Table 1. Principal interatomic distances and angles.

Distance	Å	Angle	Deg.
$Ir-P_1$	2.38(1)*	P_1-Ir-P_2	173(1)
$Ir-P_2$	2.36(1)	X_1-Ir-X_2	100(1)
$Ir-X_1$	2.42(2)	X_2-Ir-O_1	107(1)
$Ir-X_2$	2.38(2)	O_1-Ir-O_2	37(1)
$Ir-O_1$	2.09(3)	O_2-Ir-X_1	116(1)
$Ir-O_2$	2.04(3)	P_1-Ir-X_1	93(1)
O_1-O_2	1.30(3)	P_1-Ir-X_2	91(1)
		P_1-Ir-O_1	85(1)
		P_1-Ir-O_2	89(1)
		P_2-Ir-X_1	88(1)
		P_2-Ir-X_2	96(1)
		P_2-Ir-O_1	91(1)
		P_2-Ir-O_2	84(1)

* The number in parentheses is the estimated error in the least significant figure.

The positions of the two oxygen atoms and the ring carbon atoms were easily found in subsequent difference Fourier syntheses. In addition two strong peaks, corresponding to Cl and CO, were found on these maps, but they were similar in shape and height, and in neither was the C and O of the carbonyl resolved. This trial structure was refined by successive least-squares calculations, using the group refinement of the phenyl rings described previously (*6*). From this refinement and subsequent difference Fourier syntheses it was evident that the CO and Cl positions in the structure are disordered in the sense that the two electron-density peaks in question are made up of both CO and Cl contributions. A final refinement was carried out in which a Cl scattering factor was assigned to the composite peaks.

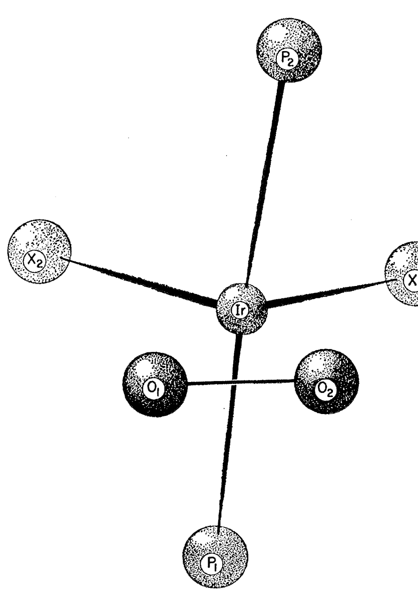

Fig. 1. A perspective drawing of the $O_2IrCl(CO)(P[C_6H_5]_3)_2$ molecule. Phenyl rings are not shown. X_1 and X_2 refer to the disordered positions of CO and Cl.

In this refinement the Ir was allowed to vibrate anisotropically and the other heavy atoms were constrained to vibrate isotropically, while each phenyl ring (including the hydrogen contributions) was assigned an individual overall isotropic thermal parameter. This refinement converged rapidly to an overall agreement factor

$$R = \Sigma \| F_o | - |F_c \| / \Sigma |F_o|$$

of 0.071 for the 1128 observed reflections.

The structure is shown in Fig. 1 and it closely resembles the one surmised by Vaska (*4*) on the basis of less direct information. The Ir may be described as six-coordinated: in the basal plane there are the Ir, the C (of the CO) and the Cl atoms (denoted by X in Fig. 1), and the two O atoms of the O_2 molecule; above and below this basal plane are the two P atoms of the $P(C_6H_5)_3$ groups. The P-Ir-P direction is essentially normal to the basal plane. Principal interatomic distances and angles, together with their estimated standard deviations, are given in Table 1. The disordering of the Cl and CO positions can be rationalized in the following way. The compound results from the attack above or below the square-planar $IrCl(CO)(P[C_6H_5]_3)_2$ by O_2. In solution, because the $P(C_6H_5)_3$ are equivalent (*4*), only one isomer is formed, and if these $P(C_6H_5)_3$ groups remain equivalent throughout the crystallization process (that is, if the relative positions of Cl and CO have no effect on this process), total disorder of the Cl and CO positions should result. Apparently this is the case, and the packing is determined almost entirely by the phenyl rings. (The volume per triphenylphosphine group is only 10 percent greater than in triphenylphosphine itself.)

