Glossary

ABL: Automated Biological Laboratory

ACP: Advanced Cooperation Project

Aphelion: The point of maximum distance from the Sun of a solar orbit. Its contrary is the perihelion.

Apoapsis: The point of maximum distance from the central body of any elliptical orbit. This word has been used to avoid complicating the nomenclature, but a term tailored to the central body is often used. The only exceptions used herein owing to their importance were for Earth (apogee) and the Sun (aphelion). The contrary of apoapsis is periapsis.

Apogee: The point of maximum distance from the Earth of a satellite orbit. Its contrary is the perigee.

Astronomical Unit: To a first approximation the average distance between the Earth and the Sun is 149,597,870,691 ($\pm$ 30) meters.

AU: Astronomical Unit

Booster: Auxiliary rockets used to boost the lift-off thrust of a launch vehicle.

Bus: A structural part common to several spacecraft.

CIA: Central Intelligence Agency

CNES: Centre National d'Etudes Spatiales (the French National Space Studies Centre)

CNR: Centro Nazionale Ricerche (the Italian National Research Centre)

Conjunction: The time when a solar system object appears close to the Sun as seen by an observer. A conjunction where the Sun is between the observer and the object is called 'superior conjunction'. A conjunction where the object is between the observer and the Sun is called 'inferior conjunction'. See also opposition.

CONSCAN: Conical Scan

Cosmic velocities: Three characteristic velocities of spaceflight:

First cosmic velocity: Minimum velocity to put a satellite in a low Earth orbit. This amounts to some 8 km/s.

Second cosmic velocity: The velocity required to exit the terrestrial sphere of attraction for good. Starting from the ground, this amounts to some 11 km/s. It is also called 'escape' speed.

Third cosmic velocity: The velocity required to exit the Solar System for good.

Cryogenic propellants: These can be stored in their liquid state under atmospheric pressure at very low temperature; e.g. oxygen is a liquid below –183°C.

Deep Space Network: A global network built by NASA to provide round-the-clock communications with robotic missions in deep space.

Direct ascent: A trajectory on which a deep-space probe is launched directly from the Earth's surface to another celestial body without entering parking orbit.

DSN: Deep Space Network

DZhVS: Dolgozhivushaya Veneryanskaya Stanziya (long duration Venusian probe)

Ecliptic: The plane of the Earth's orbit around the Sun.

Ejecta: Material from a volcanic eruption or a cratering impact that is deposited all around the source.

ELDO: European Launcher Development Organization (became part of ESA)

EOS: Eole–Venus

ESA: European Space Agency

Escape speed: See Cosmic velocities

ESRO: European Space Research Organization (became part of ESA)

ESTEC: European Space Technology Center

Flyby: A high relative speed and short duration close encounter between a spacecraft and a celestial body.

FTU: FotoTelevisionnoye Ustroistvo (photo-television system)

GCMS: Gas Chromatograph Mass Spectrometer

GE: Gas Exchange

GRB: Gamma-Ray Bursts

GSFC: Goddard Space Flight Center

GSOC: German Space Operation Center

HST: Hubble Space Telescope

Hypergolic propellants: Two liquid propellants that ignite spontaneously on coming into contact, without requiring an ignition system. Typical hypergolics are hydrazine and nitrogen tetroxide.

IBEX: Interstellar Boundary Explorer

ICBM: InterContinental Ballistic Missile. A military strategic and usually nuclear-tipped missile with a range of at least 6,400 km. Many early space launchers were adapted from ICBMs.

IKI: Institut Kosmicheskikh Isledovanii (the Russian Institute for Cosmic Research)

IMP: Interplanetary Monitoring Platform

IRAS: InfraRed Astronomical Satellite

ISEE: International Sun–Earth Explorer

JPL: Jet Propulsion Laboratory (a Caltech laboratory under contract to NASA)

J–S–P: Jupiter–Saturn–Pluto trajectory

J–S–U–N: Jupiter–Saturn–Uranus–Neptune trajectory

J–U–N: Jupiter-Uranus-Neptune trajectory

KDU: Korrektiruyushaya Dvigatelnaya Ustanovka (course correction engine)

KSC: Kennedy Space Center

KTDU: Korrektiruyushaya Tormoznaya Dvigatelnaya Ustanovka (course correction and braking engine)

Lander: A spacecraft designed to land on another celestial body.

