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THE PAST 50 YEARS IN AVIATION

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I am no safety expert. I am merely a man who has run an airline more or less safely for 40 years. It has operated with less hazard than some because the people who make up Continental Airlines have profound feelings as to how they conduct themselves around flying machines. And, if any of them displays less than serious attitudes, he might well expect to come to sudden grief. Today, he might be disciplined by time off without pay. In other days, he would do well to guard his nose, teeth, and jaw from the anxieties of his fellow employees.

I will, therefore, describe to you as best I might some lore about safety practices in early aviation from a vantage point of an observer whose funds and future were intrinsically bound to operating without accidents. And then I'll describe how some of you might today present your safety ideas and programs to your own management with a fighting chance of selling the concept of safety to a superior who finds it excess to budget!

As I have said, I am not a safety expert, but at Continental Airlines, I am the man who has said yes or no to budget requests since 1938. I know what tactics have convinced me and I will outline ways you might present safety expenditures to your bosses. It involves art forms hitherto unrevealed in public.

I have been asked to comment upon safety factors relating to ground personnel during the growing days of aviation and not on flight safety. But I fear that a factual report on early ground safety programs for this audience could be disappointing. In those long ago days of aviation, the safety of the plane was vital. If there was any safety left over, ground employees could have some. But there was no established and programmed approach to ground safety as we know it today.

However, there were surprisingly few accidents. There were reasons for such freedom from collisions and calamities. First and foremost was that usually we had large and unencumbered work areas. In nice weather, most planes were attended to outside the hangar and there were, of course, very few planes on the field. The planes themselves were small. You could stand on a milk crate to reach any part of a Lockheed Vega and walk around one with ease. Indeed, when it was to be rolled into the hangar one man would push it where it was supposed to go. No one ever hurt himself pushing it, to my knowledge, and the old-timers still with us can't recall any serious injuries in the first 15 or 16 years we flew airplanes.

An A & E mechanic then was a jack-of-all-trades, too. Not only did he have to keep the plane in flying shape, but he was also expected to repair radios, any electrical problems in the hangar, and to handle the ground-to-air radio when the station manager was selling tickets. They also loaded and unloaded the luggage. No one hurt himself lifting luggage, since we had strict restrictions on the weight of the bags. I'm not sure we shouldn't resurrect that rule for some of today's passengers who come aboard with garment bags which must include the tacking dummy of the Chicago Bears — our flight attendants are sharp, enthusiastic, and professional, but a 110-pound woman just can't seem to handle a garment bag filled with scrap iron.

In those dim days, batteries were dragged about in carts rather than tugged by tractors. There was no such thing as a lavatory-servicing truck. What used to be cleverly called the "boom jug" was fetched out of the aircraft by two pairs of pliers and handled very, very gently. The only mobile equipment that any of the old-

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times can recall was, of course, the fuel truck. Tow trucks were rarities. Even when we were flying bi-motored aircraft in the early '40s, six people were used to push a plane into a hangar rather than one tow to pull it.

Indeed, an early experience with a tow truck was not hopeful for its future. We'd hired a new man in El Paso and given him explicit instructions concerning how dangerous it was to have any form of loose gear on the runway near the airplane. Cautionously mowing by to fix a tow, he noticed a tin can under the wing of a Lodestar. He immediately dismounted to pick up the can, neglecting, of course, to turn off the key on the tow.

He retrieved the tin can as the tow continued on about its business. While the tow couldn't run very fast, it proved to be able to hold its own against him and his tin can. Someone finally chased it down in a Model A before it reached Mexico. But, as I've mentioned earlier, it didn't damage anything because we had so little of anything for it to hit.

I was not supposed to know that following the servicing of the last in-bound flight in the evening, the El Paso night shift frequently climbed aboard a car and went hunting for coyotes--on the airport runways. Armed with a shotgun, rifle, and automatic, plus an automobile possessed of some temperament, they were not much danger to coyotes. But the El Paso airport back then sheltered a section of dunes where young couples came to look at the stars and each other. Boy meets girl was interrupted once too often by Continental's wild-animal hunters. The word was passed that violence might well be met with violence, especially by soldiers from nearby Fort Bliss who were not about to be shot before they reached a combat zone and certainly not in the arms of El Paso ladies. The coyote hunts ceased.

