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DEEP SPACE PROPAGATION EXPERIMENTS AT K_a-BAND

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ABSTRACT

This presentation discusses propagation experiments as essential components of the general plan to develop an operational deep space telecommunications and navigation capability at K_a-band (32-35 GHz) by the end of the 20th century. Significant benefits of K_a-band over the current deep space standard X-band (8.4 GHz) are an improvement of 4 to 10 dB in telemetry capacity and a similar increase in radio navigation accuracy. Propagation experiments are planned on the Mars Observer Mission in 1992 in preparation for the Cassini Mission to Saturn in 1996, which will use K_a-band in the search for gravity waves as well as to enhance telemetry and navigation at Saturn in 2002. Subsequent uses of K_a-band are planned for the Solar Probe Mission and the Mars Program.

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by

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- K_a-BAND OFFERS SIGNIFICANT BENEFITS
  - TELEMETRY
    - EXPECTED x4 TO x10 IMPROVEMENT IN CHANNEL CAPACITY OVER X-BAND
  - NAVIGATION AND RADIO SCIENCE
    - REDUCED PLASMA SENSITIVITY ENABLES MORE PRECISE NAVIGATION AND HIGHER PRECISION GRAVITATIONAL EXPERIMENTS THAN X-BAND
    - 500 MHz BANDWIDTH INCREASES RADIO METRIC ACCURACY AND FACILITATES ACCURATE RELATIVITY MEASUREMENTS
  - REDUCED FLIGHT RADIO SYSTEM COSTS
    - PERMITS REDUCTION IN ANTENNA SIZE FOR EQUIVALENT PERFORMANCE AT X-BAND
    - PERMITS REDUCTION IN POWER REQUIREMENTS FOR EQUIVALENT PERFORMANCE AT X-BAND
  - REDUCED DSN TRACKING TIME vs EQUIVALENT DATA VOLUME AT X-BAND

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DEEP SPACE DOWNLINK PERFORMANCE EVOLUTION AT X-BAND AND K_a-BAND

30 DEG ELEVATION, 90% WEATHER, GOLDSTONE, CA

COMPONENT		X-BAND (8.4 GHz)		K_a-BAND (32 GHz)	
		1990	1995	1995	2000+
SPACECRAFT					
TRANSMITTER	dBm	40.0	40.0	37.0	40.0
3.66 M ANT. GAIN	dBi	48.3	48.3	59.3	59.3
POINTING LOSS	dB	-1.0	-0.1	-1.0	-0.2
SPACE LOSS	dB	-294.6	-294.6	-306.2	-306.2
GROUND					
ATMO. ATTEN.	dB	-0.1	-0.1	-0.4	-0.4
70M ANT. GAIN	dBi	74.2	74.4	84.0	85.8
POINTING LOSS	dB	-0.3	-0.1	-0.3	-0.1
NOISE SPECTRUM	dBm/Hz	-184.6	-185.9	-182.6	-182.6
SNR	dB-Hz	51.1	* 53.7	55.0	** 60.8

* X-BAND IMPROVES BY 2.6 dB FROM NOISE REDUCTION (1.3 dB) AND 1.3 dB ANTENNA AND POINTING IMPROVEMENTS REQUIRED FOR K_a-BAND

** K_a-BAND IMPROVES BY 5.8 dB FROM POWER INCREASE (3 dB) AND FURTHER TOLERANCE TIGHTENING ON ANTENNAS AND POINTING SYSTEMS

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MISSIONS WITH K_a-BAND LINKS