LaRC: Langley Research Center

Launch window: A time interval during which it is possible to launch a spacecraft to ensure that it attains the desired trajectory.

LR: Labeled Release

Lyman-alpha: The emission line corresponding to the first energy level transition of an electron in a hydrogen atom.

MBB: Messerschmitt Bölkov Blohm

MESO: Mercury Sonde

MIT: Massachusetts Institute of Technology

MJS: Mariner Jupiter–Saturn (later named Voyager)

MJU: Mariner Jupiter–Uranus

MSFC: Marshall Space Flight Center

MV: Mars–Venera (Soviet Mars and Venus probes)

MVM: Mariner Venus–Mercury (also named Mariner 10)

N-1: Nossitel 1 (Launcher 1, the Soviet moon rocket)

NAS: National Academy of Sciences

NASA: National Aeronautics and Space Administration

OAO: Orbiting Astronomical Observatory

Occultation: When one object passes in front of and occults another, at least from the point of view of the observer.

OOE: Out Of the Ecliptic

Orbit: The trajectory on which a celestial body or spacecraft is traveling with respect to its central body. There are three possible cases:

Elliptical orbit: A closed orbit where the body passes from minimum distance to maximum distance from its central body every semiperiod. This is the orbit of natural and artificial satellites around planets and of planets around the Sun.

Parabolic orbit: An open orbit where the body passes through minimum distance from its central body and reaches infinity at zero velocity in infinite time. This is a pure abstraction, but the orbits of many comets around the Sun can be described adequately this way.

Hyperbolic orbit: An open orbit where the body passes through minimum distance from its central body and reaches infinity at non-zero speed. This describes adequately the trajectory of spacecraft with respect to planets during flyby manoeuvres.

Opposition: The time when a solar system object appears opposite to the Sun as seen by an observer.

Orbiter: A spacecraft designed to orbit a celestial body.

P-L: Palomar–Leiden asteroid survey

PAET: Planetary Atmosphere Experiment Test

Parking orbit: A low Earth orbit used by deep-space probes before heading to their targets. This relaxes the constraints on launch windows and eliminates launch vehicle trajectory errors. Its contrary is direct ascent.

PAS: Plavalyuschaya Aerostatnaya Stantsiya (buoyant aerostatic station)

PEPP: Planetary Entry Parachute Program

Periapsis: The minimum distance point from the central body of any orbit. See also apoapsis.

Perigee: The minimum distance point from the Earth of a satellite. Its contrary is apogee.

Perihelion: The minimum distance point from the Sun of a solar orbit. Its contrary is the aphelion.

PR: Pyrolytic Release

PrOP: Pribori Otchenki Prokhodimosti (instrument for cross-country characteristics evaluation)

PVM: Pioneer Venus Multiprobe

PVO: Pioneer Venus Orbiter

'Push-broom' camera: A digital camera consisting of a single row of pixels, with the second dimension created by the motion of the camera itself.

RAE: Radio Astronomy Explorer

Rendezvous: A low relative speed encounter between two spacecraft or celestial bodies.

Resonance: A resonance in the solar system occurs when the rotational and orbital periods of a body are commensurate, or when they are so with another body. For example, most moons have resonant rotation and orbital periods, meaning that they complete one rotation in the same exact time it takes for them to complete one orbit. In another example, some of the gaps in Saturn's rings correspond to particles whose orbits would be resonant with the largest satellites.

Retrorocket: A rocket whose thrust is directed opposite to the motion of a spacecraft in order to brake it.

