

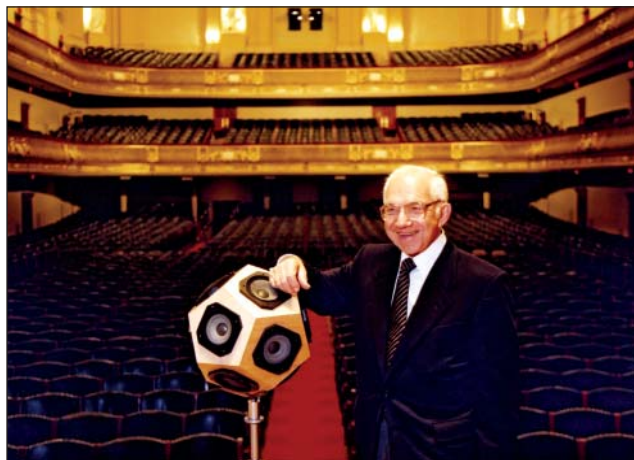
The Noisy Dawn of the Jet Age

Leo L. Beranek, Cambridge, Massachusetts

Dr. Beranek received his Bachelor of Arts degree from Cornell College in 1936 and his Doctor of Science from Harvard University in 1940. During World War II he headed the Electro-Acoustic Laboratory at Harvard. He served as Associate Professor of Communications Engineering at MIT from 1947 to 1958.

He was co-founder of the firm, Bolt Beranek and Newman of Cambridge, MA (started as a partnership in 1948) and was its President for 16 years, 1953 to 1969. During his time there, BBN became the largest acoustical consulting firm in the world. One of his efforts at BBN was putting together the group that invented the ARPANET which was the world's first packet-switched computer network and which operated under government financing from 1969 to 1989. BBN invented e-mail as we know it today. On January 3, 1983, the ARPANET, having been split in two because of its size, was joined by the TCP/IP protocol and became known as the Internet.

The architectural acoustics part of BBN is now a separate company called Acentech, Inc., and the military acoustics and computer activities are in a company called BBN Technologies.



A lifelong interest in music led him to specialize on concert hall and opera house acoustics. Following trips to over 100 of the world's leading halls and interviews of several hundred conductors and music critics, he wrote *Concert Halls and Opera Houses: Music, Acoustics, and Architecture* (Springer, 2004). He has been consultant or coconsultant on many concert halls, including the Tanglewood Music Shed in Western Massachusetts, the Meyerhoff Hall in Baltimore, the Aula Magna in Caracas, a concert hall, opera house and drama theater in the Tokyo Opera City

complex and three other concert halls in Japan.

He has received numerous awards, including the President's National Medal of Science, Gold Medals from the Acoustical Society of America, the Audio Engineering Society and the American Society of Mechanical Engineers, and the Silver Commemorative Medal from the Society of French Language Acousticians. From 1989 to 1994, he served as President of the American Academy of Arts and Sciences, and was honored in 2000 with their "Scholar-Patriot, Distinguished Service Award." He is an Honorary Member of the American Institute of Architects.

The introduction of commercial jet aircraft operations in the United States was marked by controversy. This article reviews the politics and both objective and subjective noise measurements that ultimately permitted successful jet operations at U.S. airports.

In the years between 1953 and 1958, one could travel by air coast-to-coast in a little more than eight hours on propeller-driven aircraft – all cross-country USA airline craft had four engines. American Airlines used the Douglas Aircraft DC-7. United Airlines flew both the DC-7 and the Boeing 377 Stratocruiser. Pan American boasted the DC-7C which flew overseas. TWA relied heavily on the Lockheed Super G Constellation. Air travelers from the West Coast to the East Coast often booked on the airline that scheduled a few-minutes shorter trip. This period was followed, starting in 1958, by the introduction of the Boeing 707, 4-jet-engine, aircraft which made the trip from the West to East Coast in less than 6 hours – today, a little over 5 hours. New York's Idlewild Airport (JFK) was and is a must airport for all the major airline services. The question in the 1956-1958 period, was, "What conditions will the Port of New York Authority place on jet aircraft wishing to use Idlewild?"

The Boeing 707

Perhaps the largest contribution that Bolt Beranek and Newman, Inc. made to the "welfare of mankind" was the company's assistance to the Port of New York Authority (PNYA), now the Port Authority of New York and New Jersey, in the late 1950s in regard to the first flights of jet aircraft from New York International Airport at Idlewild, now JFK, Airport.

The first PNYA/BBN meeting was held November 7, 1956, in the offices of the PNYA, located at 14th street and 8th Avenue

in New York City. In attendance were Executive Director Austin Tobin, Matt Lukens, the Assistant Director of the Port Authority, and John Wiley, Director of Aviation, and one or two others including a lawyer, and me. Tobin opened the discussion about as follows: "Pan American Airways has asked for permission to begin jet aircraft operations from Idlewild airport in November 1958. They will be flying a new jet passenger airplane, called the Boeing 707. We must know how noisy it is. We already have a lawsuit in progress at our Newark airport brought on by residents who are complaining about the noise from today's propeller airplanes. The noise surrounding Idlewild must not be worse than that created by present large propeller-driven airplanes."