The significant results relating to the oxygen attachment to the iridium are (i) the two oxygen atoms are equidistant from the iridium atom and are thus equivalent; (ii) the O–O distance, while longer than in molecular oxygen (1.20 Å), is significantly less than in a typical peroxide (1.48 Å). The equivalence of the oxygen atoms is consistent with Griffith's (*7*) picture of the π-bonding of molecular oxygen to the iron in oxyhemoglobin, which differs from Pauling's (*8*) earlier ideas on the subject. The fact that the O–O distance is intermediate to O_2 and O_2^{-2} is in striking agreement with the qualitative principles of reversible oxygen uptake suggested by Vogt, Faigenbaum, and Wiberley (*1*). That the O–O distance corresponds very nearly to that for O_2^- is perhaps misleading, for then the Ir is formally Ir(II) and yet the compound is diamagnetic. Of course in molecular complexes the concept of formal charge on the metal ion is of limited utility and validity. A less qualitative description of the bonding depends upon a molecular orbital calculation for the complex, and this in turn depends among other things upon the existence of reliable wave functions for iridium. These are as yet unavailable. At present one must be satisfied with the experimental results that the oxygens are equivalent and that the O–O bond length is intermediate to those in O_2 and in O_2^{-2}.

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5. We thank F. Holtzberg for performing this measurement for us.

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9. We thank L. Vaska for the sample and for several helpful discussions of the chemistry. Research performed under the auspices of the U.S. Atomic Energy Commission.

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Location of an Aircraft Impact from Gravity Waves

Abstract. *The energy released upon impact of an airliner that crashed into Lake Pontchartrain, Louisiana, on 25 February 1964 caused changes in water levels of sufficient duration and amplitude to be recorded by tide gages situated within the lake. Analysis of the recorded arrival times made it possible to locate the point of impact within an irregular area approximately 1500 feet (500 meters) in radius.*

On 25 February 1964, a four-engine jet airliner, enroute from New Orleans to Chicago, crashed in Lake Pontchartrain, Louisiana. After the disaster investigators of the Civil Aeronautics Board encountered the problem of locating the site of the wreckage within the 640 mi^2 (1650 km^2) lake. At the estimated impact speed of 600 mi/hr (960 km/hr) the aircraft disintegrated to the extent that no major structural part remained intact. As recovery operations continued it became apparent that only a piece-by-piece reconstruction would establish when total recovery was achieved. In this case, the location of the point of initial impact would have provided significant aid to the crash investigators.

