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EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric		
1. Storms; wind	1. Tremendous winds sort of like maybe the prevailing winds of earth but very close to the surface of Jupiter. I see something that looks like a tornado.	1. Science News, Vol. 106, September 21, 1974. a. p. 186 Science News, Vol. 107, May 10, 1975. a. p. 305 Science News, Vol. 110, July 10, 1976. a. p. 26 Scientific American, Spetember 1975. a. p. 120 b. p. 123 Scientific American, March 1976. a. p. 50 On Jupiter the zones and the Great Red Spot are high-pressure regions (anti-cyclontic) and the belts are low-pressure regions (cyclonic). That was first pointed out in 1951 by Seymour L. Hess of Florida State University and Hans A. Panofsky of New York Univ. Hence the zones and the Great Red Spot seem to be fundamentally different from terrestrial storms, which are usually cyclonic at sea level. The difference is not, however, as fundamental as it seems. Since clouds tend to form in rising air, and since rising air tends to be warm, it is reasonable to assume that the zones and the Great Red Spot are warmer than their surroundings at any particular level within the clouds. In that respect they resemble tropical cyclones (hurricanes) and mature extratropical cyclones on the earth, most of which are also warm. The resemblance is significant because terrestrial air masses that are warm tend to have high-pressure centers and anticyclonic circulation at high altitudes, the altitudes to which the Jovian observations refer. b. p. 55 Time, September 16, 1974. a. p. 82 Its atmosphere is apparently ravaged, not only by great bolts of lightning but also by winds with velocities of more than 300 mph. In fact, Jupiter's great red spot, long a puzzle to astronomers, could be the vortex of a violent Jovian storm.

EXCERPTS FROM SWANN TRANSCRIPT		TECHNICAL REFERENCES
IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric (contd.)		
1. (contd.)	1. (contd.) Same as previous page.	1. Time, May 5, 1975. a. p. 55 b. p. 55 Time, March 12, 1979. a. p. 87 Yet it was Jupiter's stormy weather that caused the greatest excitement. Voyager's electronic eyes spotted dozens of storms across Jupiter's banded face. Most of them measure about 6,000 miles wide, far larger than their earthly counterparts. Largest is the Great Red Spot, a permanent hurricane with a maximum width as much as three times the earth's diameter. University of Arizona Astronomer Bradford A. Smith was both awed and puzzled by these storms: "It's as if each of these things has a life of its own. You can stretch them, deform them and even break them apart, and they still have an inner cohesion that keeps them together."

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EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric 2. High infrared reading	2. I bet you that the surface of Jupiter will give a very high infrared count (?), reading (?) (inaudible sentence) The heat is held down.	2. Aviation Week & Space Technology, July 16, 1979. a. p. 21 Newsweek, December 3, 1973. a. p. 74 Indeed, Jupiter is just about as large as a planet can be without becoming a star, and it is unique among the planets of the solar system in emitting more energy (in the form of heat) that it receives from the sun. Science, Vol. 183, January 25, 1974. a. p. 303 The Pioneer 10 infrared radiometer has established that the excess radiation is 2 to 2.5 times the solar input and that there is no temperature change at the cloud top levels across the evening terminator of the planet. Science, Vol. 188, May 2, 1975. a. p. 447 Science, Vol. 198, December 9, 1977. a. p. 1033 Science News, Vol. 104, December 8, 1973. a. p. 356 Science News, Vol. 104, December 15, 1973. a. p. 372 Science News, Vol. 105, April 13, 1974. a. p. 236 Earth-based measurements of the temperature of Jupiter's upper atmosphere, says Kliore, have recorded no higher than about 220 degrees F. below zero. Yet Pioneer's data have now revealed that at a pressure of only half that of earth at sea level, apparently less than 125 miles down into the Jovian atmosphere, temperatures rise to a boiling 260 degrees. Farther down, at about 2.8 earth atmospheres of pressure on the day side of the planet and 2.4 in the darkness, temperatures are indicated as high as 800 degrees. The surprise is that the heating should begin at such lofty altitudes, particularly with no indications either from earthly observations or from the infrared mapping device aboard

EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric (contd.)		
2. (contd.)	2. (contd.) Same as previous page.	2. the spacecraft. "It's a huge discrepancy," admits Kliore. "I can't explain it." The closest thing to a theory is that perhaps a haze or dust layer, while confusing watchers on earth, creates a greater greenhouse effect than anyone had expected, trapping and building the sun's incoming energy to unanticipated heights. (Jupiter was known even before Pioneer 10 to radiate at least two and a half times as much energy as it gets from the sun. Science News, Vol. 106, September 21, 1974. a. pp. 186-187. Above the visible clouds lies Jupiter's invisible outer atmosphere, extending possibly as much as another 150 miles. Guido Munch of the California Institute of Technology believes that this outer layer may contain not only some ammonia, but enough mixed-in methane to absorb the sun's heat and create a temperature inversion, perhaps 21 miles above the cloud tops. Above that, there may be a layer of aerosol droplets and hydrocarbons such as ethane and acetylene (detected from earth-based infrared measurements) which also add to the heat absorption. These high, invisible, heat-absorbing layers may be the reason that one of Pioneer's experiments, a radio-occultation measurement, showed significant heating in the atmosphere to begin at much higher altitudes than was indicated by Munch's infrared heat-mapping device (SN: 4/13/74, p. 236). Science News, Vol. 106, December 7, 1974. a. p. 357 Science News, Vol. 110, July 10, 1976. a. p. 26 Scientific American, September 1975. a. p. 119 b. p. 122 It was found that the day side and night side are at the same temperature, suggesting the enormous heat capacity of the Jovian atmosphere and confirming the importance of an internal source of heat. Scientific American, March 1976. a. p. 49

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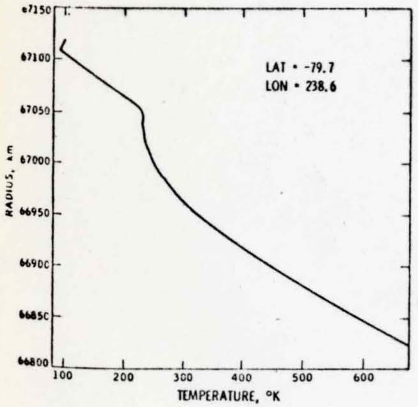
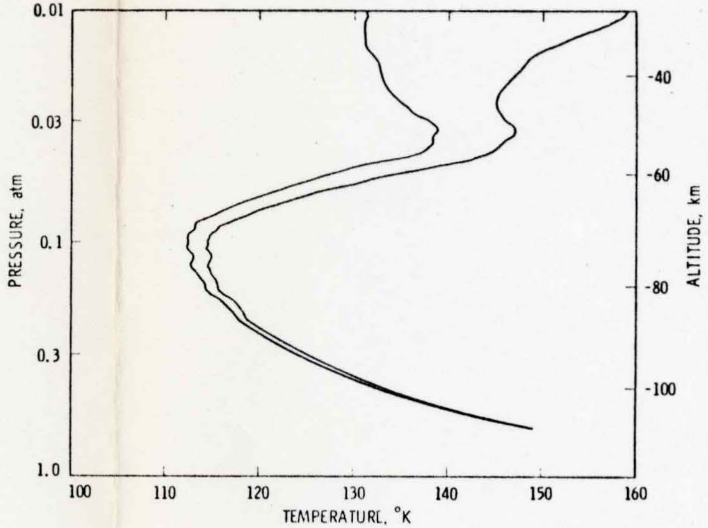
EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric 3. Temperature inversion	3. Is there a thermal inversion here? I bet there is. It's colder here, maybe it's because there's not a thermal inversion there.	3. Science, Vol. 183, January 25, 1974. a. p. 323 b. p. 324 Science, Vol. 188, May 2, 1975. a. p. 475 In particular, the appearance of the inversion at about 260 K is strikingly similar to the Pioneer 10 entry profile, although the Pioneer 11 measurement was obtained on the dark limb of Jupiter. Thus, the inversion cannot be ascribed to heating by particulate absorption of solar radiation, unless rapid circulation at the polar latitude is sufficient to maintain this effect across the terminator. 

