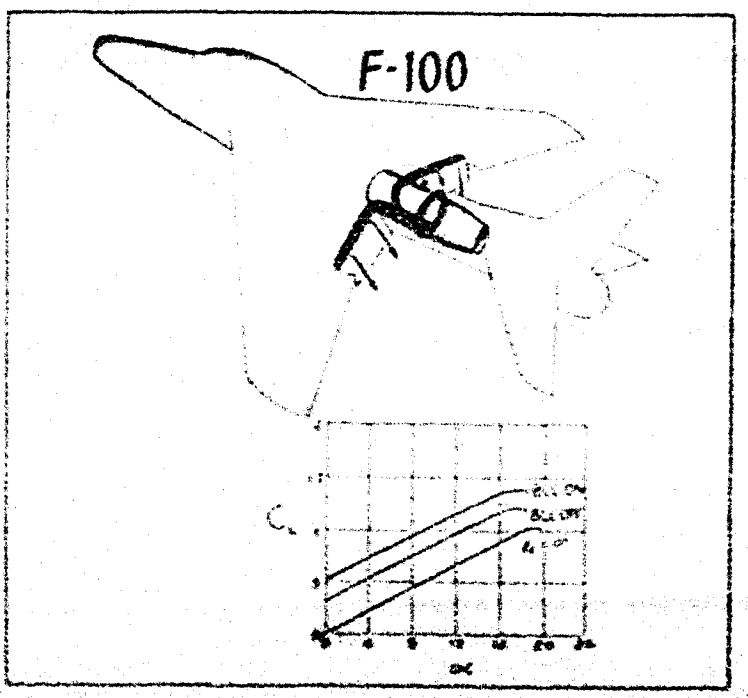

FIGURE 23

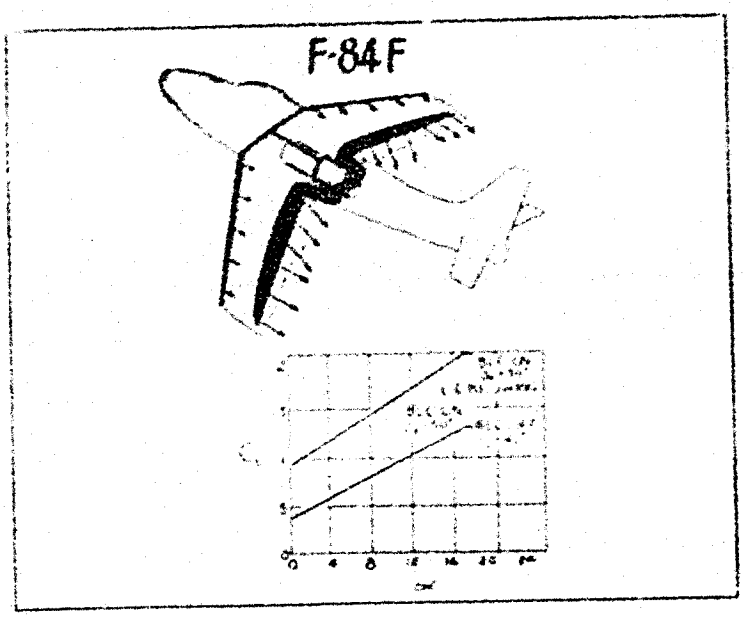

FIGURE 24

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LIST OF AIRCRAFT WITH TYPE SYSTEM

F-86	SUCTION FLAP L.E. BLOWING-EJECTOR FLAP L.E. SUCTION
F-100	BLOWING FLAP
F-101	SUCTION-BLOWING FLAP
F-104	BLOWING FLAP
F-105	SUCTION-BLOWING FLAP
T-33	L.E.-T.E. SUCTION
C-123	SUCTION-BLOWING
C-130	SUCTION-BLOWING
B-52	SUCTION-BLOWING
B-66	SUCTION-BLOWING

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FIGURE 25

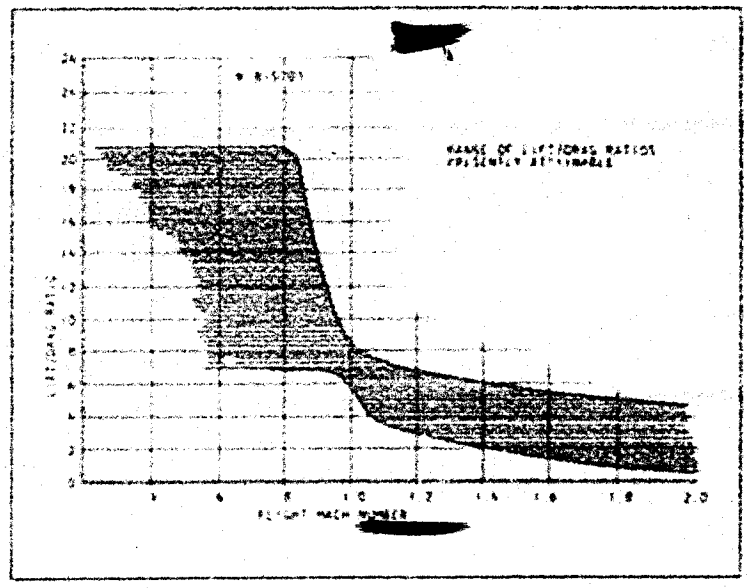

FIGURE 26

L/D ranges of aircraft are shown in Figure 26 which illustrates clearly the difficulty of obtaining great range at high speed. Figure 26 is a current-day figure and breakthroughs are expected and indicated by recent theories that will enable higher L/D values to be developed. It is interesting to note that the most efficient airplane ever built was a revised B-57 Canberra. Special wing panels account for the remarkable L/D ratio. The performance of a number of high-speed airplanes (some new) is shown in Figure 27.

