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THE AGE OF THE SUPersonic JET TRANSPORT: ITS ENVIRONMENTAL AND LEGAL IMPACT

By JOHN R. MONTGOMERY†

I. INTRODUCTION

WHEN supersonic jet air transports become fully operational in the mid-1970s they will represent the culmination of a tremendous technological effort both by government and industry. As with all advances, however, the benefits of the SST will not be enjoyed without serious drawbacks. There will perhaps be unprecedented noise around jetports, and millions of people will be exposed to sonic booms which will be generated continually as long as the SST is traveling faster than the speed of sound.

When a supersonic jet transport was first proposed in 1959 by the International Air Transport Association and when design targets were promulgated in 1962, the problems of airport noise and sonic booms received scant consideration. The volume of air traffic projected for the immediate future was sufficient of itself to make a national development effort attractive for those countries with sufficient technical and financial resources. It has been predicted that by 1985 three million passengers daily will travel by air for an average distance of one thousand miles, and at least fifty percent will be on supersonic aircraft.

Another significant factor influencing interested governments, and duly noted by the air transportation industry, is the possible adverse effect on balance of payments for any country who refuses to compete. Other more intangible justifications, such as loss of world technological leadership, a "brain drain" from the aerospace industry and effects on military aviation technology have been raised and no doubt made their marks on those responsible for a national commitment to develop an SST.

These arguments were indeed persuasive both in the United States and abroad. American competition dates from President Kennedy's decision to proceed with a federally financed SST development program, announced June 5, 1963, which has been reaffirmed by successive presidents. Efforts

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1 The supersonic transport is commonly referred to as the SST.

2 For a short historical survey of the SST development, see Problems of Supersonic Transport, 222 THE ENGINEER 408 (1966). The article points out the interesting fact that the British have never been overly concerned with sonic booms since no aircraft will be supersonic over the British Isles regardless of whether land overflights are allowed.

3 Satre, Supersonic Air Transport—Present and Future, 73 THE AERO. J. 665 (1969). Even assuming no land overflights, greater than 50% of passenger miles will be on exclusively overwater routes, entirely sufficient to economically justify the SST program.


5 Id. at 51.

6 For details of the American SST financing scheme see, Watkins, Airline Funding Aid Called
are also quite far advanced in the Soviet Union and in Europe with the joint Anglo-French Concorde. Perhaps in five years, and certainly within a decade, worldwide commercial SST operation will be a reality which will confront every nation and its people. If such an aircraft is allowed to freely operate over land as well as water, hundreds of millions of persons will be confronted directly, and perhaps many times daily, with one of man's most sophisticated technical achievements through its calling card, the sonic boom. The technical problems involved with designing and flying the SST may only be matched by the complex tangle of legal problems it will leave in its wake. It is the purpose of this paper to consider and hopefully place in perspective the technical aspects of the SST and then to evaluate the ability of present law, international and American, to cope with the problems which inevitably will occur if land overflights are allowed.

II. SST Technology: The Achievement and the Drawbacks

A call by a national leader to develop a supersonic aircraft capable of commercial operation at 1800 miles per hour and at an altitude of 70,000 feet is not translatable into a finished product without concentrated effort. As a starting point, two conflicting engineering considerations must be balanced. As an aircraft travels faster, fuel consumption increases dramatically, while friction and drag produce a considerable rise in surface airframe temperatures. These negative factors are balanced by increased engine efficiency and decreased flying time between cities as speed increases. All factors balance at about Mach 2.0 and above that velocity economic operation is feasible.

Because of the tremendous friction produced at the 1800 mile per hour cruising velocity of the American SST, the aircraft will have to withstand skin temperatures up to 500 Fahrenheit. This will require extensive use of titanium alloys in structural members and engines, which also will operate at extremely high temperatures. Special attention must as a result be given to cooling the engines and protecting their parts from heat corrosion.

Since the SST is to be a commercial aircraft, passenger safety will have to be at least equivalent to current subsonic jets. This achievement has been technologically achieved through the development of advanced materials and manufacturing techniques. Titanium alloys, in particular, have played a crucial role in the design of SSTs. Extensive use of these materials has required sophisticated metal forming techniques. Probably 200,000 pounds of titanium will be used in each aircraft.
proven to be a particularly sophisticated engineering problem involving the critical factors of temperature, pressure, and radiation. Because outside pressure at the cruising altitude of 70,000 feet is so low that blood would boil on exposure,\textsuperscript{13} cabin rupture could be fatal and adequate pressurization is of much more concern than with subsonic aircraft. Temperature control is equally vital and involves three variables: ambient outside air temperature at cruising altitude is minus 100\(^\circ\) Fahrenheit, skin temperature of the aircraft itself will be about 500\(^\circ\) Fahrenheit, due to friction and cabin temperature must remain at 70\(^\circ\) Fahrenheit. To provide the necessary cooling and to conserve weight, an extremely critical variable for economic operation, the air conditioning and engine cooling systems will be interrelated, both using the fuel supply as a type of heat exchanger.\textsuperscript{13} The other safety consideration, radiation exposure, is not as critical as either temperature or pressure. Though cosmic radiation exposure will be minimal it is recognized that sudden sun spot activity producing increased solar radiation might force flights to a lower altitude.\textsuperscript{14}

Another problem which must be considered is the effect the SST will have on air traffic operations since a traffic "mix" of supersonic and subsonic aircraft will exist. The Federal Aviation Agency has conducted some preliminary studies which indicate that supersonic aircraft can be accommodated at present airports with a minimum of disruption in normal traffic patterns. Thus, no preferential treatment will be necessary.\textsuperscript{15} However, changes will be needed in air traffic control procedures to more accurately monitor turn and acceleration maneuvers in order to minimize sonic boom. Simulator studies have predicted that, without tight guidance, an SST pilot will be unable to control altitude and acceleration closely enough to stay within acceptable limits during the critical climb-out maneuver to reach supersonic cruise conditions.\textsuperscript{16} Complete ground control during the entire flight may also be needed due to the speed at which the SST will travel.

Accurate information and guidance immediately after take-off may

\textsuperscript{13} Stapp, Assuring Passenger Safety in Supersonic Flight, 74 SAE J. 69 (1966). Consciousness lasts about 15 seconds at 47,000 feet or higher without protection. At 64,000 feet body fluids evaporate at room temperature without adequate pressurization.

\textsuperscript{14} Wassemoor & Levin, Life Support For an SST, 48 SP./AERO. 48 (1967). SST cooling requirements, both for engines and cabin, are among the most critical design variables. To a significant degree speed of an SST is limited by the cooling capacity of its fuel and not engine thrust. The key factor is designated as the "equivalence ratio" and greater than 1.0 implies that fuel needed for cooling is greater than the amount needed for propulsion. This occurs at about Mach 3.0 for present fuels and is a major reason why Mach 2.7 was chosen as a design target for the American SST. It is likely that later generations of the SST may utilize precooling of fuel to increase speed without drastic design changes or by using colder fuels such as liquid methane (\textdegree{-}259\(^\circ\) F) or even liquid hydrogen (\textdegree{-}423\(^\circ\) F). Here, velocities would go from the supersonic to the hypersonic range and the SST would evolve into a passenger space ship.

\textsuperscript{15} For a further discussion of the radiation problem see Dyment, Airlines and Airports Face SST Challenge, 76 SAE J. 60 (1968); The Supersonic Transport Aircraft, 224 THE ENGINEER 766 (1967). The average radiation dosage an SST will receive in an 8 hour flight at 70,000 feet is not considered high enough to warrant use of shielding.

prove necessary for another reason. It is known that an SST will be extremely sensitive to temperature change, so much so that an unexpected variation of about $10^\circ$ Centigrade would force consumption of an extra 4400 pounds of fuel during the initial acceleration period; this is the equivalent of twenty passengers and their baggage. Thus, it seems likely that the advent of the SST will necessitate significant changes in the present air traffic control system, primarily in the area of more sophisticated guidance and data gathering equipment.

From this cursory discussion, it is evident that formidable technical problems have been overcome in order that a supersonic jet transport can fly in the 1970s. Impressive though the engineering feat is, the SST will be at best a mixed blessing and to many no blessing at all. For in the SST, with all its benefits, exists the inherent potential to be the greatest environmental disrupter of any of man's enterprises. An examination of these shortcomings is necessary in order to gain a balanced perspective and to provide the background needed to understand the legal problems which this technical achievement will generate.

III. THE GROUND NOISE PROBLEM

The supersonic jet transport will produce more noise during take-off and landing operations than current subsonic jets simply because of the size of its engines. They will develop about 60,000 pounds of thrust versus 20,000 pounds for current aircraft. Consequently, the level of sound produced will be greater. "Sound" basically is energy in a form detectable by acoustic devices and by the ear. "Noise" may be defined simply as unwanted sound, and human noise awareness is a combination of physical, physiological and psychological factors. Sound is produced by physical motion in a transmission medium such as air or water, and a portion of the motion produces alternating compressions and rarefactions in the medium. The number of these oscillations per unit of time is referred to as the sound frequency, expressed in cycles per second.

While sound may be expressed in terms of power (in watts), its intensity is of more interest. Sound intensity is usually expressed in logarithmic units related to a certain reference intensity which is the medium level audible to an average person. The basic unit of sound is the decibel, which represents the minimum difference in intensity the average human ear can detect and relates the physical loudness of sound to its physiological effect on a person. The "perceived noise" decibel is a different

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19 Intensity is average power per unit area.
21 *Id.*
22 The decibel is commonly abbreviated as db; the "perceived noise" decibel is referred to as PNdb.
unit of measure which accounts for the ability of sound to annoy and is a function both of frequency and energy distribution.\(^9\)

In jet aircraft operation the only significant source of noise is the engine which generates sound from its exhaust and compressor. Exhaust noise is produced by pressure differential between the high velocity jet exhaust gases and the surrounding atmosphere. Due to gaseous mixing, high frequency sound is produced close to the exhaust nozzle, with low frequency sound generated farther back in the exhaust wake.\(^6\) The level of noise produced by the exhaust is related to the exhaust jet cross sectional area, exhaust gas density and relative jet velocity.\(^7\)

Compressor noise is generated from rotor and stator blade operation inside the mechanism and is audible forward of the engines. It is of high frequency and manifests itself as a whine most noticeable during landing approach. At this point, low frequency noise produced by engine thrust is at a minimum and the aircraft engines are slanted toward the ground and direct compressor whine downward.\(^8\)

There are several methods of reducing unwanted engine noise in the SST, but none seem to promise an entirely satisfactory solution without sacrificing operating efficiency. There are operational modifications which the pilot can perform and which reduce ground noise without engineering changes in the engines themselves. Most of these are already in use and include reduction of power during take-off, control of glide angles and sharp turns away from populated areas. Undoubtedly they will be continued for SST operations.\(^7\) As new airports are planned the opportunity also exists to more widely use zoning techniques in order to control building near high noise areas. Improved sound insulation for buildings is another possibility and reduction of taxes in high noise areas to reduce complaint levels also has been proposed as a solution to the problem.\(^8\) However useful these techniques may prove to be, they treat only the symptoms and not the cause. The noise itself still remains and man is forced to adjust to it.

There is, of course, a technical effort under way to discover methods of noise reduction inside the SST engine. Since engine noise is a function of gas velocity,\(^9\) the best and easiest approach is to reduce its exist velocity by some device\(^9\) or to mix external air with exhaust gases as they leave the exhaust nozzles to reduce velocity. The fan jet engine, now used on many subsonic jets, represents use of the latter approach by utilizing an ap-

\(^{9}\) Relative jet velocity is greatest at take-off and therefore the most significant factor in ground noise at this point.