Wiley carried on, "Several years ago, we told the airlines that a jet plane must make no more noise than a large propeller airplane on takeoffs and landings. Boeing claims that they have met this requirement and their evidence is that the conventional sound level meter shows the same number of decibels of noise from the jet plane during flyover as from a Super-Constellation propeller airplane. But we are worried, because we are getting reports that the 707 is much noisier. In fact, we have already received threats that if the noise around Idlewild increases, mothers with baby strollers will go on to the runways. We want you to set up a thorough program to investigate this problem so that we know what we're up against and what we should do about it."

I accepted the project for BBN and said the first thing that should be done was for PNYA to arrange for Boeing to make flyovers of the airplane just as they planned to deliver it to Pan American and that we listen to the noise, with Tobin and Wiley present, and simultaneously make measurements and recordings of the noise level.

The Boeing 707, while similar to the KC-135 military jet tanker, was a completely different airplane. It originated from the Dash 80, a prototype designed and built entirely with Boeing funds with no interest or support from commercial or government customers. It had no mufflers. Our measuring equipment consisted of the latest type of microphone and an excellent portable magnetic tape

"The Noisy Dawn of the Jet Age" is taken from a chapter in an upcoming autobiography of Leo Beranek to be published by the MIT Press sometime in 2007. Please visit <http://mitpress.mit.edu> for more information.

recorder. A few weeks after the New York meeting, Boeing flew the prototype 707 over us in Seattle at a height of 1000 ft, similar to the height they would achieve on takeoff above the nearest houses at Idlewild. We were stunned – the noise was terrible, unbelievable. Tobin, Wiley and I concurred that the noise level was completely unacceptable and they so reported to Boeing. The Boeing people appeared devastated. How could the jet plane and the prop plane measure the same on a sound level meter and yet one sounds so much louder than the other?

The explanation for the difference in ‘noisiness’ created by the two types of aircraft is that a propeller airplane has its loudest noise in the low-frequency (low tones) range of 50 to 200 Hz, while that of the jet has its loudest noise in the high-frequency range of 500 to 2000 Hz. The human hearing mechanism is many times more sensitive to high frequency noise than to low frequency noise. The sound level meter ‘hears’ high and low frequencies equally.

After we arrived back in New York, I proposed a procedure. “BBN recently has employed one of the best experimental psychologists in the country, Dr. Karl Kryter. We have one of the finest noise measuring crews with the latest equipment, headed by Mr. Laymon Miller. If you authorize BBN to go ahead, the three of us will be responsible for the whole project and we are prepared to spend almost full time on it until completion.”

The overall proposed program was to determine the annoyance that would be produced by jet aircraft in neighborhoods around Idlewild airport compared to the annoyance caused by present day large propeller aircraft and to determine what level of jet noise would be acceptable. We already knew from the Newark airport lawsuit, the limit of neighbors’ tolerance to the then daily propeller-aircraft operations.

Our investigation started with measurements of the take-off noise of propeller-driven aircraft in residential areas around Idlewild airport. The distances of test locations were determined from the start of take-off roll. We also used cameras with high-quality lenses pointed upward to determine the height of each flight. From the control tower, the PNYA was able to give us the type and ownership of each airplane that flew over, what its gross weight was on takeoff, who was piloting it, and the exact time that it started its takeoff roll.

The noise varied according to make of airplane, who was flying it, its loading and the weather. On a cool day, with partial loading, the plane might fly considerably higher and be less noisy. We found that one airline’s pilots always followed a lower flight-path on take-off than that of other airline’s pilots and the planes of that airline produced the most noise. We obtained a collection of the noise levels under all of these conditions so we knew what the residents off the end of runways were experiencing. The results of the measurements are shown in Figure 1.

The next step was for the PNYA to make arrangements with Boeing to conduct fully-loaded (with lead bars) 707 jet aircraft takeoffs using their Seattle airport runway. At positions representative of Howard Beach neighborhoods at Idlewild Airport, noise level measurements and magnetic tape recordings were made both by their engineers and by BBN personnel. The flight tests took place just after New Year’s Day, 1957, fortunately in the better weather of Seattle.