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric (contd.)		
3. (contd.)	3. (contd.) Same as previous page.	3. Science, Vol. 204, June 1, 1979. a. p. 947 b. p. 976 c. pp. 977-8 The two curves result from different assumed boundary-condition temperatures of 130 and 160 K at about the 10-mbar level, where Pioneer and ground-based infrared measurements have been used to derive temperatures in this range (6). Of particular interest in Fig. 1 are (i) the tropopause pressure of 100 mbar and temperature of about 113 K; (ii) the temperature lapse rate at lower altitudes of about 2 K/km, which matches the expected value for adiabatic conditions in Jupiter's atmosphere; and (iii) a relatively warm inversion layer in the stratosphere at the 35-mbar pressure level, which may be due either to absorption of solar radiation by a minor atmospheric constituent at this level or to upward propagating inertia gravity waves (7).  Fig. 1. Preliminary profile of atmospheric temperature as a function of pressure, as computed from the 3.6-cm radio occultation of Voyager 1 at about 12°S, 63°W (System III, 1965.0) on Jupiter. The zero of the (nonlinear) altitude scale is at the height at which the refractive index of the atmosphere is one part in a million greater than unity, which occurs approximately at the 10^{-3} atmosphere pressure level. Different assumed upper boundary conditions on the temperature yield the two separate curves which coalesce at lower altitudes. It is assumed that the atmosphere consists of 88 percent H_2 and 12 percent He by volume and that the zonal westerly wind speed at the occultation point is 20 m/sec.

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EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric		
4. Cloud color and configuration	4. From that view the horizon looks orangish or rose-colored but overhead it's kind of greenish-yellow. You know I had a dream once something like this where the cloud cover was a great arc, sweeps over the entire heaven.	4. Science, Vol. 190, October 17, 1975. a. p. 274 Phosphine on Jupiter and Implications for the Great Red Spot Abstract. A study of the chemistry and photochemistry of the recently discovered phosphine in the atmosphere of Jupiter suggests that the red colorations on this planet result from photochemical production of red phosphorus particles. Chemical-dynamical models of this red phosphorus haze imply that the intensity of the red coloration is a strong function of the strength of vertical turbulent mixing in the atmosphere. If the Jovian Great Red Spot is a region of considerable dynamical activity our model provides a self-consistent explanation for the redness of this region in comparison to the rest of the planet. Science News, Vol. 105, April 13, 1974. a. p. 237 The most conspicuous feature, never before seen by man, is a 600-mile-wide cloud head emerging near the equator, trailing an 18,000-mile cloudy plume that may be driven by a violent Jovian jetstream roaring overhead at some 300 miles an hour. Chains of remarkably symmetrical whorls of cloud extend for several times the diameter of the earth along the sharp-edged belts of Jupiter, a planet to remember--and to visit again. Science News, Vol. 115, March 10, 1979. a. p. 148 Still, striking reds, oranges, yellows, browns and even blues make Jupiter's convoluted patterns seem all the more fantastic. Turbulent interfaces analogous to jetstream interactions high in earth's atmosphere become twisted riots of color. They appear stranger still because the clashing hues often look sharp-edged down to resolutions as fine as 25 kilometers. A major goal of Voyager is to find out the nature and chemistry of the coloring agents--the Red Spot, for example, is now not red but orange-ochre, embellished in some views with white. Phosphene and other candidates have been suggested, but they have been far from certain. Science News, Vol. 116, July 21, 1979. a. p. 37 Whatever their source, however, the nature of the coloring agents remains elusive. The planet is mostly hydrogen with a bit of helium, in a ratio close to that of the sun. (If earth had enough hydrogen, compared to the silicon in its rocks, to equal the sun's hydrogen-silicon ratio, says Andrew Ingersoll of California Institute of Technology, our planet would have the comparatively tiny traces of other molecules--"dirt on the skin of

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EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric (contd.)		
4. (contd.)	4. (contd.) Same as previous page.	4. the orange," says one Voyager researcher--that may be interacting in complex ways. The Voyagers have detected some such "pollutants" (largely confirming, though with greater precision, earth-based measurements), but their working chemistry has yet to be unraveled. Hypotheses include organic polymers for the yellows, browns and oranges; large phosphorus molecules (P_4) for the Red Spot's red; ammonium hydrosulfide for white and monosulfide for yellow; and more. Scientific American, March, 1976. a. pp. 47-8 Lewis' model, which assumes that all the substances are at chemical equilibrium at each level, cannot account for the colors of the clouds. The cloud particles in that model are white, whereas the Jovian clouds are subtle shades of red, brown, white and blue. With convection bringing up exotic material from deeper levels, however, and with ultraviolet radiation from the sun energizing chemical reactions at the top of the atmosphere, it is not surprising that portions of Jupiter's atmosphere do depart from local chemical equilibrium. Only small amounts of coloring material are needed to explain the observations, and an atmosphere with the same composition as the sun's would contain all the necessary elements in a wide variety of compounds. It is currently believed that the clouds are basically as Lewis has predicted, with the colors explained by the addition of small amounts of sulfur, red phosphorus and complex organic molecules.
5. Localized climatic phenomena	5. (a) If I'm giving a description of where I've gone and am, it would be approximately where Alaska is if the sun were directly overhead which it is. I see something that looks like a tornado. Is there a thermal inversion here? I bet there is. I bet you that the surface of Jupiter will give a very high infrared count (?), reading (?) The heat is held down. (b) I seem to be stuck, not moving. I'll move more towards the equator. Tremendous wind. It's colder here, maybe it's because there's not a thermal inversion there.	5. Science, Vol. 204, June 1, 1979. a. p. 972 Infrared Observations of the Jovian System from Voyager I. Meridonal temperature cross sections show considerable structure. At high latitudes, the stratosphere is warmer in the north than in the south. The upper troposphere and lower stratosphere are locally cold over the Great Red Spot. Science, Vol. 206, November 23, 1979. a. p. 954-5 The gross belt-zone structure observed in visual imaging is apparent in the thermal maps. Relatively cold regions occur in both maps at approximately 20° to 35°N and 20° to 35°S, corresponding to bright zones seen in Voyager images. The warmest temperatures in both maps occur between approximately 15°N and 15°S, which is associated with a visually dark equatorial belt.