\(^{10}\) This is the primary reason for power cutback during take-off. The problem, however, is that reduced thrust causes a low rate of climb and increases the number of persons exposed to only a slightly reduced PNdb level, aside from safety considerations. This technique is in general use, but there is an argument to be made that use of maximum thrust will expose fewer persons to more noise, for a shorter time, and increase the margin of safety.
paratus which mixes bypass compressor air with primary jet air within the engine. Use of high bypass ratios\(^3\) allows absorption by the bypass stream of additional energy from the hot turbine gases and results in a noise reduction of from 5 to 8 Pndb.\(^4\) Fan jet noise is affected by the internal configuration of various engine components and it is possible to achieve some additional noise reduction by proper internal engine design.\(^5\) Unfortunately, there is less freedom to manipulate engine design in the SST than exists with subsonic aircraft. One of the main problems involved is the ability of the engine inlet to handle airflow distortion. Since distortion in the SST has a significant effect on engine pressure level which in turn affects performance, an SST engine with optimum noise characteristics is not readily achievable by simply redesigning the engine itself.\(^6\)

However, an alternate method which exhibits some promise is use of absorbent engine linings made of fibrous material. The lining is backed by a cavity filled with air to form a resonator system which is designed to form a phasing relationship with air in the engine and cancel sound energy passing through the lining. A most significant reduction of 15 Pndb appears feasible using this device, but again only with performance sacrifices.\(^7\)

With the possible exception of the resonator system, there is little on the technical horizon that promises SST operation at the same ground noise level as present subsonic jets. On the contrary, it is generally conceded that the SST will be significantly louder, even with an optimum noise control scheme consistent with economic operation. It is likely that a supersonic transport shortly after take-off will produce a noise level of about 124 Pndb extending 1500 feet either side of its flight path versus a level of 108 Pndb for present aircraft. An effective noise suppressor to produce equal sound levels for the two types of aircraft would add about 18,000 pounds dead weight to the SST and is considered so uneconomic as to not merit serious consideration.\(^8\)

A sound "map" for the SST has been projected, and it appears that the 100 Pndb area during take-off will extend almost one mile on each side of the runway at full thrust. In comparison the same 100 Pndb level for subsonics reaches only 500 feet on either side, a considerable difference. The equal noise point for an SST and a subsonic jet will be about 16,000 feet from the break-release point on the runway, and beyond this distance SST ground noise will be the lesser because of its greater climb-out rate.\(^9\) For a standard of comparison, it should be noted that a noise

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\(^3\) The bypass ratio is determined by the amount of air flowing through the bypass mechanism versus the amount of air passing through the compressor.

\(^4\) Leven, Aircraft Noise—Can it be Cut?, 46 SP./AER. 65 (1966).

\(^5\) Id. at 67.

\(^6\) Id. at 68.

\(^7\) Id. at 72. Use of resonators has also been suggested to reduce compressor noise. Other efforts are being made in the area of compressor inlet redesign and in raising the sound frequency to a level not audible to humans. See Soule, supra 26, at 6.

\(^8\) Plattner, Noise, Traffic Loom as Key SST Problems, 88 AVIA. WR. AND SP. TECH., Dec. 9, 1968, at 21.

level of 100 Pndb is approximately equal to the noise of a freight train traveling at 40 miles per hour heard at a distance of 100 feet. A level of 120 Pndb represents an air hammer heard from 5 feet and is above the level where shouting conversation is possible.38

There is one saving factor. Subsonic jet engines are designed for maximum power at take-off while an SST engine is sized for maximum power during the transonic climb period of flight. This will alleviate ground noise somewhat since the full power of the SST will not be utilized during take-off. Nevertheless, the fact exists that the SST will be significantly louder near airports than current jet aircraft if the existing engine design is utilized. Additionally, the ground noise problem takes on a new dimension at contemplated supersonic transport decibel levels. Some experts have already flatly predicted that the noise an SST will produce during take-off will be "intolerable to anyone within one-half mile of the runway."39

It is known that permanent hearing damage can be produced, depending on the sound frequency, from a one hour daily exposure to 105 Pndb.40 Noise levels of current aircraft are a hearing hazard only to operational and maintenance personnel working close to the plane; however, the external noise level would not have to be increased much beyond present levels and durations before legitimate claims could be made by persons living near airports that a small amount of hearing damage has occurred.41

Ground noise, while receiving much less attention than the sonic boom problem, looms as a major shortcoming of the SST technical development. Though engineering advances promise some measure of relief, it is evident that ground noise will be of a significantly greater intensity than now experienced with current jets. Not only will more inhabitants near an airport experience greater annoyance and greater decline in property values but the possibility of actual hearing loss occurring may become an unwelcome reality. The seriousness of this problem cannot be underestimated in light of the somewhat astonishing fact that there is as yet no uniform aircraft noise regulatory mechanism in existence, and the only public pressure to reduce noise lies in sporadic litigation by individuals.

IV. The Sonic Boom Problem

The more publicized effect of the SST will be its continual generation of sonic booms as long as the aircraft travels faster than the speed of sound. Sound itself is a pressure disturbance, and a sonic boom is the result of an abrupt pressure change. If a sound source is stationary then sound waves move out from it in a series of concentric spheres of pressure disturbances, analogous to the concentric waves produced by dropping a pebble into a pool of water. The same pressure disturbance pattern is produced if the sound source is moving, but at a velocity less than the velocity of sound itself. In such a case the pressure disturbance spheres are crowded

38 Shapiro & Edwards, supra note 20 at 25.
39 Dyment, supra note 14 at 60.
41 Id. at 550.
in the direction of travel of the sound source. This is the case with a subsonic jet, air molecules being pushed ahead of the aircraft and deflecting other molecules so that no pressure buildup occurs.

A different phenomenon entirely occurs when the source of sound, in this case the SST, moves faster than the velocity of sound. In such a case disturbed air molecules are moving slower than the aircraft and accumulate in conical patterns much like the bow wave of a ship. Accumulation occurs at the boundary between the disturbed and undisturbed molecules and produces an abrupt pressure increase, or shock wave. The shock waves produced at successive points along the line of flight move perpendicular to the entire shock wave front itself which slopes back from the aircraft in the form of a cone to intersect the ground at some point behind the aircraft. The motion of a sonic boom through the atmosphere is similar to a wave of water approaching a beach. The wave front itself is parallel to the shore, but the direction of travel of an individual wave is perpendicular to the front or directly at the beach.

This pressure buildup occurs at each point where there is a change in the shape of the airframe configuration, and multiple waves are therefore produced by a single aircraft. Thus, the aircraft’s shape produces a complex pattern known as the boom “signature,” and each aircraft produces a distinctive shock wave depending on its physical design. The initial pressure increase is produced by the nose, followed by smaller disruptions generated by the wings and engines. Finally, a tail shock is produced by compression of the air back to ambient pressure. In what is known as “near field” the distinctive pattern produced by each aircraft is retained. However, in the “far field” the small wing and engine disturbances tend to coalesce and move toward the extremes of the pressure wave, or toward the large noise and tail disturbances. The resulting pressure distribution pattern is in the form of the letter “N,” and the distance behind the aircraft at which this merger occurs is the boundary between near and far field.

The initial shock wave configuration depends on the relation between the velocity of the sound source and the speed of sound, which varies with temperature. Because of the variation in sound velocity, Mach number, and not absolute air speed, is the important factor to consider in sonic boom propagation. The Mach number determines the shape of the shock wave cone and the angle at which the cone spreads out behind the aircraft, which in turn affects the amount of ground which the boom will strike. The higher the Mach number the smaller the angle of propagation, and therefore the narrower the shock cone trailing the aircraft will be. If the SST is in straight and level flight, the intersection of the shock cone

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44 Id.
45 Id.
46 Id.
47 Id.
48 Thompson & Parnell, Sonic Boom and the SST, 39 AIRCRAFT ENGINEERING 14 (1967).
49 Id.
50 For a definition of Mach number refer to note 8, supra.
51 Wilson, supra note 42 at 38.
and the ground is in the shape of a hyperbola with sound heard eventually at all points inside it, but not beyond its limits.

For an SST flying at an altitude of 70,000 feet, its normal cruising height, the boom corridor on the ground will approach 40 miles in width or about three times as wide as the altitude of the aircraft. The boom duration, or time between the nose and tail shocks of the boom signature, will be about 0.3 second and will be discernible on the ground as two sharp bangs heard close together. Sonic booms will first occur about 100 miles from take-off, as the SST goes supersonic, and will cease about 100 miles from landing, as the SST goes subsonic, so there should be no boom problem in the immediate vicinity of an airport.

The effect of a sonic boom on people and property is determined primarily by its intensity, usually expressed in overpressure relative to the ambient atmosphere and measured in pounds per square foot. It is generally accepted that an overpressure of 2.0 psf is the threshold limit above which damage to glass and plaster begins to occur. An overpressure of 1.0 psf is noticeable but produces no property damage, while a level of 0.3 psf is barely audible. Boom intensity is affected both by the speed of the aircraft and its distance from the spot on earth where the boom strikes. The single most critical factor is aircraft velocity since overpressure varies with the Mach number; however, the relationship is such that little additional overpressure is produced above a Mach number of 1.3 for each additional increment of velocity. This means that above Mach 1.3 added speed alone will produce a negligible increase in overpressure and little additional ground effect. Additionally, intensity is an inverse function of distance from the sound source, therefore overpress is at a maximum directly under the flight path and decreases with increasing lateral distance from the plane's ground track.

Since the SST will continuously generate sonic booms as long as it travels at a Mach number greater than one, the relevant questions is not whether there will be booms, but instead what factors influence their intensity, the goal being as much reduction as possible. The factors which affect overpressure, and which can be controlled once altitude and speed are fixed, are aircraft design parameters such as length and area distribution. Atmospheric conditions likewise can affect intensity significantly. These conditions, unfortunately, are not subject to man's bidding.

V. THE EFFECT OF AIRCRAFT DESIGN AND ATMOSPHERIC CONDITIONS ON SONIC BOOM INTENSITY

Sonic booms are produced initially because air molecules ahead of the aircraft cannot get out of its way. Therefore, the less the air has to move the less intense is the resulting pressure increase. Aircraft design can, as

48 Thompson & Parnell, supra note 43 at 15.
50 Hereinafter referred to as psf.
51 Hutchinson, Defining the Sonic Boom Problem, 1 ASTRO. AND AERO. ENG. 56 (1963).
52 Wilson, supra note 42 at 38.
53 Wilson, supra note 42 at 40.
a result, affects boom intensity. As discussed earlier, sonic booms have both near and far field effects, and it has been shown that for an aircraft shaped like the SST the near field effects of aircraft shape on boom signature extend all the way to the ground.44 Since near field effects are attributable to airframe configuration, much research has been devoted to the relationship between overpressure and the shape of the aircraft.

Those design characteristics which produce large pressure disturbances fortunately also cause drag and usually are avoided. A slender nose and a high length to diameter ratio produce lower overpressures since intensity is a function of length.45 Because of this relationship, it proves desirable to increase the effective length of the SST without changing its physical dimensions. One way this can be accomplished is by utilizing additional surfaces projecting above the axis of air flow which alter tail boom characteristics. Such a design interrupts the shock waves that intersect to form the tail boom some distance behind the aircraft, reducing overpressure as a result. Another possibility is a “biplane configuration” with wings mounted on the vertical tail fin to change the lift characteristics of the main wing and consequently the overpressure.46

Gross weight of the aircraft also significantly affects boom intensity, overpressure increasing with poundage.47 Unfortunately, weight is largely fixed once a decision on range and passenger capacity is taken, and while some weight reduction is possible within design limits, it must be at the expense of operating economy.48 On balance this avenue appears to be of little value in reduction of overpressure.