A number of you aren't old enough to recall the era when the magic word "contact!" was exchanged between pilot and mechanic preparatory to turning the propeller. When you see such a scene in the movies, they in-

variably do it wrong. In practice, the pilot would shout "switch off!" and then the mechanic would gingerly pull the propeller about to make sure there was no oil in the lower cylinders. Then he would step back and shout "contact!" to the pilot signifying that it was okay to start the engine. Mechanics were most careful that pilots followed this ritual correctly. In the movies, it seems that everybody is babbling "contact!" to everybody else. Such chaos would have guaranteed death and destruction on a real runway.

The Douglas DC-3 was a spectacular plane and a safe one. However, it had one feature which made ground personnel wary. Back in the tail were two mighty flares which were attached to the cockpit by a cable the length of the airplane. When ground lights didn't work, the pilot would trip these magnesium flares and make an approach by their blazing light. Every airline mechanic in the nation learned that when someone mistakenly jerked the cable, these flares were apt to fall on the hangar floor and start a dandy magnesium fire right in your own little home.

It happened to us in Denver. One of our lead mechanics had newly returned from the Navy and he was hung up on drills. He had a drill for every occasion from "general quarters" to "prepare to repel boarders!" Came the day, he just completed a fire drill and someone set off our DC-3 flares. His crew scampered back, thinking it was a repeat fire drill rather than the real thing. They even managed to put a magnesium fire out with CO₂ foam, which was impossible. The Navy vet got credit for knowing when fires were most likely to start.

There is one thing that made me very proud of the airline business, both then and now. When anyone came up with a safety technique, he immediately called everybody else to share the information. We were a kind of fraternity then and, to a degree, are still. If something worked for us in the area of safety, we didn't hug it to ourselves as a secret. If it could help anyone else, even the toughest competitor, it was something which was given, and given freely. I can't recall any gadgets or

gizmos involved with safety which were ever patented or hidden away by an airman. They were free to everybody.

A case in point is something we started eight years ago at Continental. It was an idea to inhibit vehicle drivers from ducking under the low wings of a 727. One of our guys came up with the idea, and its very simplicity makes it effective. We tie fluorescent ribbons to weighted bean bags and trail them off the wing tips when the aircraft is at the gate. It has reduced accidents incredibly. The flapping ribbons gain the eye of the vehicle operator faster than any barrier. We not only gave the idea to everybody, but called to other continents to tell them what we came up with.

Twenty years ago, when we were introducing our first 707 jets, we devised our ground safety man concept. He was literally the "man in the middle." Ground crews could not move any equipment near the aircraft without the safety man. We had one on each wingtip and one at the nose, all dressed in gold helmets. Indeed, even when equipment approached the aircraft, it must do so at the pace of the safety man moving slowly before it. It was the safety man rather than the operator who ruled the motion of the machine approaching the plane.

Shortly thereafter, we developed a kind of whip antenna which reached out before the mobile equipment. One touch of the antenna to the plane and the equipment's motor immediately was cut off. Injury to the operator or damage to plane or ground vehicle was cut off as swiftly as was the motor.

Let me give you some idea of Continental's recent growth and also what it has meant to our allegiance to safety. In 1968, we had 110 maintenance men at Los Angeles International Airport. That's 110 for all shifts. Now we have 2000 people on the line there. That's an increase of 1718 per cent, a very great number of whom are new hires who had a lot of on-the-job learning to do. Yet, in the entire 42 year history of Continental, we've never had a fatal industrial accident and a full 88 per cent of the injuries which are sustained are in the area of bumps

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and bruises. There is a way we work, such wonders. It is not glamorous, not flashy, not spectacular. It is the creation of a responsibility for safety in the conscious and subconscious minds of every employee dealing with a machine or walking a runway. It is the discipline of safety.