The tapes were brought back to BBN’s laboratory where they were played back to listeners, subjects, by loudspeakers in a room with negligible reverberation. Initially, Kryter used engineers and secretaries from BBN to make judgments of the relative ‘noisiness’ of a Super-Constellation propeller aircraft and a Boeing prototype 707. The levels were adjusted downward somewhat, so that they were heard as if inside a typical home, in summertime, with open windows. Three studies were made. In the earlier one, the subjects were presented first the Super-Constellation (S-C) noise at a typical noise level, and next the jet noise. In the later studies, either the S-C or the jet noise might be first. They were asked to adjust the level of the jet noise, using a knob, until it sounded equally noisy. They were instructed “After the adjustment, you would just as soon have the Super-Constellation noise in your home periodically 20 to 30 times during the day and night as the 707 jet noise, that is to say, the Super-Constellation noise would be no more and no

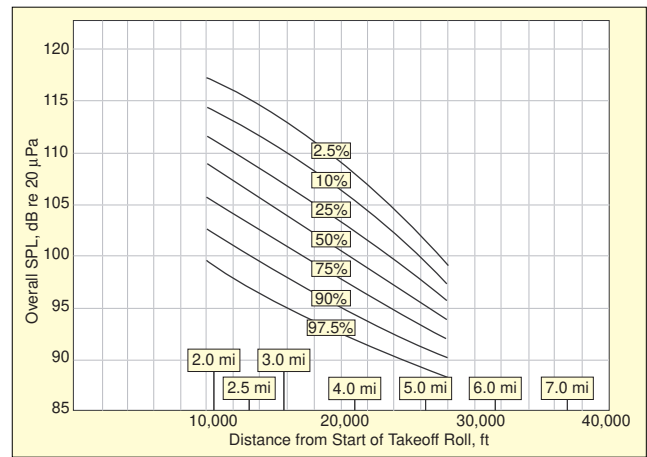


Figure 1. New York Idlewild (JFK) airport typical outdoor sound pressure levels of DC-7 & 7B, DC-7C, 1049 & 1649 Super Constellation and DC-6B aircraft (7 kt headwind, 59° F). Each curve gives the percentage of propeller aircraft flights for which the peak overall sound pressure level equaled or exceeded the amount shown on the ordinate. The nearest residence was in Howard Beach, 2.5 miles distant from the start of take-off roll. For the 25% curve, the measured overall peak noise level at 2.5 miles from start of the take-off roll was 109 dB or more. Headwind & temperature corrections – for 0 kt headwind, add 2 dB; for 15 kt headwind, subtract 2 dB; for 100° F, add 3 dB.

less disturbing to you in your home than the 707 noise.” These tests with modifications were performed at two other sites, using different crews.

When measured with the standard sound level meter, the judgments showed that the noise levels of the original 707 jet, (fully loaded, flying at the same altitude over a position equal to the nearest homes off the end of the runway at Idlewild) had to be reduced by more than 15 decibels when measured by the sound level meter (an enormous amount, equivalent to the difference between thirty 707 jet engines running simultaneously and one jet engine alone) to be no more annoying than the noise levels of a Super-Constellation propeller-driven aircraft.

The Port Authority transmitted this information to Boeing and informed them that the 707 was not acceptable for operation from Idlewild. Several from Boeing came to BBN and made the same comparisons as described above, said they understood the method, but did not comment on whether they believed the results. Boeing then went about developing the best mufflers that they could conceive of for attachment to the exhausts of the prototype 707 engines.

In the meantime, Kryter was developing a means for calculating the ‘noisiness’ of aircraft (whether jet or propeller-driven) given the levels taken from the tape recordings. That is to say, he wanted to assign calculated numbers to the jet noise and to the S-C noise such that when the two calculated numbers were the same, the two plane’s noise would sound equally ‘noisy.’ He adopted, and then modified, a procedure that is attributable to S. S. Stevens for calculating the ‘loudness’ of all types of noise, which is too detailed to present here. In brief, the method takes into account the fact that the ear is less sensitive to low frequency sounds than to high frequency sounds. The calculated noisiness quantity was named the “Perceived Noise Level” in Decibels, or, for short, PNdB. Further subjective tests verified that when the S-C and jet aircraft were judged by listeners to be equally ‘noisy’ (annoying), they would have the same perceived noise levels in PNdB.

The extensive propeller-aircraft noise data recorded at Idlewild airport by Laymon Miller’s group off the end of the runways could now be converted to PNdB. The measurements included six types of airplanes, and were the results of months of measurement (see Figure 2). The location of the nearest residence in the Howard Beach community was about 2.5 miles from the start of takeoff roll. About 25 percent of the take-offs measured there exceeded 113 PNdB, for the atmosphere condition of 7 knots headwind and 59° Fahrenheit.

