9/12

PRESENTATION TEXT - 1973 INSPECTION AND SHOW

Stop #2 - Cleaner Skies

Good (morning or afternoon), my name is ______________ and I would like to welcome you to the new wing of the Propulsion System Laboratory and to our ~~display~~ presentation entitled "Cleaner Skies."

What we will show today are some of NASA's efforts in studying the air pollution problem as it relates to jet aircraft. Today pollution from aircraft is of concern primarily in the vicinity of airports. However, the projected increase in air traffic indicates that unless steps are taken now to minimize pollutant emissions, aircraft will become a major source of pollution worldwide.

At Lewis we are studying ways of applying advanced technology to reduce aircraft pollution.

Here in the new Propulsion Systems Laboratory we can test full scale engines at various flight conditions. The testing includes measurements of all engine performance parameters as well as measurements of engine emissions at altitude conditions.

Here we have a cutaway of an aircraft jet engine. High pressure air, supplied by the compressor enters the combustion chamber where fuel is sprayed and continuous combustion occurs. The hot gases then exhaust into the turbine which drives the compressor and fan and finally exhaust from the engine to provide thrust. It is during this combustion process that pollutants are formed. (1) Our first slide shows a schematic of an aircraft jet engine combustor. A Here we have identified the principle emissions due to combustion. In addition to the normal products of combustion,

A. High pressure air enters the combustor in the primary zone where the fuel is burned. In conventional combustors, additional air is added in the secondary zone.

which are water vapor and carbon dioxide, pollutants are emitted such as HC, CO, Oxides of Nitrogen, and Smoke. It is these pollutants which are of primary concern.

The gas Turbine combustor operates at very nearly 100 percent combustion efficiency at all operating conditions except idle. At idle, with lower combustion efficiency typically results in higher levels of carbon monoxide and hydrocarbon emissions. The effects of these two pollutants are different. Carbon monoxide is an odorless invisible gas.

Extended exposure to high concentrations of carbon monoxide can be very dangerous. This is a potential problem for airport personnel that service jet transports. Hydrocarbons which are primarily unburned or partially oxidized fuel cause the odor characteristic of all major airports. When hydrocarbons are mixed with air and other pollutants and exposed to sunlight, they slowly react to form new compounds - generically named photochemical smog. This smog is an irritant to eyes and lungs and is damaging to plant life.

Smoke and. The oxides of nitrogen are primarily emitted during ~~high~~ full power operation of the engine - during take-off and climbout. B. The oxides of nitrogen are formed by the reaction shown on the next slide. At full power, high temperatures and pressures are generated within the engine which promote the reaction of the oxygen and nitrogen in the air to form nitric oxide. This occurs within the hottest portions of the flame zone. The nitric oxide formed is

B Smoke is formed when a fuel rich condition exists in the primary combustion zone very reactive in the atmosphere. To demonstrate this, we have an experiment to show the oxidation of NO to NO_2. This chamber has air on one side and a dilute mixture of nitric oxide ~~and~~ in nitrogen on the other. When we open the valve (opens valve) and allow the gases to mix, you will see the slow formation of a brown gas which is nitrogen dioxide.

The ~~oxides of nitrogen are~~ nitrogen dioxide is the principal compound~~s~~ which reach with hydrocarbons in the lower atmosphere to produce the components of photochemical smog.

The next question to be answered is how can the levels of the pollutants generated by aircraft be reduced. First we will consider idle

(3) conditions, then full power. The next slide illustrates techniques for reducing idle pollutants. Recall that the pollutants at idle are primarily CO and HC which result from incomplete combustion. One reason for poor combustion efficiency at this condition is that the fuel, when sprayed into the combustor, is not finely atomized. Due to the low fuel flow rates at idle, a coarse tulip shaped spray pattern occurs. Fuel atomization can be improved by: fuel scheduling, use of an air blast nozzle, or an air assist nozzle. In fuel scheduling, the fuel is supplied to only a small number of nozzles thus increasing the fuel flow rate per nozzle. The air blast ~~nozzle is a new device~~ technique involves a new nozzle design which uses the combustor inlet air to atomize the fuel. Air assist uses a conventional nozzle with externally supplied high pressure air injected through a secondary fuel passage.

Slide 0:30

We can demonstrate the effects of air assist using this jet engine fuel nozzle (flip light switch) and measuring emissions during idle operation of a combustor. Behind this window, we have mounted a single combustor can from a present-day jet engine. We will run the combustor at idle, and use the gas analysis instruments to your left of HC & CO

to measure the pollutants levels. These will be indicated by the dials above.

We can demonstrate the type of fuel spray in the combustor by flowing water, rather than fuel, through this nozzle at a typical idle fuel flow rate. (Start water flow in fuel nozzle) I think you can see the rather coarse Tulip shape spray formed ~~under these conditions~~. If we now add air through the secondary fuel passage, I think you will see a dramatic improvements ~~difference~~ in the atomization of the spray. (Adds air - waits - turns off experiment).

Now we will run the combustor at an idle condition without air assist so that you can observe the readings, and then we will add the air assist and you will see a drop in the levels of carbon monoxide and hydrocarbons.

Data indicating the effectiveness of air assist is shown on the next slide. We have found that as little as 1/4 of 1% of the total engine air flow injected through the fuel nozzles as we have demonstrated, can reduce idle emissions by more than a half.

As an example of what this might mean, in terms of current air traffic levels the application of ~~the~~ air assist technology would reduce idle pollutant emissions of ~~CO and HC~~ by approximately 9,000,000 million pounds per year at the Cleveland Airport.

Now lets consider the full power condition. Recall that the primary pollutant emissions during full power operation of the engine are smoke and oxides of nitrogen.

The most easily identifiable pollutant from gas turbine engines was smoke. Black smoke trails across the sky from low flying airplanes were very common only two years ago. Today, only a few of the smoky engines on most jet transports remain to be retrofitted with new smokeless combustors.

(4) The next slide shows how smoke reduction has been accomplished. By adding more air in the primary combustion zone, the fuel rich condition which produced smoke in earlier combustors was eliminated. This modification had to be made without compromising engine performance ~~altitude relight capabilities~~.

The benefits of smoke reduction can be seen at every major airport.
(5) The next slide illustrates both the old and the new in regard to smoke emissions. Here are photographs of two aircraft taking off. You can see that there is no visable smoke from the aircraft having the modified engines.