As you may have gathered from my earlier remarks, Continental didn't start out rich, and we probably never will be a satisfied giant. Our reputation is that of a lean, tough, aggressive competitor. We pride ourselves on our flight product and our passenger service pattern. We make up for less planes with greater utilization, and we ask more of our people because we have to get it to stay in the race.

At Continental we rarely take a plane out of service. In our perpetual maintenance program, we do a little bit every time it touches the ground at our main base. We even paint them in sections, one day the right side, a few days later the belly, then the nose. This obviously requires a coordination of project lists and a cooperation of ground service people not practiced in any other airline.

For us, it works because maintenance has been raised to an efficiency nobody else has even attempted. We cannot have mistakes because it would break up our entire rhythm of performance. We demand every precept of safety be a shop commandment, because it is our precious advantage over the field.

I have quite deliberately removed the sensitivity and humanity concerning safety as a shield to protect employees in my words to you here. Of course, we are deeply concerned with the well-being of our people and, of course, we profoundly appreciate our responsibility to their health and security. I could address myself in such a manner to you but so, too, could a thousand other people. I have purposefully emphasized the need for clockwork functioning of our ground support echelon to give safety a more defined place in the work role of our airline.

It is not desirable, it is essential. It is not praiseworthy, it is vital.

Safety is not a by-product, it is integral to the end result in our airline.

Tight management control via alert first line supervision speaks for safety at Continental. Once a month, 507 of our supervisors address cohesive work groups concerning practical defenses against plausible accidents. We seek to reinforce the awareness level of employees with material pertinent to their work roles. There is no theory and there is no "speechifying."

For instance, any supervisor from any shop on the floor can and does stop a man from using a grinding wheel without a face protector. There are no organizational barriers to safety. Anyone who spots an oil slick on the floor swabs it up whether he caused it to be there or not.

We have an Accident Prevention Board with representatives at every base. At Los Angeles, the Airline Maintenance Managers Council meets every month to see what we may learn from each other about safety. Safety isn't just a concern of middle management, either. One of our cargo agents was chairman of our Accident Prevention Committee at our headquarters base and did a splendid job of making certain that the safety word was carried to everyone.

Well, what does it all add up to—an insurance policy that Continental is guaranteed free from pain and claim due to accidents? No way. We will have accidents because we employ mere mortals and because we do not work in empty spaces.

But I am convinced that we will hurt ourselves less and will damage the planes less and maybe even save each others lives more because we are making an effort to do so. In great part, the programs of the National Safety Council have offered us reasonable goals and practical guidelines to structure our activity. They have been good for Continental and for our people and we are smart enough to be grateful and ask for more. They are good teachers and we need all the knowledge we can get.

I'm sure most of you have talked more than I have about safety—complete with bar graphs and pie charts, audio-visual novelties, and unimpeach-

able statistics. And a lot of you got a pat on the head or a foot in another portion of the anatomy from a boss who said it all looked very nice but he didn't have time for toys.

As you are no doubt aware, you are selling an invisible product. A purchasing manager doesn't know how to buy it. Does it come by carload lots, by the bolt, or by the pound? Where are the warranties, what is the inventory life, and how much off for cash? It is a remedy for a disease you are not sure you have.

Every chief executive officer discovers, often years too late, that someone in the outfit had a great idea and a workable program of how to lick a corporate problem which was driving us to distraction. But it never got to the chairman's desk, and he was forced to sweat blood, spend money, and bite his nails until somehow they got by the hole in the road. When you learn there was a feasible and reasonable option, you're ready to commit mayhem. Why weren't you told? Invariably, the answer is that the program was rejected at a lower level. It died before it could reach you.

I will venture a guess that such a fate has kissed and killed more safety programs than all of us could list. And so, I would like to be brief in suggesting ways that you might be able to "sell safety" up the chain of command—with concurring recommendations rather than deadly detours.

