

R. W. Iuidens

~~9/6/73~~

~~9/13/73~~

9/14/73

Lewis 1973 Inspection

Stop 3 Powered Lift

GOOD (MORNING)
(AFTERNOON)

MY NAME IS

DISCUSSION OF POWERED LIFT.

WELCOME TO THE

You are now sitting in the air passage of a large wind tunnel. To your left is the wind tunnel filter system and beyond that is an 8 foot by 6 foot supersonic test section. Several years ago, a new 9 foot by 15 foot low-speed test section was added within the existing wind tunnel structure. It is in this test section where research is underway on a new type of engine that will be required for powered lift airplanes.

IN TODAY'S PROGRAM

PRESENTATIONS

In this inspection there are three presentations devoted to describing research related to aeronautics. Their subjects are those identified in a recent government study as being the most important to the future of aviation, namely: air pollution, noise, and air traffic congestion.

PRESENTATION

This ~~step~~ will deal with the airport congestion problem and how powered lift using an advanced engine such as ~~this~~ ^{SHOWN BY SMALL SCALE MODEL} (point) will help solve the congestion problem.

Air traffic congestion is a problem that most of us have been exposed to at one time or another. Many of our large airports are operating at or in excess of their normal capacity resulting in the familiar delays in departure and arrival times. Because we're most familiar with the Cleveland area, we'd like to discuss the ^{air traffic} situation at the Hopkins Airport. ^{AN EXAMPLE OF} Assuming a westerly wind, the operation at Hopkins is illus-

SLIDE

1

ON

trated by the upper display, ^{A SSUMING A WIND FROM THE WEST, AND AIRPLANES ARRIVING FROM THE WEST.}

SLIDE

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Hopkins has a single east-west runway 6000 feet in length. (Light Runway) (Start Airplanes) The flashing lights represent conventional commercial passenger transports approaching the runway at 160 mph. They

are spaced in the air at the minimum safe separation distance. Thus the runway is operating at its capacity as shown here in fast time, that is, at a takeoff about every three minutes in real time.

That a congestion problem is imminent at Hopkins, as well as other major airports, is shown by this slide. Here we've plotted the projected number of passengers that will fly each year in the United States against the year ^{as projected by the Air Transport Association.} Air travel has increased in the past and it is projected to continue to increase perhaps as much as five times by 1990. We could increase airport capacity if we could add new runways but, at Hopkins as at most airports there is not room for long runways within the present boundaries.

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The solution to this dilemma lies in observing that about half of all the air travel is for trips of less than 500 miles range.

At present both short and long range trips are made by the same airplanes which require the same long runways. However, these (point) short range trips are feasible and economical for airplanes that use shorter runways. Thus one approach to relieving the congestion is to direct the short range traffic to new or alternate shorter runways. Such a runway could be located on the Hopkins Airport, as shown above.

SLIDE
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This additional short runway will increase the airport capacity only if the airplane approach paths for the two runways don't interfere with each other. Fortunately this is the case, ~~as we have illustrated above.~~ The airplanes using the shorter runway must approach at a slower speed, about 100 mph. (Start STOL airplanes) Because of the slower flight speeds the airplanes can approach more steeply ~~(steeper)~~ and make smaller

This
~~flight~~

radius turns closer to the airport (~~point~~). ~~The~~ flight path ~~can~~ requires advanced approach control systems that are currently being developed by the F.A.A. ~~As shown, this approach~~ The flight path shown uses airspace not used by the long runway airplanes. ~~with no mutual interference.~~ Thus the combination of long and short runway airplanes can double the capacity of this or any existing major airport.

A short field length airplane can be used in another way to relieve congestion at the major airports. Around any large metropolitan area there are a number of smaller airports. The situation in the Cleveland area is shown ~~in this slide~~ ^{here.} Here is Hopkins airport. ~~and~~ There are nine other smaller airports in and around Cleveland that have runways over 3000 feet long. As examples the Burke Lakefront Airport is in downtown Cleveland, and The Cuyahoga County Airport is conveniently located for Cleveland's east side. With a short field length airplane these smaller airports can be used to relieve the congestion at Hopkins, and at the same time improve the convenience of air travel for the people in the vicinity of those airports. Because the short runway airfields are smaller, and are located within business or population centers it is necessary that the airplanes that use them be much quieter than the conventional airplanes that operate out of the major airports.

SLIDE
3
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As we've just shown, an attractive approach to relieving the congestion problem is the short runway airplane. To address the question of how to get such an airplane, ~~the next slide~~ ^{we've shown} shows the relation between ~~runway~~ ^{field} length, approach speed, and lift system. Conventional commercial airplanes require a 5000 to 9000 foot runway because they approach at

SLIDE
4
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speeds of about 160 mph. The wing with mechanical flaps provides all the airplane lift and the engine is used only to provide the thrust.

To achieve runways of 2000 to 3000 feet requires approach speeds of about 100 mph. This is accomplished by the use of powered lift. By powered lift we mean that the wing and engine work together to provide a greater amount of lift than the wing alone can provide. With this higher lift the airplane can fly at a slower speed and the landing distance is then shorter. The engine now has two functions; it must work with the wing to provide lift and it must still provide the airplane thrust.

~~regarding the more powerful engine and the shorter runway~~
~~the engine now has two functions; it must work with the wing to provide lift and it must still provide the airplane thrust.~~

We will demonstrate the principle of powered lift for the kind of system called the externally blown flap.

This is a wind tunnel with a transparent wall. In the wind tunnel is a wing with the flap retracted, and engine located under the wing. ~~It is a wind tunnel with a transparent wall.~~ (turn on wind tunnel). The white bands of fog, ~~formed by injecting liquid nitrogen in the airstream,~~ let us see the airflow. Consider that the wing is flying at approach speed. The wing alone with flaps retracted and at zero angle of attack produces nearly straight flow streamlines. This indicates little lift as shown by the first lift bar. In general, the magnitude of the lift can be judged by how much the streamlines are displaced from a horizontal position.

~~When the flaps are extended all~~ When the flaps are extended all

the streamlines are displaced upward and in particular, ^{ily, the bottom two.} ~~the bottom two.~~

~~The corresponding increase~~

in lift is indicated by the second bar. In order to achieve this lift

its necessary to have these slots in the flap to ^{help} keep the flow attached

to the wing and flap upper surfaces. This is an example of the mechanical

~~flap system that is used by today's commercial airplanes. Only the wing~~

~~This is like the mechanical flap system used on today's long runway air-~~
~~planes in that its aerodynamics do depend on the engine running. Now~~
we'll turn on the engine. This is powered lift.