Distribution of airframe components such as engines is another method of attacking intensity since overpressure is also a function of the aircraft’s cross sectional area.49 Investigation has indicated that optimization of the arrangement of airframe components could result in an intensity reduction of about 10%, a goal which must be balanced against the 10% decrease in payload which would be necessary to achieve it.50

An objective appraisal of the research done in this area indicates that an overpressure reduction of about 10% is entirely feasible with relatively minor design modifications. However, this is possible only by sacrificing

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45 Wilson, supra note 42 at 40. Length of the aircraft theoretically affects overpressure since intensity varies as the three-fourths power of the effective length.
46 George, Reduction of Sonic Boom by Azimuthal Redistribution of Overpressure, 7 A.I.A.A. J. 29 (1969). The negative effect of such charges is to increase drag which adversely affects economy. There is no evidence to suggest that these changes are being utilized in the final SST design.
47 McClean & Shrout, supra note 49, at 519. For empirical studies correlating, among other variables, gross weight and boom intensity see Maglieri, Hubbard, Ground Measurement of the Shock-Wave Noise From Supersonic Bomber Airplanes in the Altitude Range From 30,000 to 50,000 Feet, NASA TN D-880 (1961). This study showed that a 100,000 pound airplane produced an overpressure of 1.4 psf at an altitude of 30,000 feet and Mach number of 1.6. To maintain this same overpressure a 650,000 pound SST flying at about the same speed would have to maintain an altitude of about 60,000 feet. The boom reduction achieved by increased altitude is just about balanced by the increase in weight.
48 Whitlow, Airplane Size and Staging Effects on SST Cruise Boom, NASA TN D-4677 at 1 (1968). This study also examined the concept of a two-stage SST but concluded that no advantage was to be gained by such a design.
49 Thompson & Parnell, supra note 43 at 15.
50 Id.
payload or increasing fuel requirements, and the question remains open
whether a small reduction in overpressure is important enough to justify
the increased expense. Unfortunately, the answer will not be known with
finality until regular operations begin, which may be too late as far as
people exposed to sonic booms are concerned.

While aircraft design influences the nature of sonic booms as propagated,
atmospheric conditions affect them during the period of travel from the
aircraft to the earth's surface and may either increase or decrease over-
pressure significantly. Temperature variation probably produces the largest
deviation from expected intensity levels. Since the speed of sound in-
creases as temperature increases and decreases with altitude, a shock wave
front passing through air of different temperatures does not remain in a
straight line. As it approaches warmer air the wave front may be re-
fracted slightly as light is refracted when passing from one medium to
another. Upon refraction the entire wave front tends to pivot around its
lower segment which is entering the warmer air and becomes skewed to-
toward the vertical. As this happens individual sound rays, which move at
all times perpendicular to the wave front itself, are directed less and less
at the ground. If the skew is severe enough and approaches a perpendicular
angle with the earth's surface, individual rays will travel parallel to the
ground and never strike it. The boom fails to reach the ground and de-
genерates into an acoustic disturbance without the characteristic bang
effect. This phenomenon occurs only at low Mach numbers when the
propagation angle is large and the wave front is initially generated al-
most perpendicular to the ground. The aircraft velocity at which this
occurs is designated the cut-off Mach number.

Wind direction and force are also important arbiters of sonic boom
overpressure. A following wind of greater velocity at high altitudes than
at ground level will tend to accelerate the upper segment of the wave
front and keep it directed at the ground, insuring that sonic boom will
reach the earth. On the other hand, a head wind gradient aligns the shock
front more toward the vertical by producing an upward pivoting effect
and can therefore produce the same result as temperature.

Obviously, no one atmospheric factor occurs in an isolated instance; all
phenomena interact simultaneously making prediction of boom intensity
on the ground somewhat unreliable. The information available does indi-
cate that for steady flight above a Mach number of 1.3, the total effect of
varying atmospheric conditions on overpressure is relatively small. Ob-
served overpressure differs only about 7% from predicted values, a varia-
tion of little significance as far as ground effects are concerned. However,
for Mach numbers between 1.0 and 1.3, atmospheric conditions may pro-

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1 Wilson, supra note 42 at 41.
2 As light travels from air to water, its velocity is slightly reduced in water and a refraction,
or bending, of the direction of the light ray results.
3 Since the wave front is almost perpendicular to the ground temperature change alone is
sufficient to deflect sound rays parallel to the ground and cause the cut-off phenomenon to occur.
44 Kane, Some Effects of the Nonuniform Atmosphere on the Propagation of Sonic Booms, 39
duce a significant deviation from predicted levels, as much as 25% in some instances. At present, three different effects are known to be attributable to wind-temperature interaction. First, extreme lateral spread of shock waves may occur over a wider area than expected. As a practical matter, the overpressure in this situation becomes too small to detect past a certain distance. Thus, if high wind velocities occur between the aircraft and the ground, large lateral spread will not occur. The jet stream may therefore preclude this phenomenon in many cases. Second, the wind-temperature interaction may produce cut-off with no shock waves reaching the earth's surface, as discussed above. This occurs somewhere between the aircraft and the ground and is characterized by the degeneration of the shock wave into an acoustic front similar to that produced in subonic flight. The exact mechanism by which this happens is not fully understood, but occurrence is limited to Mach numbers slightly above 1.0. The third effect, triggered by wind and temperature, is focusing, a concentration of successive booms into a small area with a significant increase in overall intensity. Focusing has been the subject of much investigation because of its possible consequences to persons and property and merits separate treatment.

VI. The Focusing Phenomenon

Focusing is usually defined as a local increase in shock wave overpressure above predicted values. Several factors, alone or in combination, can produce focusing, among them atmospheric effects, certain aircraft maneuvers and ground reflections. Under normal conditions two successive shock waves generated by a moving aircraft will travel a parallel course and strike the ground at different points. If, however, some interfering factor changes the velocity of one of the waves or distance it has to travel, such as passage through a temperature gradient, then the courses of travel are no longer parallel. In such a case it is possible for a later wave to "catch up" with an earlier one, both arriving at the ground at the same instant and in almost the same spot. The physical result is an increase in overpressure due to the additive effect of the two or more waves arriving simultaneously.

Temperature change is one factor which may cause focusing by differing mechanisms. Passage of a shock wave through an air mass with internal temperature variation results in distortion of the wave front. One consequence is to concentrate sound energy initially distributed over a long segment of the wave into a smaller area with consequent magnification of overpressure at this point. Usually only those temperature variations within 15,000 feet of the ground promote this mechanism since continued passage of the wave front through the atmosphere will produce

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Focusing has aptly been referred to as "superboom."

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60 Id. at 527.
61 Id. at 528.
62 Id.
63 Id.
a redistribution of energy over the entire wave front and eliminate the energy concentration. The other effect of temperature gradient, its bending effect on portions of the wave front, was discussed earlier. One wave may become skewed and redirected by passing through a region of different temperature, while a later wave may miss the temperature pocket entirely. The result is that the change in direction and velocity of the earlier wave cause both to arrive at the ground simultaneously. Small temperature pockets near the ground are largely responsible for this situation, and they commonly occur over water or over cities where inversions are frequent.

In much the same manner wind may distort a portion of successive shock waves, causing them to focus at some point with a resulting increase in overpressure. If such an intensification occurs high above the earth passage through a region of either little wind or of intense wind will dissipate the concentrated energy and no increase in overpressure will be experienced. Because of this, wind alone is not likely to cause significant amounts of focusing. The effects of temperature and wind are difficult to predict, but it is generally agreed that a doubling of overpressure is probable due to atmospheric focusing by either temperature or wind alone.

The other important cause of focusing is aircraft maneuvering which produces acceleration. Level turns, climbing to gain cruising speed, or “topping out” at cruising altitude all involve acceleration and the possibility of causing focusing. It will be remembered that near Mach 1.0 the boom propagation angle is almost 180°, the shock wave front being almost perpendicular to the ground as it is generated. As an aircraft accelerates its speed is constantly increasing and the propagation angle becomes smaller. As a result, during acceleration no two successive waves are exactly parallel as they leave the SST, but are directed at different angles toward the ground. Since the angle of propagation and distance to the ground may be different for each successive shock wave during an accelerating climb, later waves may overtake earlier ones, all arriving at the ground simultaneously to produce a focus. For a normal acceleration to cruising speed, the ground area affected would be about one square mile and a doubling of overpressure could be expected.

For a “push-over” maneuver which may occur either at the end of ascent to cruising altitude or on initiation of descent, shock waves again would not be traveling parallel courses and focusing is possible. The same is true for a level turn because of acceleration of the aircraft. Unfortunately, for push-overs and turns, acceleration is much greater than that produced from a normal increase in velocity during level flight and as

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62 See generally, Dressier, Sonic Booms in Strong Winds, FAA Rep. No. 97 (1964). The report points out that in most cases wind and temperature will be interacting and it is entirely possible to get more than a doubling of overpressure in rare cases.
much as a 400% overpressure increase is thought possible during these maneuvers.\footnote{Id. at 27.}

The character of the surface of the ground beneath the SST also may influence the strength of sonic booms. Normally 90% of the energy of a shock wave is reflected by smooth surfaces, such as walls, water, pavement, and fields. For this reason it is entirely possible for a structure to be hit simultaneously by a direct shock wave and by a reflected wave of almost full force which strikes nearby terrain an instant earlier. The effect is an increase in overpressure, which is the same as atmospheric focusing.

Focusing obviously makes the already unpleasant sonic boom even more undesirable. Not only does it increase the annoyance factor by increasing the loudness of the noise experienced, but intensity is magnified to the point where property damage is almost certain to occur for a number of persons. While focusing attributable to aircraft maneuvers can be controlled reasonably well, the atmospheric effect is completely unpredictable. Therefore, it is a forgone conclusion that land overflights of the SST will expose a certain percentage of the population to at least double expected overpressure at some irregular interval, causing increased property damage and annoyance.

VII. THE EFFECTS OF SONIC BOOM ON PERSONS AND PROPERTY

It is now settled, after design changes in 1968, that the American SST will generate a maximum overpressure during climb-out of about 3.5 psf, with an intensity during cruise of 2.0 psf.\footnote{Plattner, supra note 36 at 21. The Boeing Aircraft Co., prime airframe contractor for the SST, has taken the adamant position that supersonic transport design should not be altered to lessen boom intensity, based on the questionable industry argument that people become "accustomed" to sonic booms. Thus, the company has made the value judgment, for it cannot be anything more than that at this time, that increased operating efficiency is more desirable than a 10% reduction in boom intensity. This may very well be true but it would seem that the general population who now will forgo this reduction, or at least their government, should have had a major say in the matter, instead of being told flacily that they will become "accustomed" to the increased intensity.}

The Anglo-French Concorde will operate at somewhat lower levels, 2.0 psf during acceleration and 1.4 psf during cruise. If overland SST flights are permitted in the United States, it has been estimated that 65 million people will be exposed to an average of 10 booms daily, of which 98% will be in the 2.0 psf intensity range and 1% above 4.0 psf.\footnote{Kryter, Sonic Booms from Supersonic Transports, 163 SCIENCE 359 (1969).} Sonic booms of this general level of intensity will affect persons and property in different ways, depending on exposure conditions. A person standing outside when a boom strikes will have an entirely different reaction than an individual inside a building. As a shock wave strikes in the open air, diffraction of the wave around the human body may lead to a pressure doubling on the side facing the shock, if the sound is of high frequency. It has been theorized that the pressure differential between two sides of the body in a superboom situation could produce the sensation of being "hit" by the boom,\footnote{Von Gierke, Effect of Sonic Boom on People: Review and Outlook, 39 J. Acous. Soc. Amer. S43, S47 (1966).} although it is conceded that the possibility is remote.
The effects of a boom inside a building are modified by the structure itself. Shock is filtered by the transmission properties of the building, which lowers intensity, but produces oscillation which may continue for a short period because of a resonance effect. The vibration produced is a combination of air-borne shock waves and the building vibration itself. As indicated, it is possible for a structure to receive more than one boom because of ground reflection. If this happens a window may receive a boom on its outside face and then receive on its inside face a delayed, reflected wave coming through another building opening. Intensity and stress on the structure are both increased, and therefore raise the likelihood of property damage.