First, always consider that everyone in a company is paid to do one of two things—either make money for the company or save money for the company. If you can't fulfill a job rating in these two categories, someone is carrying you as extra baggage. If your duties are vague, your reporting structure infirm, your role in the business more cosmetic than vital, you are in trouble from the start. You may be considered scholarly or charming, but your work will be pigeon-holed as "well-intended" or "specialized."

You will rarely get a fair hearing for your programs, because your boss cannot relate your effort to everyone else's. You are a luxury, and your budget requests subsidiary to proven capital and staff needs in operating divi-

sions.

Safety is not ornamental and the role of a corporate safety director is an important one. Yet, as you all have had reason to learn, it does not fit neatly into the table of organization. You sometimes are fitted into a box so far from the trunk of the tree that you nearly go off the board. Other times, you can be tucked under the arm of such a major division that you are an alien in a nation of people speaking a different language. Depending on the immediate divisional boss, this can result in a life in limbo or one of outright harassment. Bosses are uncomfortable supervising a unit whose activities they cannot accurately measure and whose role in their ballwick seems suspicious.

May I offer an idea as to how a safety expert might find his way out of such a corporate swamp before he drowns in boredom or is eaten by alligators with very big teeth?

Please treasure the three familiar letters A, B, and C, and take them to mean "Allies Build Careers." In corporate life, people who are consistent achievers are those who enjoy the support and cooperation of their fellows. They work well with people, they display good communication skills. In short, they have presented their programs, their goals, and themselves to be possessed of logic, energy, and clear objectives. They make everybody look good.

Consider for a moment the allies required by a safety expert. They are rarely within your circumscribed area. There is an excellent illustration of the value of safety to be made by the statistics of safety. The case history, the comparisons reporting results, not gauging projections, are persuasive. The very best audience for such material is officials who are themselves involved in the measurements of cause and effect. Engineers, researchers, analysts, accountants, corporate planners are all men and women whose lives center about the extraction of probabilities from masses of data. Many many of these skilled thinkers rise to corporate high office.

My advice, then, is pertinent and direct. Seek allies from those of your

corporate structure who are likely to give you the most favorable hearing. Demonstrate safety technique while at the same time creating a safety constituency of well-placed corporate officers who can plead your case in higher realms far better than you could ever do by yourself.

Work within boundaries. Gain permission from your immediate superiors to make presentations to others outside the division. Hand-tool the program to particular needs and never, never, never exceed stipulated budgets in showing that safety works well and works cheap.

There is an immeasurable benefit to all your plans if you can create the aura of safety by repeated successes. I mentioned that allies build careers by their recognition of merit and their sponsorship of what they think will be good for the company. They can find a budget for a safety survey that the finance department never knew they'd squirreled away. They can establish a pilot program from half-a-dozen pockets to let you prove yourself. They can afford supervisory seminars and select equipment for practice runs that they've successfully "lost" from internal audit.

Recall that I suggested allies build careers, and never forget that build is the operative word. If you wish, consider that early efforts to create a positive base are an elementary way to begin a program, although, sadly, few ardent zealots ever seem to accept this basic of corporate life. But it is important that you display greater skills in advanced work. Build...

Allies view a successful protégé, which by great good fortune you may become, with a certain fondness, but also with a certain impatience. You will not bask in the sunshine of their smiles if you seem content to win in a minor league. There is nothing more damning in industry than to attempt to cover yourself warmly and sit out a pension when everyone else is risking his pelt in seeking new challenges. If you have proven you are enterprising, intelligent, and able, you will continue to receive the support of your allies only if you dare to use your head and risk your future.

An executive who stands still is either a target or a wall.

I am not a business philosopher, and those I have read seem absorbed in the meshes of power clans and cults that really are most short-lived in industry. As in public life, there is a rapid turnover among politicians in business. The arena is much the same. You've got to be good, and the people have to believe you're good, to hold your seat. Forget about arcane rules of "game-manship" and how Machiavelli might have done it. Try to do a good job and do what you do best. In your line of work—safety—you can save somebody's life rather than just add a penny to the dividend. It means appreciably more to the guy whose life you saved. And to you, too, or you wouldn't be in the safety business.