Rj: Jupiter radii (approximately 71,200 km)

Rn: Neptune radii (approximately 24,750 km)

Rover: A mobile spacecraft to explore the surface of another celestial body.

Rs: Saturn radii (approximately 60,330 km)

RTG: Radioisotope Thermal Generator

RTH: Radioisotope Thermal Heater

Ru: Uranus radii (approximately 25,600 km)

SERT: Space Electric Rocket Test

SETI: Search for Extraterrestrial Intelligence

SNAP: System for Nuclear Auxiliary Power

SNC: Shergottites–Nakhlites–Chassignites meteorites

Solar flare: A solar chromospheric explosion creating a powerful source of high energy particles.

SOREL: Solar Orbiting Relativity Experiment

Space probe: A spacecraft designed to investigate other celestial bodies from a short range.

Spectrometer: An instrument to measure the energy of radiation as a function of wavelenghts in a portion of the electromagnetic spectrum. Depending on the wavelength the instrument is called, e.g. ultraviolet, infrared, gamma-ray spectrometer etc.

Spin stabilization: A spacecraft stabilization system where the attitude is maintained by spinning the spacecraft around one of its main inertia axes.

SS: Surface to Surface missile

SSB: Space Science Board of the National Academy of Sciences

STAR: Self-Testing And Repairing

STS: Space Transportation System (the Space Shuttle)

Synodic period: The period of time between two consecutive superior or inferior conjunctions or oppositions of a solar system body.

Telemetry: Transmission by a spacecraft via a radio system of engineering and scientific data.

3-axis stabilization: A spacecraft stabilization system where the axes of the spacecraft are kept in a fixed attitude with respect to the stars and other references (the Sun, the Earth, a target planet etc.)

TOPS: Thermoelectric Outer Planet Spacecraft

TRW: Thompson Ramo Wooldridge Inc.

UDMH: Unsymmetrical DiMethyl Hydrazine

Ullage rockets: Small rockets, usually solid fueled, used to provide sufficient acceleration in weightlessness to force liquid propellants towards the pump intakes prior to starting a larger rocket engine.

UMVL: Universalnyi Mars, Venera, Luna (Universal for Mars, Venus and the Moon)

UTC: Universal Time Coordinated (essentially Greenwich Mean Time)

V2: Vergeltungswaffe 2 (vengeance weapon 2)

Vernier engines: Small attitude control engines mounted in clusters and firing trough the spacecraft's center of mass. Attitude control is obtained by simple differential throttling of the engines.

Vidicon: A television system based on resistance changes of some substances when exposed to light. It has been replaced by the CCD.