MARS OBSERVER – SEPT 16, 1992

- **IMPLEMENTING 10 mWatt BEACON TO EVALUATE PERFORMANCE OF LINK RELATIVE TO X-BAND BASELINE**

CASSINI (SATURN) – APRIL 8, 1996

- **DESIGNING A 5 Watt TELEMETRY LINK AS A MISSION ENHANCEMENT TO AUGMENT X-BAND BASELINE**

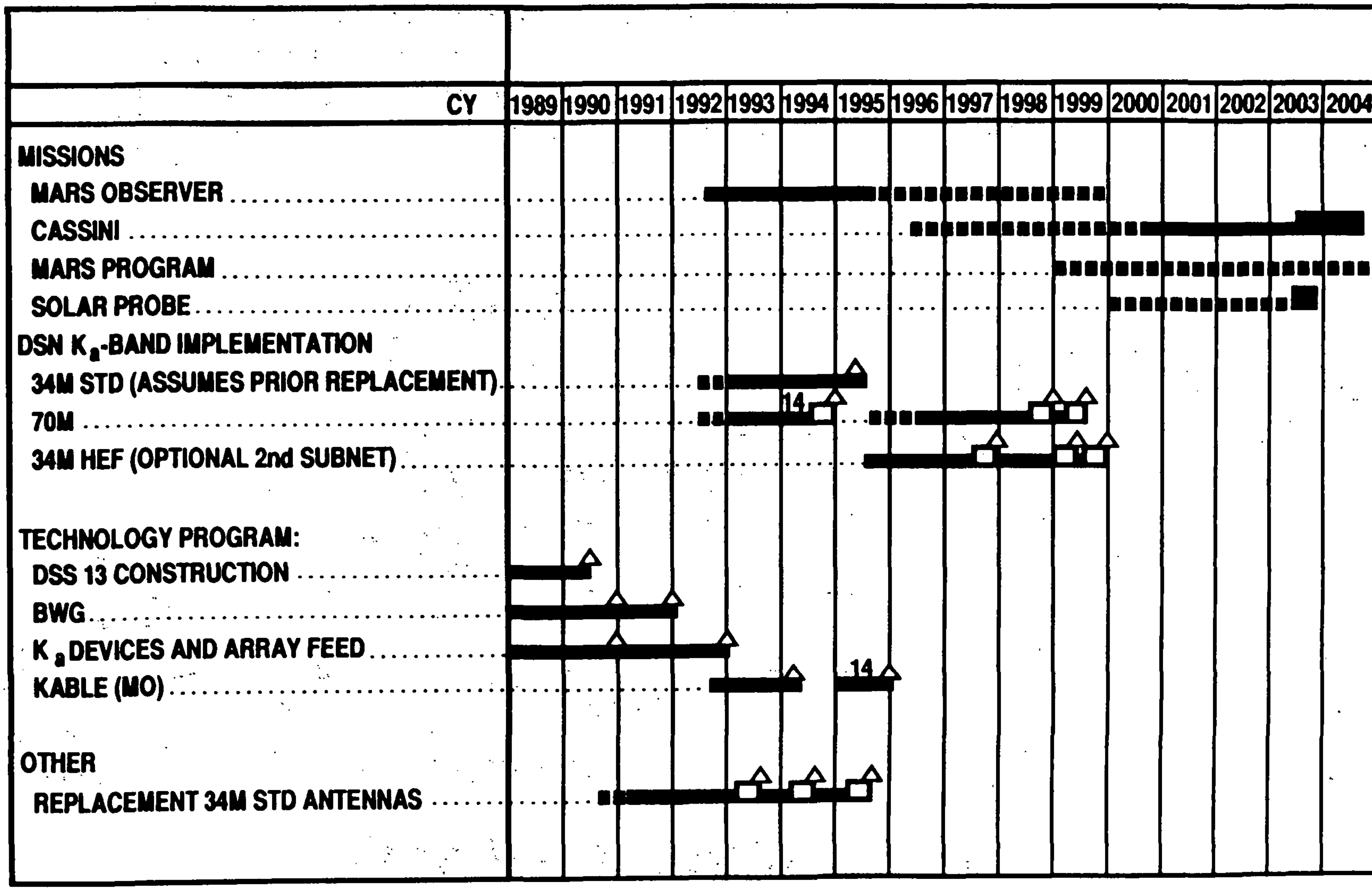
SOLAR PROBE – ABOUT THE YEAR 2000