~~Now we'll turn on the engine. (turn on engine) In this arrangement we've~~

~~achieved powered lift.~~ The jet blows into the flaps where it is turned

down and increases the lift in two ways. (1) Deflecting the jet down

yields jet lift directly and (2) the location of the deflected jet at the

wing trailing edge increases the lift on the wing itself. As can be seen,

all the streamlines are further displaced upward and the lowest streamline

now passes over the ^{TSP} of the wing. The lift has about doubled as shown by

the third bar. With this powered lift system we now have ^{generated} ~~provided~~ enough

lift to ~~reduce the airplane~~ ~~speed and~~ use the short runways.

This is an example of powered lift that was first suggested at the NASA
Langley Laboratory.

~~As noted,~~ Displacing the streamlines upward is favorable
~~because it results in an increase in lift.~~ ^{indicates} However, it also causes a
very high upflow angle for the engine inlet. Designing inlets to operate
properly in this high lift environment is one of the problems we're work-
ing on in our low speed wind tunnel.

As we noted earlier, low noise is especially important for short

runway airplanes. An arrangement of engine and wing system which has been found to be quieter than the one just demonstrated is shown ~~here~~ ^{here.} ~~the~~ ^{right}. Here the engine is located above the wing. This shields the engine jet noise from the people on the ground. This arrangement is also being considered for conventional airplanes to reduce their noise. One might wonder if the jet is now turned downward by the flap as it was with the engine under the wing. ~~Let's turn the engine off and see.~~ (Turn on right w.t.) Again, for no flap deflection there is little lift and the streamlines are straight. With the engine off, but with the flap deflected the streamlines are displaced and the wing produces a significant lift. (point to lift bar) However the flap system does not have slots and you'll notice the flow is separated from the flaps. When we turn on the engine, the jet attaches itself to the flap and is turned down just as it was with the engine under the wing. All of the streamlines are displaced upward, and again the bottom streamline has reached the wing just as it did for the engine under the wing. The lift has again increased (point to lift bar) to the value required for a short runway airplane.

SLIDE
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The two powered lift systems we've just demonstrated are called blown flap systems because the engine jet blows into or over the flaps.

What airplanes look like that use these powered lift systems is shown for an under the wing installation; an over the wing (as) This by these two models. They both have high wings. This allows for the large deflection of the jet ~~downward~~ when the airplane is using powered lift near the ground just prior to landing.

~~The engine is located under the wing in the over the wing~~

~~There are other types of powered lift systems. One of these, ^(point) ~~the augmentor wing~~, is the augmentor wing which is currently being tested~~

There are other types of powered lift systems. One of these, ^(point) ~~the augmentor wing~~, is the augmentor wing which is currently being tested on a research airplane at the NASA Ames Research Center. In this design powered lift is obtained by ducting engine air into the wing and exhausting it at the wing trailing edge through a duct formed by splitting the flap.

SLIDE
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The military also have important applications of short runway airplanes and early military operation ~~of these airplanes~~ will yield technology to support the later civil airplanes.

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In our discussion we've shown that powered lift systems are attractive approaches to achieving shorter runway airplanes. The next speaker will discuss the kinds of engines that the blown flap airplanes will require.

41-5

-8-

The engine required for powered lift is new and different. We call it the quiet propulsive lift engine. Over here (point) we have a model of such an engine. The actual engine will be perhaps 8 feet in diameter/ and have a thrust of about 25,000 pounds. We'll compare the quiet propulsive lift engine with existing types engines and then discuss the research it requires. The engine/ shown here are a turbojet which is used in military fighters, a low bypass turbofan such as those used on narrow body transports like the 727, a high bypass turbofan as used on the wide bodied DC10 and 747, and the newest engine, the quiet propulsive lift engine. The turbojet engine has only one flow stream, that is, all the air passes through the compressor and turbine. The three bypass engines have two flow streams, the outer stream that passes only through the fan, (point) and the core stream (point) that passes through the fan and then the core compressor and turbine. The quiet propulsive lift engine has a very large quantity of air passing through the fan compared with the flow through the core. The bypass ratio, the ratio of airflow through the fan duct to that through the core, is about six for the high bypass turbofan. For the quiet propulsive lift engine, the ratio will be roughly double that.

SLIDE
6

We've listed three characteristics of these engines; their noise, jet velocity, and jet temperature. First, we will consider noise. This column lists the ^{effective} perceived noise level measured in decibels, for each of the engines at a station 500 feet to the side of the runway during take-off. sizes of the engines shown and the noise levels are scaled to the same thrust. The / The short runway capability requires a higher thrust and this ordinarily would mean that the airplane will be noisier. However, the short runway airplane will have to be much quieter than conventional airplanes. The slide shows that the quiet propulsive lift engine is quieter by a wide margin. It meets the noise goals that have been set for the short runway airplane.

The engine noise is related to the jet velocity and as you see, the engine with the lowest noise also has the lowest jet velocity. But jet velocity is important for a second reason. When the engine jet blows into the wing flap system, this generates additional noise. This flap noise is reduced with lower jet velocity. Thus the quiet propulsive lift engine also yields the lowest flap noise.

Because the engine jet must flow into the wing and flap structure, it is desirable that the exhaust temperature be low enough to be compatible with the lightweight, low cost construction materials. The slide shows that the quiet propulsive lift engine also yields the lowest jet temperature, and one which is compatible with an aluminum structure. For the quiet propulsive lift engine; the engine noise is lowest, the jet velocity is lowest which results in reduced flap noise, and the exhaust jet temperature is lowest. This engine meets three / ^{important} requirements for the externally blown flap powered lift system whereas the other engines do not.

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We have listed some of the areas that require research to arrive at an engine with optimum characteristics and will now discuss each of these in turn.

~~SLIDE~~

The high bypass ratio results in a large fan diameter and hence a large nacelle as is evident on the airplane models. With conventional nacelle design and construction methods these nacelles would be heavy. There are several things we can do to keep the nacelle weight reasonably small (Go to engine model). First, we can keep the nacelle as thin as possible, and secondly, we should keep it short. The length is determined partly by the length of the acoustic treatment required. Thus acoustic treatment that is effective in a short length will reduce nacelle weight. Integrating the acoustic material with the nacelle structure will also reduce weight.

SLIDE
8

Another reason for a short thin nacelle is to reduce its drag. This is especially important for high bypass engines.

One of the factors making it difficult to design a short thin nacelle is the high up flow angle at the engine inlet during powered lift. This effect, you'll recall, was illustrated in the wind tunnels. Research on both fans and inlets is required to achieve designs that will perform satisfactorily at high inlet flow angles.

