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A SUMMARY OF AVAILABLE PROBE-TO-BUS COMMUNICATION-RATES FOR A MARS 1971 MISSION

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GREENBELT, MARYLAND

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INTRODUCTION

Recently, a NASA working group comprised of representatives from NASA Headquarters, Langley Research Center, Ames Research Center, Jet Propulsion Laboratory, and Goddard Space Flight Center was formed for the purpose of considering a low-cost multiple-probe mission to Mars in 1971. Goddard Space Flight Center, by virtue of its unique past and present role in the study of planet atmospheres, has a strong interest in the scientific capability of such a mission and in providing suitable probe instruments.

Our study of the overall scientific capability of a Mars 1971 multiple-probe system immediately presented the question as to what restrictions are placed on the system by the probe-to-bus transmission-rate-limits. These limits are determined (1) by what, at the present time, is a feasible configuration of probe transmitter, probe antenna, probe radiated power, bus antenna, bus receiver, and bus storage capacity and (2) by the communications geometry for each specific probe trajectory.

Probe radiated-power was taken as 20 watts since, at this level, there will be no occurrence of antenna arcing due to the low ambient pressure in the Martian atmosphere. Transmitter frequency was taken at 500MHz because smaller antennas are then possible, but with the reservation that the optimum frequency of 300MHz would be used if required. An all-transistor PCM-PM transmitter was determined to be feasible at the above power and frequency. The probe transmitting antenna was assumed to have a circularly polarized, cosine field-intensity pattern and was conservatively estimated to have a power gain of 3db. The bus receiving antenna was assumed to be a helix and conservatively estimated to have a power gain of 10 db.

The geometric constraints were obtained in the following ways.

1. It was assumed that the approach of the bus to the planet Mars will be selected to obtain the best probe-mission. This assumption must certainly be made in view of the facts that the Mars "71" mission is proposed as a <u>first</u> probe-mission, that it will have been preceded by two comprehensive missions (1964, 1969) in which the mission had been optimized for the bus science, and that a probe-optimized-mission does not appear to seriously degrade the bus science proposed for the Mars "71" mission.

2. It was assumed that there will be two bus vehicles and that each bus will release two probes. It was further assumed that the two probes from bus #1 will be released to those two different impact points on Mars' surface which will best accomplish the scientific objectives of the probe mission as ordered in importance by the working group. It was assumed that the two probes from bus #2 will be released to impact points which were different from those of the first two probes and will be used to complete the attainment of the ordered scientific objectives to the greatest degree possible.

3. It was assumed that probe transmitter turn-on will be accomplished by means of an accelerometer, for a lower atmosphere probe or by means of electron density measurement for a combined lower-upper atmosphere probe, and as a result the total transmission time will be limited to 10 minutes or less.

CASE I

It is generally agreed by Ames, JPL, and GSFC that the two-probe bus mission which satisfies the highest priority scientific objectives of lower and upper atmosphere profiles and their diurnal variation is at the same time the most difficult mission from the standpoint of probe-to-bus communications.

Specifically, as suggested by JPL and shown in Figure 1, the requirement is for the first bus vehicle to receive data from two probes, one probe impacting on the dark side of the planet, fairly close to sunrise at the maximum measurement altitude, and the other probe landing as far as possible toward mid-afternoon on the light side of the planet.

For the above worst case geometry, our calculations yield a transmission rate of 3000 bps. This result is consistent with the 1500 bps rate obtained by Seiff at the Ames Research Center with a slightly more difficult geometry.

Tables I and II present some of the data used in the transmission-rate calculations.

CASE II

The second case was also suggested by JPL and is in response to the requirement for measuring seasonal and geographical variations in the atmosphere, the ordered scientific objectives which immediately follow those to which Case I is directed. It is proposed that both probes from the second bus impact at around noon; that probe #1 impact in the wave of darkening at 5° N; and that probe #2 impact at 30-40° N and out of the wave of darkening. A planar and simplified geometry for this configuration is given in Figure 2. Our calculation for this case gives a transmission rate of 7500 bps.

CASE III

As an additional exercise the transmission-rate was computed for the case where each bus carries a single probe. For this case communication distance and antenna look angles are less than those for Case II and a transmission rate of 12,000 bps was obtained. This result is in agreement with the transmission rates in excess of 10,000 bps given by the recent AVCO-AMES Mars study for a similar geometry.

CONCLUSIONS

A satisfactory mass spectrometer configuration for this mission involves (11-90 AMU) × (3 words per mass) × (10 bits per word) ÷ (3 seconds per sweep) = 800 bps.

Further calculation confirms that the worst case transmission-rate of 3000 bps will allow the use, on a single probe, of the proposed upper and lower atmosphere mass-spectrometers, as well as all other experiments that were proposed to the working group for inclusion in this mission. Indeed, probe transmission-rates in excess of 3000 bps are not needed for the probe missions that have been considered by the working group, and the capability for higher rates, as achieved for cases II and III, would be used to best advantage in achieving reduced transmitter power and/or increased transmission margin.