- **PLANNING ON K_a-BAND AS THE BASELINE**

MARS PROGRAM

- **SIGNIFICANT USE OF K_a-BAND**

OVERVIEW K_a-BAND SCHEDULE



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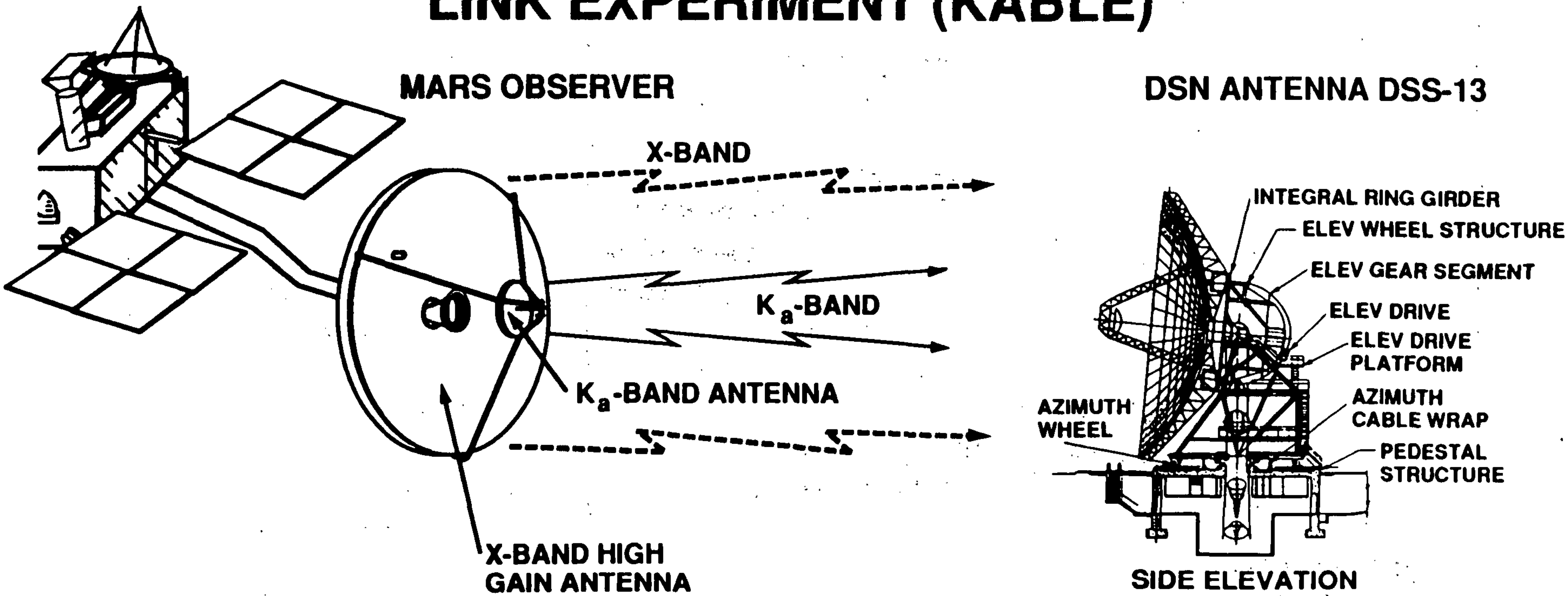
MARS OBSERVER K_a-BAND LINK EXPERIMENT (KABLE)



OBJECTIVE

- EVALUATE K_a-BAND LINK PERFORMANCE RELATIVE TO X-BAND OVER THE SAME PATH AND OVER THE DURATION OF THE MISSION