Another important research area is thrust reversal during landing. After the airplane touches down for a landing, the engine together with the brakes bring the airplane to a stop in a short distance. Reversing the thrust of the engine to stop the airplane is standard airline operating procedure. The noise you hear and the retarding force you feel soon after your airplane touches down results when the pilot "turns on" the engine thrust reversers. As shown on the next slide, the conventional engine thrust reverser may consist of a vee-shaped target, which is inserted into the engine exhaust flow to reverse the flow direction as shown here. For the quiet propulsive lift engine with the much higher fan flow, a conventional thrust reverser like this would have to be large and heavy.

A lighter weight, more effective method of obtaining reverse thrust with the propulsive lift engine is to reverse the fan flow within the engine. The fan in this engine model is designed so that the setting angle of the blades can be varied. The blades are now at their normal setting angle. When we change the blade angle setting by 75°, air will pass through the fan in the reverse direction producing a reverse thrust. We'll start the engine with the blades set in the forward thrust position. We have placed tufts at three locations to indicate the direction of flow. Now we'll change the blade angle and you see the tufts change

SLIDE
9

SLIDE
10

SLIDE
11

SLIDE
OFF

direction indicating a reversing of the direction of the airflow, and a reverse thrust. Flaps such as this one on the nozzle of the engine will open to accommodate the airflow that now must enter from the rear. On the next slide we have indicated the effectiveness of this method of obtaining reverse thrust. Positive and reverse thrust are plotted on the vertical scale. Tests here at Lewis have indicated that the reverse thrust obtained by turning the rotor blades is about two-thirds of the engine forward thrust, more than ample for a short stopping distance. You'll recognize that what we've shown is similar to a reverse pitch propeller. However, a fan has 15 to 30 blades which must change angle compared with two to four blades for a propeller. We're learning how to design the fan blading and the mechanism, and to develop the bearings and materials, so that this can be done very compactly. This concept shows great promise and we are pursuing its development.

SLIDE
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SLIDE
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The fan is the largest rotating component in the engine; therefore, it should be as light in weight as possible. We have a research program to develop blades made of new composite materials such as those that contain glass or graphite fibers. These can potentially cut the weight of the fan in half while maintaining high aerodynamic efficiency.

SLIDE
13

In the quiet propulsive lift engine the flow through the turbine is much smaller than that through the fan, so the turbine itself is small relative to the fan. Since the turbine must drive the fan, we've posed a very tough design problem for the turbine. The next slide shows three possible turbine designs for driving the fan of the propulsive lift engine.

SLIDE
14

SLIDE
15

If conventional turbine stages are used, a long, heavy turbine as shown here would be required. There are two approaches to solve this problem. One is to use gears between the fan and turbine, another is to

increase the work done by each turbine stage. We are investigating both of these concepts. The gear system allows the small diameter turbine to run at a higher rotative speed than the large fan so that only two turbine stages are required. However, this gearing must transmit a power larger than has ever been built into an airplane engine before. ^{a part of our} Thus research is directed to the problems of lightweight, compact, high powered gearing. A second alternative is shown here. If the work done by each turbine stage can be increased, we can reduce the number of stages from that required for the conventional turbine, and still use a direct drive as shown. Research on such high work per stage turbines is underway at this Center and we have an example experimental turbine here (point). This four-stage turbine can produce the same power as would normally require eight stages, but presently at a somewhat lower efficiency.

SLIDE
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The engine fuel flow, engine speed, wing flap position and other parameters must be controlled automatically to fly the steep and curved flight paths. This requires a new integrated digital control system. Such systems are now in early development. Continuing research is required to make these systems a reality in time for use by powered lift airplanes.

SLIDE
16

The quiet propulsive lift engine will also have a low pollution combustor. This and noise suppression techniques will be discussed at other stops on your tour.

SLIDE
17

A significant part of the work at Lewis on airbreathing engines is to develop the technology for the quiet powered lift engine. Much of the research is being done by contract to private industry. The core of this

SLIDE
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engine will very likely be based on technology and hardware developed for military engines. The present planning is to have an experimental engine under test in three years. Powered lift, short runway airplanes using these engines will probably be in service in the 1980's.

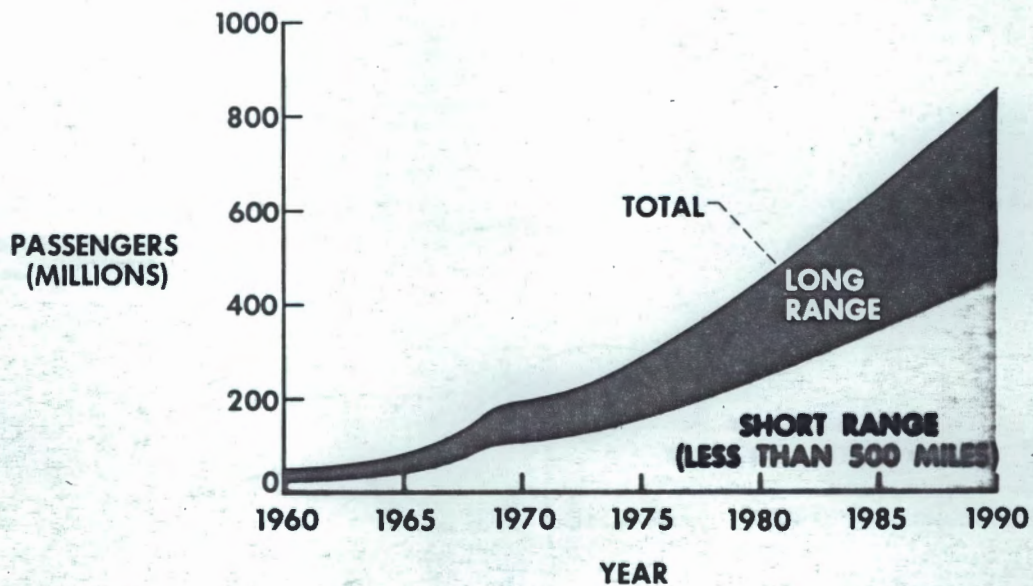
From the advanced engine research underway at Lewis, (point to engine model) and the research on the aerodynamics of powered lift at the Ames and Langley Research Centers (turn on wind tunnel), we can achieve a solution to the airport and air traffic congestion problem (turn on airport model).