Austin Tobin did not at first speak of aircraft noise in PNdB. In a letter (available to the media) of July 23, 1958, he mentioned only

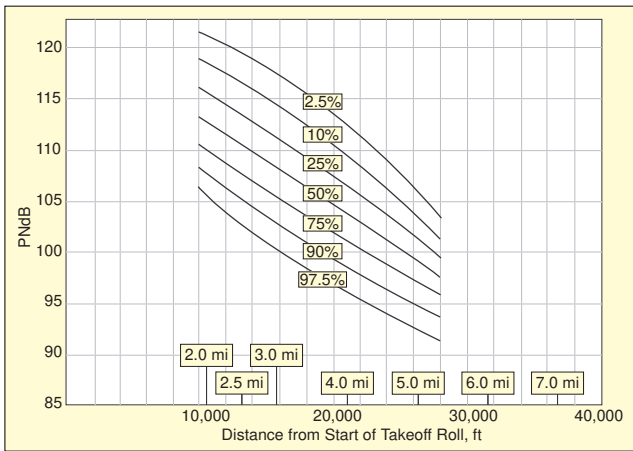


Figure 2. New York Idlewild (JFK) airport typical outdoor Perceived Noise Levels of DC-7 & 7B, DC-7C, 1049 & 1649 Super Constellation and DC-6B aircraft (7 kt headwind, 59° F). Each curve gives the percentage of propeller aircraft flights for which the peak Perceived Noise Level (PNdB) (calculated from the data of Figure 1) equaled or exceeded the amount shown on the ordinate. For the 25% curve the peak Perceived Noise Level at 2.5 miles from start of take-off roll was 113 PNdB or more. Headwind & temperature corrections – for 0 kt headwind, add 2 PNdB; for 15 kt headwind, subtract 2 PNdB; for 100° F, add 3 PNdB.

“Bolt Beranek and Newman’s factor of subjective equivalence to the sound of a piston engine plane.” *Aviation Week*, in an article of September 8, 1958, said that “the Port Authority will not publicly evaluate its noise test data.” Tobin soon after quoted one example of equivalent ‘noisiness,’ when measured by a standard sound level meter, as being 102 dB for the Boeing plane and about 117 dB for a piston engine plane, a difference of 15 decibels.

Then came a fortuitous event that, in fact, reduced jet takeoff noise in communities significantly. The airline Air France notified the PNYA that they wanted to fly between Paris and Idlewild using their new Caravelle jet airplane. Austin Tobin’s reply was, “We’ll consider it. In addition to various safety requirements, you must meet the requirement that the plane not make more noise over communities around Idlewild than present-day, large, propeller-driven aircraft.” The French invited the Port Authority to send a crew to Orly airport outside Paris to make Caravelle noise measurements.

Laymon Miller, George Kamperman and I conducted the noise tests March 19-20, 1957, with the help of French engineers. Measuring stations were set up at five positions; the closest distance pertinent to Idlewild was at 2.5 miles from start of take-off roll. Sixteen take-offs were measured. An important new flight concept was introduced, that after becoming airborne on takeoff the airplane would climb at a steep ratio of 1:5 and engine rpm of 8000 (10,000 lb thrust, each Rolls-Royce Avon RA26 engine) until it had reached an altitude of 1200 ft, (about 10,000 ft from start of take-off roll). Then it would cut back power to 7100 rpm and climb at a ratio of 1:17, passing over the 2.5 mile point at an altitude of about 1300 ft. The recorded data were then analyzed according to the perceived noise level method, yielding the level in PNdB. With this steep climb and power cutback procedure, the ‘perceived noisiness’ of the higher frequency noise of the Caravelle and the lower frequency noise of the prop planes were nearly the same. Hence, BBN stated to PNYA that “It is our conclusion that the total Caravelle noise output is approximately comparable as far as listeners are concerned to that of large present-day four-engine propeller-driven airliners.” On May 25, 1957, the Caravelle was given permission to use the airport regularly with that take-off procedure.

In November 1957, Laymon Miller and Bob Hoover measured the noise characteristics of the British Comet 4 during takeoff in England. PNYA personnel were present. The Comet 4 used the same novel takeoff procedures as did the Caravelle. They did not intend to start trans-Atlantic flights immediately, so the PNYA said that the noise tests, while acceptable, would have to be repeated at Idlewild when they were ready.

When Boeing had equipped the prototype 707 with their best muffler design, the Port Authority and BBN were invited back to



Figure 3. (Left to right) Austin Tobin, John Wiley and Leo Beranek at the measurement site in Seattle, WA, April 22, 1958, 2.5 miles from start of take-off roll. Shown is the Ampex 601 reel-to-reel precision tape recorder – then one of the best portable tape recorders available.

make noise measurements. The tests were conducted between April 21 and 24, 1958, in Seattle. The aircraft was fully loaded (with lead bars). The pilots used normal take-off procedures. Five measuring stations were set up at points between 2.5 and 5 miles after beginning of takeoff roll. Three stations were manned by BBN personnel and three (one overlap) were manned by Boeing engineers. Prior to this session, great pains were taken to be sure that all microphones were properly calibrated. Everything was recorded. Austin Tobin and John Wiley visited the station manned by Beranek (see Figure 3). The microphone and camera are just outside the picture. The result was that the equivalent noise levels in PNdB were significantly above those for large propeller-driven airplanes. The 707 mufflers alone were not satisfactory and Boeing was so informed.