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric (contd.)		
5. (contd.)	5. (contd.) Same as previous page	5. Perhaps the most striking aspect of the maps is the abundance of relatively localized features. In some cases, these areas can be correlated with visual features seen in the Voyager images. For example, the cold area observed at 602 cm^{1} near 23°S 105°W is associated with the Great Red Spot, and the warm feature near 13°N, 215°W coincides with one of the dark brown elongated spots discussed by Smith et al. (2). On the other hand, many other thermal variations are not obviously correlated with visual features. Comparison of localized features in the 602-cm^{1} map with those at 226 cm^{1} is also of interest. Warm features within the equatorial belt in both maps correlate rather well. Other features, however, do not. For example, the Great Red Spot is not very apparent at 226 cm^{1}. The reasons for the local variations in brightness temperatures are not yet fully understood. Scientific American, March, 1976. a. p. 51

FEATURE	INFRARED MEASUREMENTS	CLOUD HEIGHT	VORTICITY	PRESSURE	TEMPER-ATURE	VERTICAL VELOCITY	EXPECTED CLOUDS	COLOR
BELT	HOT	LOW	CYCLONIC	LOW	COLD	DOWN	LOW, THIN	DARK
ZONE	COLD	HIGH	ANTICYCLONIC	HIGH	HOT	UP	HIGH, THICK	LIGHT
GREAT RED SPOT	COLD	HIGH	ANTICYCLONIC	HIGH	HOT	UP	HIGH, THICK	ORANGE

CHARACTERISTICS OF FEATURES in the Jovian atmosphere are summarized. The zones and the Great Red Spot are similar in all important respects except shape. The belts are the reverse of the zones in all respects. Taken together the data suggest that all the features are not different and isolated phenomena, and that they all must be linked together as part of one global weather pattern.

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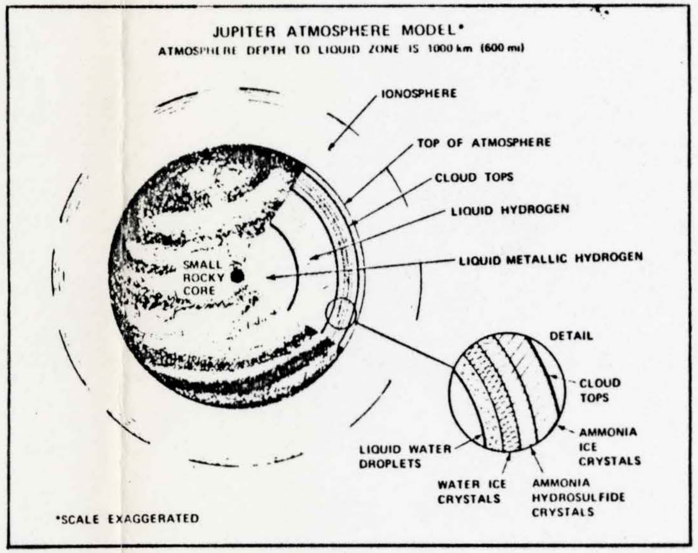
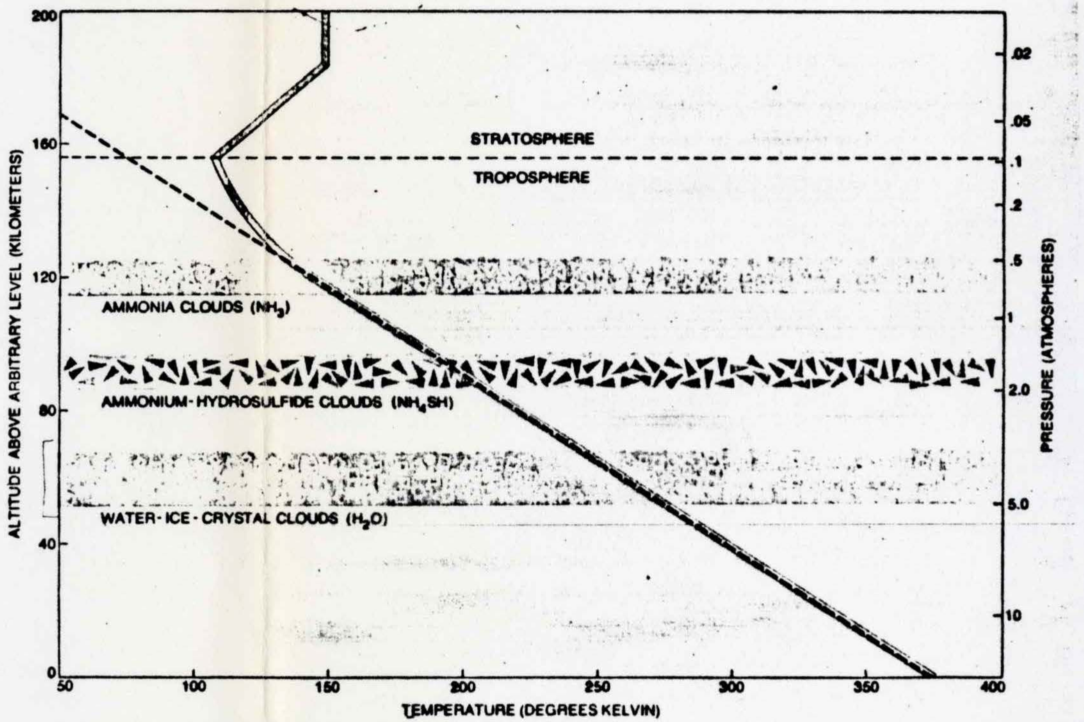
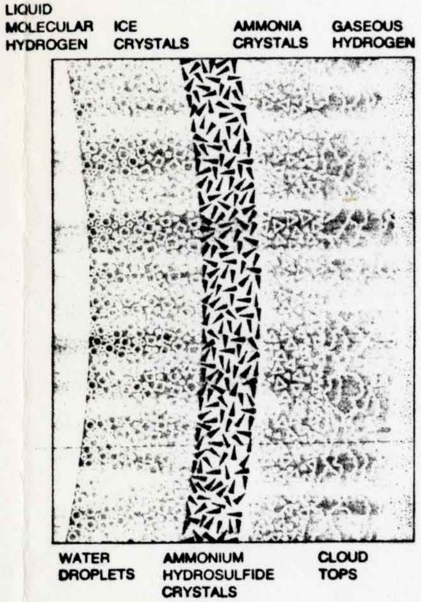
EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric		
6. Water and ice crystals	6. I get the impression, though I don't see, that it is liquid. I get the impression that that must be a band of crystals similar to the outer ones, kind of bluish. They seem to be sort of in orbit, permanent orbit down through another layer farther down which are like our clouds but moving fast. There's another area: liquid like water. Looks like it's got icebergs in it but they're not icebergs.	6. Newsweek, December 3, 1973. a. 74 Science News, Vol. 106, September 21, 1974. a. p. 186 b. p. 186 Farther down may be frozen water crystals and possibly even liquid water, the Pioneer researchers suggest, although water has never been observed there. c. p. 187  Science News, Vol. , February 15, 1975. a. p. 102 Water vapor in the atmosphere of Jupiter--"The first oxygen-bearing molecule identified in the outer planets"--has been discovered by a team of astronomers from the University of Arizona.

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric (contd.)		
6. (contd.)	6. (contd.) same as previous page	6. b. p. 47 The relatively low vapor pressure of water at the temperatures characteristic of the Jovian cloud tops also explains why water vapor was found there only recently: water cannot be detected spectroscopically unless it is in the form of a vapor. In 1974 Harold P. Larson and his co-workers at the University of Arizona detected water on Jupiter for the first time by observing radiation that emerged through holes in the upper cloud layers from water molecules at deeper levels. c. p. 52  **VERTICAL CLOUD STRUCTURE** of the atmosphere of Jupiter has been computed from a theoretical model devised by John S. Lewis of the Massachusetts Institute of Technology. In an atmosphere composed primarily of the noncondensable gases hydrogen and helium there are distinct layers of clouds. The color line indicates the temperature of the atmosphere at various depths and pressures; it is based on an analysis of infrared data made by Glenn S. Orton of the Jet Propulsion Laboratory of the California Institute of Technology. The black broken line indicates the theoretical temperature of the atmosphere at the same depths and pressures if the atmosphere were perfectly adiabatic (completely mixed by convection). The planet's atmosphere is nearly adiabatic except at uppermost levels.