- 07500 1) MAJOR AIRPORTS ARE CONGESTED
- 07501 2) AIR PASSENGER TRAFFIC IS INCREASING
- 07502 3) CLEVE AREA AIRFIELDS OVER 3,000'
- 07503 4) SHORT RUNWAYS REQUIRE POWERED LIFT
- 07504 5) AUGMENTOR WING RESEARCH AIRPLANE
- 07505 6) THE ENGINE FOR POWERED LIFT IS DIFFERENT
- 07506 7) RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE (TWO ARROWS)
- 07507 8) " " " " " " " (#3)
- 07508 9) " " " " " " " (#4)
- 07509 10) CONVENTIONAL THRUST REVERSERS
- 07510 11) VARIABLE PITCH FAN REVERSE THRUST
- 07511 12) RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE (#5)
- 07512 13) " " " " " " " (#6)
- 07513 14) FAN DRIVE SYSTEMS FOR QUIET PROPULSIVE LIFT ENGINE
- 07514 15) RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE (#7)
- 07515 16) " " " " " " " (#8)



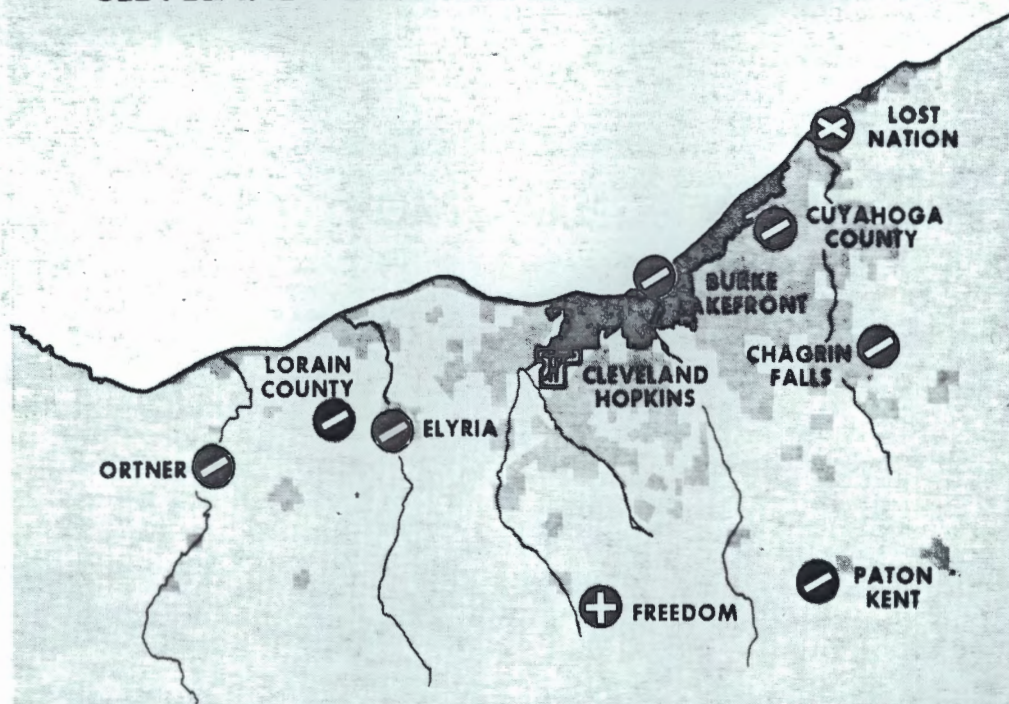
SLIDE 1 (CS-67576)

AIR PASSENGER TRAFFIC IS INCREASING



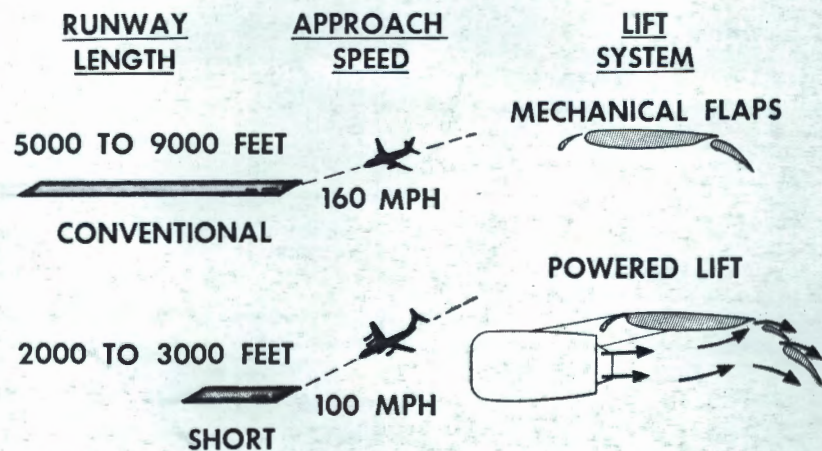
SLIDE 2 (CS-67577)

CLEVELAND AREA AIRFIELDS OVER 3000 FEET



SLIDE 3 (CS-67578)

SHORT RUNWAYS REQUIRE POWERED LIFT

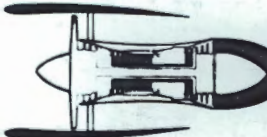
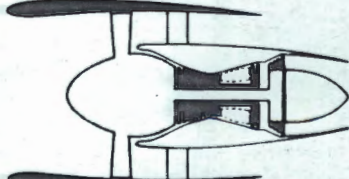


SLIDE 4 (CS-67579)



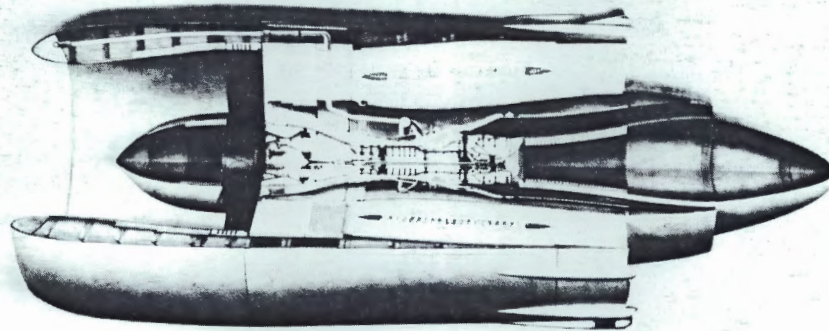
SLIDE 5 (CS-67580)

THE ENGINE FOR POWERED LIFT IS DIFFERENT

	ENGINE NOISE EPNdB AT 500 FT.	JET VELOCITY F.P.S.	JET TEMPERATURE °F
 TURBOJET	135	1500	1100
 LOW BYPASS FAN	127	1000	950
 HIGH BYPASS FAN			
 QUIET PROPULSIVE LIFT ENGINE	95	600	400

SLIDE 6 (CS-67581)

RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE

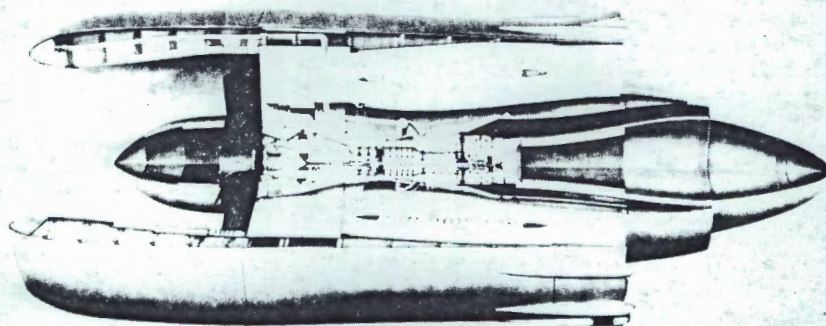


- SHORT/THIN NACELLES
- EFFICIENT ACOUSTIC TREATMENT
- INLETS FOR HIGH UPFLOW ANGLES
- LOW WEIGHT THRUST REVERSAL
- COMPOSITE MATERIAL FAN BLADES
- GEAR DRIVE/HIGH WORK TURBINE
- INTEGRATED DIGITAL CONTROL SYSTEM
- LOW POLLUTION COMBUSTOR

SLIDE 7

(CS-67582)

RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE

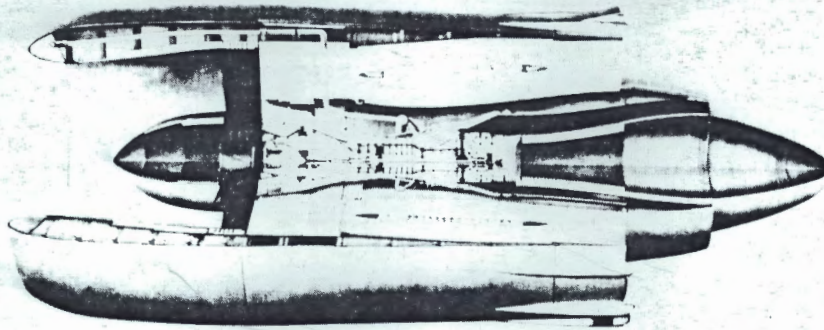


- SHORT/THIN NACELLES
- EFFICIENT ACOUSTIC TREATMENT
- INLETS FOR HIGH UPFLOW ANGLES
- LOW WEIGHT THRUST REVERSAL
- COMPOSITE MATERIAL FAN BLADES
- GEAR DRIVE/HIGH WORK TURBINE
- INTEGRATED DIGITAL CONTROL SYSTEM
- LOW POLLUTION COMBUSTOR

SLIDE 8

(CS-67583)

RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE



SHORT/THIN NACELLES

COMPOSITE MATERIAL FAN BLADES

EFFICIENT ACOUSTIC TREATMENT

GEAR DRIVE/HIGH WORK TURBINE

INLETS FOR HIGH UPFLOW ANGLES

INTEGRATED DIGITAL CONTROL SYSTEM

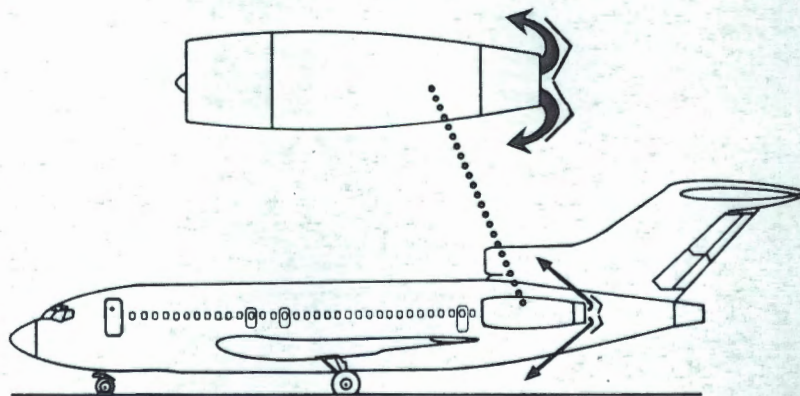
→ LOW WEIGHT THRUST REVERSAL

LOW POLLUTION COMBUSTOR

SLIDE 9

(CS-67584)

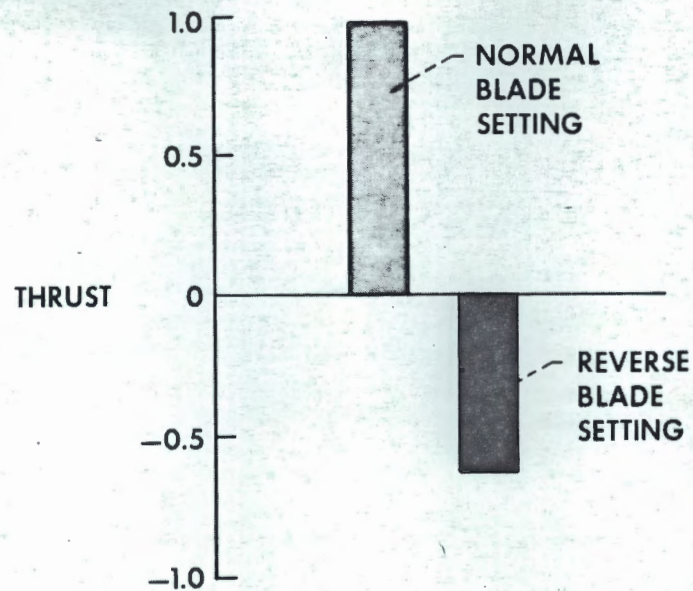
CONVENTIONAL THRUST REVERSERS



SLIDE 10

(CS-67585)

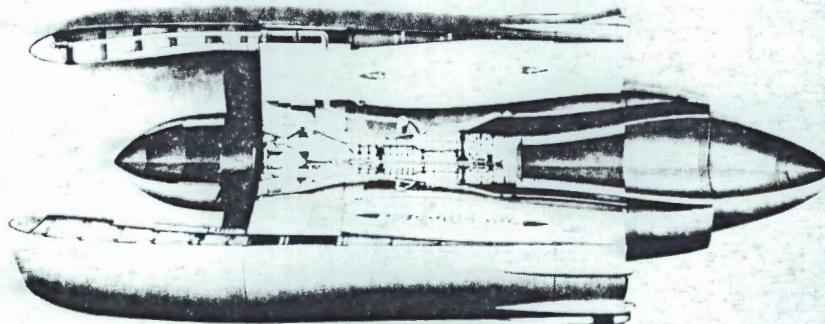
VARIABLE PITCH FAN REVERSE THRUST



SLIDE 11

(CS-67586)

RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE



SHORT/THIN NACELLES

EFFICIENT ACOUSTIC TREATMENT

INLETS FOR HIGH UPFLOW ANGLES

LOW WEIGHT THRUST REVERSAL



COMPOSITE MATERIAL FAN BLADES

GEAR DRIVE/HIGH WORK TURBINE

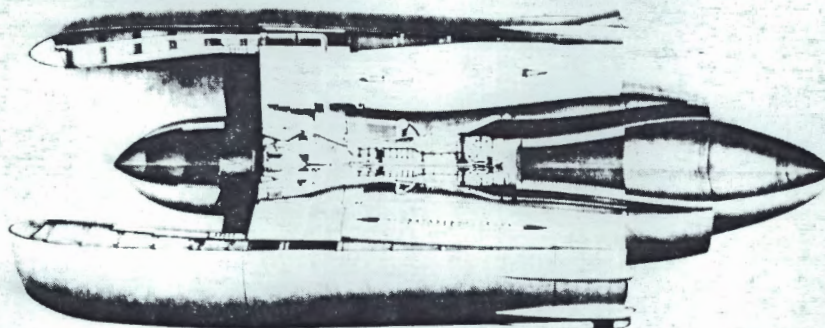
INTEGRATED DIGITAL CONTROL SYSTEM

LOW POLLUTION COMBUSTOR

SLIDE 12

(CS-67587)

RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE



SHORT/THIN NACELLES

COMPOSITE MATERIAL FAN BLADES

EFFICIENT ACOUSTIC TREATMENT



GEAR DRIVE/HIGH WORK TURBINE

INLETS FOR HIGH UPFLOW ANGLES

INTEGRATED DIGITAL CONTROL SYSTEM

LOW WEIGHT THRUST REVERSAL

LOW POLLUTION COMBUSTOR

SLIDE 13

(CS-67588)

FAN DRIVE SYSTEMS FOR QUIET PROPULSIVE LIFT ENGINE



CONVENTIONAL TURBINE WITH DIRECT DRIVE



CONVENTIONAL TURBINE
WITH GEARED DRIVE

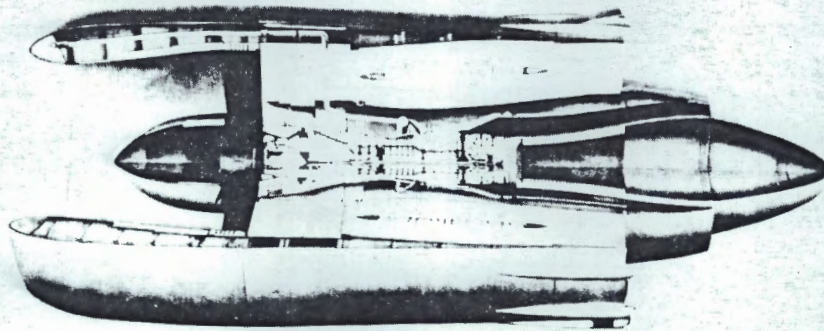


HIGH WORK TURBINE
WITH DIRECT DRIVE

SLIDE 14

(CS-67589)

RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE



SHORT/THIN NACELLES

COMPOSITE MATERIAL FAN BLADES

EFFICIENT ACOUSTIC TREATMENT

GEAR DRIVE/HIGH WORK TURBINE

INLETS FOR HIGH UPFLOW ANGLES → INTEGRATED DIGITAL CONTROL SYSTEM

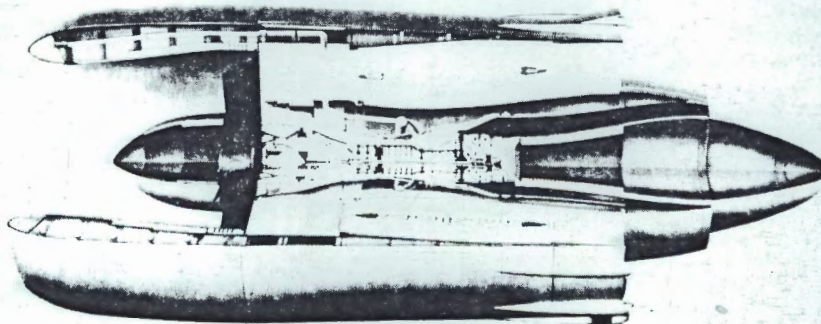
LOW WEIGHT THRUST REVERSAL

LOW POLLUTION COMBUSTOR

SLIDE 15

(CS-67590)