During the month of May, 1958, PNYA personnel spent many days at BBN, going over the psychoacoustic data with Kryter, taking the tests themselves, and reviewing all the noise measurements made by BBN around Idlewild and at Boeing. At their request, Kryter made a demonstration tape, showing the difference in annoyance (as heard indoors with open windows) by a 707 jet with mufflers and by a Super-Constellation, both following standard take-off profiles. This tape demonstrated clearly that the difference in ‘noisiness’ was still substantial.

Between June 7 and June 13, Austin Tobin, John Wiley, Matt Lukens, and another PNYA person took Beranek and Kryter with them to visit the heads of airports in Germany, Amsterdam and Paris. BBN carried along loudspeakers and the demonstration tape. These tapes caused the airport operators to worry for the first time about the upcoming jet invasion. When word of this trip and the demonstrations reached Boeing and Pan American, they were outraged. They had hoped to get other airports to accept higher noise levels, so they could put pressure on the PNYA to be more lenient.

In desperation, Boeing convened a meeting in Seattle, on July 15, 1958, to which all airport heads, airline heads, Douglas Aircraft Company, and government aviation regulators were invited. Their intent was to show that BBN did not have a solid base on which to recommend to the PNYA what constituted equality of noisiness between propeller-driven and jet aircraft. I stood almost all day with only a break for lunch, at a blackboard in an auditorium before about 150 persons. I described how Kryter had arrived at the 15 dB difference between levels of the jet and propeller aircraft when they sound equally noisy. I showed them how much data we had on propeller aircraft operations at Idlewild. I emphasized that the final numbers (decibels) selected by the PNYA would be equal to some percentage level of the current operations at Idlewild, as measured in Howard Beach, 2.5 miles from start of take-off roll. There is no evidence that anything came of this meeting. Afterwards, Tobin wrote in a letter (released to the media) dated July



Figure 4. (Left to right) Laymon Miller, Leo Beranek and Weldon Clark of BBN in Seattle, Washington, July 18, 1958, with a Boeing 707 in background.

23rd, “Throughout the day the Boeing engineers questioned Dr. Beranek on the validity of this subjective differential of 15 decibels between hearers’ response to a jet plane as compared to a piston engine plane. In our opinion, Dr. Beranek defended this theory and his figures very effectively, though . . . [he admitted] . . . future experience might indicate that the differential is several decibels lower than his present estimate of 15 decibels.”

At that moment, the Boeing engineers could see no solution to the 707 noise problem. They did not want to put on heavier mufflers. The present ones were adding considerable weight. Heavier ones would mean either (1) fewer passengers, or (2) shorter distances owing to less weight allowed for fuel, or (3) taking off at Idlewild with partial fuelling, and landing in Boston for full fuelling. They were then told about the French and British take-off procedures, which they said they would take under consideration.

Boeing did do further research on mufflers, made some improvements, and invited the Port Authority and BBN to return to Seattle to make noise measurements of the fully loaded 707 on the morning of July 18, 1958 (see Figure 4). This time they used the flight profile initiated by the Caravelle and Comet 4 planes during take-off, i.e., climbing steeply and cutting back power to reduced thrust at 1100 ft altitude. Even using this procedure, the 707’s measured sound level was still higher than stipulated by the Port of New York Authority. Austin Tobin then declared that to meet PNYA requirements, the airplanes would have to turn away from the residential areas as soon as they reached their leveling-off position. Pan American Airlines strongly objected to both a steep climb and, after leveling off, a turn, saying that they believed such a procedure was not safe. They then declared that the pilots would have to decide, not the Port Authority, because the Federal aviation rules state that the pilot is responsible for an airplane’s safety.

On July 23, 1958, Tobin addressed a letter to Western European airport operators in which he wrote that, “There is serious doubt as to whether the fully loaded 707s (coast-to-coast for American or trans-Atlantic for Pan American) can operate from New York International except under very severe operating limitations.” After the transmittal of this letter, both London and Paris took precautions against uncontrolled jet operations at their airports. This letter caused dismay among the airlines and Boeing. In a related paragraph, *Aviation Week* of September 8, 1958 wrote: “Port Authority’s reaffirmation of its original 1951 ban of all jets not satisfying its noise level requirements served notice to manufacturers that they must make efforts to suppress jet aircraft noise. Some credit certainly must go to the agency for the fact that suppressors have been designed and installed.”