The primary gaseous pollutants at full power are the oxides of
(6) nitrogen formed during high temperature combustion. The next slide illustrates some of the basic concepts employed to reduce these emissions. Recall that O_2 & N_2 react when air is heated to very hi temperature for a sufficient length of time. The oxides of nitrogen ~~Since the oxides of nitrogen are formed in the hottest portions of the flame zone, these~~ emissions can be reduced by lowering the flame temperature and reducing the time the gases reside in the

hottest portions of the flame. This can be accomplished by leaning or the fuel-air mixture, premixing the fuel and air, and segmenting the flame zone. Leaner mixtures are achieved by directing most of the combustion air into the primary burning zone. In the premixing method, the fuel and air are mixed prior to entering the combustion zone. Breaking the flame zone into a large number of segments is the approach used in the modular swirl-can combustor invented at Lewis. The next slide illustrates the basic features of the swirl-can concept. These are premixing the fuel and air, small burning zone, and rapid mixing with bypass air. The illustration on the board shows how the individual modules are assembled to make the full-scale combustor on display. We have been extensively testing this combustor design and have shown it to significantly reduce oxides of nitrogen emissions. The next slide shows these reductions at engine operating conditions typical of today's narrow and wide bodied jet transports. The oxides of nitrogen emissions from the swirl can combustor are approximately half of that of current combustors. Based on these results,

the amount of oxides of nitrogen produced by aircraft flying over the United States by approximately 240 million pounds per year.

To achieve the reduced emissions we have discussed, we must transfer laboratory technology to practical engine use. ~~This is the goal of~~ the Experimental Clean Combustor Program. This program is a contracted as well as an in-house effort to investigate new combustor designs that have the potential of significantly reduced emission levels. The Clean

Combustor program will require all of our skill and knowledge plus that of the major commercial engine manufacturers if we are to achieve our reduced emission goals and meet the standards of the EPA for 1979. These standards require that emissions of HC, CO, and NOx be reduced to approximately 1/3 of current levels. [We have contracts with two of the major commercial jet engine manufacturers to explore a variety of new combustor designs.] The final phase of the CCP will include testing of the best combustors installed in full-scale engines to demonstrate the reduced emission levels. We expect to complete this program during 1976. We have some charts showing the combustor designs being studied arranged along the right side of this area.

At present, the Environmental Protection Agency Standards for aircraft emissions only apply at altitudes below 3000 feet. But, there is growing concern over emissions at all altitudes. Because of this concern, the Department of Transportation is conducting the Climatic Impact Assessment Program.

The purpose of this program is to measure pollutant concentrations within the upper atmosphere and determine what effect, if any, an increase in those levels by jet aircraft would have upon the atmospheric balance. This program is a national cooperative effort between government and industry.

At Lewis, we are involved in measuring the concentration of pollutants at all levels of the atmosphere. Our monitoring of pollutant levels in the urban atmosphere uses a wide variety of data gathering instruments. Some of these instruments can be seen on the display tables.

Slide here

A major atmospheric measurement effort is our Global Air Sampling Program. This program is concerned with measuring the constituents of the atmosphere at the 20 to 40 thousand foot altitudes where most present-day jet transports cruise. To make these measurements, we are installing instrument packages in some 747 aircraft, at the location shown on the next slide. (10) In flight, air samples will be ducted to the instruments through the sampling probe. We will continuously record the levels of atmospheric constituents as well as the position of the aircraft. As the quantity of these data grow, we hope to determine if pollutant concentrations in the upper atmosphere are changing due to air traffic.

The routes to be covered by our first two instrumental aircraft are shown on the next slide. (11) Extensive sampling over the United States will occur during our initial flights starting in December of 1974. Global coverage will begin with the flights of the second instrumented aircraft. NOTE: ADD MOCK-UP ON DISPLAY...

Another contribution by Lewis to the Climatic Impact Assessment Program is to determine engine emissions at flight conditions. These measurements are made in test facilities such as these you see here to your left and right. The engine on your left is the Quiet Engine which you have heard about or will hear about at another stop. This engine is being tested to determine the effect of the low noise features on altitude performance. Emission measurements will also be made at simulated altitudes from 20 to 40 K ft. On your right, we have a J-58 engine installed and instrumented to measure emissions. Emissions measurements will be made on this engine at simulated altitudes up to 70,000 ft. and flight Mach numbers up to 3. These tests will give us information as to the levels of pollutant emissions generated during high altitude supersonic flight.

During this brief presentation, we have shown you what Lewis is doing to apply advance technology to minimize pollutant emissions from jet aircraft and touched briefly on what we are doing to measure pollutant concentrations in the atmosphere. This concludes our presentation.

Thank you.

1973 Inspection and Show

Stop #2 "CLEANER SKIES"

Demonstrations during talk:

1. JT8D Engine Cutaway
2. Parts per million demonstration
3. Oxides of Nitrogen demonstration tube
4. Fuel nozzle--air assist demonstration
5. Mock-up of Global Air Sampling Instruments in 747
6. Advanced low emissions combustor technology
7. Full scale combustors
8. Combustor demonstration of low emissions technology
9. Emissions measuring instruments

Additional Static Displays

1. Air monitoring equipment and instruments (Fordyce)
2. Global Air sampling display of instruments, charts etc.

STOP 2 R. JONES 8184

1) AIRCRAFT ENGINE EMISSIONS 40x60 CS 67563

2) OXIDATION OF NITROGEN CS 67564

3) EMISSIONS REDUCTION AT IDLE CS 67565

4) IDLE EMISSIONS REDUCTION BY AIR ASSIST CS 67566

5) SMOKE REDUCTION CS 67567

6) AIRCRAFT SMOKE REDUCTION CS 67568

7) EMISSIONS REDUCTION AT FULL POWER CS 67569

8) SWIRL-CAN CONCEPT CS 67570

9) COMPARISON OF NO, NO_2 EMISSIONS CS 67571

10) CLEAN COMBUSTOR PROGRAM CS 67572

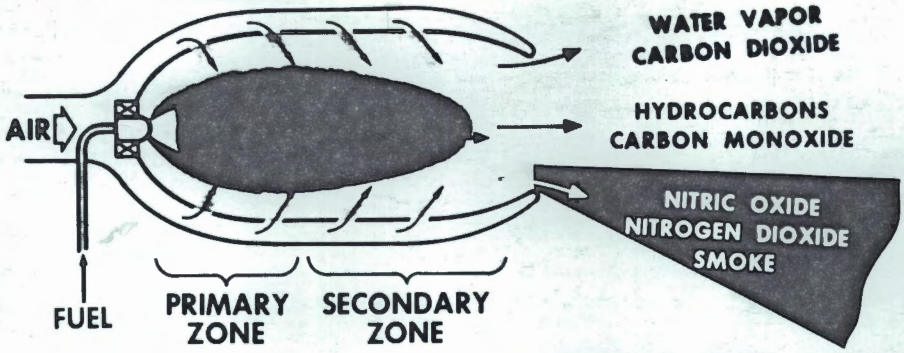
11) GLOBAL AIR SAMPLING PROGRAM (CHART) CS 67573