The extent of damage which continuous SST operation will cause remains highly speculative and subject to much emotion. With regard to property it is known that an overpressure of 2.0 psf marks the level where commercially installed windows begin to suffer damage. This intensity is unlikely to cause significant structural damage beyond plaster cracking and glass breakage. However, focusing, which on the average doubles overpressure, will increase damage potential when it occurs. Therefore, it seems safe to assert that regular SST flights over land will cause a steady stream of minor property damage which will accumulate to a significant yearly dollar value.

The effect of sonic booms on individuals is equally difficult to predict. It is clear that human response to sonic booms will be unlike reaction to normal sounds. Booms noise, unlike that from a train or subsonic jet, will be heard instantaneously without gradual buildup. A startle reaction is to be expected in most persons since shock waves will come completely without warning. It must be expected that the suddenness of the noise will produce falls, minor accidents, and other interruptions in daily routine which the same noise level gradually increasing to peak intensity would not cause. There is little empirical data as to the amount of monetary loss which this type of reaction will cause in terms of injuries and property damage, but again it seems certain that loss will occur. One writer has estimated that personal injury due to the startle effect and property damage losses will amount to 90 million dollars annually, assuming operation of the SST throughout the United States.

While there certainly will be personal injury caused indirectly by reaction to booms, it seems highly improbable that the intensities expected will directly cause physical injury. Persons have been subjected to overpressures of up to 144 psf without physical harm, and eardrum rupture is not likely below an overpressure of 720 psf. Even though direct physical injury may not occur, there will remain substantial annoyance and dis-

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77 Id.
80 See generally, Von Gierke, supra note 77, for a discussion of the startle effect.
81 Keyter, supra note 76 at 160.
comfort associated with continuous exposure to expected SST overpressure levels. The notorious Air Force study in the St. Louis, Missouri area in the early 1960s indicated that almost 60% of the persons exposed were annoyed by the continuous boom propagation. This study also found that annoyance increased with increased exposure and that, subjectively, sonic booms were less acceptable when heard inside.\textsuperscript{84}

Studies have also been conducted to compare sonic boom acceptance with comparable noise levels produced by subsonic jets. When heard outside and under the flight path, sonic boom noise apparently will be less bothersome than noise from a subsonic jet one and one-half miles from take-off. Heard indoors under the same conditions, the boom would be more annoying. Most significant, it was determined that persons indoors, in a path 16 miles wide and beneath the flight path, would be annoyed by a sonic boom of expected SST intensity to the same degree as persons inside a dwelling and directly under the flight path of a subsonic jet one and one-half miles from take-off.\textsuperscript{85} Translated into decibel levels, persons in the 16 mile wide corridor will be exposed to a noise level of 112 PNdB outside and 95 PNdB inside. Another study has concluded that cruise boom directly under the flight path of an SST will be equivalent to the noise of a subsonic fan jet at an altitude of 500 feet or around 120 PNdB when heard outdoors.\textsuperscript{86}

Taking either study, it must be concluded that people will be exposed to a level of sound intensity well within the range considered objectionable for subsonic jets, though duration of exposure and average number of incidents per day will be somewhat less than would exist for persons living near an airport. Not only will there be property damage and personal injury, but some 65 million people in the United States will be regularly exposed to noise levels now experienced by only the relatively small group of people living near airports. It seems inescapable that, with its other effects, overland SST operation will cause depreciation of property values within boom corridors as surely as if the property had been located near a jet runway. This, of course, assumes that scheduled flights will follow established, permanent routes between cities, a situation which almost certainly will exist as more and faster aircraft utilize the same air corridors.

**VIII. CONSEQUENCES OF WORLDWIDE SST OPERATION**

Although a preliminary decision has been made to limit SST operations to overwater routes, undoubtedly there will be intense industry pressure to fly over land as well. Should this come to pass, a possibility which must be realistically appraised, the consequences will be felt both on the national and international level.

On the national level, as already indicated, the most obvious effect will

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\textsuperscript{84} Nixon & Hobbard, Results of the USAF-NASA-FAA Flight Program to Study Community Responses to Sonic Booms in the Greater St. Louis Area, NASA TN D-2705 (1965).


\textsuperscript{86} Kryter, supra note 76 at 360.
be the generation of unwanted noise, both around the nation’s airports and at all points within boom corridors. The intensity of airport noise will be significantly greater than at present, assuming no technical breakthrough to limit it at the source. Certainly, the increase will produce a swell of additional litigation by already irate property owners. The area of land around airports which will suffer a value decline must increase and it is possible that some areas will be rendered completely uninhabitable. While more sophisticated use of airport zoning could diminish this problem around new jetports, it is likely that the SST, at least in its early stages, will mainly use existing airports where zoning will be of dubious assistance. In addition to the extra annoyance and decline in market values, there exists the unpleasant possibility that actual deafness will be caused among some percentage of persons living in close proximity to airports. Thus, there may be an additional kind of damage caused not yet existing at current noise levels.

Away from the airport and in flight, the SST will generate sonic booms in a corridor about 40 miles wide for the entire duration of its supersonic flight. Persons living within a 16 mile swath inside this corridor will probably experience the same noise levels as those now living close to airports. The question must be asked, if persons living near an airport may recover damages for enduring a certain noise level, why should persons subjected to the same kind of disruption away from the airport not be allowed compensation? It seems entirely possible that property within a regular boom corridor will suffer a price decline. Given a choice, people undoubtedly would pay a premium to be free of sonic booms. Moreover, decline of property values, while perhaps the largest potential elements of damages, will not be the only loss. There will be some property damage and damage to businesses, especially farming. The startle reaction will additionally give rise to a steady toll of personal injuries and some deaths.

Such consequences simply do not exist with current subsonic jets flying at normal cruising altitude, and there must be some method of arriving at just compensation for those who suffer loss. Here, additional difficulties present themselves. While causation is no problem for ground noise where the intruder is highly visible, an SST at cruising altitude will be entirely invisible and 20 miles away by the time sonic boom reaches the ground. If litigation against individual airlines is attempted, determining exactly which aircraft belonging to what airline is responsible will be almost insurmountable, even with highly sophisticated control procedures. Another

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87 See generally, Katz, Airport Approach Zoning: Ad Coelum Rejuvenated, 12 U.C.L.A. L. Rev. 1451 (1965). There are serious problems associated with airport zoning. First, airport authorities usually can zone only within a limited radius around the airport itself and SST noise is going to extend much further than subsonic jet noise, which is already spawning litigation. Second, zoning power around airports may be diffused among several units of local government which may effectively neutralize each other. For example, zoning power at Dulles International Airport, near Washington, is divided between two countries which have not been cooperative with the FAA in its request to zone the area in accordance with the noise the airport operation will generate. One solution is to place adequate zoning power in the hands of the airport authorities.

88 New York is in the process of planning a new airport to accommodate expected increases in traffic. N.Y. Times, Feb. 16, 1970, at 63, col. 1.

89 This is the opposite position from the industry claim that annoyance goes down as people become “accustomed” to noise.
problem is appointment of damages in those cases where several airlines follow the same route. Whether any aircraft is above allowable speed or below cruise altitude and thus responsible for more damage than those following prescribed operating conditions again be a question difficult to ascertain.

There remain the problems of focusing and superbooms which are entirely attributable to atmospheric effects, not to an aircraft maneuver. A boom which is incapable of structural damage as propagated could be magnified sufficiently by the atmosphere to knock out every window for miles. Who should bear the risk of loss in such a case since the aircraft was not the direct cause of the damage? Such problems present difficult policy questions as to limitation of liability which must be resolved. In addition, there is the real problem of a multitude of inconsequential individual claims which are too trivial to justify the expense of a law suit but which are nonetheless losses. Insurance is a possibility here, but should an innocent party suffering damage be forced to bear the cost of insuring himself?

There are other, more subtle effects of SST operation which nevertheless merit consideration. A possibility beginning to receive more attention, but as yet undocumented, is the effect of SST engine discharge on the upper atmosphere. Some experts feel that this discharge may be a problem both from a pollution standpoint and, more dramatically, because of effects on the world's weather. An answer here must await further definitive investigation. Back on earth, it remains to be seen whether there can exist a true "wilderness" within the federal statutory definition of that term if SST booms continually penetrate the confines of the area. The alternative to doing away with the wilderness concept is, of course, to pilot the SST around such areas or fly a course which misses them all to begin with.

On the international level much the same problems of causation and kinds of damage will exist, but the overall picture will be much more complicated for the individual claimant. On an SST flight from Europe to the Orient many countries will be overflown without landing, and, in some of these countries, the operating airline will probably have no assets. Hardship on the individual claimant will in such case be multiplied beyond the problem of causation. Assuming a judgment could be obtained, it must then be recognized and executed in the courts of a country where the airline has assets. Some form of international control and financial responsibility is clearly called for to meet these problems.

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80 There are believed to be two opposing mechanisms involved and scientific opinion is divided on which one may ultimately prevail. On the one hand it is theorized that increased carbon dioxide content in the thin upper atmosphere will cause increased absorption of solar radiation high above the earth's surface and reduce the amount of heat which the lower atmosphere receives. The result would be a cooling of the atmosphere. The opposite position argues that increased carbon dioxide content will reduce the amount of heat the earth radiates back into space, therefore producing an overall warming of the atmosphere. Whichever theory is the more correct, any temperature change in the atmosphere will manifest itself through climatic changes. The problem, therefore, cannot be underestimated because the effects may be extremely far reaching.

81 The National Wilderness Preservation Act, 16 U.S.C. § 1131(c) (1966) defines wilderness as an area where the earth and its community of life are untrammeled by man... "Sec. 3 of the statute restricts use of airplanes within a designated wilderness area and arguably would exclude SST flights over or near such an area because of sonic booms."
With these consequences in mind the present state of the law in the United States and on the international plane must be examined to determine if existing remedies and institutions can adequately provide control of the SST and compensation for the losses it will produce should land overflights become a reality.

IX. THE STATE OF AMERICAN LAW

In the United States there has been considerable litigation caused by aircraft noise near airports, but only a smattering of cases treating the sonic boom problem. It is best to consider each of these areas separately to accentuate the differences involved.

Aircraft Ground Noise. Only recently has the Federal Aviation Administration decided even to consider the promulgation of engine noise limits, and their ultimate effectiveness remains unknown at the time of this writing. Thus far, regulation, where it exists, has been left to the local government agency which owns or operates the airport facility. As a consequence, the only significant deterrent to excessive noise has been litigation by private individuals.