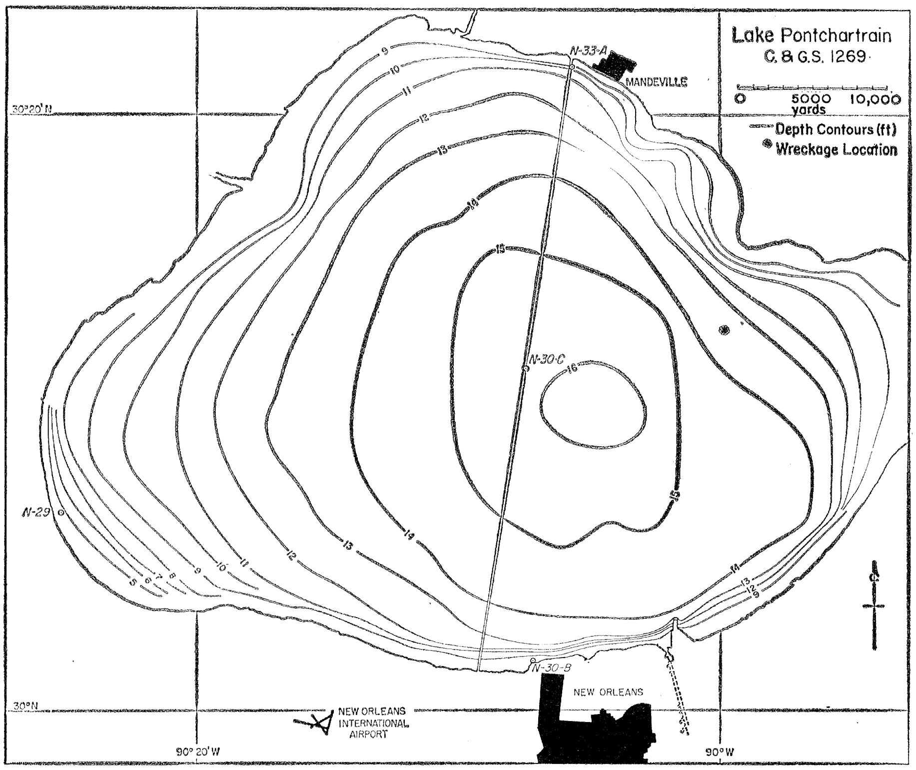

Fig. 1. Lake Pontchartrain, smoothed bathymetry.

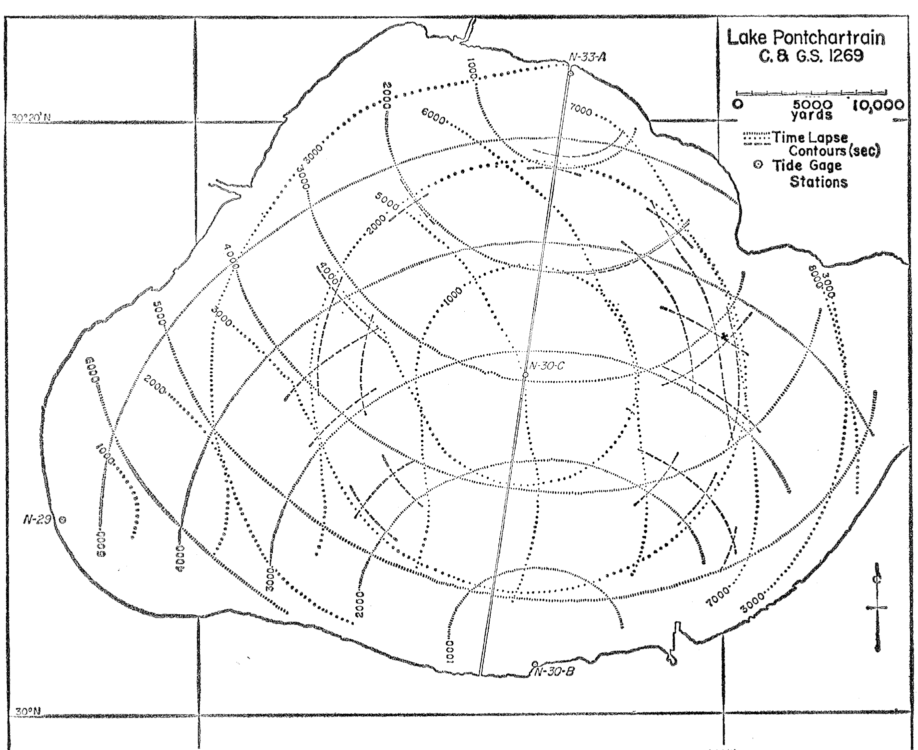

Fig. 2. Lake Pontchartrain, contours of travel time from tide gage stations.