12) GLOBAL AIR SAMPLING (747) CS 67574

13) GLOBAL AIR SAMPLING ROUTES (MAP) CS 67575

STOP 2

AIRCRAFT ENGINE EMISSIONS



IDLE

- CARBON MONOXIDE
- HYDROCARBONS

FULL POWER

- SMOKE
- OXIDES OF NITROGEN

SLIDE 1 (CS-67563)

OXIDATION OF NITROGEN

DURING COMBUSTION:

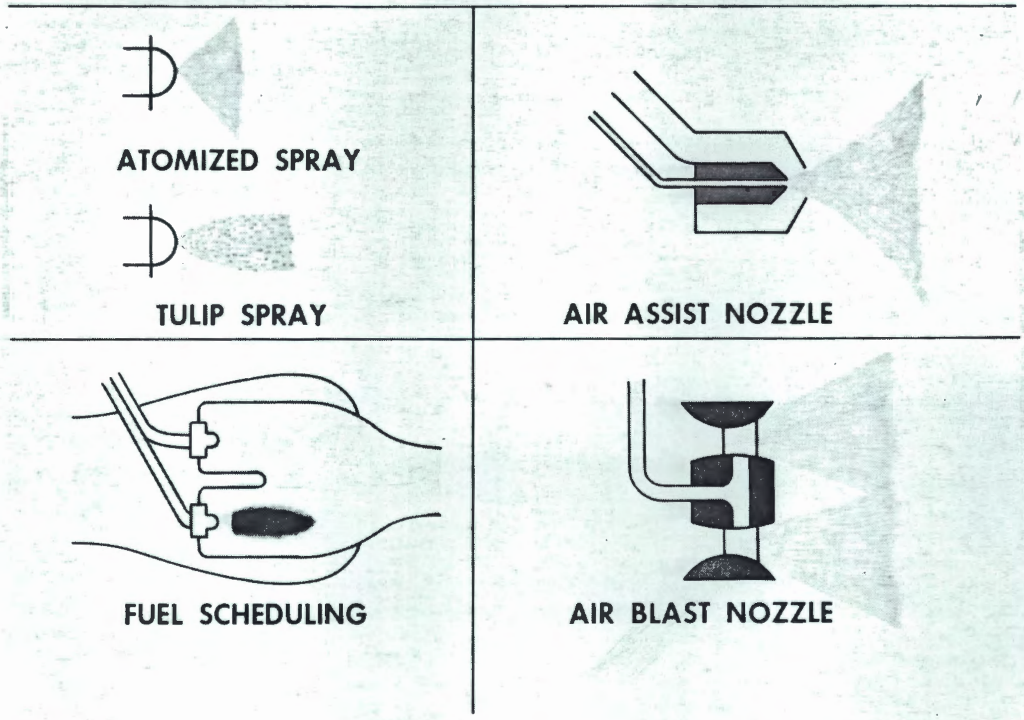
$$AIR\ (N_2 + O_2) + HEAT \rightarrow NO$$

IN ATMOSPHERE:

$$NO + AIR\ (O_2) \rightarrow NO_2$$

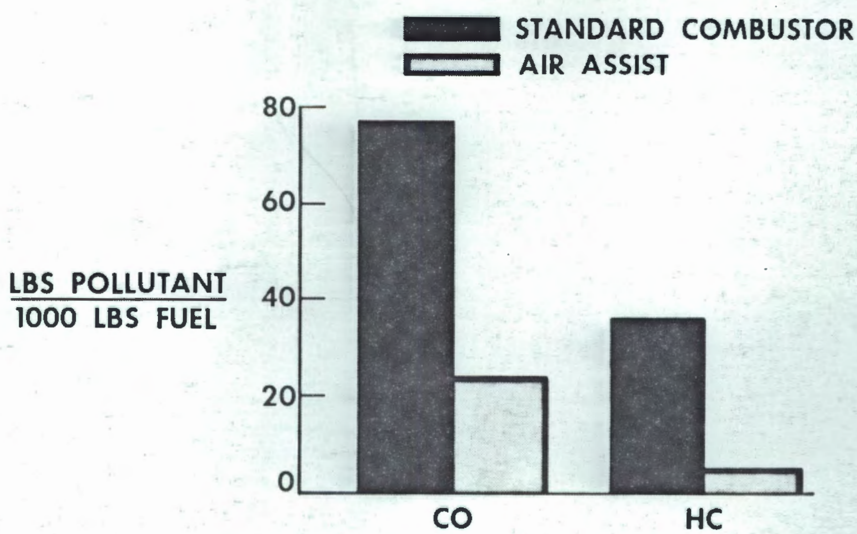
SLIDE 2 (CS-67564)

EMISSIONS REDUCTION AT IDLE



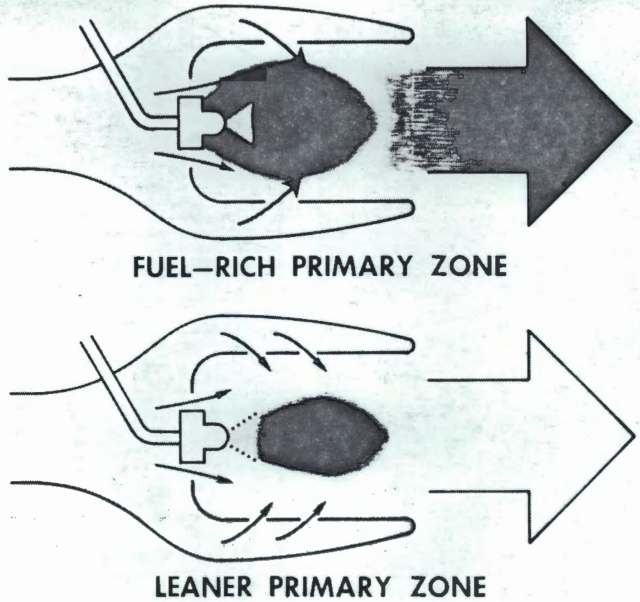
SLIDE 3 (CS-67565)