RESEARCH AREAS FOR QUIET POWERED LIFT ENGINE



SHORT/THIN NACELLES

COMPOSITE MATERIAL FAN BLADES

EFFICIENT ACOUSTIC TREATMENT

GEAR DRIVE/HIGH WORK TURBINE

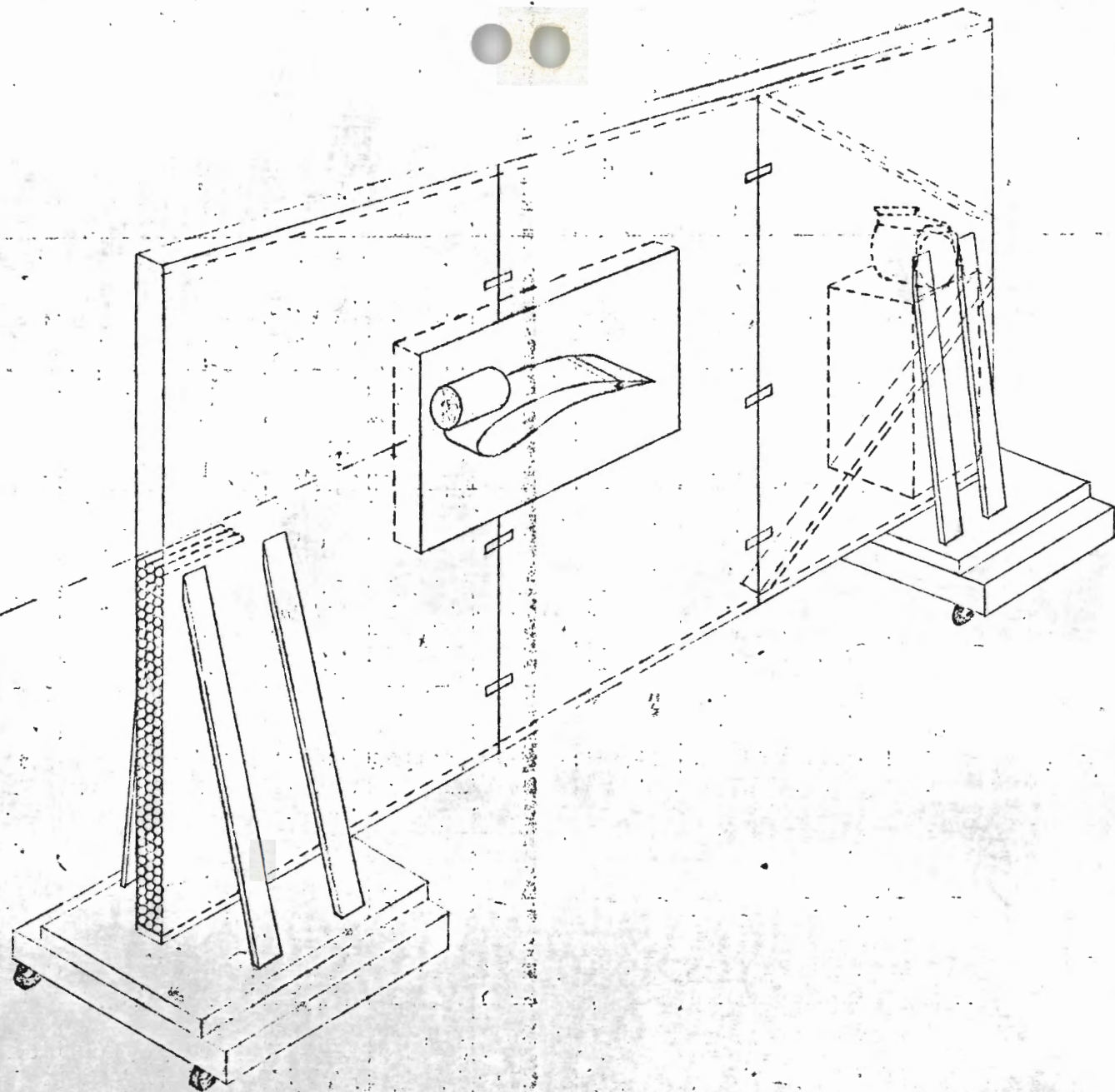
INLETS FOR HIGH UPFLOW ANGLES → INTEGRATED DIGITAL CONTROL SYSTEM

LOW WEIGHT THRUST REVERSAL

→ LOW POLLUTION COMBUSTOR

SLIDE 16

(CS-67591)

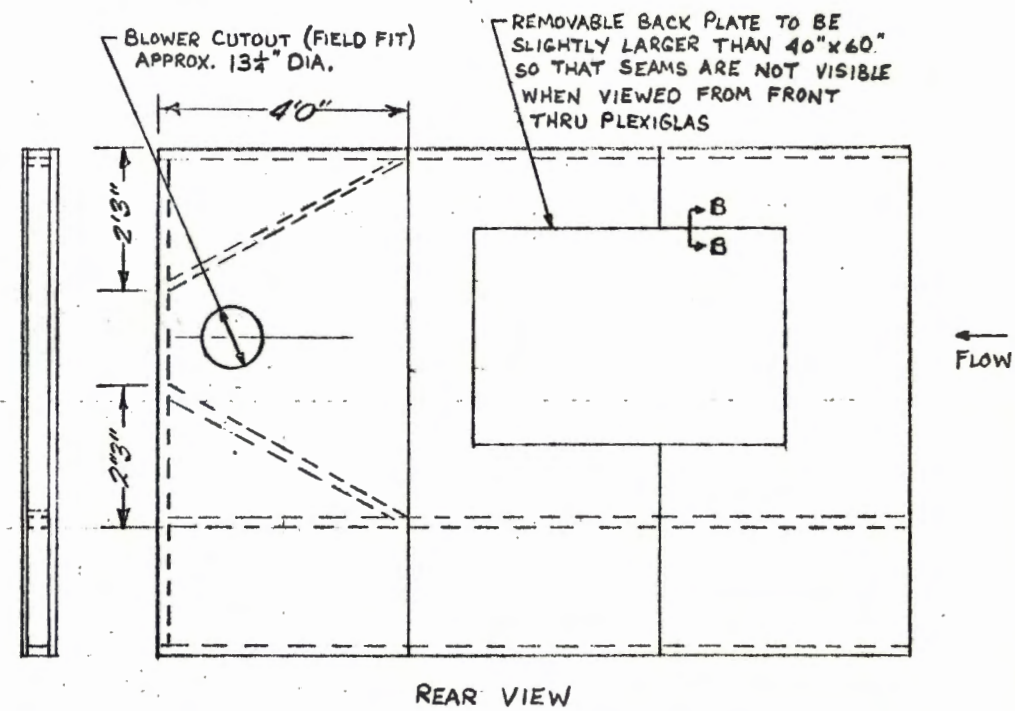
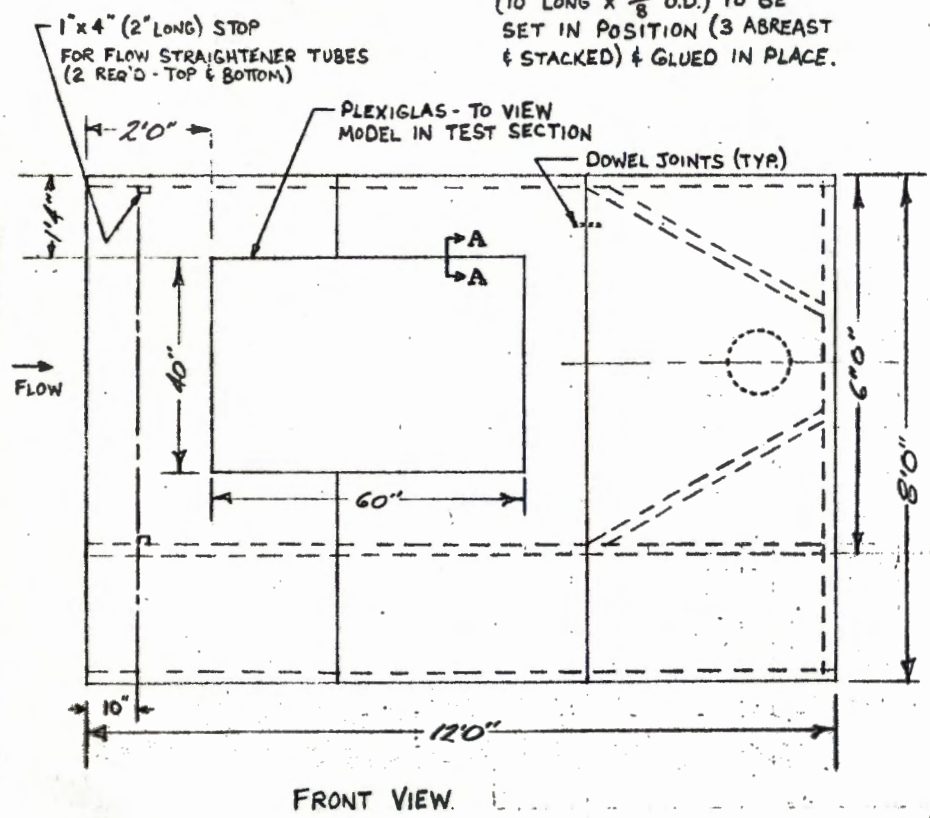
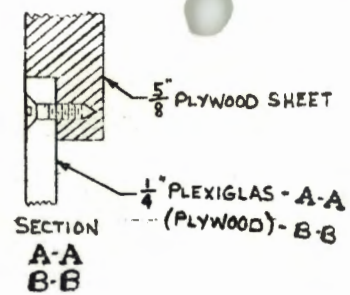