On July 25, 1958, Boeing decided to make their own judgment tests on the relative noisiness of jet and propeller-driven aircraft. Kryter and I were invited as observers, with the request that afterward we would not disclose the tests to the PNYA or anybody

outside of Boeing. We agreed not to disclose the results of those tests until the PNdB was broadly accepted. The tests involved the same type of propeller and un-muffled jet airliners that were investigated in Kryter’s laboratory studies. Boeing had access to a house in a Seattle suburb over which the flights took place. In the house, with open windows, they located about 20 Boeing employees with pencils and pads in the living room. Perhaps, Boeing thought that people loyal to Boeing might not be as critical as the subjects were in Kryter’s tests. Each person was asked to indicate independently the relative loudness of each overflight on a scale from 1 to 10. Engineers outside measured the noise levels. The two types of airliners were flown over at various heights and under various power conditions. After the day’s events were concluded, we were invited to sit with them while they analyzed the data. When the results were tabulated, the engineer in charge turned to the Boeing management personnel and said, “BBN is right, its 15 dB”. They never disclosed this finding to the public.

On August 11 and 12, 1958, BBN re-measured the noise characteristics of the British Comet 4 during takeoff at Idlewild. Austin Tobin, John Wiley, Laymon Miller and I were present when we presented the data (see Figure 5). It was agreed that if the aircraft (with Rolls-Royce Avon RA-29 engines, equipped with noise suppressors), were to climb at maximum takeoff thrust (8000 rpm) to a height of 1200 feet and then cutback to 7350 rpm, the airplane would meet the comparative noise limit over Howard Beach houses.

Austin Tobin now had to make a judgment, which happened sometime during August of 1958. To convince himself of the noise level that the PNYA should proclaim as the maximum that jet aircraft could inflict on neighborhoods near Idlewild, he went to a home near the end of the runway in Howard Beach and sat on the porch. Several of us from BBN were with him to make measurements. Whenever a propeller plane flew over the house after takeoff, we would advise him of the maximum PNdB that was measured. He would then consult our chart of Figure 2. After a time, he came to a conclusion. He stated that a person owning a house near the airport should be able to sit on his porch and enjoy life. He was convinced that if the noise exceeded 112 PNdB, that quality of life was not possible. Thus 112 PNdB became his decision and it remained his decision forever after.

The 707 and Comet 4 Reports

Then came a disturbing rumor which appeared to PNYA staff to mean that Pan American World Airways was planning to bring suit against PNYA and BBN jointly saying that there was insufficient basis for the 112 PNdB noise limit. It was intimated that this suit would be filed on the day that PNYA had agreed to state officially their noise requirements for operations of the 707 out of Idlewild. It was also intimated that Austin Tobin had paid (bought off) BBN to confirm his desire that the aircraft be substantially quieter than Boeing had at first planned. As the basis for this thinking, Pan American had inquired into the PNYA’s public record files and found that, although fees had been paid, not a single report on 707 noise could be found in their files written by BBN for PNYA. That was true.

The PNYA had requested at our first meeting that BBN present all of its data to them orally at meetings (generally held in New York). The reason was that all reports received by PNYA were open to public inspection. A neighborhood lawsuit against PNYA was in process in Newark and the plaintiffs would have loved detailed measurements of aircraft noise to bolster their case. Also, there were many communities around Idlewild who were holding meetings in anticipation of the loud noise of projected jet aircraft operations. PNYA did not want our early measurements and evaluations of jet noise (without mufflers and flight procedures) to get into the hands of the general public. The notes they took at our meetings were protected by executive privilege.

In light of that rumor, Tobin asked BBN to assemble all data as soon as possible and have it ready for inclusion in a detailed report. He added, “When you have adequately organized the data, and I hope fairly soon, we will call a meeting of all our senior staff, including our lawyers, and have you make a presentation of your

material. Then we will collectively make up our minds as to how far we want to go in pressing our noise requirements for the 707 operating at Idlewild.”

The meeting promised by Tobin took place the last week of August 1958. Afraid that it would become known to the media, about 25 persons, including Kryter and me, were flown by several helicopters from the top of the PNYA building in mid-Manhattan to the home of John Wiley, the Director of Aviation, in Connecticut. We landed, noisily, in his back yard without permission from the neighbors, the FAA, or anyone.

The meeting ran from 4 p.m. to 8 p.m. The two of us presented the noise measurements on propeller and 707 aircraft and the psychoacoustic data that led to the creation of the PNdB method for rating the ‘noisiness’ of aircraft noise. Tobin told of his 112 PNdB decision. We were questioned unmercifully by the PNYA staff and lawyers. After we finished there was some discussion among them. The PNYA personnel then voted unanimously to adopt Tobin’s 112 PNdB limit for take-offs at Idlewild. It was further agreed that BBN should proceed with all dispatch to produce a written report.

The deadline for this report was October 4th, 1958, the date that was previously stated as when the PNYA would inform Pan American of all regulations that would be required for 707 operations at Idlewild. That gave us only a month to produce a mammoth report. Worse, there had to be two reports, the other on the British Comet 4, to avoid criticism that PNYA was treating the British different from the Americans.