IDLE EMISSIONS REDUCTION BY AIR ASSIST



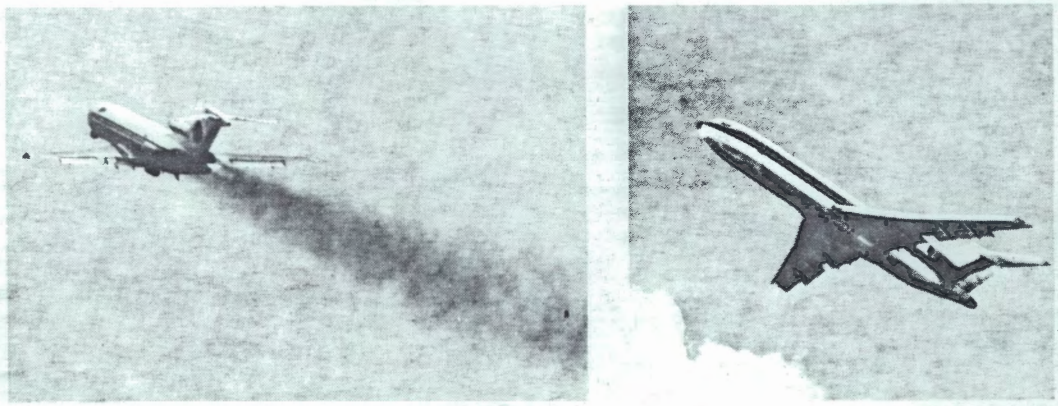
SLIDE 4 (CS-67566)

SMOKE REDUCTION



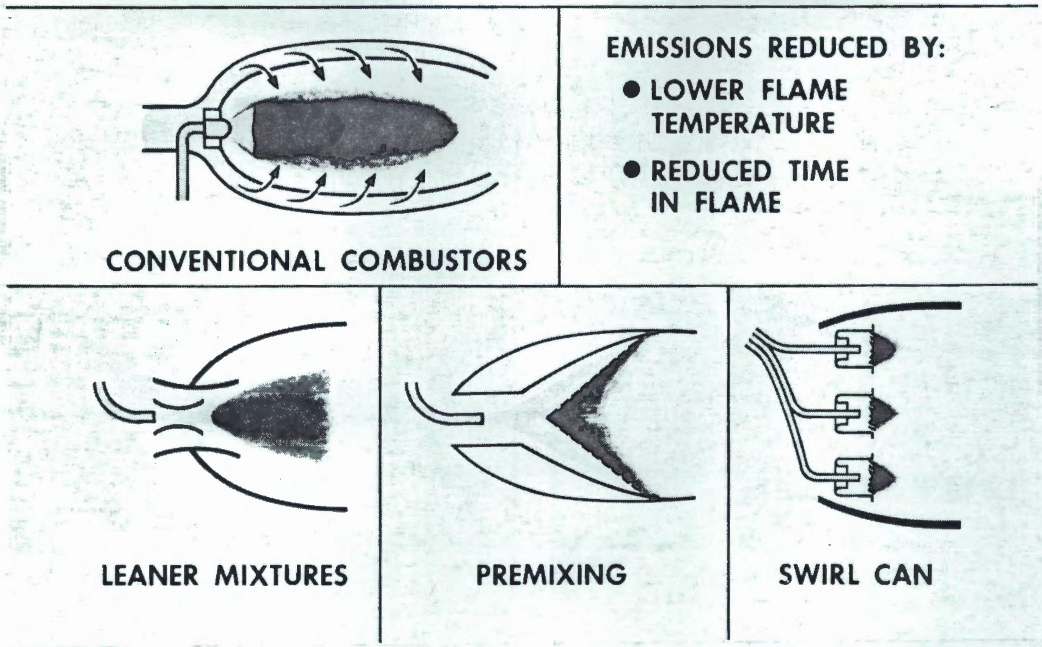
SLIDE 5 (CS-67567)

AIRCRAFT SMOKE REDUCTION



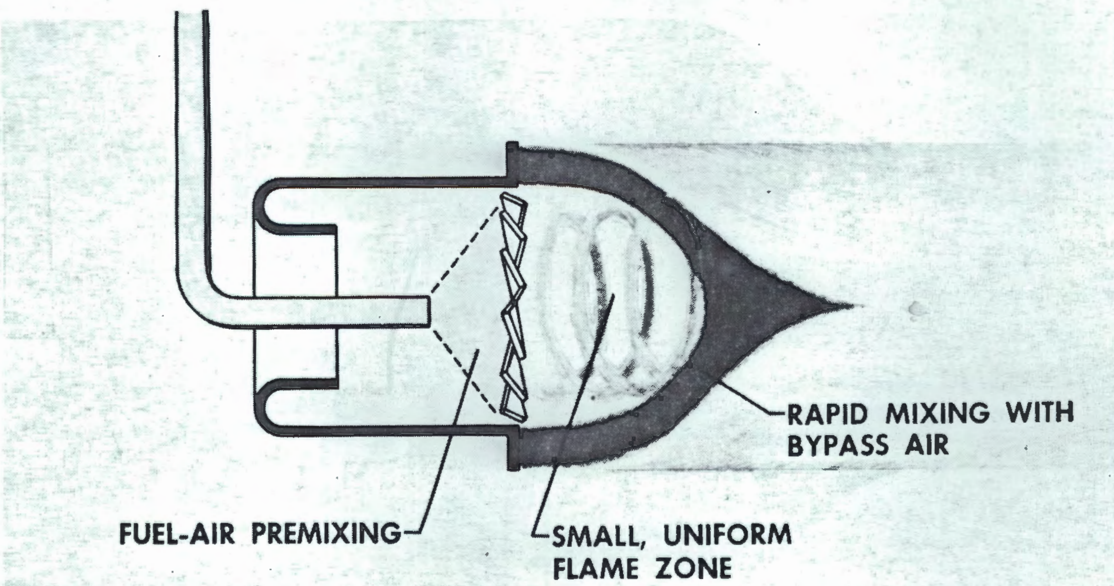
SLIDE 6 (CS-67568)