When a solid object impacts a fluid surface, impulsively generated waves are formed and propagate radially outward. The magnitude and character of the disturbance of the water surface depend upon the fluid properties and the amount of energy which is transformed into the water-wave system. This prompted us to examine the records of water level as recorded on the lake for this date. Four continuously recording tide gages, maintained by the U.S. Army Corps of Engineers, are located on Lake Pontchartrain (Fig. 1). An examination revealed a number of short-duration excursions (blips) from the mean recorded level.

A realistic test to determine whether these excursions resulted from the impulse phenomena would be to establish a single spatial and temporal point of origin for the blips observed on all four records. If the time of origin so determined coincided with the known time of the crash (2:09 A.M., C.S.T.), it follows that the position of origin locates the point of aircraft impact.

Similar techniques are used by oceanographers to locate areas of storm generation at sea. Also, the prediction of times of arrival at coastal areas of a tsunami is based upon the propagation speed of a water wave away from its point of generation, by whatever cause.

The kinetic energy of the aircraft at impact was estimated at 2.4×10^9 ft-lb (3.3×10^{10} kg-m). If all of this energy were translated into the potential and kinetic energy of a simple surface wave system covering the entire lake, a wave height of 0.13 foot (4 cm) would result.

In a more realistic sense, if we consider that (i) only 5 percent of the total impact energy goes into the generation of a water wave system or surge, (ii) the wave system is propagated within an annulus 1200 feet in width at the time it reaches the lake shore, (iii) a mean radius of the annulus is 13 miles (21 km), and (iv) the wave propagates as a long wave, we compute a probable wave height of 0.17 feet (5 cm).

The tide gages are constructed so that they filter out short-period waves. They have a response factor which is a nonlinear function of H/T^2, where H is the wave height in feet and T is the wave period in seconds. Consequently, recorded deflections, in order to be attributed to the aircraft impact, must result from short-period waves with large amplitudes or from relatively long-period waves. For the former case, the recording should show a positive and negative excursion from the mean recorded tide level. The typical long solitary wave is primarily a positive excursion; further, a long wave would be reflected strongly at the beaches and would be likely to cause secondary deflections to be recorded. Tide gage records (see Fig. 3) show substantial evidence supporting the long wave case.

To present in a usable form the information contained in the records, we initially constructed a chart of travel-time contours (Fig. 2) based on the lake bathymetry and the propagation speed of a long wave, $c = (gh)^{\frac{1}{2}}$, where g is gravity and h is the undisturbed depth of the water. The actual elapsed times (between impact and recorded surges) were obtained from the gage records with the use of a micrometer stage microscope. The intersection of actual time lapse contours from each gage defined the impact area, as shown in Fig. 2. This area is unique in that all four records contribute deflections whose time-lapse contours pass through it. These deflections are labeled with crosses in Fig. 3. The center of a circle containing these intersections of time lapse contours lies 1200 feet south of the center of the actual wreckage. Discussion with the chief investigator of the Civil Aeronautics Board at the time of this study indicated that wreckage was being recovered from beneath the bottom of the lake (that is, dug out of the mud) at the site indicated in Fig. 1.

The numerous blips in the records do not rule out the conclusions made here. Evidently most recorded disturbances were not generated by the aircraft because their time-lapse values either do not produce correlated areas of intersection or fall outside the lake. At two stations, N-30-C and N-33-A, the time lapses of the blips (labeled R in Fig. 3) immediately after the deflections marked by the crosses can be identified by estimates as reflections off the shore of the primary long waves.

