SPACE PROBES AND PLANETARY EXPLORATION

by

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7. The probability of planetary biological contamination by the spacecraft should be small ($< 10^{-4}$).
8. The trajectory should be accurate enough so that designing instrumentation with large dynamic ranges will be unnecessary.
9. U.S. launchings are restricted to the Eastern and Western Test Ranges. Only certain launch azimuths are permitted if land masses are to be avoided.

There are also limiting physical laws that will act as constraints upon the more advanced missions of the future. For example, spacecraft cannot equal or exceed the velocity of light. The energy content of fuel is limited by $E = mc^2$. Of course, neither of these limits is approached at present.

TABLE 5-2. SPACE-PROBE MISSIONS

Mission Type	*Required Propulsive Functions**	*Extant Programs*
Planetary Missions:		
Simple flyby	BXM, BOXM	Mariner
Crocco or resonance flyby	BXM, BOXM	
Planetary orbital injection	BXMO, BOXM	
Hard or soft landing	BXMX(R or P)	Voyager
Sample return	BXMXRBXMXR **	
Solar Missions:		
Flyby at 0.1 to 0.3 A. U.	BXMO	
Impact	BXM	
Out-of-Elliptic Missions	BXMO	
Asteroidal Missions:		
Fly-through belt	BXM	
Rendezvous with asteroid	BXMXZ	
Sample return	BXMXZXMXR	
Cometary Missions (same as for asteroids)		
Interplanetary Space Missions:		
Solar orbit	BXO	Pioneer
Eccentric Earth orbit	BO	IMP
Interstellar Missions	BX	

* B = boost from Earth's surface
X = escape or capture maneuver
M = midcourse correction
O = orbital injection
R = reentry or entry
P = powered descent
Z = rendezvous
** Note the complexity of a sample-return mission

Space-probe missions can be defined by exclusion: they comprise all space missions excluding Earth-satellite and manned missions. Even though the bulk of the national space program is discarded by such a definition, a great variety of stimulating scientific missions remains. Restricting the field further, this book does not deal with lunar probes.

The number and variety of the missions listed in Table 5-2 make it obvious that space-probe design will be difficult to generalize. The scientific payoff of any one of the missions, however, is likely to be worth considerable effort.

5-3. Review of Some Techniques of Space Mechanics

In the early days of astronautics, crude trajectory *feasibility* studies were the rule. Even today (and probably tomorrow too), new space missions are planned or "scoped," using simplified techniques based upon coplanar, circular planetary orbits, and instantaneous applications of thrust at various points along the trajectory. In such calculations, the spacecraft is first boosted into an Earth-satellite orbit or an escape trajectory. Then, an instantaneous impulse is applied and the craft is

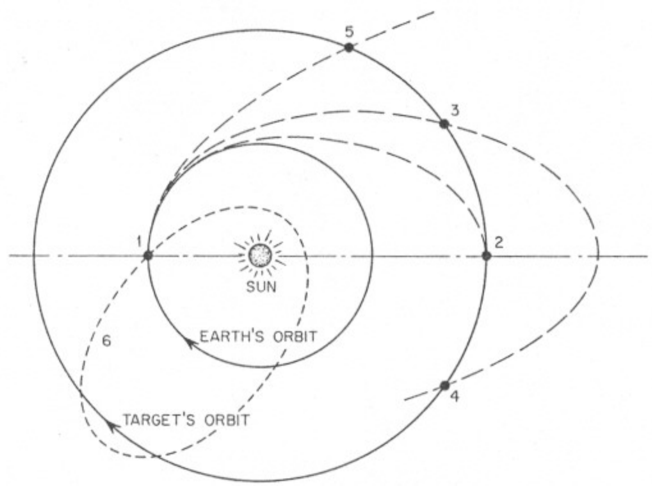

Fig. 5-1. Various types of interplanetary ballistic trajectories. (1) Impulse applied to leave Earth orbit. (2) Impulse applied to leave Hohmann cotangential transfer orbit and enter orbit of target planet. (3) Impulse to terminate short-path elliptical transfer orbit. (4) Impulse to terminate long-path elliptical transfer orbit. (5) Impulse to terminate fast hyperbolic transfer orbit. (6) Crocco or resonance orbit with a period such that the spacecraft meets the Earth after an integral number of revolutions. Planet flybys do not require impulses at (2), (3), or (4).