EMISSIONS REDUCTION AT FULL POWER



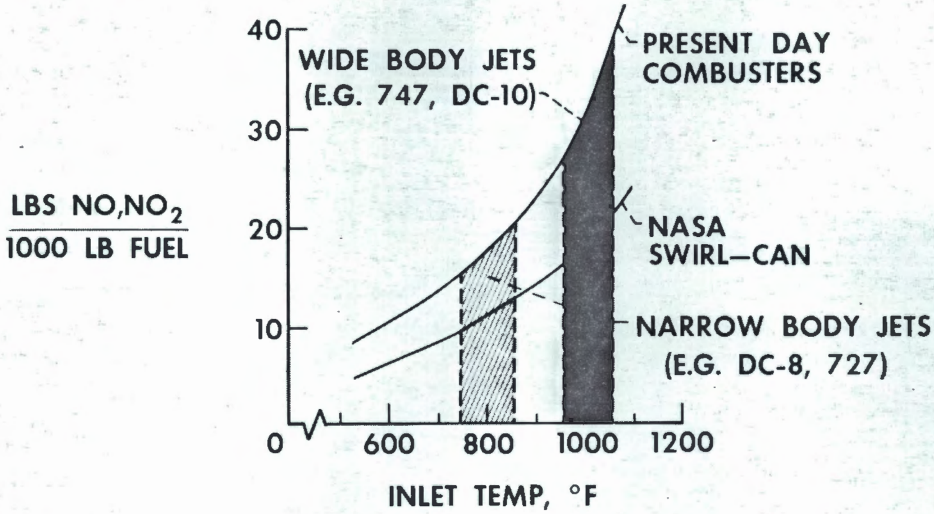
SLIDE 7 (CS-67569)

SWIRL-CAN CONCEPT



SLIDE 8 (CS-67570)

COMPARISON OF NO,NO_2 EMISSIONS



SLIDE 9 (CS-67571)

CLEAN COMBUSTOR PROGRAM

- ADVANCE LABORATORY TECHNOLOGY TOWARD BENEFICIAL USE
- BEST OF NASA AND INDUSTRY TECHNOLOGY
- MEETS 1979 EPA STANDARDS
- TWO CONTRACTORS
- COMBUSTORS TESTED IN ENGINES

SLIDE 10 (CS-67572)

GLOBAL AIR SAMPLING PROGRAM

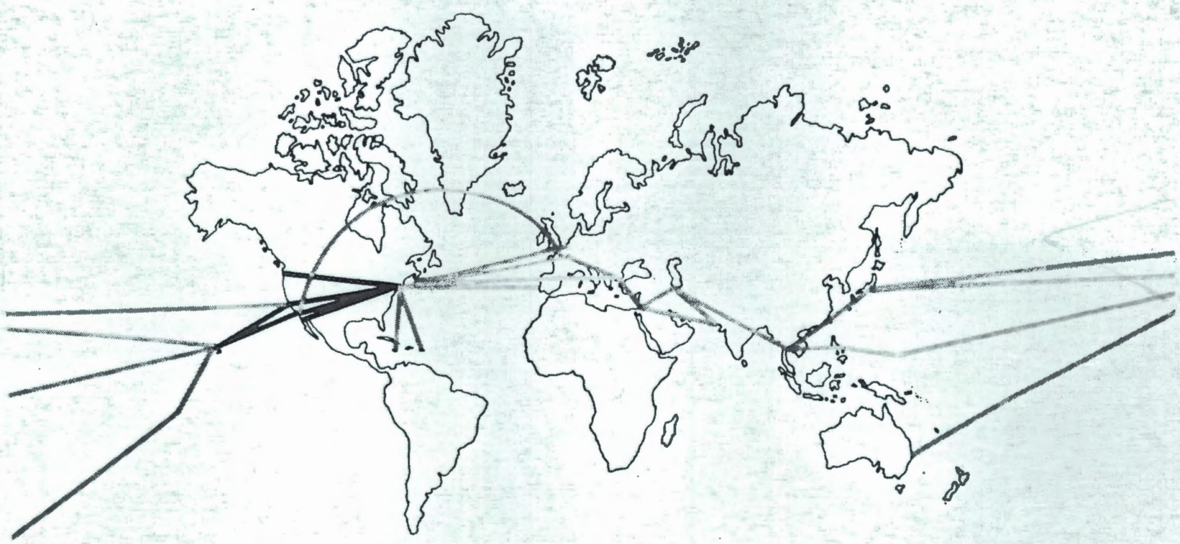
PURPOSE: TO DETERMINE CHANGES IN THE CONCENTRATION OF POLLUTANTS IN THE WORLD AIRWAYS.