ENHANCEMENT OPPORTUNITY

- DEMONSTRATE ABILITY TO RECEIVE TELEMETRY AT K_a-BAND (EARLY OUTER CRUISE PHASE OF MISSION)
- EVALUATE DOPPLER AND INTERFEROMETRIC NAVIGATION USING K_a-BAND AND X-BAND

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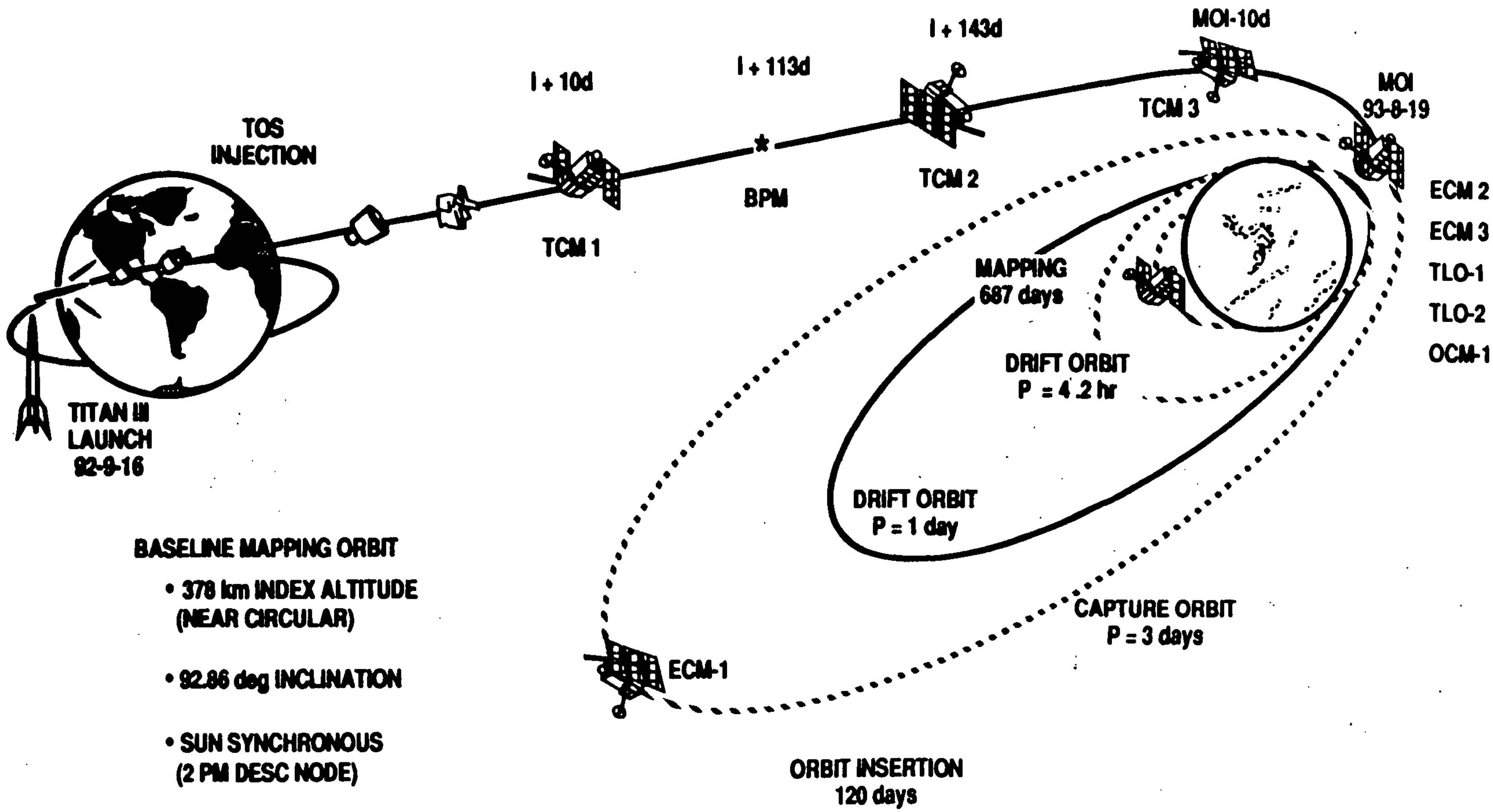
MARS OBSERVER
MISSION SCENARIO