Port Authority called in about 20 PNYA police officers, each in full regalia with bouncing pistols and handcuffs on their belts.

The data and graphs were all assembled by September 11th. We were instructed that the report had to be written so that the people living around Idlewild could understand it as well as the PNYA people. Karl Kryter, Laymon Miller and I divided the task and wrote as well as we could under pressure.

As we completed a section of the report, I would fly with it to New York and sit down with Tobin, Lukens, Wiley, and their chief legal counsel to polish the wording so that it was understandable by laymen. No attempt was made by anyone at PNYA to change any of our conclusions or to leave out any data.

Because there were no Xerox machines in those days, all of the final text had to be typed on mimeograph stencils. A stencil was a thin blue sheet of special composition attached to a heavy paper backing. The stencil and backing were placed in a manual typewriter and the type would cut the shape of a letter or number into the stencil. Then, the backing sheet was removed and the blue sheet placed on a perforated drum having a diameter of about 10 inches and ink was poured inside the drum. As the drum rotated, it pulled a white sheet of paper through and the ink passed through the stencil to create a duplicate copy. The drawings also had to be put on these mimeograph sheets. BBN draftspersons came to New York from Cambridge to do this; there were no computers in those days. One thousand copies of each of our two reports were required one for the 707 and the other for the Comet 4. The Port Authority said they had more mimeograph machines than any other organization in New York, so the printing job could be done in-house.

Two reports were produced, each containing about 170 pages. The title of the main report was, “Studies of Noise Characteristics of Boeing 707-120 Jet Airliner and of Large Conventional Propeller-Driven Airplanes,” Prepared by Bolt Beranek and Newman (address), October 1958 for the Port of New York Authority, 111 Eighth Avenue, New York 11, NY. The other report had the same title, except the name of the Comet 4 Jet Airliner was substituted.

The afternoon of the day before the reports had to be issued had now arrived. By about 4 p.m., all mimeographing had been completed. In a very large room, four squares, each about 20 ft per side and made up of 3-ft wide tables were laid out. The individual pages for each report were laid out on these squares. Ten pages took nearly 10 ft, so that 170 pages required 160 ft of tables, i.e., two



Figure 5. Group in New York discussing the noise measurements of the British Comet 4 jet aircraft, August 15, 1958. Laymon Miller is seated at the far left. Beranek wears glasses. John Wiley and Austin Tobin are standing second and third from the left, respectively. The others are representatives from British Airways and Port of New York Authority.

such squares for each of the two reports. Each page was in a pile, 2 reams, 1000 sheets high. There were no collating machines and because time was so limited the Port Authority called in about 20 PNYA police officers, each in full regalia with bouncing pistols and handcuffs on their belts. Each officer was to circle two squares and come up with a 170 page report which was then placed in a box. For one report, this required 1000 man-circles around two squares, about 50 for each officer, 100 for each officer for the two reports. Before midnight all 2000 reports were in boxes. With wailing sirens, the reports were delivered by PNYA police cars to the binders for covers and stapling. By 6:00 a.m., the reports were bound. A fleet of about 100 cabs received instructions for the places the reports had to be delivered. By 9:00 a.m. the reports were in the hands of the essential parties. **No lawsuit resulted.**

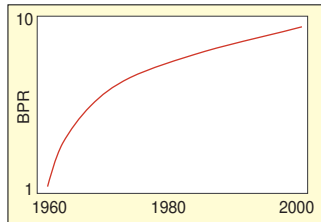
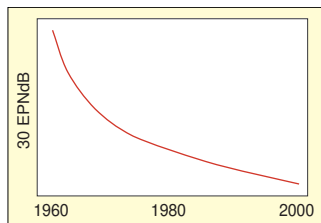
The *Wall Street Journal* on October 4 wrote (statement slightly shortened), “The New York Port Authority gave permission on October 3 for jet flights at Idlewild. The restrictions are: a) in good weather use runways over water. b) in bad weather make turns to the right as soon as possible. c) If the flight must go over communities, do so at 1200 ft, with engines throttled back, accompanied by turns. d) All take-offs between 10 p.m. and 7 a.m. must be over water. An exhaustive 170 page booklet was published by Bolt Beranek and Newman. The airlines argued that the PNYA does not have jurisdiction over aircraft operations. The Civil Aeronautics Authority has jurisdiction, but it stated will not police flights at a non-government airport.” *The New York Times* on October 4th, reported the same information and added, “Pan American says that if such operating conditions were to become permanent restrictions at Idlewild and other airports throughout the U.S. and the world, they would impose a severe, unjustifiable and, therefore, discriminatory handicap on all aircraft.”