It is now fashionable to point to the incredible record of flight safety and

mark with awe and wonder on the inevitability of progress. Well, I'm here to tell you that progress isn't so inevitable.

Everything that American commercial aviation has achieved has been by the wit and courage and endurance of the people who made it possible for a man to defy gravity and get back to earth with his body unbloodied and his airplane in one piece.

We dared—with safety. We pushed back the barriers of man's experience on earth—with safety. We experimented with how high we could climb and how deeply we could dive—with safety.

And it is my hope that each of you is going to assist us into a limitless aviation future when all our planes will go higher, faster, farther. And with safety.

THE NEXT FIFTY YEARS IN AVIATION

By JOHN SWIHART
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The title, of course, is the "Next Fifty Years" and I hope that some of these things will come to pass in substantially less time than that. I want to talk about where we are as we move from the present generation of jet transport airplanes into our new family. I know you've read in the news media about the 757, 767, and 777. I'll move beyond those to what are called "energy efficient transports" and then on to new product possibilities such as quiet short haul, advanced freighters, SST, hypersonic, and perhaps even touch on nuclear airplanes. I think you'll see good reason why we want to do that.

Our current family of airplanes consists of the 707, 737, 727, and 747. Our new family the 757, 767, and 777 will be described for you.

There are a lot of technical developments that could come to pass in the next 50 years. The next family of Boeing airplanes will have new air-foils, new structure, new quiet engines, and advanced cockpits. I will also try to tie in what we are doing now with what might come along in the future in air traffic control that might improve flight safety. I will talk a little about the potential for STOL type and the airplanes beyond that.

Today, we stand in a place in the air transport world, where, if plotted passengers against range, there are a lot of airplanes in the 100-135 seat class; then there are airplanes about 230 seats on up and with ranges from around 1000 miles on out to 6000 miles. We believe there is a hole in the middle of the market, and that was recently proven when we took a good look at our product. Our 737, in mixed class, normally seats around 100, the 727 about 135, the 707 about 150, and the 747 operates with anything from around 360 up to 500 seats. Note that

there is no airplane in or around the 200-seat market. So we believe that is a very active market for us which was recently proven when British Airways and Eastern Airlines committed to the 757, which is nominally a 175-seat airplane designed for good operation in the 1000 to 1500 nautical mile range. United Airlines, of course, started the 767 back in July. That is a 200-seat airplane with one stop U.S., and shortly will have non-stop U.S. capability. A derivative of the 767 is the 777 airplane, which I look on as a replacement for the 707 and DC-8 for use on the long thin routes where people are operating one, two, and three frequencies per week today. It will be a long time before the bigger airplanes take over that particular market.

The three airplanes I'm going to talk about are the 757, 767, and 777, as we have them today. First of all, the 767 is the airplane that United ordered in July. We are thinking about making a transcontinental version of this airplane very shortly, and we hope that some of the other major trunk airlines are interested in either of these two airplanes. A derivative of that airplane, of course, would be the 777. The 757 is what I call a new technology derivative. It uses the body of the 737 and 727; however we stretched the body, took out the third engine, put on new wings and a new tail.

On the technology level, the first thing I want to stress is that fuel is becoming the most important parameter in the direct operating cost of an airplane. Fuel at today's price is 38 per cent of the direct operating cost. Our estimate is that by 1985 it will be 46 per cent of the direct operating cost, by far the largest single element in the direct operating cost formula which is made up of fuel, crew, maintenance, depreciation, and insurance.

One of the first elements is to get the advantage of the high bypass ratio engines which were started on the 747, DC-10, and L-1011 into these new airplanes and improve on them.

New airplanes are going to have about a 25 to 30 per cent improvement in fuel burn compared to older airplanes. Engines for the 767, 777, and 747 are in the 35,000 lb thrust class. British Airways and Eastern Airlines bought a Rolls-Royce engine as the basic engine, but Pratt & Whitney and General Electric have competitive engines. We are offering each of those on the airplane as well. On the 767, United Airlines bought the Pratt & Whitney JT9D-7, an improvement over the present JT9D engine, and Rolls-Royce and General Electric also have derivatives that they are proposing for that class of airplane. We offer all the major engine company's engines on each of the airplanes, because the competitive aspects will get a better airplane for all the airlines to use.