BASELINE MAPPING ORBIT

- 378 km INDEX ALTITUDE (NEAR CIRCULAR)
- 92.86 deg INCLINATION
- SUN SYNCHRONOUS (2 PM DESC NODE)
- 117.5 m PERIOD
- FROZEN (APSIDES)

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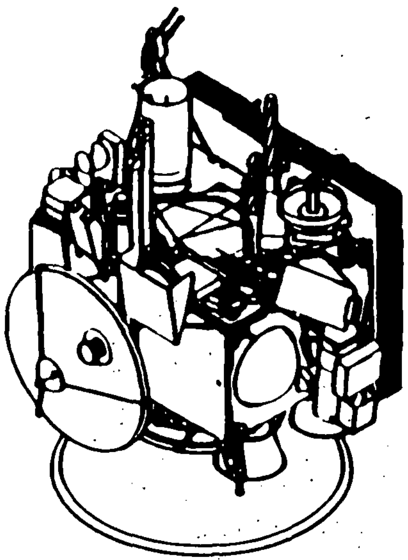
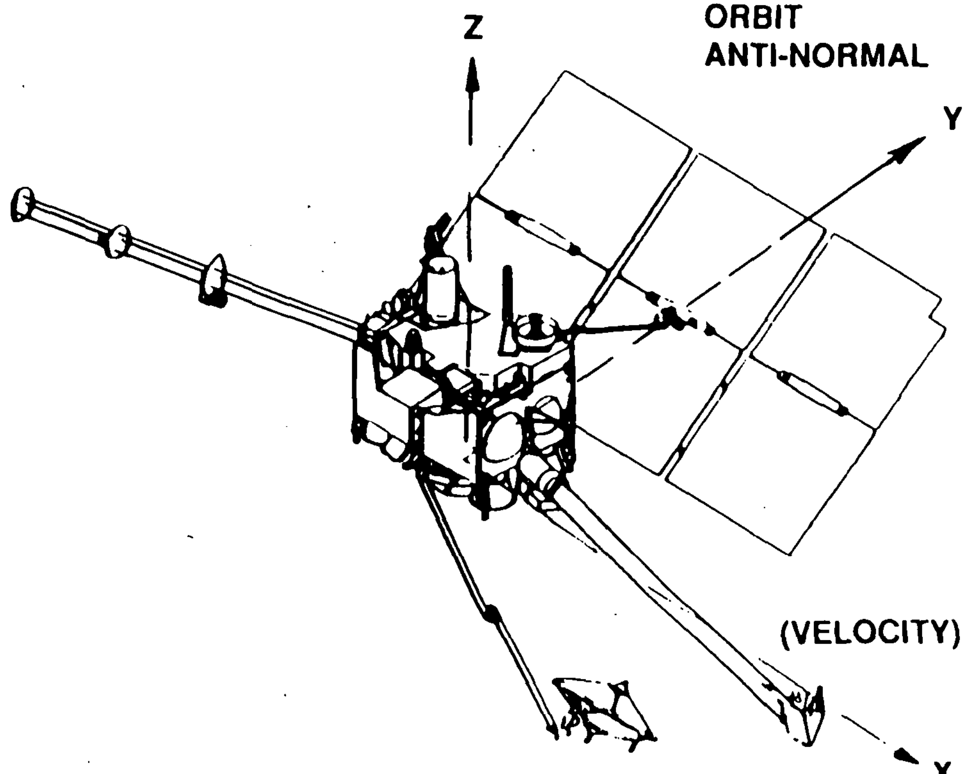
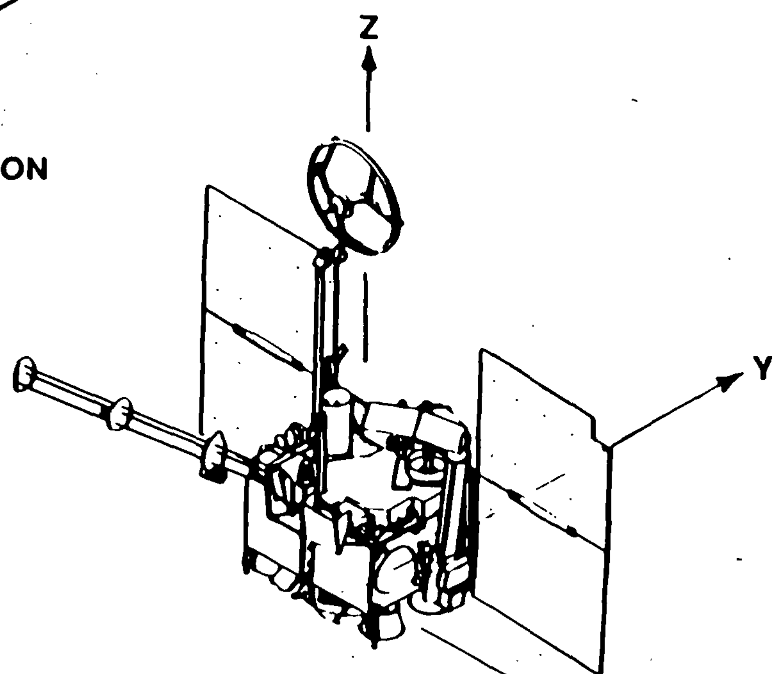
MARS OBSERVER
SPACECRAFT CONFIGURATIONS