VIM: Voyager Interstellar Mission

VLA: Very Large Array

VOIR: Venus Orbiting Imaging Radar

VPM: Visual Polarimeter–Mars

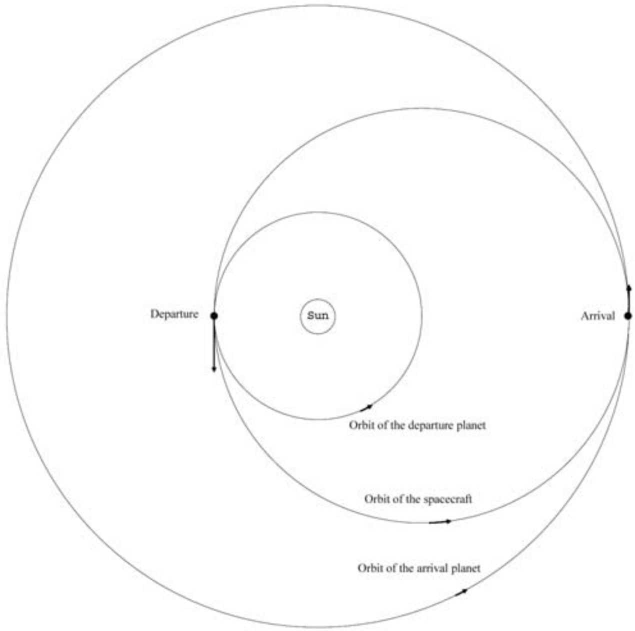
Appendix 1

FINDING YOU WAY THROUGH THE SOLAR SYSTEM: A CELESTIAL MECHANICS PRIMER*

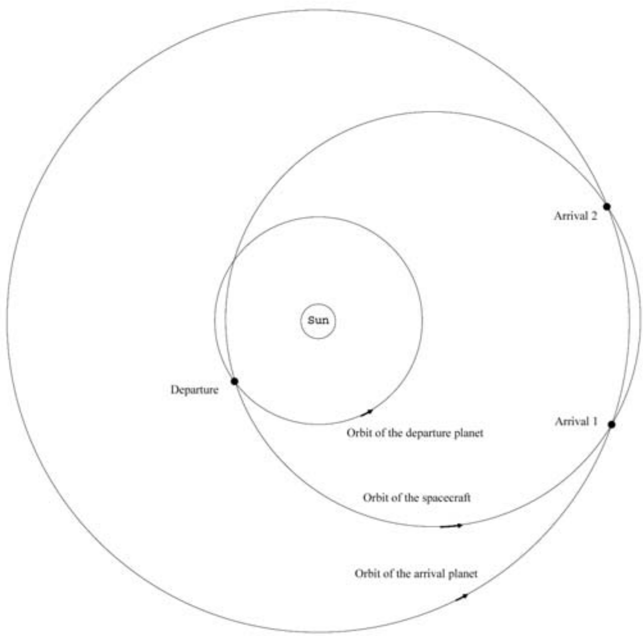
Hohmann Transfer Orbits

The easiest way to travel from one planet to another within the solar system is by way of a Hohmann transfer orbit. Although attributed to Walter Hohmann in Germany in 1923, the Russian mathematician Vladimir Vetchinkin had invented it several years previously. Assuming the orbits of the two planets to be circular and co-planar, Hohmann showed that the optimum way to travel between them (i.e. the least expensive in terms of the energy requirements) was by an ellipse that was tangent to the orbit of the departure planet at departure and tangent to the orbit of the arrival planet at arrival. Thus, after traveling half of its orbit, the spacecraft would reach its target. Of course, the approximation of these 'bi-tangent' orbits is purely theoretical, and a spacecraft for an exterior planet usually departs slightly after the perihelion of the transfer ellipse and arrives slightly before or after aphelion. The same applies for a flight to an interior planet if the word perihelion is substituted for aphelion, and vice versa. In practice, the target can be reached when the spacecraft has subtended an angle of either less than 180 degrees around the Sun, or more than 180 degrees. If less than 180 degrees, the orbit is called a type-1 transfer; if more than 180 degrees it is a type-2 transfer. Each has its merits: a type-1 orbit reduces the duration, while a type-2 reduces the relative speed with respect to the target at arrival – which might be desirable if an orbital insertion burn is intended, or if a landing is to be attempted. In any case, it must be ensured that the target planet and the spacecraft arrive at the arrival point simultaneously, which is ensured by the use of a proper 'launch window'.

* While no mathematics is used in this appendix, a basic knowledge of vector algebra is needed.



A tangential Hohmann transfer orbit.



Type-1 and Type-2 transfer orbits.

Different targets have different requirements in terms of the amount by which the spacecraft must increase or decrease its speed in order to reach them, the duration of the flight and so on; the following table summarizes some of these requirements.

Hohmann transfer ellipses from Earth

Target	Ellipse semimajor axis (AU)	Velocity change needed at departure* (km/s)	Time of flight (Years)	Relative Speed at arrival (km/s)
Mercury**	0.694	–7.53	0.289	9.6
Venus	0.862	–2.5	0.400	2.7
Mars**	1.262	2.95	0.709	2.6
Jupiter	3.102	8.79	2.731	5.6
Saturn	5.270	10.29	6.048	5.4
Uranus	10.091	11.28	16.03	4.7
Neptune	15.529	11.65	30.60	4.1
Pluto**	20.220	11.81	45.46	3.7
Escape Sun		12.34	–	–

* Negative values are in the opposite sense to the Earth's orbital motion. Positive values are in the same sense.