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric (contd.)		
6. (contd.)	6. (contd.) Same as previous page	6. Early estimates, says Harold Larson of the university's Lunar and Planetary Laboratory, suggest that the water vapor exists at between 300 and 400 degrees K. (300 degrees K. is about room temperature--81 degrees F.) and at a pressure equivalent to 20 earth atmospheres or less. The ratio of water vapor to hydrogen, the dominant element on Jupiter as well as in the universe as a whole, appears to be about one part per million in the Jovian atmosphere--and there could be more water in other forms. b. p. 100 Scientific American, September, 1975. a. p. 121  b. p. 124 Scientific American, March, 1976. a. p. 47 His calculations show that the deepest and thickest clouds are condensed water, since both oxygen and hydrogen are abundant in the atmosphere.

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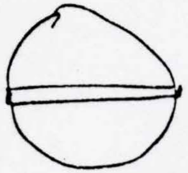
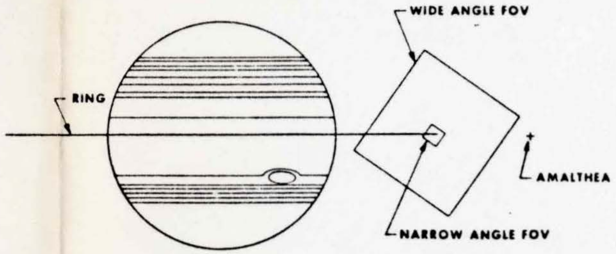
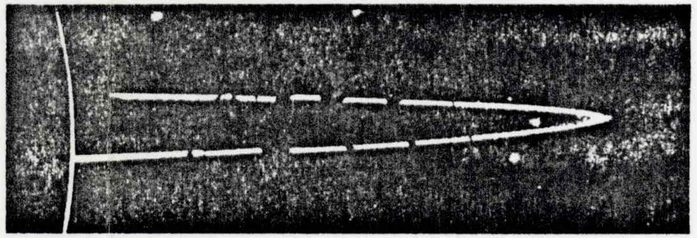
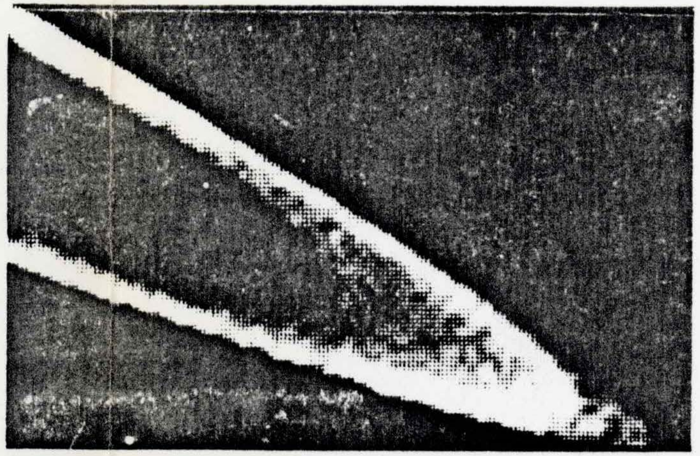
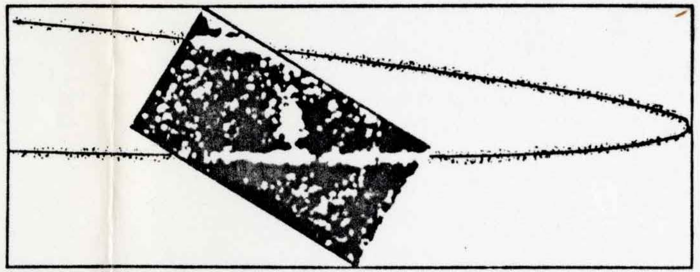
EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Gravitational Phenomena 1. The ring	1. Very high in the atmosphere there are crystals, they glitter, maybe the stripes are like bands of crystals, maybe like rings of Saturn, though not far out like that, very close within the atmosphere. (Unintelligible sentence.) I bet you they'll reflect radio probes. Is that possible if you had a cloud of crystals that were assaulted by different radio waves?  	1. Aviation Week & Space Technology, July 16, 1979. a. pp. 16-17 b. p. 20 Science, Vol. 204, June 1, 1979. a. p. 955 b. p. 960  Fig. 11. (Left) Multiple images of Jupiter's ring. Six individual ring images (see text) are shown along with several trailed star images (wavy lines). The dark dots are reseau marks placed on the vidicon faceplate for geometric calibration purposes. The dark vertical lines near center are caused by a data "dropout" as the picture was being received at the tracking station. (Right) Diagram of Jupiter and its ring showing the location of the narrow-angle frame, the wide-angle field of view (*FOV*), and Amalthea. A wide-angle image shuttered simultaneously with the narrow-angle image was saturated by the high-energy particles surrounding Jupiter and therefore does not show the ring. SCIENCE, VOL. 204 Science, Vol. 206, November 23, 1979. a. p. 926 b. p. 927 c. pp. 932-933 Two Voyager 2 pictures, taken prior to ring plane crossing when the spacecraft was 2.5° above the plane, show distinct inner and outer boundaries of the brightest part of the ring system. In them the rings were viewed in backscattered sunlight, at a time when the center of the 0.1° diameter solar disk was 0.03° below the ring plane. Although the signal was weak, no obvious gaps were visible. A second set of images was acquired during the ring plane crossing. They confirmed Voyager 1 observations that the ring system is optically very thin with a well-defined outer edge. Smearing caused by spacecraft motion prevented any improved definition of ring thickness; the 30-km upper limit set by Voyager 1 is still the best estimate.

EXCERPTS FROM SWANN TRANSCRIPT		TECHNICAL REFERENCES
IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Gravitational Phenomena (contd.)		
1. (contd.)	1. (contd.) same as previous page	1. The most spectacular ring pictures were obtained by Voyager 2 on 11 July at a phase angle of nearly 180° while the spacecraft was 2° below the ring plane and in the shadow of Jupiter. Strong forward scattering by ring particles gave well-exposed images that provided substantially better definition of the ring structure than had been possible earlier. Figures 9 and 10, acquired during this sequence, were taken with both the narrow- and the wide-angle cameras through the clear, violet, and orange filters. The outer part of the ring system is made up of a relatively bright segment about 800 km wide surrounded by a somewhat dimmer and broader segment about 5200 km across. Other, less distinet divisions are barely visible in Fig. 10. The interior of the ring is filled with much fainter material, probably extending downward into the top of the atmosphere of Jupiter itself. This material may contribute to the ultraviolet absorbing haze in Jupiter's upper atmosphere if stratospheric winds could give it planet-wide distribution. It is even possible that the ring material is a source of oxygen to the upper atmosphere that could be related to the abundance of carbon monoxide (12). The discovery of this inner material reinforces an earlier suggestion (11) that much of the ring system represents a steady state between loss and supply, being neither a leftover from the original accretion and condensation events that formed the planet (as Saturn's rings may be) nor fragments of a disrupted satellite. Candidates for sources to supply this material include cometary and meteoritic debris, impact ejecta from the inner satellites, and volcanic ejecta removed from Io, possibly by magnetospheric forces. The small newly discovered satellite (13) with an orbital radius of 1.81 Jupiter radii (R_4) may provide an explanation for the location of the outer boundary of the ring system.  Fig. 9. This Jovian ring mosaic is comprised of two wide-angle and four narrow-angle pictures. These data were taken while the Voyager 2 spacecraft was 2° below the Jovian equatorial plane in Jupiter's shadow at a range of 1,550,000 km. Gaps between several of the images account for the discontinuities seen here. Jupiter's shadow is cast on some of the upper ring segment (the part that is closest to the spacecraft).