LAUNCH CONFIGURATION



MAPPING CONFIGURATION



CRUISE CONFIGURATION

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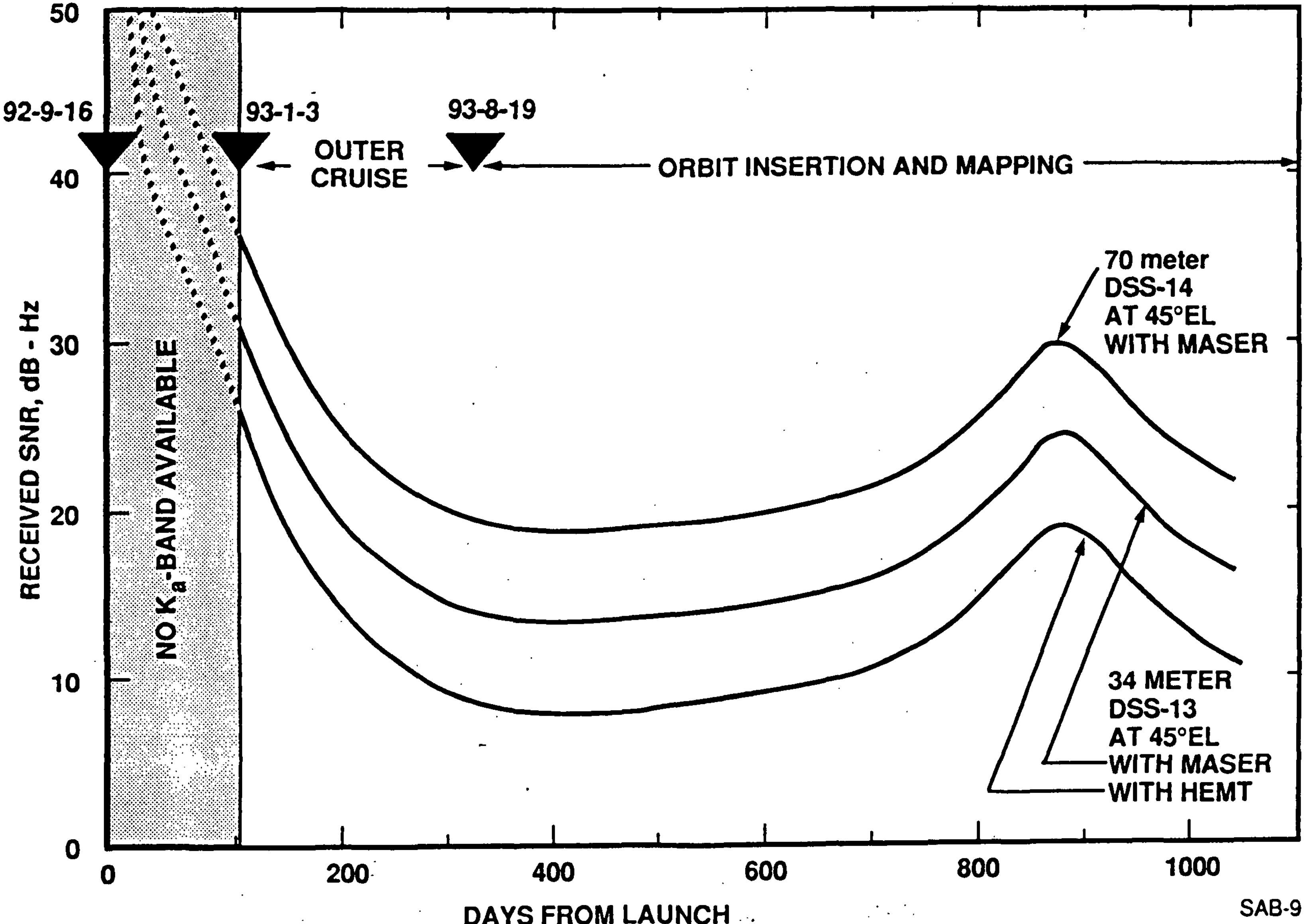
MARS OBSERVER

K_a-BAND BEACON PERFORMANCE, 90% WEATHER AT GOLDSTONE, CA



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DOWNLINK BUDGETS FOR MARS OBSERVER TO DSN 34M ANTENNA AT GOLDSTONE CA

FOR 90% WEATHER AT 30 DEG ELEVATION

MISSION, DISTANCE AND DATE		MARS OBSERVER AT 2.45 AU, 1994	
SPACECRAFT SYSTEM		X-BAND	K_a-BAND
FREQUENCY	(GHz)	8.42	33.7
XMTR. PWR.	(dBm)	43.0	10.0
ANT. GAIN	(dBi)	40.0	37.0
POINTING LOSS	(dB)	-0.8	-0.5
EIRP	(dBm)	82.2	46.5
SPACE LOSS		-282.4	-294.4
GROUND SYSTEM			
* ATMO. ATTEN.	(dB)	-0.1	-0.4
ANT. GAIN	(dBi)	67.8	78.0
POINTING LOSS	(dB)	-0.1	-0.2
* NOISE	(dBm/Hz)	-184.6	-182.6
SIGNAL/NOISE	(dB-Hz)	52.1	12.1