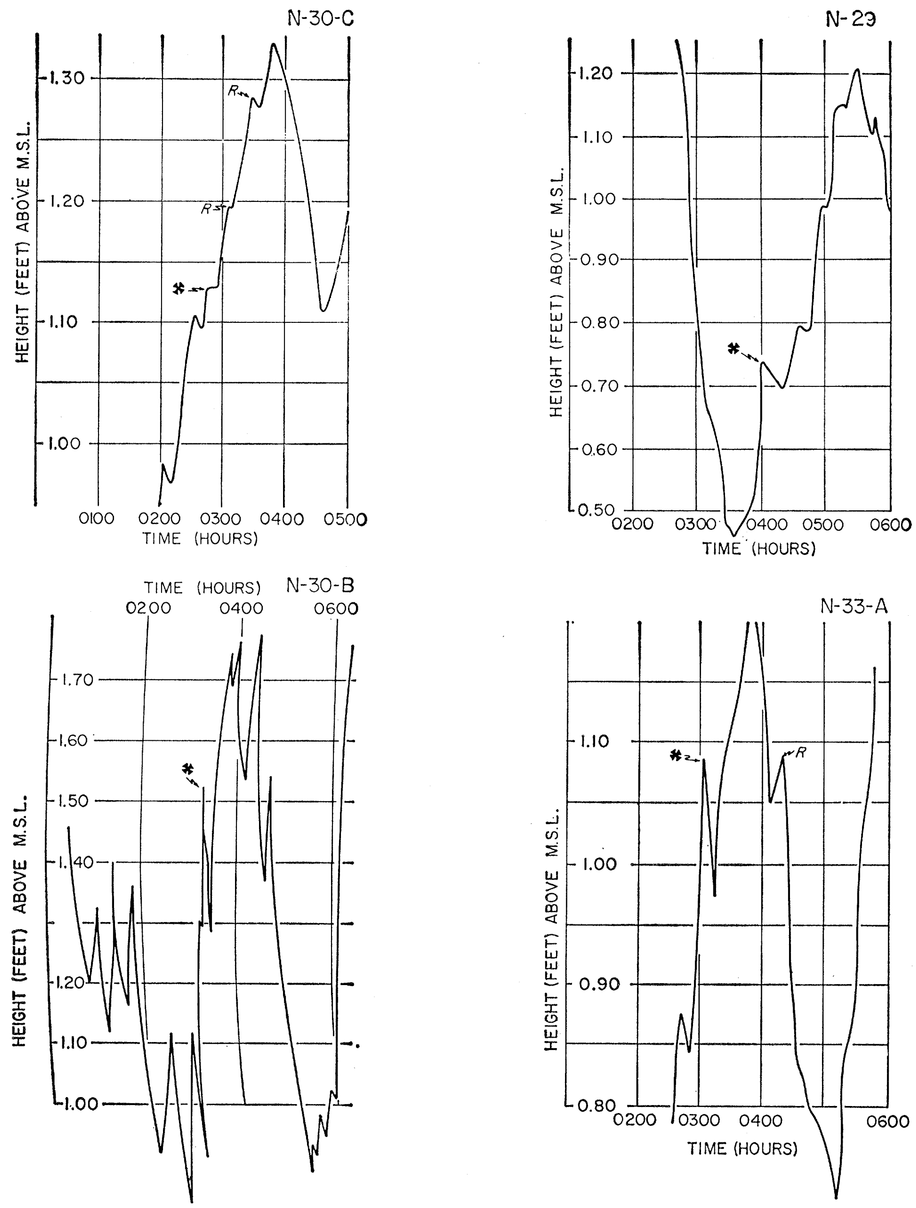

Fig. 3. Records reproduced from tide gages taken 25 February 1964. M.S.L., mean sea level.

For the problem treated here, the approximate time of impact was known. Had this information not been available, the impact area would have been defined by using the method of relative time difference instead of absolute time lapse. The construction of time-difference contours follows directly from the time-lapse contours by connecting the intersection points of equal time difference.

In view of the aircraft speed and the shallowness of the lake, it appears that the impulse time is too short for a substantial water wave to have been generated directly from the aircraft impact at the surface. We surmise that the deformation of the layers of sediments after penetration was the primary mechanism by which the kinetic energy of the airplane was translated into water wave energy. Such a wave would probably be of the solitary type, and the possibility of a bore having been formed should not be ruled out.

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Note

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