** On average, because the orbits of these planets are markedly elliptical.

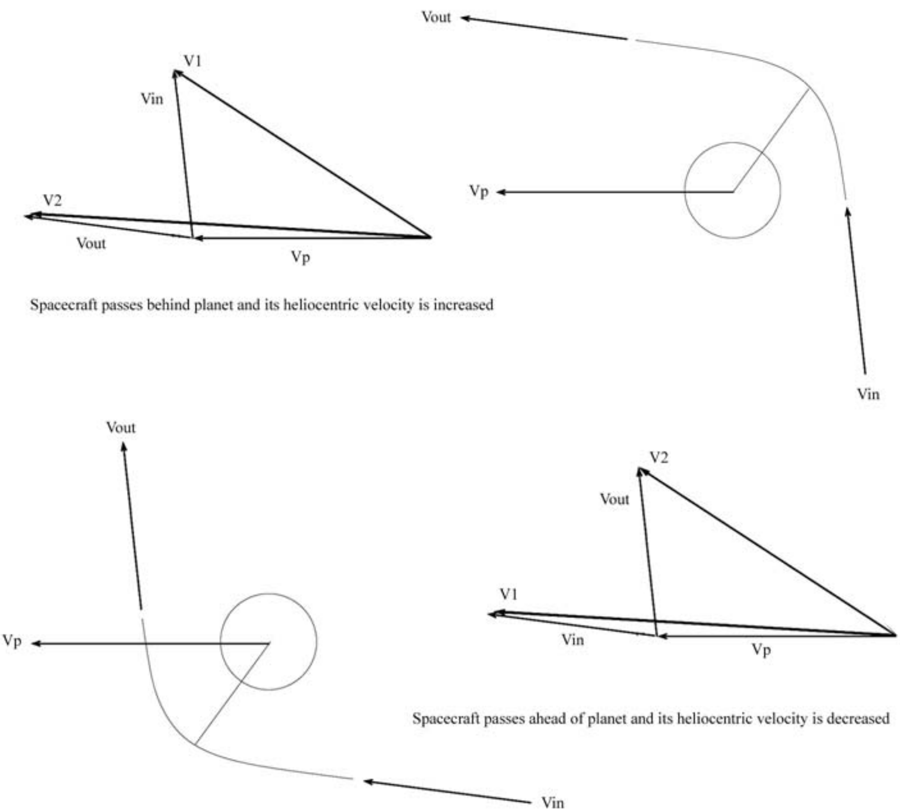
Note a few things about the data in the table:

1 Planets beyond Saturn cannot be reached with a Hohmann orbit within a reasonable time.
2 Contrary to intuition, distant Jupiter and nearby Mercury have similar departure speed requirements.
3 Venus and Mars have similar requirements in terms of speed at departure, but a flight to Mars takes almost twice as long as a flight to Venus.

Of course, these values are valid only for a bi-tangent co-planar Hohmann transfer orbit; real orbits yield longer flight times and larger speeds at departure and arrival.

Gravity-Assists

Consider the case of a spacecraft that catches up with a planet from 'behind'. Due to the gravity of the planet, the path of the spacecraft will be deflected through an angle that depends on the mass of the planet, on the distance of closest approach, and of the square of the relative speed between the spacecraft and the planet (Vin or Vout). Note that the velocity of the spacecraft is unchanged in modulus, only in direction. The velocity of the spacecraft with respect to the Sun (i.e. its heliocentric velocity) is the vectorial sum of the velocity of the planet (Vp) and of the spacecraft with respect to the planet (Vin or Vout). Hence summing Vp with Vin and with Vout gives the heliocentric velocity of the spacecraft before and after the encounter. Notice that the



How gravity-assist ‘slingshots’ work

velocity before the encounter (V1) is smaller than the velocity afterwards (V2). Now consider what happens when the spacecraft passes in front of the planet instead of behind it. In this case, the heliocentric velocity is reduced; this technique can be used to slow a spacecraft down. Such ‘slingshots’ have been used extensively in solar system exploration, first when Mariner 10 used Venus to reach Mercury, then when Pioneer 11 used Jupiter to reach Saturn, but most spectacularly to enable Voyager 2 to reach Uranus and Neptune – the latter mission would have been otherwise impracticable using Hohmann transfers.