EXCERPTS FROM SWANN TRANSCRIPT		TECHNICAL REFERENCES
IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Gravitational Phenomena (contd.) 1. (contd.)	1. (contd.) same as previous page	1.  Fig. 10. Enlarged portion of a wide-angle picture taken by Voyager 2 through the clear filter, showing the brightness variations within the ring ansa: the thin brightest region and somewhat dimmer regions both interior and exterior to it. It appears that ring material may extend down to Jupiter's cloud tops. The brightest segment is approximately 1.8 R_J from the center of Jupiter. This picture was taken at a range of 1,556,000 km from the center of Jupiter, about 27 hours after closest approach of Voyager 2. Science News, Vol. 115, February 15, 1979. a. pp. 108-9 Science News, Vol. 115, March 10, 1979. a. p. 149 Science News, Vol. 116, July 14, 1979. a. p. 20  *Jupiter's twisted cloud patterns (right) and ring system, which may extend all the way into the planet itself*

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Gravitational Phenomena (contd.)		
1. (contd.)	1. (contd.) same as previous page	1. b. p. 21 Voyager 2 also rephotographed in spectacular fashion the thin ring system of particles surrounding the planet, discovered in a single photo by Voyager 1. Seen precisely edge-on at that time, it was purposely shaped a few degrees out-of-plane by Voyager 2, revealing a structure whose brightest rotation spans about 6,500 km radially, but which, judging from early impressions, may also contain lesser concentrations of material inside the main ring element. It may be, says Smith, that "that material goes all the way down to the surface of Jupiter." Matched images of the Jovian ring system taken through colored filters will give Voyager scientists a chance to attempt some conclusions about the rings' particle size and perhaps composition. Time, March 19, 1979. a. p. 86 Coming within 278,000 km (172,400 miles) of the swirling Jovian cloud tops, the robot survived intense radiation, peered deep into the planet's storm-tossed cloud cover, provided startling views of the larger Jovian moons and, most surprising of all, revealed the presence of a thin, flat ring around the great planet. Said University of Arizona Astronomer Bradford Smith: "We're standing here with our mouths open, reluctant to tear ourselves away." b. p. 87 The most unexpected phenomenon, however, occurred when Voyager began detecting a stream of matter inside the orbit of Amalthea. Fortunately, mission controllers had preprogrammed the camera shutter to remain open for 11.2 minutes on the remote chance--no one took the possibility very seriously--that Jupiter had some kind of ring. To everyone's amazement, Voyager's time exposure produced a streaky image that the scientists could explain only as a ring of boulder-size debris. The findings seemed so unlikely that the NASA team delayed making the information public for several days while the data were checked and rechecked. Saturn was long the only planet known to have rings and considered to be the only one that could have them. In 1977 that theory was shattered with the discovery of rings around the planet Uranus. Jupiter itself was surveyed earlier by the Pioneer 10 and 11 spacecraft, but it is easy to see why no Jovian ring was found. Jupiter's is almost paper thin, perhaps 1 km (0.6 miles) high, and impossible to view from earth. Time, July 23, 1979. a. p. 74 b. p. 74

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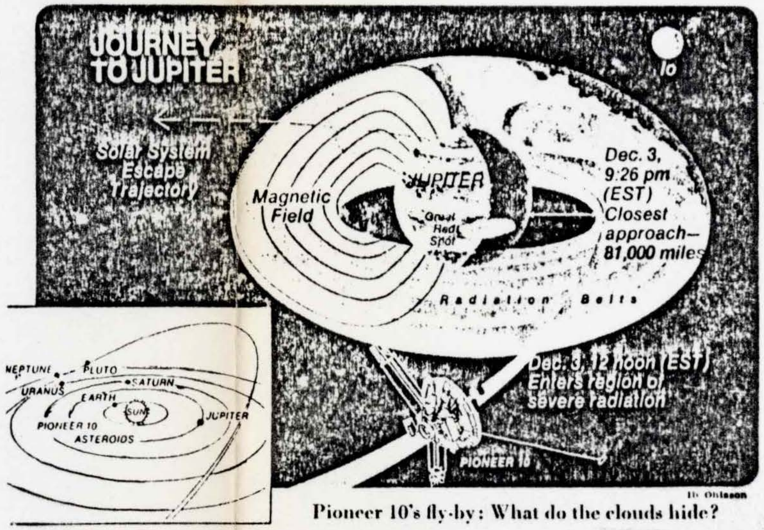
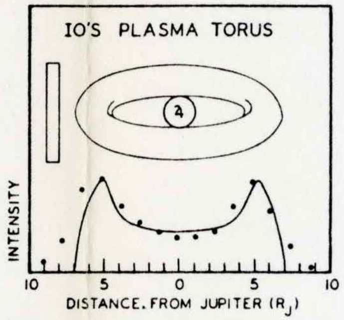
EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
<u>Magnetic and Electromagnetic</u> 1. The Io hydrogen torus	1. I think that it must have an extremely large hydrogen mantle. If a space probe made contact with that, it would be maybe 80,000-120,000 miles out from the planet surface. 	1. <u>Newsweek</u>, December 3, 1973  Pioneer 10's fly-by: What do the clouds hide? <u>Science</u>, Vol. 183, January 25, 1974. a. p. 317 <u>Pioneer 10 Observations of the Ultraviolet Glow in the Vicinity of Jupiter</u>. A two-channel ultraviolet photometer aboard Pioneer 10 has made several observations of the ultraviolet glow in the wavelength range from 170 to 1400 angstroms in the vicinity of Jupiter. Preliminary results indicate a Jovian hydrogen (1216 angstrom) glow with a brightness of about 1000 rayleighs and a helium (584 angstrom) glow with a brightness of about 10 to 20 rayleighs. In addition, Jupiter appears to have an extensive hydrogen torus surrounding it in the orbital plane of Io. The mean diameter of the torus is about equal to the diameter of the orbit of Io. Several observations of the Galilean satellites have also occurred but only a rather striking Io observation has been analyzed to date. If the observed Io glow is predominantly that of Lyman-α, the surface brightness is about 10,000 rayleighs.