Mainly because of difficulties with sovereign immunity, claimants bringing actions against governmental owners of airports have relied almost exclusively on the theory of inverse condemnation for recovery. Injunctive relief to stop flights altogether or restrict them to minimum altitudes over built up areas has not proved successful, courts taking the position that even though noise is damaging, the public interest in uninterrupted air transportation is paramount and that adequate remedies for resulting damages exist at law.

Inverse condemnation is based on the principle that excessive public interference with a private right is a "taking" of property which requires compensation, just as if the land in question had been taken in a formal eminent domain proceeding. In applying this remedy all courts are faced with the difficult policy question of determining at what point to limit the liability of the public agency. How this has been resolved largely accounts for the divergent holdings in ground noise cases. Bearing on this issue are the provisions of both the United States and state constitutions. The federal charter and many state constitutions as well provide compensation only for a "taking," while a large number of states provide relief both for "taking" and "damages" caused by a public instrumentality. Clearly, liability will be extended to cover a greater number of people where compensation is required not only for an actual taking but also for merely damaging private property.

At this point in time the decided cases fall into two broad groups. The

93 For a discussion of this problem in aviation ground noise law, see 51 MINN. L. REV. 1087, 1090 (1967). Problems in this area largely result from uncertainties in the Federal Tort Claims Act, 28 U.S.C. § 1346(b), 2680 (1964), concerning whether such an action would be within the discretionary duty exemptions of the act.

94 See generally, 51 MINN. L. REV. 1087 (1967).

more restrictive, based on a narrow construction of the word "taking", define that term as a public act which is a direct physical invasion of the claimant's property and which renders it substantially unusable for its intended purpose. Those courts taking a broader view allow compensation in inverse condemnation for public acts which cause some degree of damage, manifested as a decrease in value of the affected property, but without the necessity of proving either a direct physical invasion or substantial impairment of use.

Cases adopting a policy of minimum public liability stem primarily from United States v. Causby, the first United States Supreme Court pronouncement on responsibility for damages caused by aircraft noise. In that case almost total impairment of a farming operation was caused by the noise of military aircraft flying directly over the damaged property at an altitude of less than 100 feet. While the liability of the federal government was upheld, the Court indicated that physical invasion caused by aircraft flying directly over the property in question "... so low and so frequent ... as to be a direct and immediate interference with the enjoyment and use of the land ..." must be established before a compensable taking within the context of the United States Constitution occurs.

The lower federal courts have followed this rationale in suits where the United States has been the airport owner, confining recovery to those instances of direct overflight and annoyance so great as to render normal habitation almost impossible. The leading lower court case, Batten v. United States, denied recovery in the absence of these elements, even though there was vibration sufficient to rattle windows, smoke blown into windows during the summer and a measured noise level of 117 PNdB on the damaged property which had decreased in value by about 55% as a result of the disturbances. The court justified this position on the basis that the fifth amendment of the United States Constitution provides compensation only for a "taking," not mere damages, and that no taking can occur without a physical invasion of airspace above the property which renders it substantially uninhabitable. The damages caused were characterized as "consequential," to be borne by the owner at the expense of the public interest in aviation.

The question of the limits of public responsibility for damage caused by aircraft noise has been resolved quite simply by these cases. Damage to property not directly overflown need not be considered, since, as a matter

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95 328 U.S. 256 (1946).
96 Id. at 266.
97 306 F.2d 580 (10th Cir. 1962), cert. denied, 371 U.S. 915 (1965).
98 Id. at 581.
99 Id. at 581. State court decisions which have followed Batten and refused compensation without a direct physical invasion include: City of Atlanta v. Donald, 221 Ga. 135, 143 S.E.2d 737 (1965); State ex rel Royal v. City of Columbus, 3 Ohio St. 2d 154, 209 N.E.2d 405 (1965); Bowling Green-Warren County Airport Bd. v. Long, 364 S.W.2d 167 (Ky. 1962).
of law, there is no "taking" without an actual trespass. Simplicity of application, unfortunately, is the only reason to commend the use of the rule, and it has been criticized as arbitrary and unrealistic. There certainly is no logical basis for drawing the line of recovery in such a manner; noise-caused damage can be as great adjacent to the flight path of an aircraft as directly under it. Adoption of such a policy seems to strike a most uneven balance between the public interest in aviation and the right of a private land owner to reasonable use and enjoyment of his property.

That group of cases which would impose broader public liability for aircraft ground noise requires much less stringent interference with property to justify compensation. *City of Jacksonville v. Schumann*, while also involving a direct overflight, allowed recovery without the necessity of a finding that the damaged property was rendered substantially uninhabitable. Evidence of noise annoyance, vibration, and smoke causing enough interference with normal property use to cause a demonstrable decrease in property value was sufficient.

*Martin v. Port of Seattle* and *Thornburg v. Port of Portland* are representative of a policy favoring the widest possible public liability, allowing recovery in all cases in which damage can be proved regardless of whether there has been direct overflight. *Martin* allowed recovery to all property owners subjected to high noise levels either because they lived directly under the flight path or near enough to it to suffer damage, which was caused in that particular instance by 1500 flights a month at an altitude of about 500 feet. The *Thornburg* case similarly adopted the policy that a noise level high enough to depress property values is a compensable "taking" regardless of direct overflights. This policy was justified on the grounds that freedom from unreasonable noise is a right which the law should protect. It was recognized that noise can inflict damage regardless of whether it comes from straight above the damaged property or from either side and that only "sterile formality" could support a distinction based on the direction from which noise comes or the altitude at which it is propagated.

Those cases which do not require direct overflight have essentially adopted the position that limitation of public liability for aircraft noise is a question of fact, compensation to be required for all property which has declined in market value as a result of the noise. This approach is, of course, by far the more equitable and reasonable solution from the property owner's viewpoint. There are difficulties, however, with treating the problem as a question of fact. The cases diverge on exactly what evidentiary approach to follow, and commonly resort to use of both trespass and

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104 167 So. 2d 95 (Fla. Ct. App. 1965).
105 Id. at 97.
106 64 Wash. 2d 309, 391 P.2d 540 (1964).
107 233 Ore. 178, 376 P.2d 100 (1962).
109 *Thornburg v. Port of Portland*, supra note 105 at 184, 376 P.2d at 105.
110 Id. at 192, 376 P.2d at 106.
111 Id. at 198, 376 P.2d at 109.
nuisance elements. The Thornburg court, however, has characterized the problem as sounding strictly in nuisance and calling only for evidence of annoyance and interference with use.

Whichever position, whether narrow or broad public liability, a court adopts, it must determine as a matter of policy the balance to strike between the effect that wide recovery would have on the position of an industry of vital national interest and protecting the individual's right to reasonable use and enjoyment of his property. As the SST becomes operational and noise levels heighten, there will be increasing pressure toward greater liability to assuage those persons who will suffer significant annoyance and perhaps the conservative position requiring direct overflight will no longer be tenable.

One other case not bearing directly on limitation of liability should be mentioned at this point in the discussion, Griggs v. Allegheny County. The importance of this decision lies in the fact that it settled the issue, at least for the present, of who is the proper defendant in an aircraft noise case. The United States Supreme Court there held that the owner of the airport is ultimately responsible for aircraft noise damage because it controls, subject to federal approval, where the airport will be located, the runway layout and the directions of take-offs and landings; consequently, it is the taker of damaged property in the constitutional sense. The test evidently to be applied is degree of control and the party most responsible for inflicting excess noise on adjacent property must bear the liability. Since the individual airlines have no power to alter their approach or take-off patterns, but are guided by the local airport control tower and the physical layout of the runways, this test dictates that not they, but the airport owner, make compensation for damage caused by the aircraft using access routes to and from the airport.

In light of the additional problems the SST will cause with respect to ground noise, it seems probable that the present inverse condemnation approach will be a sufficient remedy to compensate those additional persons whose property will be damaged by the higher noise levels expected. As far as a decline in property values is concerned there will only be a difference in degree between the amount of damage an SST will cause and that already produced by subsonic jets and recovery will largely be a matter of extending liability to include the additional damage. However, the inverse condemnation approach may prove unsatisfactory if damage other than a decline in property values is caused by the SST and that eventuality is possible since some hearing loss may occur in persons who now only suffer property damage. The only recovery awarded in inverse condemnation is for taking or damaging property. Physical injury is not compens-

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111 396 U.S. 84 (1962).
112 Id. at 89, 90.
113 Id. Mr. Justice Black, in dissent, argued that the airspace over the airport and its vicinity had been taken by Congress for a public use. That action, coupled with FAA requirements that local airports must have all plans approved by it, he felt was sufficient to justify a finding that the federal government does the taking and not the owner of the airport.
able in such an action. However, as long as claimants are forced by the Griggs decision to seek recovery against only the governmental agency who owns the airport, and not the airline, problems of sovereign immunity channel litigation into the inverse condemnation theory. Thus, present case law forces litigation under a theory which is inadequate to compensate for all the kinds of damage which the SST may cause. It must be concluded that present law is not entirely adequate to respond to the SST situation and some modification is indicated in order to assure compensation for all of the kinds of the damage likely to occur.

Sonic Boom Damage: As yet there has been no sonic boom created by a regularly scheduled commercial aircraft and the few cases dealing with sonic booms are exclusively concerned with military aircraft operated by the federal government. The situations are not directly comparable since military aircraft generate disturbances only in isolated instances or in test situations of a few months duration where property values are not affected. Nevertheless, it is of benefit to examine the principles of law applied to determine their possible use for commercial aviation problems.

From the few decided cases it is clear that the most difficult problem associated with sonic booms generated by military aircraft has been proof of causation. Claimants have relied either on the Federal Tort Claims Act\(^1\) or the Tucker Act\(^2\) for recovery, basing their actions on negligence in operation of the aircraft causing the sonic boom. In Neher v. United States\(^3\) sonic booms were produced by Air Force bombers flying at Mach 2.0 and at an altitude ranging from 30,000 to 50,000 feet. The building damaged was located about 10 miles to one side of the ground track of the aircraft. In defending against the claim the government contended that its aircraft could not have caused the damage in question since calculations indicated that the expected overpressure could not have been severe enough to cause damage. Nevertheless, recovery was allowed, the court recognizing that atmospheric factors could produce an unexpected increase in intensity\(^4\) and that it was more probable than not that sonic booms did cause the glass and plaster damage which occurred.