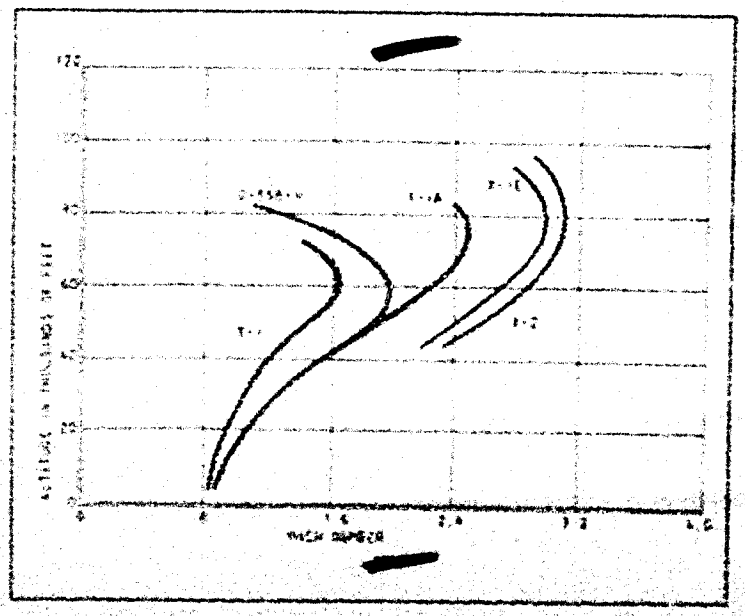

FIGURE 27

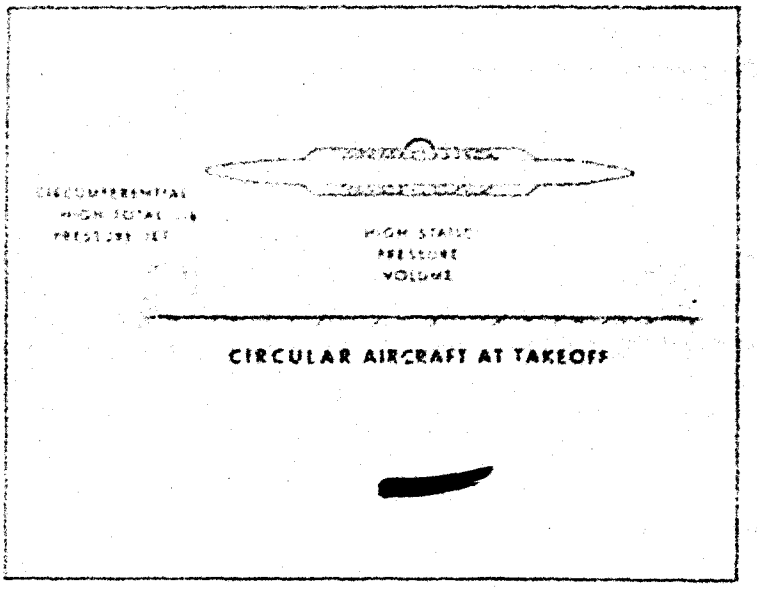

FIGURE 28

Among the new and romantic type of aircraft are the circular aircraft currently being developed. Their appearance is shown in Figures 28 and 29. At the current time they are entirely experimental but appear to offer vertical take-off and reasonable forward speeds.

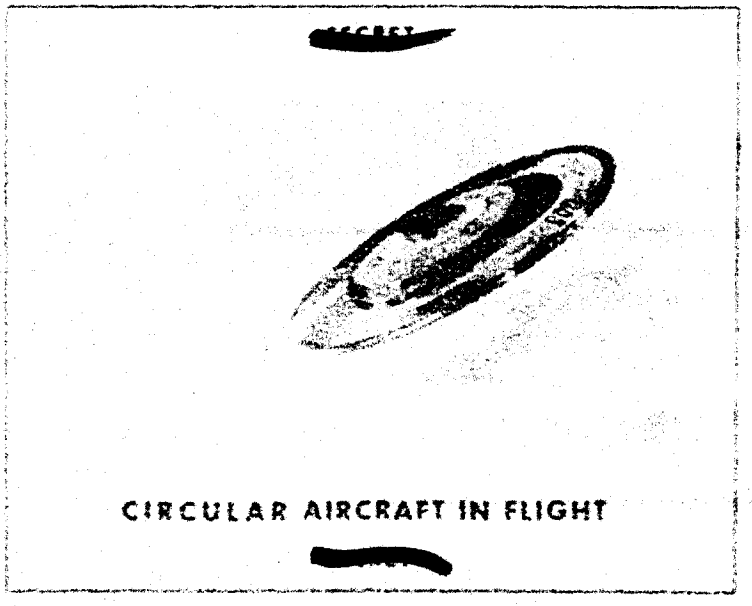

FIGURE 29

While no pictures were shown of the nuclear-powered airplane, it was mentioned that its layout is such that its bomb bay will necessarily be in a field of high radiation. Accordingly, all materials and components of atomic weapons should be immaterially affected by radiation.

In conclusion, the progress shown by Russia furnishes ample requirement for the maximum increase in performance of our aircraft and the atomic weapons they will be carrying. In turn, these atomic weapons will have to withstand new levels of heat, altitude and radiation.

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