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Magnetic and Electromagnetic (contd.)		
1. (contd.)	1. (contd.) same as previous page	1. b. p. 318 Finally, hydrogen channel signals were observed from the equatorial plane of Jupiter during periods when neither the planet nor its satellites were in the field of view. These emissions of several hundred rayleighs in intensity are tentatively interpreted as due to a toroidal cloud of neutral hydrogen in orbit around Jupiter, similar to the hydrogen torus proposed by McDonough and Brice (7) for Saturn and Jupiter (8). Preliminary analysis indicates that this gas cloud occurs at approximately the orbit of Io, suggesting that this satellite is the source. Science, Vol. 204, June 1, 1979. a. p. 979 Extreme Ultraviolet Observations from Voyager 1 Encounter with Jupiter. Observations of the optical extreme ultraviolet spectrum of the Jupiter planetary system during the Voyager 1 encounter have revealed previously undetected physical processes of significant proportions. Bright emission lines of S III, S IV, and O III indicating an electron temperature of 10^5 K have been identified in preliminary analyses of the Io plasma torus spectrum. Strong auroral atomic and molecular hydrogen emissions have been observed in the polar regions of Jupiter near magnetic field lines that map the torus into the atmosphere of Jupiter. The observed resonance scattering of solar hydrogen Lyman α by the atmosphere of Jupiter and the solar occultation experiment suggest a hot thermosphere (≥ 1000 K) with a large atomic hydrogen abundance. b. p. 979  Fig. 1. The data points show the measured intensity of the 685-Å feature as a function of distance from Jupiter measured in the orbital plane of the satellites. A model torus used to fit the data is shown to scale above the data; the intensity predicted by this model is shown by the solid line. Other observations show intensities at eastern and western elongation points differing by a factor of up to 2.

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EXCERPTS FROM SWANN TRANSCRIPT		TECHNICAL REFERENCES
IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Magnetic and Electromagnetic (contd.)		
1. (contd.)	1. (contd.) same as previous page.	1. Time, March 12, 1979. a. p. 87 Voyager also discovered a dazzling, doughnut-shaped cloud of electrically charged particles that formed displays similar to the earth's northern lights. Time, March 19, 1979. a. p. 87.
2. Auroras	2. Inside those cloud layers, those crystal layers, they look beautiful from the outside, from the inside they look like rolling gas clouds--eerie yellow light, rainbows.	2. Aviation Week & Space Technology, July 16, 1979. a. p. 19 One of the Jovian phenomena that may be related to Io and its torus is the auroral radiation detected by Voyager 1 and 2. Particles moving along the Jovian magnetic field lines may be affected by the torus before they plunge into the planet's atmosphere, and the resulting effect causes the auroral activity observed near Jupiter's north and south poles. Science, Vol. 204, June 1, 1979. a. p. 947 b. p. 955 Phenomena on the dark side of Jupiter. Phenomena identified so far in the systematic examination of images of the dark (nighttime) hemisphere of Jupiter are diffuse auroras and lightning. The auroras appear to occur in at least three layers about 700, 1400, and 2300 km above the cloud tops. These diffuse auroral layers are bright by terrestrial standards and vary on time scales of less than 1 minute. They are seen in the north polar region in Fig. 10 but extend equatorward to latitude +60° Science, Vol. 206, November 23, 1974. a. p. 926 b. p. 959 c. p. 963 Aurora. Among the most exciting discoveries of Voyager I was the localized sources of bright EUV radiation near both polar regions of Jupiter (1). The emission was identified as auroral excitation of H Ly α and the Lyman and Werner bands of H_2. The location of the observed auroral zones indicates that they are magnetically linked to the plasma torus at Io's orbit. Science News, Vol. 116, July 21, 1979. a. p. 37 One major product of the field is the region of brillant auroras discovered around the planet by Voyager I and further studied by its successor; yet this, too, is a fickle thing, since the auroras seem to have been virtually absent during the Pioneer 10 visits a few years before.

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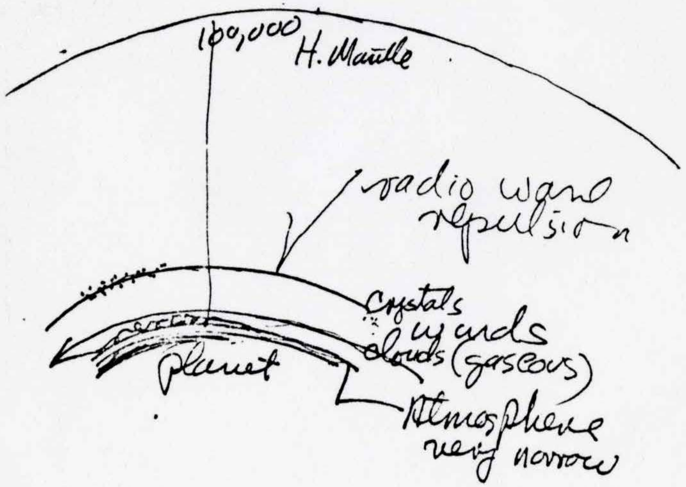
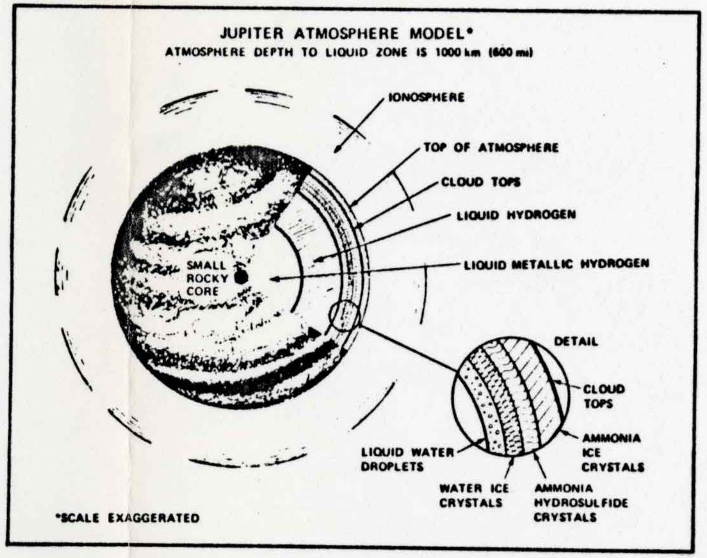
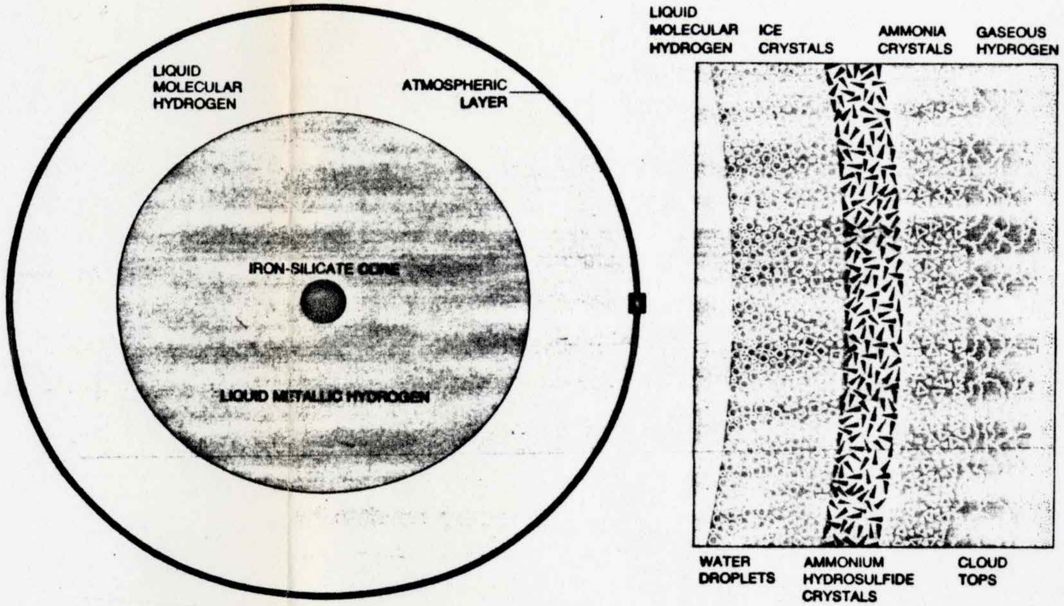
EXCERPTS FROM SWANN TRANSCRIPT