8044
~~238~~
8031

check with Lundgren
to be sure can use for
show

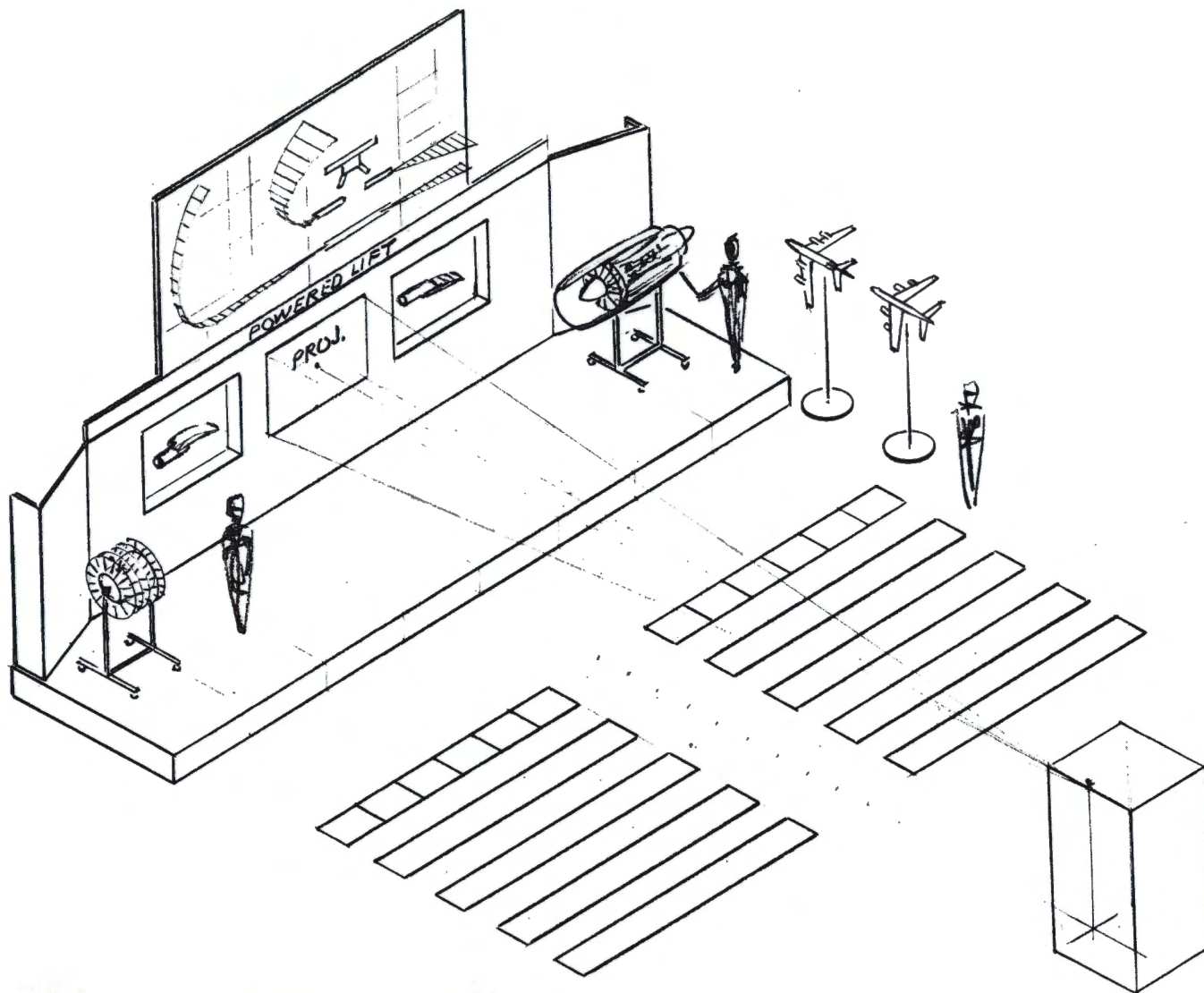
NOTES

- (1) ALL FRAMING 2" x 4"
- (2) FRONT & REAR FACES COVERED WITH $\frac{5}{8}$ " PLYWOOD. INTERIOR (FLOW PASSAGE) TO BE "A" GRADE.
- (3) FRONT FACE "DRESSING" TO BE $\frac{1}{4}$ " MASONITE COVERING $\frac{5}{8}$ " PLYWOOD (TO BE ADDED LATER).
4. BUT-JOINT PLYWOOD SHEETS WITH DOWELS TO INSURE SMOOTH (NO STEP) JOINT SURFACE - ESPECIALLY INTERIOR (FLOW PASSAGE).
5. POSSIBLE CONSTRUCTION MODIFICATION MAY LATER BE REQUIRED - ATTACHMENT VIA SCREWS SUGGESTED.
6. FLOW STRAIGHTENER TUBES (10" LONG x $\frac{7}{8}$ " O.D.) TO BE SET IN POSITION (3 ABREAST & STACKED) & GLUED IN PLACE.
7. CUTOUT & SUPPORT STAND FOR SQUIRREL-CAGE BLOWER & MOTOR TO BE FIELD FIT & CONSTRUCTED.
8. REMOVABLE BACK PLATE. VIEWED SURFACE TO BE EVENTUALLY PAINTED FLAT BLACK



SMALL SCALE WIND TUNNEL		
INSPECTION STOP 3 - 9 x 15 "POWERED LIFT"		
RON ROSKILLY GARY KELM	4/30/73	J.O. - X012533

Have already issued a w.o. to Frank Winkler



STOP #3 POWERED LIFT
9x15

$\frac{1}{8}'' = 1'$

R.S. 4-25-73

8' x 6' SUPERSONIC WIND TUNNEL