In Lorick v. United States\(^5\) recovery was denied for a claim alleging structural damage attributable to sonic booms and caused by military aircraft at an altitude of about 300 feet. The plaintiff was unable to prove satisfactorily that the aircraft involved were supersonic while flying over his property and although there was structural damage the court laid heavy emphasis on the fact that there had been no glass breakage, usually the first effect of sonic booms on dwellings.\(^6\) As a result it was concluded that the aircraft overflight was not the proximate cause of the damage.\(^7\)

\(^3\) 265 F. Supp. 210 (D. Minn. 1967).
\(^4\) Id. at 217.
\(^6\) Id. at 100.
One other case should be mentioned, Coxsey v. Hallaby,\textsuperscript{121} involving an attempt to enjoin the government from continuing sonic boom tests. Relief was denied on the basis that the testing was necessary to promote the national interest in aviation technology and that no damage had occurred which could not be recovered in an action at law.\textsuperscript{122}

These few cases indicate that if recovery is sought for structural damage caused by sonic booms from negligently operated aircraft, the burden of proving a causal relationship between aircraft operation and ground damage will be fraught with difficulties. A plaintiff will have to establish initially that the aircraft in question was moving at supersonic speed to prove that a sonic boom was actually generated. Additionally, there will have to be damage of the kind that a sonic boom is likely to cause and defense contentions that predicted overpressure is too low to cause damage will have to be overcome. There is the considerable additional problem, as yet undecided, of whether an aircraft properly operated within governmentally established air routes is even responsible for sonic boom damage since it may not be primarily negligent. This perhaps would force actions to be brought only against the government for negligence in establishing routes which could cause damage. Also to be considered is the appropriateness of a negligence theory in the potentially vast number of cases where the significant loss may not be minor structural damage but depreciation of property values caused by continuous overflights. It is evident from the few existing negligence cases on sonic boom damage that serious evidentiary and policy issues have not as yet been resolved sufficiently to insure an orderly handling of the legal complications the SST will no doubt create. Indeed, it must be seriously considered whether a comprehensive statutory solution not only is desirable but necessary to avoid producing the same inequities which today exist in the area of aircraft ground noise cases.

Toward this end, there is in existence in several states the Uniform Aeronautics Act which provides in part that "... the owner of every aircraft which is operated over the land or waters of this state is absolutely liable for injuries to persons or property caused by ascent, descent, or flight of the aircraft..."\textsuperscript{123} This provision, or one similar to it, has been adopted by many states,\textsuperscript{124} and could serve as the basis for a uniform approach to problems created by the SST. On its face such a statute appears broad enough to encompass sonic boom damage which is clearly caused by "flight of the aircraft." Furthermore, there is no restriction on the type of recovery possible, which would allow compensation for personal injury, property damage and property value depreciation in the same action. There are, however, problems involved with widespread use of such a statute, and unfortunately interpretative litigation has been scant. It remains undecided whether use of this type of statute on a state-to-state basis would impose

\textsuperscript{121} 231 F. Supp. 978 (W.D. Okla. 1964).
\textsuperscript{122} \textit{id.} at 979.
\textsuperscript{123} \textit{Id.} at 979.
\textsuperscript{124} See, e.g., S.C. CODE ANN. \textsection 2-6 (1962).
\textsuperscript{125} See, e.g., S.C. CODE ANN. \textsection 2-6 (1962).
\textsuperscript{126} For a compilation and review of state statutes on this subject, see R. Fixel, \textit{Finkel on the Law of Aviation} (4th ed. 1967).
an unreasonable burden on interstate aviation commerce. Further, it is not clear whether Congress, by the Federal Aviation Act of 1958, intended to preempt the airspace above certain altitudes, thus making state law inoperable at SST operating conditions.

In *Prentiss v. National Airlines, Inc.*, the commerce question was raised for the first time in an action involving the constitutionality of a New Jersey statute imposing absolute liability for ground damages caused by an aircraft. The action arose from loss caused as a result of aircraft, crashing into the ground after a mid-air collision. The validity of the statute was upheld on the basis that aircraft operation is an ultra-hazardous activity, justifying imposition of liability without proof of negligence. The court found no unreasonable interference with interstate commerce since the statute imposed no financial burden on the average aircraft as would a tax, and had no effect on movement of air commerce since it did not become operative until after damage had occurred.

The same problem was again considered in *Wildwood Mink Ranch v. United States*, an action for damages caused by military aircraft flying below the minimum altitude prescribed by government flight regulations. Damages were sought both under the Federal Tort Claims Act and a Minnesota statute that imposed absolute liability for ground damages. The government argued that the state statute was inapplicable because Congress had created a public highway in navigable airspace which confers freedom of air travel and preempts state legislation, and that the state law placed an undue burden on interstate commerce. The case was ultimately decided on the basis of the Federal Tort Claims Act and the preemption question was never reached. With regard to the commerce argument, it was recognized in dicta that *Prentiss* was authority for a finding of no unreasonable burden, at least where an actual crash in is involved.

These decisions leave much unresolved as to the feasibility of uniform state legislation to compensate for SST damages. The preemption question remains completely open and the interstate commerce question is settled only to the extent that there is no unreasonable burden where damage is caused by an actual crash. It is unclear what the situation would be for an SST overflying several states, each of which has its own compensation plan for ground damage. The economic burdens on air commerce would certainly be greater in that event, and the argument of an unreasonable burden more persuasive.

Even assuming the constitutional problems were resolved favorably, the wisdom of using present state legislative schemes imposing absolute liability

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125 72 Stat. 739, 740, 798 (1958), 49 U.S.C. §§ 1301(24) 1104, 1508(4) (1964) authorize the FAA to determine by regulation what altitudes constitute navigable airspace. These statutes effectively limit the amount of airspace a landowner can claim above his property and sanction flights through such airspace in accordance with federal regulations. Thus, flights in such airspace may be privileged and damages caused by them nonactionable, at least under a negligence or trespass theory.


for ground damage caused by SST flights remains open to doubt for other reasons. Shock waves from an SST follow behind it and to either side and strike the ground as much as 20 miles away from the aircraft. In many instances the boom causing damage in one state may have been propagated in an adjacent state, the SST having never entered the airspace of the state in which damage is inflicted. Litigation in such situations could only generate additional problems of choice of law, jurisdiction, venue and limitation of liability. While admittedly these difficulties are not insurmountable, they nevertheless should force serious examination of whether use of existing state aviation liability statutes represents the best way to handle the SST sonic boom damage question.

Considering present United States law, both in the areas of aircraft noise and sonic boom damage, the absence of federal action is glaring, especially in light of state judicial and legislative developments which on the whole seem inadequate to cope with the problems the SST may impose on the country's legal framework. While present remedies may be adequate for subsonic jets, which cause ground damage relatively infrequently, a continuation of this policy for the SST and its cross-country boom corridors may prove entirely unsatisfactory.

X. The Status of International Law

There are three sources of international aviation law and regulation which would affect the SST. The Convention on International Civil Aviation,120 is the basic instrument of international aviation law and defines the rights and duties of contracting states with regard to all forms of civil aviation. Its operative agency, the International Civil Aviation Organization (ICAO),121 is responsible for executing the Convention and in general promoting international air commerce. Its work has been largely confined to establishing minimum technical standards and recommended practices for airlines of participating states. The Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface,122 the other applicable international aviation convention, deals exclusively with ground damages caused by overflying aircraft of foreign nationality and is in some respects similar to the Uniform Aeronautics Act which several American states have adopted.123 The other widespread mechanism of regulating international aviation is the bilateral agreement, executed by individual states to cover problems of joint interest to the two countries and usually confined exclusively to commercial matters.

These three devices will necessarily have a major role in the evolution of an international policy on SST problems. Thus, a separate examination of each is necessary to ascertain their usefulness, either alone or in combination, as a means of handling the legal issues which will be thrust upon the world community.

121 Hereinafter referred to as the ICAO.
122 Opened for signature on 7 Oct. 1952.
123 R. Fixel, supra note 124.
The Convention on International Civil Aviation and the ICAO. The Chicago Convention, an outgrowth of an international aviation conference in 1944, is a multilateral agreement which seeks to promote the efficient development of international civil aviation through a framework defining the rights and obligations of parties to the Convention. Its two most important substantive provisions are Articles 1 and 5. Article 1 provides that each contracting state retains exclusive sovereignty in the airspace above its territory. This recognition of sovereignty is unmodified by subsequent articles, which attempt to encourage the granting of reciprocal benefits to the contracting states consistent with the goal of developing international aviation. To this end, a right is provided for negotiating privileges for scheduled airlines as long as the concessions granted are consistent with the principle of exclusive sovereignty.

Article 5 provides that any civil aircraft not engaged in scheduled international air service has the right to fly over or land in the territory of a signatory party for non-traffic purposes. Scheduled airlines do not enjoy this same privilege because of a failure to arrive at a workable formula agreeable to all parties. However, Article 6 does provide a mechanism for negotiating privileges for scheduled carries and two separate instruments, the International Air Services Transit Agreement and the International Air Transport Agreement, provide for the exchange of commercial rights.

Because of the structure of the Convention with its emphasis on exclusive airspace sovereignty, it would be difficult to contest the validity of a contracting state’s regulatory scheme to control or even prohibit SST operation within its boundaries if the plan is at all within the limits of the Convention. Article 9(a) provides for prohibition for reasons of “public safety” of flights over designated areas. Article 11 grants wide-ranging power to a contracting state to regulate all aircraft navigating within its territory so long as no distinction is made on the basis of nationality. As it has been pointed out, these provisions are sufficiently broad to prohibit SST operation over specific areas of a country or to support imposition of such stringent restrictions as to make operation un-economic even in a relatively large nation. For example, nothing would

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124 Article I provides: “The contracting states recognize that every state has complete and exclusive sovereignty over the airspace above its territory.”
125 This is provided for in Article 6 of the Convention.
126 Article 5 states in part: “Each contracting state agrees that all aircraft of the other contracting states, being aircraft not engaged in scheduled international air services shall have the right . . . to make flights into or in transit non-stop across its territory . . . .”
127 Article 6, dealing with scheduled air services, allows such commercial flights only with “special permission or other authorization.”
130 “Each contracting state may, for reasons . . . of public safety, restrict or prohibit uniformly the aircraft of other states from flying over certain areas of its territory . . . .”
131 Article II provides in part that “. . . the laws and regulations of a contracting state relating to the admission to or departure from its territory . . . shall be applied to the aircraft of all contracting states . . . and shall be complied with . . . while within the territory of that State.”
bar a contracting state from requiring that an SST go subsonic before entering its airspace and remain so until exiting.

The Chicago Convention, as it stands, could be unilaterally utilized by several nations to completely disrupt long distance SST operations over land and nullify its only advantage, speed. While some will argue that it is good that such power of regulation already exists as an international convention, there is much weight for the proposition that unilateral prohibition of the SST by each of several contracting states would seriously undermine continued multilateral cooperation in aviation matters. A retributive, defensive posture perhaps would evolve as the norm to be followed in international aviation negotiations which could only hinder efforts to arrive at a workable international SST control program. For this reason it would be to the benefit of all if the ICAO could arrive at an effective solution to the SST problem to obviate the necessity of individual contracting states having to unilaterally exercise their reserved powers under the Chicago Convention.

ICAO does provide a vehicle for SST regulation if the contracting states can agree on a course of action. That organization came into being in 1947 when the Chicago Convention became operative, and was established to "develop the principles and techniques of international air transport." Having a membership of 116 member states in 1969, ICAO conducts its affairs largely through its Council which is made up of 27 contracting states elected by the Assembly for a 3 year period. The Council is vested with a variety of legislative, executive, and judicial functions. From the standpoint of SST control, its most important activity is in the legislative arena through formulation and adoption of International Standards and Recommended Practices which the Council is empowered to adopt under Article 37 of the Convention. These standards and practices are enacted in the form of Annexes to the Convention and, when accepted by the contracting states, constitute the regulations to which international airlines should conform in their scheduled operations.