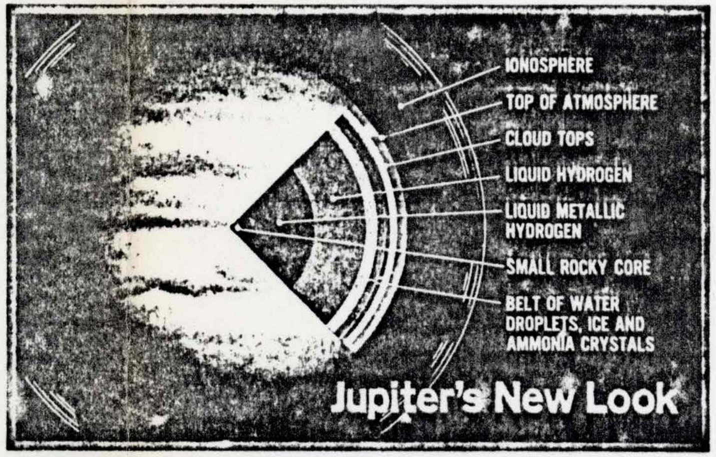
TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
<u>Summary Description</u>	I'm back, O.K. (Hal - very interesting) The atmosphere of Jupiter is very thick. I mean ... (Ingo draws) ... Explanation of drawing: This is what appears to be a hydrogen mantle about 100,000 miles off the surface. Those here are bands of crystals, kind of elements. They're pretty close to the surface. And beneath those are layers of clouds or what seem to be prevailing winds. Beneath that is the surface which I saw was, well, it looked like shifting sands made out of some sort of slippery granulated stuff. And off in the distance, I guess, to the East was a very high mountain chain 30,000 feet or so, quite large mountains. I feel these crystals will probably bounce radio waves. They're that type. Generally, that's all. 	<u>Science News</u>, Vol. 106, September 21, 1974. a. p. 187 

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Summary Description (contd.)	(contd.) same as previous page.	Scientific American, September, 1975. a. p. 121  MODEL OF JUPITER'S INTERNAL STRUCTURE, shown here in cross section, is based on the assumption that liquid hydrogen makes up the bulk of the planet's interior except for a possible small, iron-silicate core. The existence of such a core is based on the argument that the abundance of the elements in Jupiter must be similar to that in the sun. The model predicts a temperature of 30,000 degrees Kelvin in the core region. A thick shell of liquid metallic hydrogen surrounds the core Metallic hydrogen is an electrical conductor, and electric currents in the shell may be the source of Jupiter's magnetic field. At approximately 46,000 miles from the center of the planet there is a transition from liquid metallic hydrogen to liquid hydrogen in its molecular form. The pressure in the transition region is about three million atmospheres, and the temperature is estimated to be about 11,000 degrees K. The shell of liquid molecular hydrogen is about 24,000 kilometers thick. Above the liquid hydrogen lies Jupiter's gaseous atmosphere, which is about 1,000 kilometers thick. An enlarged detail of the transition from liquid hydrogen to gaseous hydrogen is given at the right.

EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Summary Description (contd.)	(contd.) same as previous page	Time, September 16, 1974. a. p. 82 The data returned by the spacecraft also support the long-held theory that Jupiter is unique among planets: a great ball of whirling gases and liquids with no solid surface. Its outermost 600 miles consist of at atmosphere of hydrogen and helium gases laced with clouds composed of crystals of ammonia, ammonia hydrosulfide and water ice. The rest of the planet is mostly a seething cauldron of liquid hydrogen, except perhaps for a small, rocky, possibly iron-bearing core. b. p. 82  Time, March 12, 1979. a. p. 86 Seething gases and liquids mask its rocky core. Its frigid atmosphere consists mostly of hydrogen and helium. Great cyclones and hurricanes swirl in its turbulent sky, with brilliant red and orange clouds constantly merging and breaking apart in ever changing patterns. Often the turbulence creates trails of sinuous white vapors thousands of miles long.

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EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Surface Phenomena		
1. Liquid composition	1. I feel that there's liquid somewhere. If I turn, the whole thing seems enormously flat. I mean if I get the feeling that if a man stood on those sands I think he would sink into them (laugh); maybe that't where that liquid feeling comes from.	1. Aviation Week & Space Technology, November 19, 1973. a. p. 53 A reason is that Jupiter may be all atmosphere. Lack of radar reflectivity points to a gel-like rather than solid core. Newsweek, December 3, 1973. a. p. 74 Speculation: Astronomers know that the colors they see represent just the tops of Jupiter's clouds, which spectroscopic analysis has shown to be predominantly methane and ammonia. Above the clouds the planet has an atmosphere that consists largely of hydrogen. But of the regions below the clouds, the scientists can only speculate. Some experts believe that Jupiter has no solid surface at all and consists instead of a liquid or slushy center. Science News, Vol. 106, September 21, 1974. a. p. 186 Science News, Vol. 110, July 10, 1976. a. p. 26 Science News, Vol. 110, July 17, 1976. a. p. 44 In fact, liquidity seems to be the most salient overall characteristic of Jupiter. Pioneer 10 found the planet to be in hydrostatic equilibrium, very symmetrical and with no gravitational irregularities. It is 70,000 kilometers from the cloud tops to the center of the planet, and some rather strange fluids occupy the cross section. The outer layer is gaseous hydrogen mostly. As the pressure increases the hydrogen gradually passes to a liquid state. The transition zone is around 1,000 kilometers down, and the temperature there is about 2,000°C. The liquid molecular hydrogen changes to liquid metallic (atomic) hydrogen at 25,000 kilometers down. The temperature here is 11,000°C and the pressure 3 million earth atmospheres. At the center the temperature is 30,000°C and the pressure 100 million earth atmospheres. The center is apparently inhabited by a small rocky core with 10 to 20 times the mass of the earth. Scientific American, September, 1975. a. p. 119 b. p. 121

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EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Surface Phenomena (contd.)		
1. (contd.)	1. (contd.) same as previous page	1. Scientific American, March 1976. a. p. 46 b. p. 46 The amount of heat Jupiter radiates implies that the interior of the planet is hot. If it were cold, there would not be enough heat in the interior to have lasted until the present time. A consequence of the hot-interior model of Jupiter is that solids cannot form in it. According to current thinking, the planet is mostly liquid, with a gradual transition to a gaseous atmosphere in the outermost few thousand kilometers.
2. Mountain range	2. If I look to the right there is an enormous mountain range. Those mountains are very huge but they still don't poke up through the crystal cloud cover. And off in the distance, I guess, to the East was a very high mountain chain 30,000 feet or so, quite large mountains.	2. Science, Vol. 183, January 25, 1974. a. p. 303 The magnetic field measurements at Jupiter will also enable us to investigate more exactly the core of the planet. Several models of the core have been proposed which include either frozen or liquid metallic hydrogen as well as a rocky core containing several tens of earth masses (5). Science News, Vol. 105, April 13, 1974. a. p. 236 Science News, Vol. 106, September 21, 1974. a. p. 186 Science News, Vol. 110, July 10, 1976. a. p. 26 Some things in this picture "we all agree on," says Andrew Ingersoll of the California Institute of Technology:" Everything in the picture is cloud. There's no solid surface within a conceivable range of what we see. The planet is entirely fluid. (Some would opt for a tiny rock core.) b. p. 27 One of the most famous features of Jupiter's atmosphere is the great Red Spot. Astronomers have engaged in endless speculation and argument about its nature. Observers have suggested that it was a column of the atmosphere hooked on the top of an extra-high mountain, or that it was a permanent hurricane. It seems now that these old explanations must be discarded in favor of one that sees the spot as a pure atmospheric feature, a kind of frozen wave pattern. Science News, Vol. 110, July 17, 1976. a. p. 44