Those high bypass ratio engines in themselves are quieter than our older engines; however, there are new noise rules, and therefore they are not quiet enough inherently without requiring a lot of work on our part to meet the rules. So, we have built a full scale inlet for one of the competitor engines and have tested it with lining all through the engine. On the basis of those tests, we are confident that we can meet the new noise rules that are in existence at this time. The noise rules have a way of changing with time, and if you look at this as sideline noise, in other words, noise to the side of the airplane on the airport as a function of the thrust of the engine, back in the 1950's when the first 707s came out, noise was very high (above 110 EPN dB).

With time, the technology has improved the particular noise levels so that now we're talking about noise levels for the next generation that are around 95 EPN dB. At this noise level you are reaching the point where airframe noise may become a predominant part of the noise around the airport. As you attain the ability to reduce the noise, then the regulatory agencies make that become law and you

have to reduce the noise, so that the next generation by law will be six to eight EPN-dB quieter than the older airplanes. Every three EPN-dB cuts noise power in half, so that is a tremendous change in the noise of the airplane, just to give you a feeling for that, the new noise rules compared with the current noise rules for a 300,000 pound twin-engine airplane are eight EPN-dB quieter at take-off, seven on the airport sideline, and three on approach. That means they are going to be substantially quieter than our current airplanes. We are confident at this time we can meet those rules for the new generation.

The new generation of airplanes, because of fuel is going to have a new wing. We have worked since 1971 on 75 individual wing designs, with many tailorings of each. We have run 15,000 wind-tunnel test hours developing a new wing. That's like being in a wind-tunnel for almost two years for 24 hours a day. To make it very simple, the new airfoil at the same speed as a 747 airfoil is 22 per cent thicker. We are going to use that thickness to get some more span on the airplane, to reduce the sweep, because that improves take-off and landing noise and speed, and we're going to end up with a thicker wing which will have more fuel volume in it. That will give us a lot of flexibility to fit different route requirements for the airlines. All in all, the new wing will be thicker with more span and less sweep and will result in a fuel saving.

This is efficiency—aerodynamic efficiency plotted against the altitude that the airplane flies. Compared to our 727, which is a mighty fine airplane, the new 767 will have something like that change in 12 to 14 in terms of over-all efficiency. A remarkable change when you consider the 767 is a wide-body, twin-aisle airplane and the 727 is a narrow-body, single-aisle airplane. A remarkable change in overall fuel efficiency.

When you're building a new generation of airplanes, you're going to try to advance the state of the art as far as you can in each of the areas with safety and confidence. We have some new aluminum alloys. They are very

similar to our current 2,000 series alloys, as we call them. They are controlled a little more closely at the mill during the melting process, and they're controlled a little more closely in the rolling process, and they actually have a little change in their metallurgical make-up, a little less zinc. Going this way, the new alloys are moving in the direction to have about 10 per cent improvement in strength-weight ratio and about 10 per cent improvement in toughness, simultaneously, thus you can save a little weight on the airplane and in turn save a little fuel or take more people for the same fuel.

We are also going to use some graphite composite material on the airplane. The elevator and the rudder will be advanced composites as will the ailerons, the spoilers, the landing gear doors, the engine cowlings, etc. Graphite composites made up into honeycomb structure is actually about 10-12 per cent lighter than fiberglass honeycomb and about 23 per cent lighter than aluminum honeycomb, and hence again we're going after fuel saving by advancing the state of the art in structure. A graphite composite elevator for a 737 compared to the current aluminum elevator gives about a 60 per cent reduction in the number of fasteners, about a 29 per cent reduction in the over-all weight of the structure. Again, the purpose is to save fuel. When you can save almost 40 per cent fuel per seat with the new airplane and fuel is 38 per cent of your direct cost, you are going to have a substantially lower seat-mile cost and hence assist the airlines in continuing to offer tickets at today's price and make a profit. That is one of the ways the airplane has improved over the previous 50 years, and we hope to continue that in the future. The 777, as compared to the 707, shows these results. The 707 burns 36 per cent more fuel per seat and yet the 777 carries about 205 seats—actually, it will carry up to 220 seats. Thus, a substantial saving in fuel which results in a saving on the bottom line.

