Chapter 1

INTRODUCTION AND SUMMARY

1.1 RANGE OF ENGINEERING VARIABLES

Titan is the largest satellite of Saturn, sharing Saturn's heliocentric distance and year, but having a radius comparable to that of Mercury. Its rotation is usually assumed to be synchronous with its revolution about Saturn, with its pole perpendicular to its orbit (in Saturn's equatorial plane); thus its "day" is 16 days, its "seasons" result from an inclination of 27° (comparable to the Earth's), and its "year", 30 years long, has 675 "days". Its probable structure, comparable to that of the other large satellites of the outer planets (J I-IV, and Triton), is described by Lewis (1971), and includes a rocky, muddy core, a liquid (H_2O solution) mantle (most of the volume), possibly an ice crust, and an atmosphere. The atmosphere is considerably more massive than that of Mars, and far outweighs the wisps of gas possessed (at most) by any other satellite.

Many of the data are given with considerable reluctance, as a reading of Sections 1.1 and 1.2 will suggest. Nevertheless, they represent our state of knowledge in mid-1973 and the consensus of the Workshop. Table 1-1 shows the basic parameters, after Morrison's discussion. The mass is well determined, but the uncertainty in the radius reflects into the mean density, surface gravity, and measured albedo. It is not known whether the radius is that of the solid body or of a layer high in a dense atmosphere. The temperatures given represent equilibrium between thermal radiation and absorbed solar energy. The temperature T_{max} is probably not realized under an atmosphere as massive as Titan's; it is appropriate for bodies like Mars or the Moon.

Table 1-2 shows the wide range of possible compositions compatible with spectroscopic data. The baseline atmosphere outlined in the box represents Trafton's actual measurements and analysis. The molecular column densities also represent the volumetric proportions. If the atmosphere contains optically dense clouds, the total column densities could be much greater. The absolute minimum atmosphere is obtained by leaving out the H_2 and taking the lower error limit for CH_4: an abundance of 1.5 km-A and a surface pressure of 10 mb.

Table 1-2 illustrates the fact that the derived abundance of CH_4 depends on assumptions about other constituents, through their pressure broadening of spectral lines. Several sample atmospheres are shown, involving CH_4 with either H_2 or N_2; mixtures of all three could also be considered. The larger H_2 abundances, shown in parentheses, are not compatible with observation. N_2 is not observable, but could be present as a dissociation product of NH_3. A few cm-A of NH_3 could be present near the surface if it is as warm as 140°K. Other trace gases that could be considered are Ar^{40} from radioactive decay, and primordial rare gases such as neon. There is no more reason to suppose that Titan retained the latter than did Earth. Helium escapes so readily that an appreciable abundance is most unlikely.

Table 1-1. Titan Parameters

Radius	$R = 2500 \pm 250$ km
Mass	$M = 1.37 \pm .02 \times 10^{26}$ g
Distance from the Sun	$a = 9.546$ AU
Orbital period	$P = 15.95$ days
Mean density	$\rho = 2.1 \pm 0.6$ g cm^{-3}
Acceleration of gravity	$g = 146 \pm 30$ cm s^{-2}
Geometric visual albedo	$P_v = 0.20 \pm .04$
Bolometric albedo	$A_{bol} = 0.26 \pm .08$
Maximum sub-solar temperature	$T_{max} = 116 \pm 3$°K
Effective temperature	$T_e = 82 \pm 2$°K

Table 1-2. Possible Atmospheric Abundances (km-A)*

CH_4	H_2		N_2	
2.0 ± 0.5	0		0	
1.4	5.0		0	Baseline
1.0	15.0	or	1.5	
0.1	(220)	or	20.0	
0.01	(2500)	or	210.0	

* 1 cm-amagat (cm-A), also called cm-atm, is a column density of 2.687×10^{19} (Loschmidt's number) molecules per cm . Surface partial pressure for 1 km-A is 10.4, 1.3, 18 mb (CH_4, H_2, N_2).

Pressures and temperatures are summarized in Table 1-3. The stratosphere is warmer than the effective temperature because the dark aerosol absorbs solar ultraviolet radiation (as does ozone in the Earth's stratosphere). Thermal emission from this warm region has been observed. Table 3 gives several candidate surfaces, lettered in such a way as to suggest that there are many intermediate possibilities. Surface (a) corresponds to a methane atmosphere, with or without some H_2. Surface (m) would require around 30 km-atm of N_2. The last one supposes a methane "ocean" containing about 5% of the mass of Titan. This medium could be liquid or gaseous, depending on the relation of the CH_4 critical point to the actual pressure-temperature situation.

Diurnal and seasonal variations of temperature are probably small; they could perhaps reach a range of 10°K for the thinnest atmospheres considered. Not only does the atmospheric gas carry heat around, there is a great deal of latent heat available from condensation and evaporation of CH_4.

Since the Workshop, several detailed models of the atmosphere have been prepared by Divine (1973).

Table 1-3. Pressures and Temperatures

REGION	p (mb)	T (°K)
Entry	.001 - 1	150 ± 50
Candidate Surfaces		
(a)	20	80
(m)	~ 500	150 - 200
(z)	10^6	150 - 1000
A fine, red-brown aerosol is probably present up to at least the 1-mb level. It is irrelevant for engineering purposes. CH_4 cloud may be present at or below the 20-mb level, and haze at greater heights.		