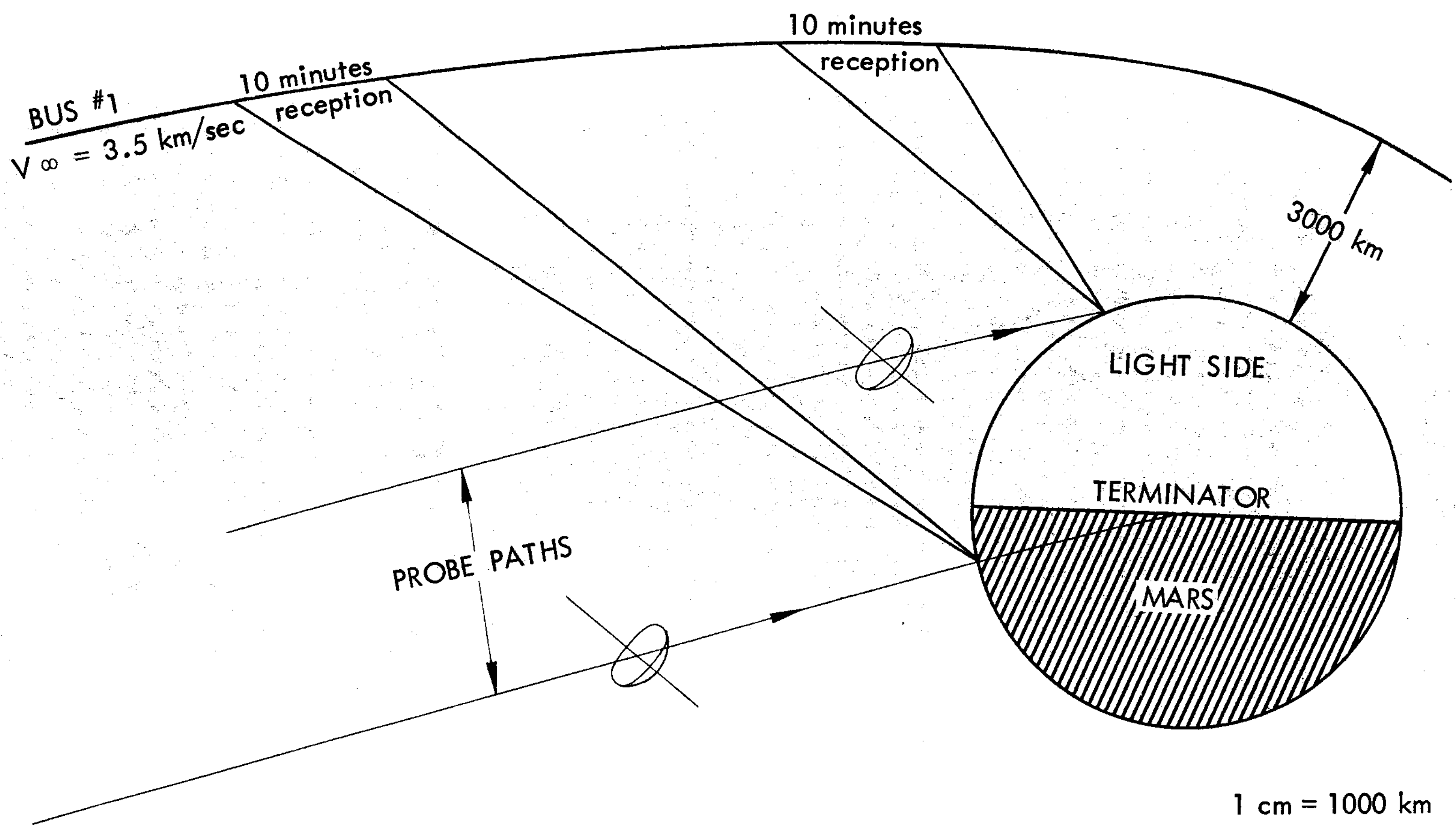

Figure 1. Case I Geometry

TABLE I

Data Power Budget (20 watt radiated power)	
Range Loss (14000 KM, 500 MHz)	-169.8 db
Bus Ant. Gain	+10.0 db
Probe Ant. Gain	+3.0 db
Probe Ant. Circularity Loss	-0.8 db
System Losses	-1.5 db
Carrier Lock Phase Noise	-1.0 db
Ant. Efficiency	-1.2 db
System Losses	-161.3 db
Rcvr. Noise Density	-169.8 dbm
Data Power = +42 dbm	
Rcvd. Data Power = -119.3 dbm	
S/N = +10 db	
Margin = 6 db	
Rcvd. Data Power w/margin = -125.3 dbm	
Noise Power = -125.8 - 10 = -135.3 dbm	
B_N = -135.3 + 169.8 dbm = +34.5 db	
Post Detection Bandwidth = 3000 cps	
$\therefore$ Bit Rate $\geq$ 3000 bit/sec	