Those are the kinds of airplanes you're going to see coming onto the market starting in 1982. They will be

the backbone of the major trunk fleets in the period starting in 1982 through at least about 1990 to 1995.

Another area is the level of technology that's represented by digital calculators, an electronic revolution, and it's going to take place in the airplane. For example, a little micro-computer that you can put in the airplane will do things that we were never able to do before. For example, the cockpit of the 767 as United Airlines has purchased it has a cathode-ray tube for the attitude direction indicator. Another cathode-ray tube is used for the horizontal situation (or compass, to we laymen). A flight management computer on both sides has both alpha-numeric input. A question and warning system for the pilot is a light emitting diode, and behind that is a whole system of triple channel digital computers. The autopilot stabilization system and the inertial reference system are all digital computers.

The flight director on the airplane is designed to give the pilot more command information than he's ever had in the past and yet reduce his workload. For example, he's 510 feet in the air, he's flying 165 knots, and a little dot says he's a little fast for the position that he's in at this particular time. You can have this display in full color. Tells the pilot at a glance where he is and what he's doing. It's quite simple. You can put his weight stations on, you can bring the weather radar up behind in full color, you can show him where his airplane is, and furthermore, you can tell him if he stays in that bank where he will be in 15, 30, and 45 seconds. You give him predictive information that he's never had before. It will not be very long before you can couple in time and get to a four-dimensional air traffic control system.

Why are we going to these kind of things? If you look at the number of units in the cockpit—the number of switches, readouts, and lights, with time these things have all been growing, we have been making the pilot's job more complicated than in the past, so we've taken steps to reduce the number of lights, switches, and indicators in the cockpit and reduce the nuisance warning you give the pilot and

yet give him command information. That's the kind of thing we're doing. The reason for it is that it saves weight, it saves power, and therefore gives the pilot a better environment because it reduces the heat generated in the cockpit. The number of line replaceable units is reduced and the whole cockpit is about one-third less expensive than today's analog systems. So we save the airline management cost of ownership. All of those things are in the new generation of airplanes.

Let us move on and talk about some airplanes for the future. First of all, in the quiet short haul area, we are doing a substantial amount of work, building-block work if you will, to obtain improvements in these airplanes. We are building a lot of composite structures of one kind or another to improve the weight ratio and make them more efficient. We have, of course, built two prototypes for military competition of an airplane that has two 50,000-pound-thrust engines. They blow over the upper surface of the wing. This airplane, which has a fuselage the size of a 747 and will carry a main battle tank that weighs 60 tons can take off in 800 feet. It will stop in 600 feet. We've demonstrated it all over the world.

Another airplane we are considering for the future can receive eight-foot by eight-foot by 40-foot long containers into the tip of the wing. This airplane is quite large. Here is a potential of a massive freight movement airplane. If there comes a time when fuel is very, very expensive you might find that this means of transportation could become the cheapest per pound of fuel, providing the cheapest movement of freight per pound of fuel in the world.

We had an SST project, but it was cancelled by Congress about two years before the fuel crisis. That is probably the best thing that happened from that particular standpoint. The airplane represented a large improvement in productivity over a 747, because it flew twice as many seat-miles per hour as a 747. This airplane had 300 seats, as compared to a Concorde of 100 seats. However, had we maintained the level of technology that we had in 1971,

there was no way the airplane would have been an economic success. Hence, we have to advance in this field substantially if we are going to achieve the productivity and time saving that you can get through an SST. We have 1971 in aerodynamic efficiency, but there are further improvements, and we're going to have to go in that direction even more to have an economical SST.