ICAO regulatory activities are largely determined by technical advances in the aviation field, and compliance requirements are sufficiently flexible to accommodate the technical and economic problems which states at varying levels of development must face. As a result, a consensus type of regulatory process has evolved which is geared primarily to technical activities without undue interference in economic and political questions. With some exceptions contracting states have no binding obligation to implement or comply with the regulations set forth in duly promulgated Annexes unless they find it "practicable to do so." Therefore, the operating

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143 Chicago Convention, Art. 44.
145 Chicago Convention, Art. 50(a), Art. 50(b) provides that certain groups of states with specific qualifications will always be represented on the Council.
146 For a description of the various Council powers see, ICAO Secretariat, Memorandum on ICAO, 13 (5th ed. 1966).
147 Adoption of standards and recommended practices in the form of Annexes is a mandatory function of the Council under Art. 54(1).
148 Chicago Convention, Art. 28.
standards and regulations prescribed in the various Annexes are not binding legislative enactments in the traditional sense, but desirable goals to meet for the sake of efficiency and safety of operation. For this reason, even if there was an agreement that a regulatory system for the SST should be adopted, a contracting state could, within the Convention, refuse to comply and again force other states to resort to damaging unilateral action to protect their citizens from unwanted SST effects.

There are, however, certain mandatory requirements under the Convention by which all contracting states must abide. Under Article 33 a signatory must recognize as valid a certificate of airworthiness and a license of operation issued or validated by another contracting state as long as the certificate or license is above the minimum standards established by the ICAO. Because of the possible sanction of exclusion from international air commerce, contracting states wishing to engage in such commerce cannot afford to adopt less stringent standards of aircraft certification than those promulgated by the ICAO.

Traditionally, airworthiness certification has been concerned exclusively with safety of the aircraft, involving such factors as engine power and rate of climb. There has, however, been speculation that the FAA will be forced to resort to engine noise limits as one test of airworthiness for United States aircraft in the face of rising public fury. Up to 1969, though, no ICAO contracting state as yet had taken this step. From the language of the Convention at least, there is no reason why the concept of airworthiness could not be expanded to include both engine noise limits and design requirements intended to minimize sonic boom overpressures if the contracting states so desire. By building aircraft failing to meet such minimum ICAO airworthiness standards, a nation would risk excluding its carriers from international air commerce, a multilateral sanction which could be most effective as an incentive to minimize the adverse effects of an SST before it becomes operational.

While as yet the ICAO has not considered such a technique, there are at least signals that it is beginning to study SST problems. The organization is well aware that international SST operation will necessitate coordination of air traffic control procedures, weather forecasting and airport modifications. Because the SST will create problems common to many countries, the Legal Committee of the ICAO has urged solution of as many of the legal problems as possible through a multilateral approach rather than the traditional bilateral technique. Most significantly, the ICAO Assembly has passed resolutions on both the engine noise and sonic boom by

150 ICAO, Technical Panel on Supersonic Transport Operation 1-21, Doc. 8776 SSTP/1 (1968).
152 ICAO, Assembly Resolutions in Force A16-3, Doc. 8770 (1968). The resolution on noise commits the Council “to establish international specifications and associated guidance material relating to aircraft noise” and to consider a separate noise Annex.
153 Id., Resolution A16-4. The sonic boom resolution unfortunately is much less specific than the engine noise proposal. It instructs the ICAO Council to “. . . review the Annexes and other
problems which indicate that the consensus of the contracting states is to move toward some form of international standards in those critical areas.

The Chicago Convention and the ICAO seem equipped to handle \textit{regulation} of the SST if it is the will of the signatories. While there are problems to resolve, it is of some importance that an international organization already in existence has formally committed itself at least to consider the SST problem areas before regular operation is initiated.

\textit{The Rome Convention on Surface Damage.} Unfortunately, the ICAO was conceived only for the purposes of promoting and, in some instances, regulating international aviation. The complex legal problems involved with ground damage caused by foreign aircraft, a major consideration with the SST, were left to be treated in a separate convention.

The Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface\textsuperscript{144} was specifically designed to deal with this problem. The agreement provides for absolute liability of foreign aircraft owners or operators to any person whose damage \textit{\ldots} was caused by an aircraft in flight \ldots Nevertheless there shall be no right to compensation if the damage \ldots results from the mere fact of passage of the aircraft through the airspace in conformity with existing air traffic regulations.\textsuperscript{145} From the history of the Convention it seems clear that liability was never intended for noise caused in the normal course of operations. In fact, the initial draft contained language expressly precluding recovery for damage caused by noise. However, the wording finally accepted was thought to be sufficiently broad to exclude this contingency.\textsuperscript{146} Since a sonic boom is also \textit{"noise"}, it arguably would be excluded from the operation of the Convention as well. Thus, it is doubtful whether the Rome Convention would be applicable at all to any type of damage caused by noise alone.

There are additional difficulties in using the Convention for the SST, even disregarding its inapplicability to the noise problem. Once a judgment is obtained by an individual claimant under the law of the country in which the damage occurs,\textsuperscript{147} the Convention provides that, upon application to the court of that state, final judgment may be enforced either where the judgment debtor has his principal place of business or wherever assets are located.\textsuperscript{148} Execution of the judgment may be refused for a variety of reasons, most significantly because it would be contrary to the public policy of the enforcing state.\textsuperscript{149} This is important in light of the fact that, while a contracting state may request the operator of a foreign air-

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\textsuperscript{144} Hereinafter referred to as the Rome Convention.
\textsuperscript{145} Rome Convention, Art. 1.
\textsuperscript{147} Id. Art. 20 (1).
\textsuperscript{148} Id. Art. 20 (4).
\textsuperscript{149} Id. Enforcement may also be refused for inadequate notice, insufficient due process generally, or a pre-existing judgment on the same point between the same parties.
craft to provide satisfactory evidence of financial responsibility, such a guarantee is not mandatory. Further, if assurance is not forthcoming it is up to the individual states to work out their differences. Unless financial guarantees are provided, a claimant will have to take his chances with the courts of a foreign state which are empowered under the Convention to refuse relief on vague "public policy" grounds. This is an out which could become extremely important should SST damage claims begin to mount in a state whose government is desirous of protecting its national airlines from financial burdens.

The Rome Convention appears of little use where the SST is concerned. It is fairly clear that the Convention does not apply to noise damage, and enforcement procedures are uncertain and not designed to handle a large volume of claims. Not to be overlooked is the fact that the United States, a major future SST operator, never signed the Convention, which would greatly undermine its ultimate effectiveness. American objections have centered primarily around the idea of absolute liability, and the financial responsibility plan which was criticized as too severe an administrative burden.

All things considered, it must be concluded that at present there is no adequate international legal arrangement to handle the problem of ground damage caused by noise, an unwelcome revelation in light of what the SST promises.

The Bilateral Agreement. The bilateral agreement has been the traditional method of resolving aviation problems not already covered by a multilateral convention. Most arrangements deal exclusively with commercial problems such as routing, allowable stopping points within a country and rate questions. Because the bilateral agreement is in such widespread use among nations, it must be considered as one means by which individual countries may approach the SST question.

While the technique has been confined primarily to commercial activities, there is precedent for its use as a means of imposing noise restrictions in airport areas. In 1957, the United Kingdom and the Soviet Union agreed that aircraft would be required to reduce noise to an "acceptable" level, to be determined by the authorities of each contracting party. However, the agreement was aimed only at operating techniques such as angle of climb and evidently was never used as a method of inducing aircraft engineering changes under threat of disruption of services.

There is no reason why the bilateral agreement could not be utilized to

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160 Rome Convention, Art. 15.
162 Id. at 137. The United States also felt that the whole issue of financial responsibility should be left to bilateral agreements between individual countries.
163 For a general discussion of the mechanics of bilateral agreements, see Lissitzyn, Bilateral Agreements on Air Transport, 30 J. Air L. & Com. 248 (1964).
164 A comprehensive list may be found in, ICAO, List of Agreements and Arrangements, 1919 to Date (1969 Supp.).
regulate SST operations between states unless they deem it more expedient to unilaterally regulate under Article 11 of the Chicago Convention. Additionally, such agreements are possible candidates to solve ground damage problems if no other satisfactory technique is found. However, it is questionable whether this is the most desirable way to approach the problems involved with the SST.

To begin with, there would be a lack of uniformity of results and unevenness of bargaining positions between individual nations would also be a factor to contend with. Further, there are economic considerations involved in international aviation policy which exert an obscure but significant effect on the content of many bilateral agreements, making them of doubtful value in realistically treating the SST situation. As is well known, in the early 1960s there was a tremendous international rush by less developed countries to purchase subsonic jet aircraft. Whether this was prompted by nationalism, the urge to capitalize on tourism, or a hard sell by aircraft exporters is hard to determine, but a sizeable export trade was generated. To finance their purchases many countries obtained loans from the Import-Export Bank or borrowed directly from the United States. Many of these countries were either too small or too poor to provide a domestic market sufficient to support regular jet service, and they naturally turned to the international market in order to gain funds to repay their loans. Here they were in direct competition with well established American carriers for the lucrative international tourist business. As a result, the United States was placed in the vexing position of attempting to increase its own share of traffic but not at the expense of those competitors to whom it had loaned money and who were without other means to raise funds to pay off loans which the United States held.

This conflicting position was aided by the independent avenues of policy followed by those responsible for foreign trade and the Civil Aeronautics Board which negotiates bilateral aviation agreements. After a decision to promote export sales and lend funds is made, the government, through the CAB, has little choice but to negotiate favorable bilateral agreements with those countries indebted to the United States and dependent on a lenient policy in order to pay off the loans.

This process then is subject to pressures not immediately obvious on the face of the matter. Complex economic considerations influence and may even dictate the nature of the concessions which one country, especially one like the United States which will push SST exports, is willing to grant to another. While as yet there has been no rush by smaller nations to order the SST, lending some hope that future agreements will not be embroiled in financial problems, the same reasons which sold the subsonic jet to the world will undoubtedly be used again.


167 For an extensive treatment of United States international economic policy toward small nations in the field of aviation, see F. Thayer, Jr., Air Transport Policy and National Security 272-315 (1965).

168 Robinson, supra note 142 at 841 n.24.
These considerations make the bilateral agreement a slim thread on which to base international SST regulation, and a mechanism less subject to external pressure clearly would be preferable. Existing multilateral aviation conventions represent a much more desirable solution for no other reason than uniformity of approach.

Taking an overview of the current framework of international aviation law and regulation, there is room both for optimism and pessimism. On the more positive side, it is of significance that the basic international conventions and organizations which must deal with the SST and its problems already are in existence and functioning. Further, it appears that effective control and a workable compensation scheme could be achieved by them if the interested parties could agree to some basic modifications. On the negative side of the picture, chances for the needed changes being made in time to do any good must be realistically assessed as small. The international organization which must do the regulating of the SST, the ICAO, has moved very slowly so far and is giving no signal that it intends to increase its pace. The all important problem of compensation is receiving almost no international attention, and the Rome Convention, the framework in which the compensation problem could be solved, has always been received less than thunderously by the international community. What changes should be made, however, is a different problem from whether a consensus exists to make them, and it remains to be considered in what ways existing law, international and American, may be altered to handle the SST problem.

XI. A Critique and Proposals for Change

There seems to be a general consensus among those who have considered the problem that the external costs which overland SST operation may generate should be internationalized and thus reflected in airline rate structures by holding the carriers themselves absolutely liable for all SST-caused ground damages. The arguments in favor of this approach are difficult to rebut. The cost to society of worldwide supersonic jet transport operation in terms of depressed property values, structural damages and personal injuries may be enormous. No one really knows. If these possible damage costs are not reflected in fare structures and thus ultimately borne by the class of people who will benefit from the SST, but are absorbed by government or society, the aircraft will be indirectly subsidized in comparison with subsonic jet operation.