Subsequent Happenings

Later in October, the *Times* wrote that between October 4 and 13, five of 25 trial jet take-offs at Idlewild by BOAC and Pan American had successfully followed the climb and turn rules. John Wiley of PNYA sent the pilots letters of congratulation. The paper also wrote that an agency spokesman said that sound level meters and cameras had been placed in nearby communities to record take-offs. One microphone, camera and recording equipment was supplied by BBN, located 2.5 miles from start of takeoff roll, at the edge of Howard Beach.

Starting late afternoon of October 26, 1958, a Pan Am Boeing 707-120, with a full complement of passengers, flew from New York City to London from Idlewild International Airport. Starting later, a British Overseas Airways Comet 4, fully loaded, flew from London to New York City, both with PNYA approval, thus opening the U.S. entry into international jet travel. There was no

Advances in Jet Noise Control Technology



Each new generation of passenger jets has been significantly quieter than previous models. In some circumstances, today's airplanes are 30 EPNdB (Effective Perceived Noise in dB) quieter than early jets such as the Boeing 707. For example, the Boeing 747 is 20 EPNdB quieter than the Boeing 707 and the 777 is 10 EPNdB quieter than the 747. This is primarily due to the increase in bypass ratio, which is the amount of air being pushed through the fan of the engine versus what is going through the turbo-jet. This reduces the velocity of the jet, and since noise goes as the 8th power of the velocity – it significantly reduces the noise the jet produces. As the bypass ratio increases, the noise created by the other sources goes up, making technology developments to reduce other sources of noise increasingly important. Boeing continues this development activity through its Quiet Technology Demonstrator (QTD) activities.

community reaction to the noise.

On April 30, 1959, *The New York Times* wrote that the PNYA had issued a new rule that noise over communities from jet aircraft must not exceed 112 PNdB as measured outdoors on the ground. This is in addition to previous rules. Achievement of this level requires 1200 ft altitude and 8000 lbs thrust for each engine. *Aviation Week* wrote that under the original jet noise rules, the PNYA specified certain actual procedures that the airlines were to follow after take-off, including power settings and turns. With the 112 PNdB rule, the method of flying over populated areas was now up to the carrier.

On August 26, 1960, the Port Authority reported that compliance with the anti-noise rules at Idlewild was better than 92% in July 1960 as against only 70% in July 1959. They said that there had been a steady drop in percentage of jet flights violating PNYA take-off rules since November 1958. The report repeated, take-offs over communities are limited to the hours of 7 a.m. to 10 p.m. and night take-offs are restricted to two over-water runways.

The airlines fought the regulations and the use of perceived noise decibels for nearly a decade. BBN, and particularly me, were openly hated by the industry. The FAA made a second study around Idlewild (JFK) airport using personnel from NASA. Their results confirmed BBN's measurements. BBN made measurements in the neighborhoods around Idlewild in late 1965 that showed that because the PNYA was monitoring noise at only one location, the airlines cut their power as they flew over that measuring point and then reverted to full power immediately afterward. The NASA report confirmed that fact. To counteract this, PNYA added measurement sites.

Perceived Noise Level Approved Internationally


In November 1966, a meeting of airport operators, airlines, airplane manufacturers, and government regulators was convened in Lancaster House in London. It was called "International Conference on Aircraft Noise." The FAA issued the invitations. BBN personnel were not invited and when queried, the FAA said that

they did not want Beranek there. I went to the meeting location, and gained admission to the meeting by simply walking in. Many attendees spoke, including me, about the noise problem and the use of PNdB to evaluate it. A professor from Copenhagen, Denmark, Fritz Ingerslev, made a motion that PNdB be officially adopted for measurement of aircraft noise. The motion would not have passed, if it had not been for Frank Kolk, a vice president of American Airlines, who urged its passage because it was the best known measure, was the result of careful and substantiated research, and because adopting it would stop controversy. **The motion carried.**

Closing Remarks

I claim that BBN made the jet age immediately feasible, preventing the advent of women with baby strollers on the runways to stop the jets. That initial noise regulation, enforced by the PNYA, led to the rapid development of high bypass ratio jet engines and a decade later to the promulgation of the FAR 36 regulations by the FAA which covered the design of new jet aircraft and of hush-kits for existing jet aircraft.

On September 26, 2006, Boeing Aircraft jointly with General Electric proudly announced that the new Boeing 747-8 aircraft had measured noise levels that were 10 decibels below those of the 747-400 and 10 decibels below International Civil Aviation Organization's (ICAO) standards. They said, "These results demonstrate our effort to design the 747-8 with the community and environment in mind."

The Port Authority's vigilance and Federal regulations resulted in the ICAO standards. Credit must be given to Austin Tobin for financing the study, accepting the results, and setting and enforcing limits of 'noisiness' in the face of intense industry and government objections. Of course, great credit must go to the engine and aircraft manufacturers for their continued diligent work in arriving at quieter engine designs. 

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