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Surface Phenomena (contd.)		
2. (contd.)	2. (contd.) same as previous page	2. Scientific American, September, 1975. a. p. 121 From the Pioneer observations a model of Jupiter's interior has been devised by John D. Anderson of the Jet Propulsion Laboratory of the California Institute of Technology and William B. Hubbard of the University of Arizona. The model is consistent with what is known of Jupiter's gravitational and magnetic fields and with extrapolations of laboratory studies of the behavior of hydrogen at high temperature and pressure to even higher values. The model allows for a small rocky core at the center of the planet, where the temperature is thought to be about 30,000 degrees Kelvin. The core would be composed mainly of iron and silicates, the materials that make up most of the earth's bulk. Such a core is expected for cosmogonic reasons: if Jupiter's composition is similar to the sun's, then the planet should contain a small proportion of those elements. Since they are relatively dense, they would aggregate at its center. The core cannot be detected through gravitational studies, however, so that its existence cannot be proved. b. pp. 122-3 Scientific American, March, 1976. a. p. 53 Let us now turn to the Great Red Spot and similar spots in Jupiter's atmosphere. For a number of years the only theory that seemed capable of explaining the Great Red Spot was the Taylor-column hypothesis put forward by Raymond Hide, who was then at M.I.T. (see "Jupiter's Great Red Spot," by Raymond Hide; SCIENTIFIC AMERICAN, February, 1968). Because of the Great Red Spot's long lifetime, its constancy in latitude and its uniqueness it seemed that it must be connected with an underlying solid object or topographic feature that was giving rise directly to the flow patterns at the visible surface. A Taylor column is the cylinder of stagnant fluid that was believed to join the solid object to the red cloud we see at the top of the Jovian atmosphere. Since it now seems likely that Jupiter has no solid surface at any depth, the Taylor-column hypothesis is not as compelling. Moreover, the recent observations have brought out the similarity between the Great Red Spot and the zones. In fact, the spot's long lifetime and its constancy in latitude are no more unique than the long lifetime and the constancy of latitude of the zone in which it is embedded. The Great Red Spot also drifts irregularly westward relative to Jupiter's magnetic field, which would presumably be rooted in the solid surface of the planet if there were one. Finally, other zones seem to have their own red spots, suggesting that the Great Red Spot is not unique.

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EXCERPTS FROM SWANN TRANSCRIPT		TECHNICAL REFERENCES
IMPRESSION CLASSIFICATION	IMPRESSION	DATA
<u>Surface Phenomena</u>		
3. Crystals	3. Then I came through the cloud cover, the surface it looks like sand dunes. They're made of very large grade crystals so they slide. Those grains which make that sand orange are quite large. They have a polished surface and they look something like amber or like obsidian but they're yellowish and not as heavy. If I turn, the whole thing seems enormously flat. I mean if I get the feeling that if a man stood on those sands I think he would sink into them (laugh); maybe that's where the liquid feeling comes from. Beneath that is the surface which I saw was, well, it looked like shifting sands made out of some sort of slippery granulated stuff.	3. No reference.

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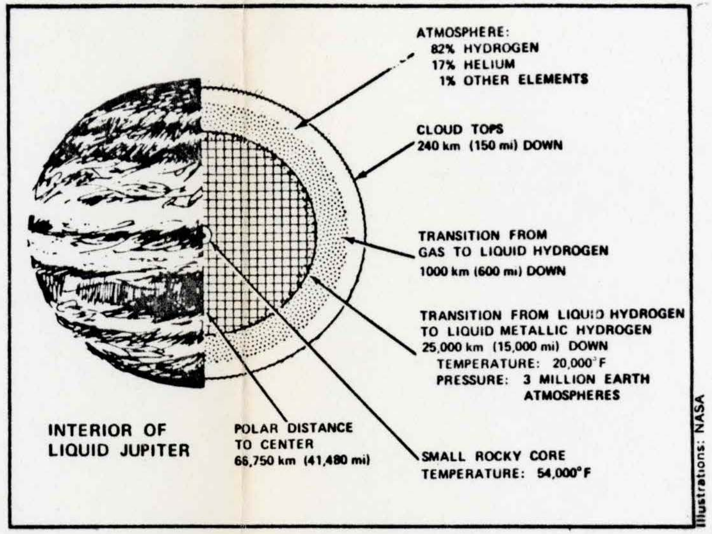
EXCERPTS FROM SWANN TRANSCRIPT

TECHNICAL REFERENCES

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
<u>Atmospheric & Surface Phenomena</u>		
1. Hydrogen composition	1. I think that it must have an extremely large hydrogen mantle. If a space probe made contact with that, it would be maybe 80,000-120,000 miles out from the planet surface.	1. <u>Aviation Week & Space Technology</u>, July 16, 1979. a. p. 20 Jupiter essentially is a large ball of gas--composed primarily of hydrogen, with helium as its second most abundant element. b. p. 20 One concept proposed for the planet's structure theorizes that Jupiter has a small molten iron-silicate core. A thick layer is thought to surround the core in which hydrogen is the most abundant element. Hydrogen in this zone is expected to exist in liquid metallic, and molecular forms. The Jovian atmosphere begins above this zone and extends to the cloud tops. The atmospheric clouds are composed of minute particles that represent only a small part of the atmospheric mass. The particles are suspended in a mixture of the Jovian gases. <u>Science News</u>, Vol. 104, December 15, 1973. a. p. 372 <u>Science News</u>, Vol. 105, April 13, 1974. a. p. 236 What they have measured, by repeatedly refined studies of the planet's reflected ultraviolet light, is a mixture of 84 percent hydrogen and 15 percent helium, with one percent left over for methane, ammonia and other molecules. <u>Science News</u>, Vol. 106, September 21, 1974. a. p. 186

IMPRESSION CLASSIFICATION	IMPRESSION	DATA
Atmospheric & Surface Phenomena (contd.)		
1. Hydrogen composition (contd.)	1. (contd.) same as previous page	1.  Science News, Vol. 108, October 18, 1975. a. p. 247 Scientific American, September, 1975. a. p. 121 Above the hypothetical core is a thick stratum in which hydrogen is by far the most abundant element; this stratum makes up almost all the mass and volume of the planet. The hydrogen is separated into two layers; in both it is liquid, but it is in different physical states. The inner layer extends from the core to a distance of approximately 46,000 kilometers from the center, where the pressure is estimated to be about three million earth atmospheres and the temperature near 11,000 degrees K. In this layer the hydrogen is in the liquid metallic state, a form of the element that has not yet been observed in the laboratory because it exists only at extremely high pressures. In the liquid metallic state hydrogen molecules are dissociated into atoms and the fluid is an electrical conductor. The outer layer extends to about 70,000 kilometers and consists mainly of liquid hydrogen in its molecular form. Above the layer of molecular hydrogen, and extending another 1,000 kilometers to the cloud tops, is the atmosphere. Scientific American, March 1976. a. p. 46