This is not yet a significant problem with present jets. Even though the aviation industry is not now forced to bear the social costs of damage by engine noise,169 total dollar values of such claims are probably minor when compared with overall industry costs and would have a negligible effect on passenger rates. But this may not be true for the SST. Ground damage, even excluding depression of property values, has already been estimated at 90 million dollars annually for the United States alone.170

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170 Kryter, supra note 76, at 360.
fly, such external costs should be assessed via an absolute liability system to the operating carriers and passed along to passengers in the form of increased rates so they can determine if the added cost is really worth the added convenience of speed. Such a policy of necessity would have to be adopted both internationally and in the United States.

However a workable legal mechanism which insures that external damage costs are reflected in the SST’s fare structure represents a most difficult achievement, one which has been traditionally resisted by carriers and many governments as well. Even so, some consideration must be given to implementation of such a mechanism. The thoughts presented here represent little more than the rudimentary conceptual framework of a possible international regulatory-compensation system based largely on existing organizations, but they may serve to identify some possible approaches to the problem. It would seem that a dual phase program at the international level is advisable if SST land overflights become a continuing reality. First, absolute liability should be imposed on aircraft operators for all ground damage, including damage caused by engine noise or sonic booms, through international convention. In addition to such a compensation arrangement, multilateral regulation of the SST through the ICAO should be initiated. Such a two stage effort seems to be essential to adequately cope with the situation but it should be recognized that compensation is the backbone of any workable plan. If airlines are not held directly liable for ground damages they will oppose vigorously any standards which impose restrictions on engine noise or boom intensity because it can only cost them money through reduced operating efficiency. If faced with liability, there may be an incentive to advocate design standards which, though sacrificing some operating economy, may nevertheless save the carriers much more in damage claims.

As to the implementation of these proposals, the Rome Convention on Surface Damage was an early, if unsuccessful, attempt at imposition of absolute liability for ground damage on foreign aircraft operators. It could serve as a basic model if enlarged to specifically include loss from engine noise and sonic booms, the two greatest potential sources of damage from the SST. There also should be imposed mandatory financial responsibility on each airline as a condition of overflight, sufficient to cover any claims which may result. Further, the method of executing judgments in another nation, created by the Rome Convention, is unrealistic when the possible number of damage claims which may be produced is considered. While each nation should formulate its own adjudication system to handle damages, the goal on the international level must be elimination of the necessity of an individual ever having to resort to the courts of another country for compensation.

To achieve regulatory standards which are binding on all nations the concept of airworthiness under the ICAO should be expanded to include

171 For a comprehensive discussion of the concept of internationalization generally and its specific application to water pollution, see A. Knese, THE ECONOMICS OF REGIONAL WATER QUALITY MANAGEMENT (1962).
areas other than safety, specifically engine noise limits and overall airframe design to achieve minimum overpressure at a given Mach number. Since airworthiness certification is binding on all contracting states under the Chicago Convention, the standards which the ICAO establishes in this area will have to be met in order to prevent the possibility of a nation’s aircraft being excluded from international air commerce.

There is no question that such proposals would place serious economic burdens on the SST if it is to operate over land. But, it must be pointed out, the burden will be only as severe as the one the SST imposes on society. No one is forcing the SST to operate over land and, if the burden is so great that passengers will not pay for it, subsonic jets should be used. It seems essential that such proposals be implemented on a multilateral basis and not left to individual nations as a matter of negotiation. Any decision a single nation makes, either to allow or bar SST land overflights, will be much more objective and easier to take with the knowledge that a multilateral body exists which can handle damage problems without the threat of direct economic repercussion which could exist if individual states attempt to solve the problem bilaterally.

An international compensation and regulatory plan for foreign airlines solves only a portion of the SST problem. The United States must still face the same questions internally and great difficulties exist with our present aviation law. The same necessity for social cost internalization exists within the United States as exists without and present law will simply not accomplish the desired result. Under the test formulated in the Griggs case, the agency which exerts the most control over an aircraft is responsible for the damage it causes, at least for damage caused by engine noise. Since it is likely that nationwide air traffic control and comprehensive route planning will be needed by the federal government to facilitate SST operation, if the courts retain the present control test then the United States may become the party legally responsible for all sonic boom damage. Since government will be the proper party to sue, the inverse condemnation theory now used only for engine noise near airports will be the logical remedy to utilize and it is foreseeable that the courts will find a "taking" has occurred through vast areas of the country within boom corridors. Because the proper measure of damages in such an action is the amount of decline in property values, either plaintiffs will have to bring separate actions to recover for personal injury, or the courts will have to twist the existing remedy to allow recovery in an eminent domain type of action.

The Griggs control test has already caused tremendous maneuvering among local government units, the FAA, and Congress. Each wants enough power to control and regulate within its own bailiwick but not so much as to get stuck with the financial burden which presently accompanies the unlucky party found by the courts to exert the most significant "control." As a result neither the FAA nor Congress has been over zealous in the field of noise regulation and each accuses the other of dragging its heels while

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172 Chicago Convention, Art. 33.
the public suffers. Consequently, local government which already has to pay is the only source of noise regulation, and this usually takes the form of difficult to enforce noise restrictions imposed by the airport itself. The result is stagnation, while the airlines are generally free to operate as they please, without an economic deterrent to excessive noise. Should the situation continue there will likewise be no effective deterrent to sonic booms while the government agencies struggle among themselves to regulate but not "control."

This must be avoided if at all possible, and to do so current American aviation law must be changed. Therefore, any international agreement on absolute liability should be implemented in the United States by federal legislation imposing absolute liability on aircraft operators for all ground damage. Obviously there will be great pressure exerted to limit liability on the basis that the public receives significant benefit from air commerce, enough to justify it bearing some portion of the ground damages produced. These arguments have weight and have been successful before, but to accept them in the SST situation would be erroneous. It is true that the public benefits greatly from an efficient air commerce system but it has borne part of the burden of building airports and control facilities for the use of the airlines and will continue to do so when the SST arrives. The aviation industry already bears responsibility for personal injuries it causes during flight, and there is no logical reason why it should not do so for ground damage. Only in this way can the true social cost of the SST be reflected in user rates, thereby forcing the important economic comparison to be made between the SST and subsonic jets for use on land routes.

Efficient administration of a national absolute liability system for all aviation ground damage may prove to be a difficult matter to handle. Damages such as loss of hearing near airports and property value depreciation will be caused by continuous overflights and probably could best

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174 N.Y. Times, Feb. 21, 1970, at 78, col. 6. The FAA consistently has contended it has no power to enforce noise restrictions even though it has authority to establish them but Congress feels it has provided sufficient authority. The statutory language around which the controversy centers is 49 Stat. 395 (1968), 49 U.S.C. 1431(a) (1970 Supp.). It states: "In order to afford present and future relief and protection to the public from unnecessary aircraft noise and sonic boom, the Administrator of the Federal Aviation Administration . . . shall prescribe and amend standards for the measurement of aircraft noise and sonic boom, and shall prescribe and amend such rules and regulations as he may find necessary to provide for the control and abatement of aircraft noise and sonic boom, including the application of such standards, rules, and regulations in the issuance, amendment, modification, suspension, or revocation of any certificate authorized by this subchapter."

175 For a discussion of noise restrictions imposed by the Port of New York Authority at New York airports, see J. STEPHEN, LEGAL AND RELATED ASPECTS OF AIRCRAFT NOISE REGULATION 70 (1967). These restrictions are imposed as a "condition of use" in the lease which airlines must sign to use facilities. Though many major airports have adopted such restrictions, their success has been uncertain. At Kennedy Airport in New York, the Port of New York Authority measures ground noise levels three miles from the end of the runway to enforce compliance with standards. This method is not entirely adequate since it has been alleged that pilots reduce power as they pass over the measuring devices and thus circumvent the control system.

176 This type of solution has already been suggested. See Baxter, The SST: From Watts to Harlem in Two Hours, 21 STAN. L. REV. 1 (1968). Professor Baxter has proposed a statutory contingency fund, supported by increased SST passenger fares, to satisfy damage claims, and would be the proper defendant in all damage suits, with proper venue in the federal district court where the damage has occurred. The fund itself would also provide for attorney's fees. One of the difficulties with such a system is that it would presumably require a lawsuit to recover even minor damages.
be handled through normal judicial channels with all airlines responsible being jointly and severally liable in proportion to the percentage of flights made through the given area. However structural damage and personal injury may run the spectrum of a five dollar window pane to even death, and will usually be caused by a single aircraft of a given airline, exactly which one being difficult to determine. These claims will be repetitive and perhaps could be of the order of magnitude of automobile accident claims which now clog the court system.

To handle this second type of damage, some consideration should be given to imposing on the industry as a whole a mandatory insurance pool, the premiums to be paid by individual carriers in proportion to the estimated number of persons exposed to their SST flights, taking into consideration the number of flights a day in a given area by a particular carrier. In this way the great volume of claims, especially those of a minor nature can hopefully be handled through existing claims channels of the insurance companies without the necessity of utilizing the courts. An insurance pool of 100 million dollars to begin with could be established on the basis of existing estimates of structural damage and personal injuries.

An insurance pool is recommended for a variety of reasons. First, there seems no other method of as easily handling those small items such as a single broken window which are compensable but which are too minor to justify a court action. Second, the problems of proving causation on the part of an individual airline for a specific instance of damage are almost insurmountable and it would be inequitable to allow individual carriers to escape liability for this reason. Therefore each carrier should bear its pro rata share of all damage based on how much of the population it individually affects. And finally, the type of damage involved here will occur again and again, making use of the courts to treat the problem unwise and impractical. This will not be the case for depression of property values, where a single action will recover all allowable damages.

The administration of claims will be a most difficult problem to solve adequately and equitably and the proposals suggested here can only be of a skeletal nature. There, of course, will exist the always present difficulty of fraudulent claims and the intricacies involved with determining whether claimed damage was in fact caused by sonic boom should not be minimized. Nevertheless, these problems cannot be allowed to impede adoption of a system which can cope with both the diversity and volume of individual instances of damage which the SST will undoubtedly generate.

XII. Conclusion

The SST may have international consequences of a tremendous magnitude and realistically must be handled on a multilateral, international basis. Individual nations who choose for some reason to allow SST overflights within their sovereign territory must be assured that their citizenry will be protected by a workable compensation plan to cover the inevitable damages. This should be accomplished by adoption of an international
absolute liability plan, covering all ground damages which the SST may produce, and assessing them directly against the carriers. Only in this way will the true social cost of the SST be reflected in rates which the airlines charge and force those who benefit by the SST, the flying public, to determine if the benefit they receive is worth the added cost. Additionally, the International Civil Aviation Organization must shoulder the burden of establishing minimum engine noise and sonic boom intensity standards via the concept of airworthiness in order that any aircraft which exceeds the limits imposed can be effectively excluded from operating in international air commerce. Such standards, coupled with a scheme of absolute liability, will be recognizably difficult to achieve and will require an attitude of great flexibility on the part of the governments involved. Nevertheless, efforts in this direction must be initiated if the SST is not to overwhelm an unprepared world.

While the aviation industry's claim that people will become "accustomed" to the noise of the sonic boom may or may not prove true, that is really a moot point. Even if the population does become "accustomed" to the noise, it is extremely unlikely that it will ever become complacent and forget about the innumerable broken windows and cracked plaster which the SST will surely cause. If it does not become "accustomed" to the sonic boom, then other kinds of damage claims will arise. Thus, regardless of the sonic boom's subjective effect on the population, there will always be a need to compensate those who are damaged. This is the crux of the SST issue and it must be attacked with responsibility, foresight, and alacrity.