- DUE TO AIR TRAFFIC
- OVER A 5 TO 10 YEAR PERIOD

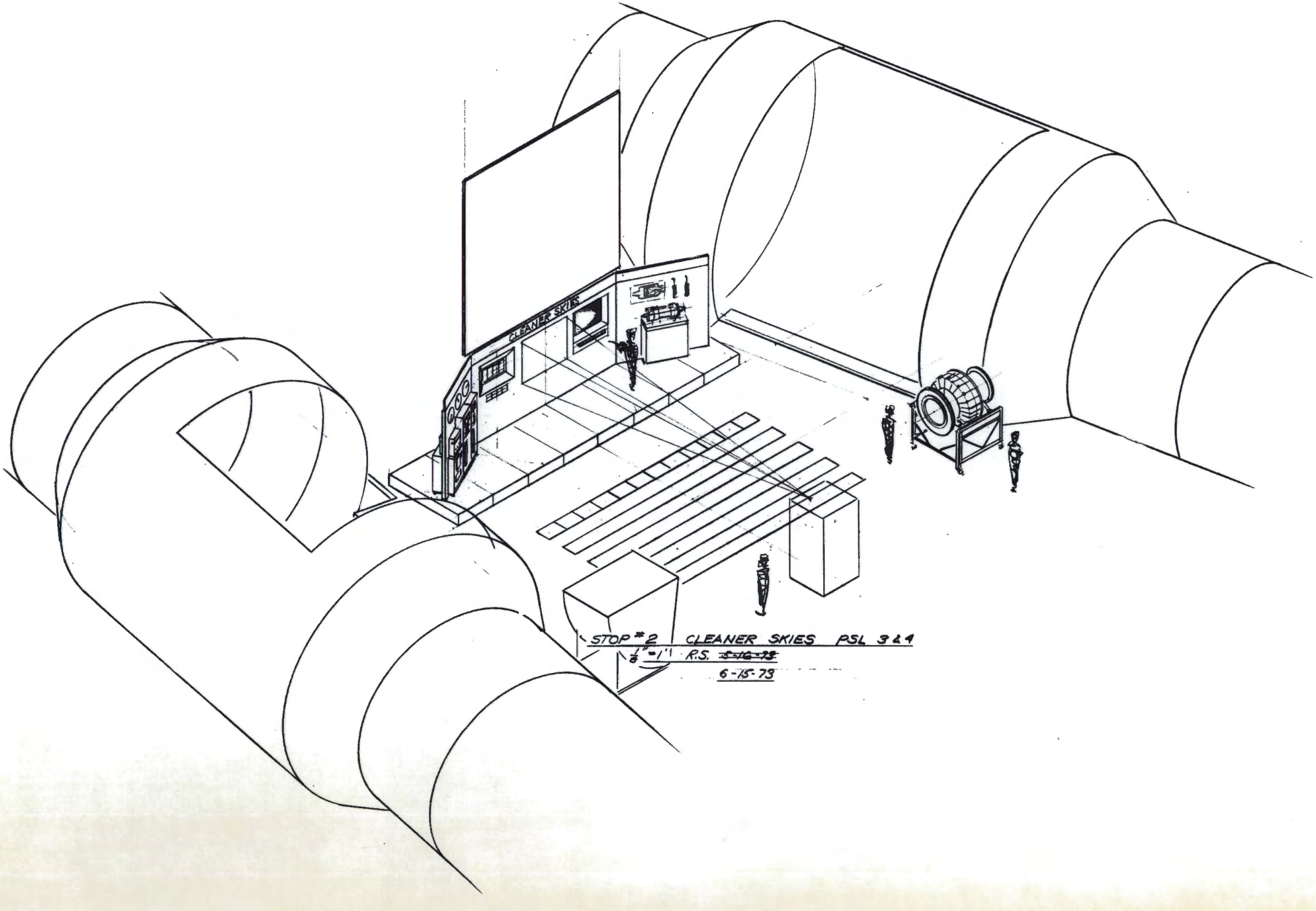
SLIDE 11 (CS-67573)

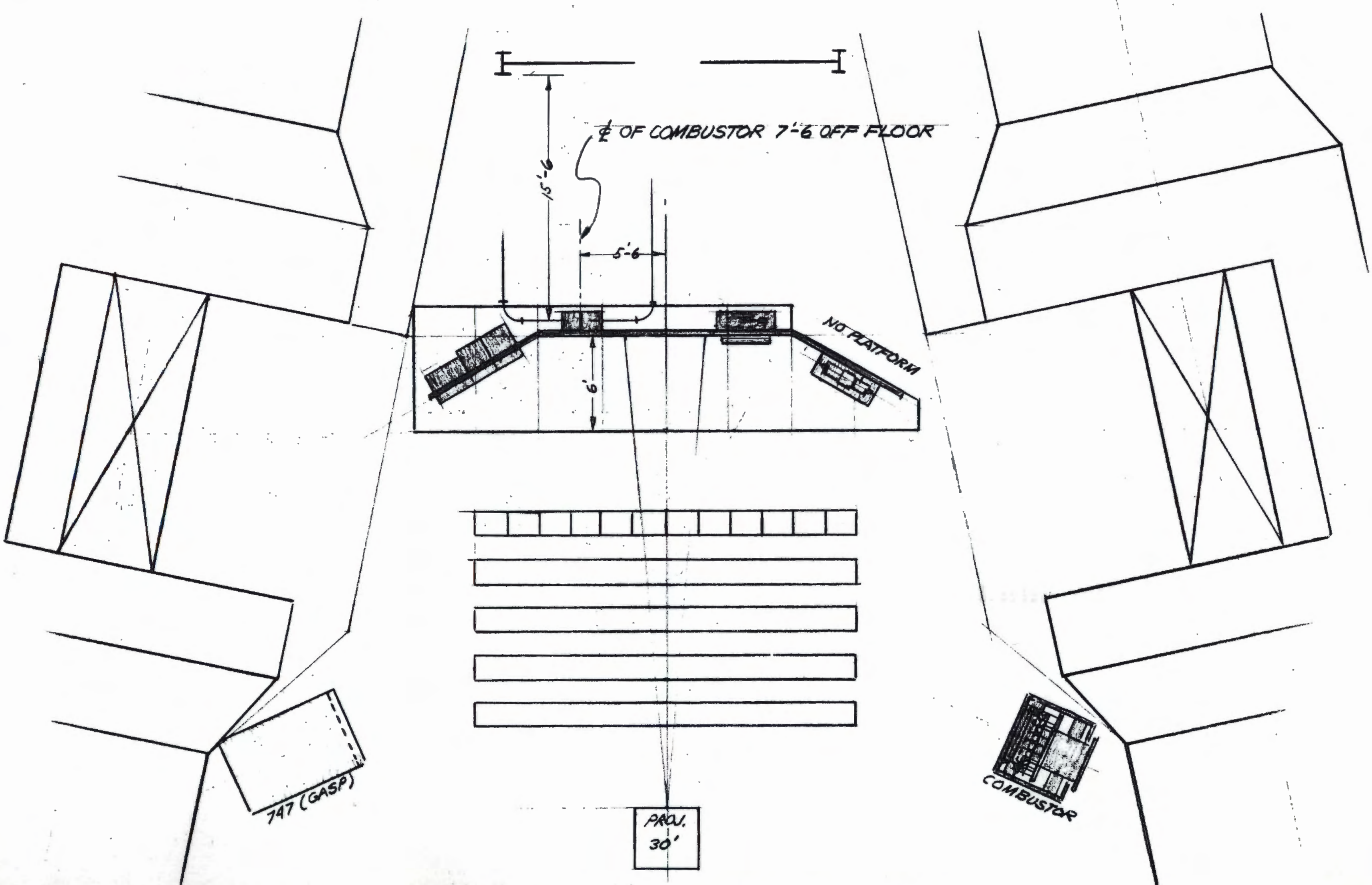
SLIDE 12 (CS-67574)

GLOBAL AIR SAMPLING ROUTES



SLIDE 13 (CS-67575)