We are working on the structure. If you want to fly like we believe is proper, about Mach 2.7 (the Concorde flies about Mach 2) we're going to fly here. A graphite polyimide structure offers substantial improvements in structural weight over some of the applications we had a few years ago. We are working in this area as well as with titanium.

We are also working on engines, because the engine is fundamental to making a successful airplane. Boeing has built an engine that acts as a turbofan for take-off, similar to the engine on a 747, then by operating a valve the engine acts like a turbojet during supersonic cruise, which is most efficient in this regime. Boeing has a patent on this engine, and Pratt and Whitney has participated in its development. We have made substantial improvements in fuel burn with this type of engine as compared to the older engines on the airplane.

Coupled together, these improvements have greatly increased the range of our study SST. Today, we can talk about actually doing flights like London to Chicago, flying the distance from the coast to Chicago at high subsonic speed and not make sonic booms over land, only over the water. This kind of improvement is certainly attractive, but I'm not going to tell you that the airplane is around the corner, nor will I tell you that it would compete effectively with a 747, especially with a stretched 747 which will probably come on the market before an advanced SST.

Let's talk now about aircraft fuels. Right now we have excess production capacity. There are as many predictions about this as there are people, but our prediction is that roughly by

the year 2000 we could be at the place where consumption is equal to capacity. That could be a very tough thing for the air transport industry. But when you remember that the 767, for example, gets the equivalent of about 65 miles per gallon per passenger, which is substantially better than automobiles, maybe we have a reason to believe that the jet transport industry should get some special consideration in fuel, because we believe that clear out to the year 2000 the air transport fleet will not be exceeding four per cent of the total fuel used. So, it could be that some allocation procedure is needed to make sure airlines get fuel, but perhaps they won't. If they don't, we ought to be looking at alternate sources and alternate ways of continuing to improve fuel consumption. We're looking at some new types of engines. There is an engine and a new type of quiet propeller that seem to have the potential of the best specific fuel consumption of any power plant we can have. I know that going back to propellers is abhorrent to a lot of us, but if the fuel situation got tough enough, that's a way we could stay in business in the future.

Another way is to look at alternate fuels. We can consider making a synthetic kerosene; however, the plant that you have to build to make it out of coal would probably cost about a billion dollars. You might have to have one close to each airport, and that might be fairly expensive.

You can think of methanol, but the relative mass and relative volume get substantial relative to kerosene, which says you're going to have a storage problem onboard the airplane. You can

think of methane, and methane is pretty good except the minus 162 degrees Centigrade storage, which means you're going to have a vacuum bottle for a fuel tank. That's not impossible. It can be done, but it looks like its price could be two to three times that of kerosene. The one that has the most potential, because it produces 50,000 Btus per pound as compared to 18,000 Btus for kerosene, is hydrogen. Unfortunately, hydrogen has a couple of drawbacks. One is it's very cold, minus 253 degrees Centigrade, or minus 424 degrees Fahrenheit. The other is that today it's very expensive and requires a tremendous amount of energy to make the hydrogen itself. So, some time in the future, you might think about making hydrogen from a nuclear power plant. If you can make hydrogen from a pure nuclear source, it could be the fuel of the future.

Let's talk about energy efficiency. NASA has a ten-year program to spend something like \$600 million to develop energy efficient airplanes. They're working on active controls, alternate fuels, new engine cycles, and laminar flow. Laminar flow is a means of keeping the air that's very close to the surface slippery, so to speak. If you can keep it slippery by sucking on it, you can raise the relative cruise efficiency considerably. You can make about 25-30 per cent reduction in fuel burn per passenger, because the air goes down and you can make the air stay laminar so that skin friction drag stays very low. There's a lot of work going on in that area, and hopefully, we could someday make a transport of it.

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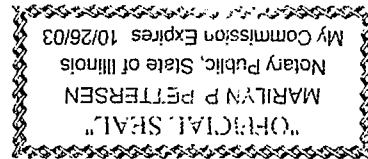
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