* VARIES WITH ANTENNA ELEVATION ANGLE AND ATMOSPHERIC CONDITIONS. PROBABILITY IS 90% THAT VALUES WILL NOT BE EXCEEDED

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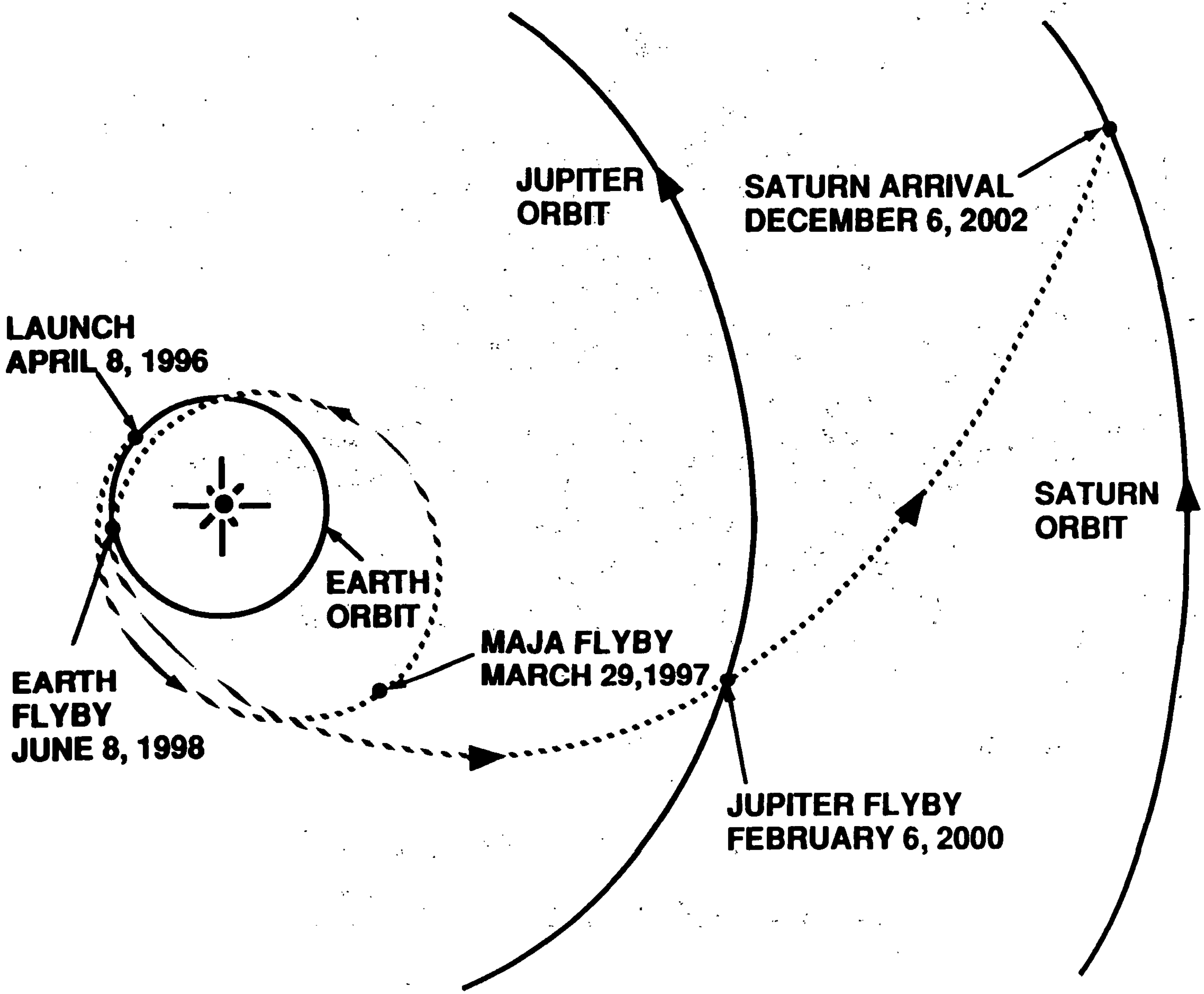
CASSINI
INTERPLANETARY TRAJECTORY