CLEANER SKIES
STOP #2 CLEANER SKIES PSL 3 & 4
1/8" = 1' R.S. ~~5-16-73~~
6-15-73

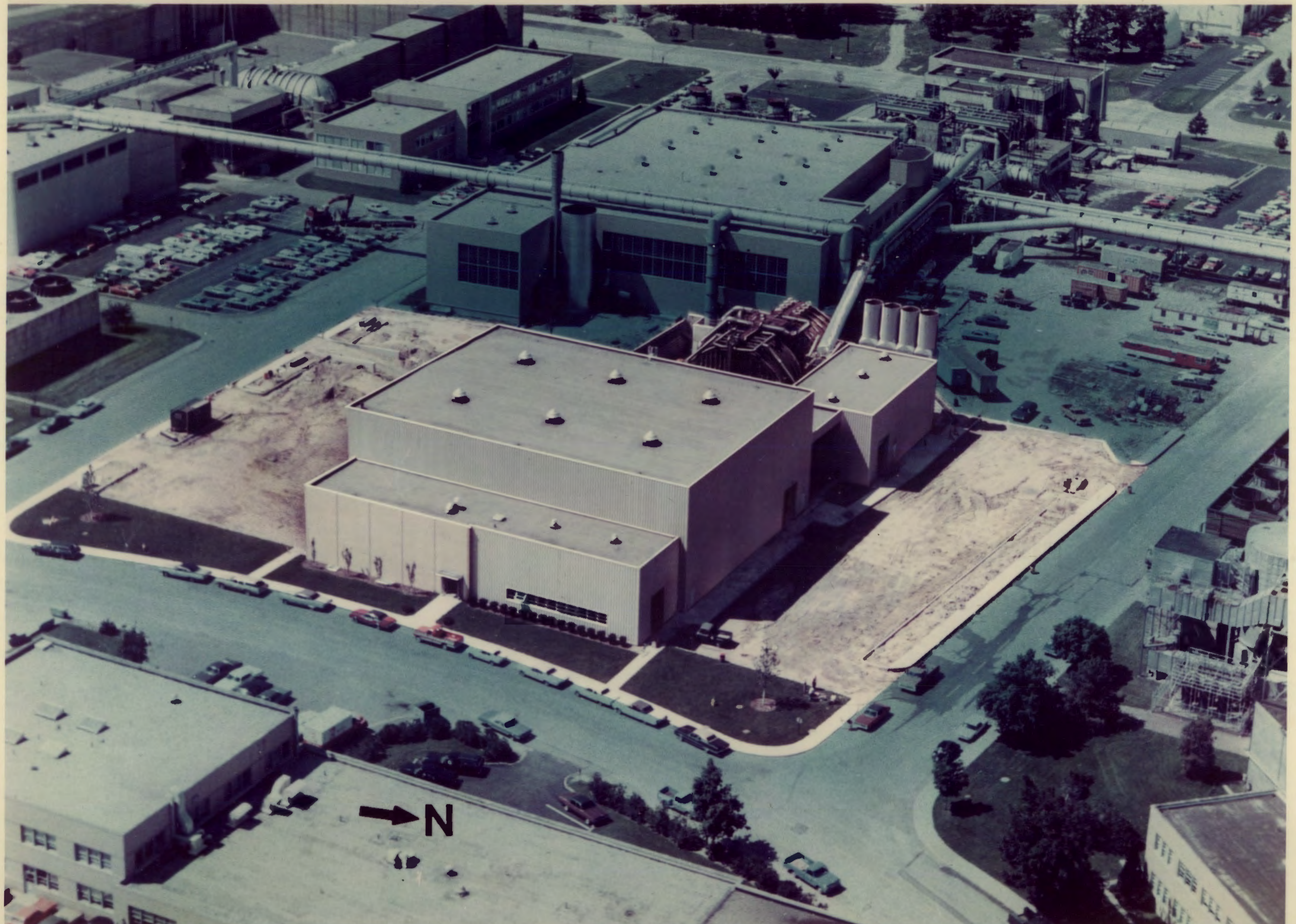


STOP #2 CLEANER SKIES PSL 3&4

1/8" = 1' RS ~~5-15-73~~ 6-15-73

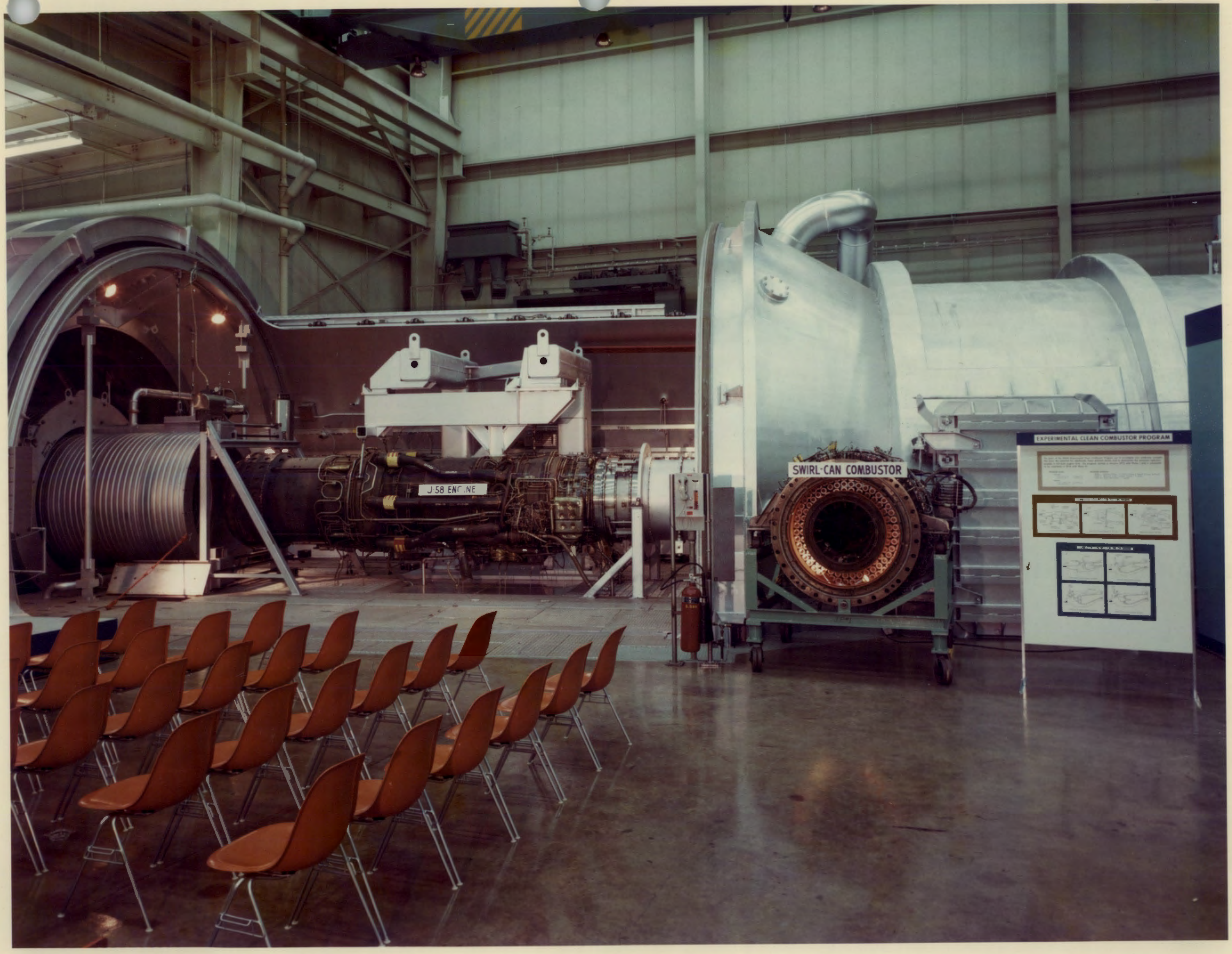
NASA
C-73-1529

PSL ENGINE TEST BUILDING

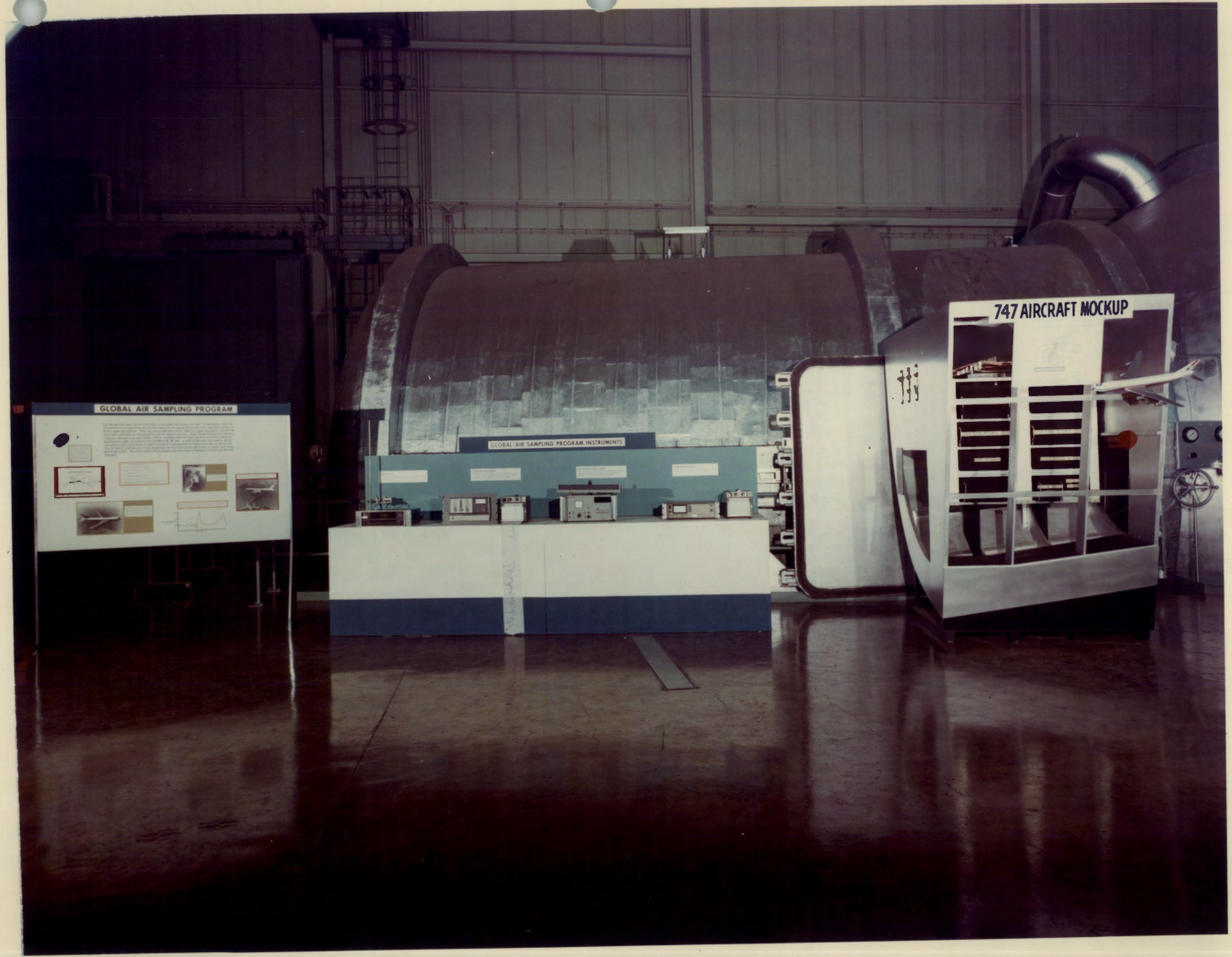


NASA
C-73-3373

NASA
C-73-3376



NASA
C-73-3380



NASA
C-73-3379


GLOBAL AIR SAMPLING PROGRAM
For the past ten years jet aircraft traffic in the upper atmosphere has been increasing at a rapid rate. The exhaust emissions from jet aircraft engines is increasing the burden of air pollution injected into the upper atmosphere. Other sources of pollution which reach the upper atmosphere include that from man's activities on the ground as well as natural sources. GASP (Global Atmospheric Sampling Program) attempts to answer whether the air pollution from all these sources combined is adversely affecting the upper atmosphere from 20,000 to 40,000 feet. Quality of the upper atmosphere will be measured using instruments on board regularly scheduled airline flights using Boeing 747 aircraft. The 747 will be used because it has ample room for the instruments and it flies on routes over a large part of the world. The instruments will be located near the cargo compartment and will operate automatically.