TABLE II

Carrier Lock Power Budget (20 watts radiated power)	
Range Loss (14000 KM, 500 MHz)	-169.8 db
Bus Ant. Gain	+10.0 db
Probe Ant. Gain	+3.0 db
Probe Ant. Circularity Loss	-0.8 db
System Losses	-1.5 db
Rcvr. Noise Temp.	620°K
Ant. Noise Temp.	150°K
Ant. Efficiency	-1.2 db
System Temp.	770°K
Noise Power Density (P_d)	-169.8 dbm
Noise Bandwidth (460 H_z)	+26.6 db
Required C/N = +6 db	
P_N = -169.8 dbm + 26.6 db = -143.2 dbm	
Received Carrier Power	
-144.2 dbm + 6 db = -137.2 dbm	
Using 6 db Margin = -131.2 dbm	
-131.2 dbm = P_c + System gain	
P_c = +160.3 db - 131.2 dbm	
Carrier Power = +29.1 ≈ +29 dbm	
= 0.90 watts	

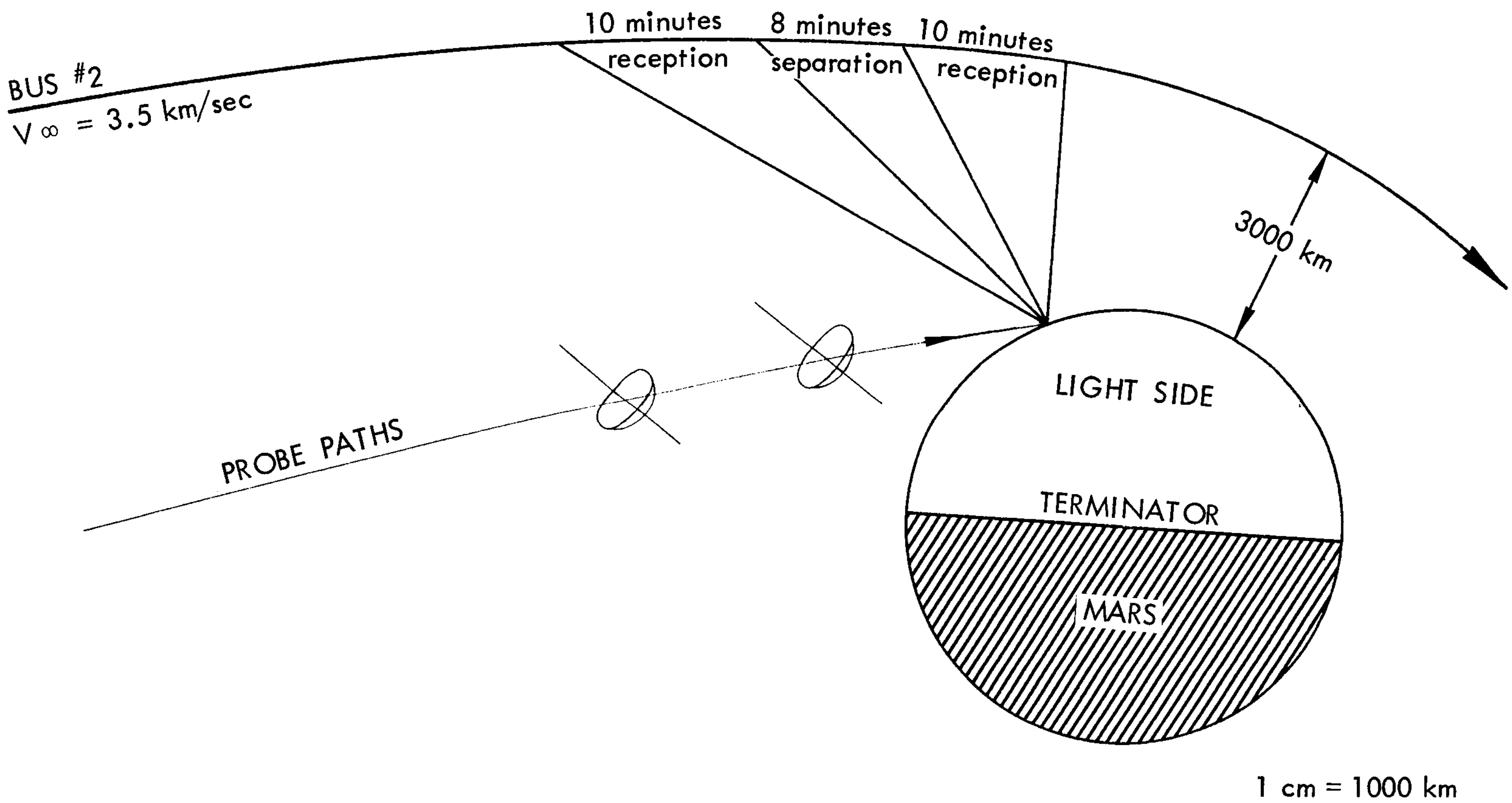

Figure 2. A Planar and Simplified View of the Geometry for Case II