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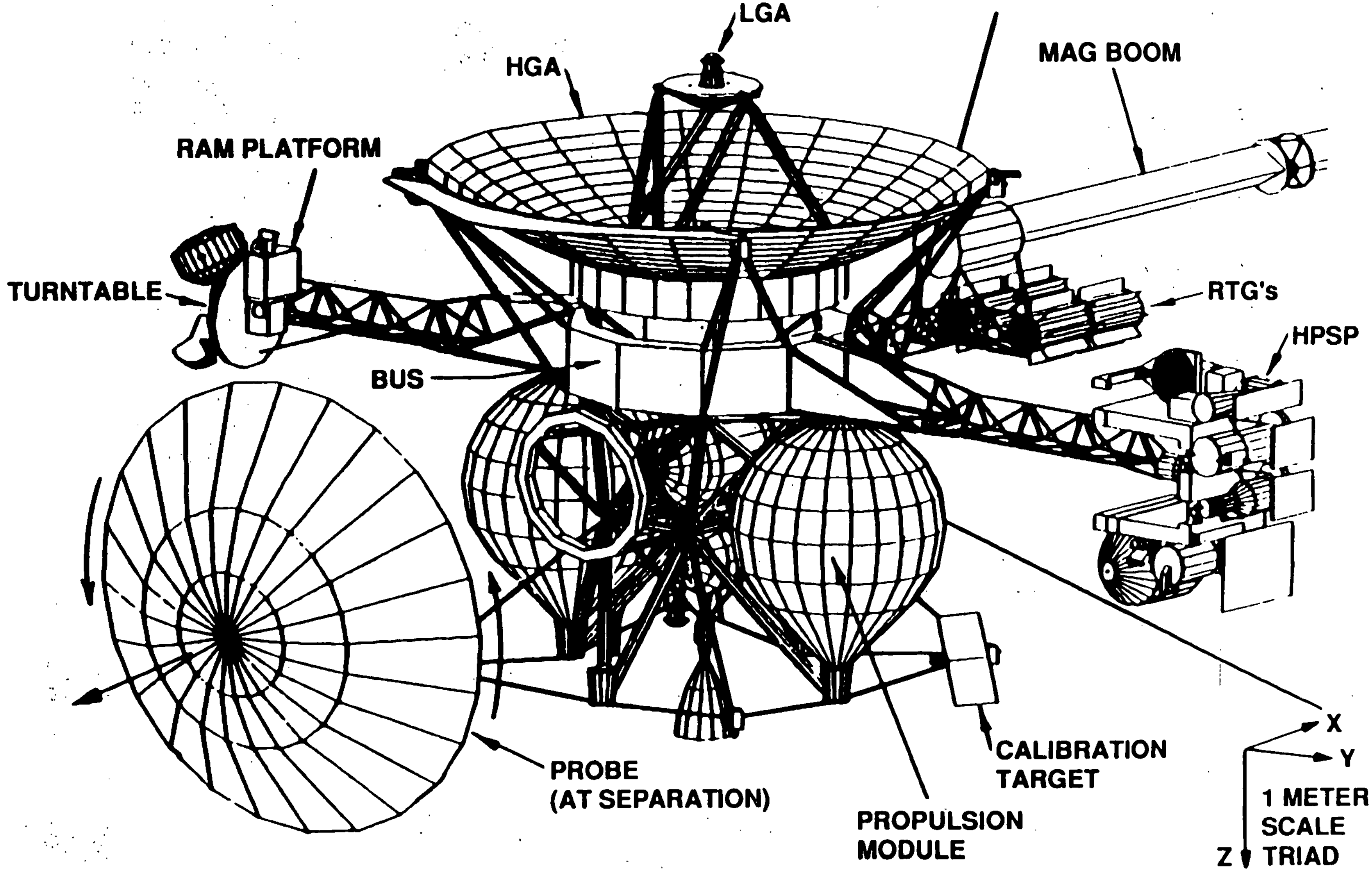
CASSINI SPACECRAFT
DEPLOYED FRONT ISO VIEW



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K_a-BAND ADVANTAGES FOR THE CASSINI MISSION

- REDUCED SPACECRAFT DC POWER (16 Watts) FOR TELEMETRY
- ENHANCED TELEMETRY
  - HIGHER TELEMETRY RATES AT LESS POWER
  - AVOID TAPE RECORDER CAPACITY CONSTRAINT
- IMPROVED RADIO SCIENCE
  - REDUCED PLASMA NOISE
  - IMPROVED SMALL BODY MASS DETERMINATIONS
  - GRAVITATIONAL WAVE DETECTION
- IMPROVED NAVIGATIONAL ACCURACY
  - 4 TO 6 dB REDUCED THERMAL NOISE FOR DOPPLER
  - WIDER BANDWIDTH FOR VLBI

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CASSINI K_a-BAND DOWNLINK SYSTEM ASSESSMENT

PARAMETER	BASELINE X-BAND	K_a-BAND
• CLASS	A	A
• FREQUENCY (GHz)	8.4	32.0
• ANTENNA GAIN (DB)	48.3	59.3
• POINTING ACCURACY REQUIREMENT (MRAD, 3σ)	2.0	0.87
• RF POWER OUT (W)	10.6	5.0
• POWER REQUIREMENT DURING DOWNLINK (W)		
• TRANSMITTER DC POWER INPUT	40.0	20.0
• K_a EXCITER	–	3.5
• SUN SENSOR	1.4	2.0
• TOTAL	41.4	25.5
• MAGNETIC TAPE RECORDER	HIGH DUTY CYCLE	LOWER DUTY CYCLE
• MASS (KG)		
• MASS DELTA (REDUNDANT EXC, PWR COND, TWT)	–	16.0
• SUN SENSOR	0.5	1.0
• TOTAL	0.5	17.0
• BENEFITS		
• ACHIEVABLE DATA VOLUME @ 10 AU ON 70M G & M WITH 2 RATES PER PASS (GBITS/DAY)	3.6	8.3
• RADIO SCIENCE	HIGH	HIGHER
• NAVIGATIONAL ACCURACY	HIGH	HIGHER

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SUMMARY

- K_a-BAND OFFERS SIGNIFICANT BENEFITS TO NASA FOR FUTURE MISSION SCIENCE RETURN
- A DEVELOPMENT ROADMAP IS IN PLACE AND BEING FOLLOWED
- PROPAGATION EXPERIMENTS WILL PLAY A KEY ROLE