Appendix 2

SOVIET PLANETARY PROBE DESIGNATIONS

Code	Role	Record
Korolyov's probes		
1M	Mars flyby/lander	2 failures
1V	Venus lander	Canceled
1VA	Venus flyby	2 failures including Venera 1
2MV-1	Venus lander	2 failures
2MV-2	Venus flyby	1 failure
2MV-3	Mars lander	1 failure
2MV-4	Mars flyby	2 failures including Mars 1
3MV-1A	Test	2 failures
3MV-1	Venus lander	2 failures including Zond 1
3MV-2	Venus flyby	Not flown
3MV-3	Mars/Venus lander	1 failure (Venera 3)
3MV-4	Mars/Venus flyby	Zond 3, plus 3 failures including Zond 2 and Venera 2
Lavochkin's probes		
1F*	Mars/Phobos orbiter	Fobos 1, 2
1M	Mars flyby/lander	Canceled
1V	Venus lander	Venera 4 plus 1 failure
2M	Mars orbiter	Atmospheric capsule deleted, 2 failures
2V	Venus lander	Venera 5 and 6
3MS	Mars orbiter	Mars 4 and 5, plus 1 launch failure
3MP	Mars lander	Mars 2, 3, 6 and 7
3V	Venus lander	Venera 7 and 8, plus 2 failures
4M	Mars lander/rover	Canceled
4NM	Mars lander/rover	Canceled

4V-1	Venus orbiter/lander	Venera 9, 10, 11 and 12
4V-1M	Venus orbiter/lander	Venera 13 and 14
4V-2*	Venus orbiter/radar	Venera 15 and 16
5VK*	Venus–Halley flyby	Vega 1 and 2
5VP*	Venus balloon carrier	Canceled
5VS*	Venus orbiter	Canceled
5M	Mars sample return	Canceled
5NM	Mars sample return	Canceled
DZhVS	Venus lander	Canceled
YuS*	Jupiter, Saturn, solar probe	Canceled

* Will be covered in later volumes.

Appendix 3

REPORTED SPACECRAFT DISCOVERIES OF PLANETARY SATELLITES

Preliminary Designation	Official Name	Planet	Spacecraft
1979J1	Adrastea	Jupiter	Voyager 2
1979J2	Thebe	Jupiter	Voyager 1
1979J3	Metis	Jupiter	Voyager 1
1979S1	Epimetheus (?)	Saturn	Pioneer 11
1979S2	Janus	Saturn	Pioneer 11
1979S3	Unconfirmed	Saturn	Pioneer 11
1979S4	Unconfirmed	Saturn	Pioneer 11
1979S5	Unconfirmed	Saturn	Pioneer 11
1979S6	Unconfirmed	Saturn	Pioneer 11
1980S26	Pandora	Saturn	Voyager 1
1980S27	Prometheus	Saturn	Voyager 1
1980S28	Atlas	Saturn	Voyager 1
1980S33	Telesto	Saturn	Voyager 1
1980S34	Unconfirmed	Saturn	Voyager 1
1981S6	Unconfirmed	Saturn	Voyager 2
1981S7	Unconfirmed	Saturn	Voyager 2
1981S8	Unconfirmed	Saturn	Voyager 2
1981S9	Unconfirmed	Saturn	Voyager 2
1981S10	Unconfirmed	Saturn	Voyager 2
1981S11	Unconfirmed	Saturn	Voyager 2
1981S12	Unconfirmed	Saturn	Voyager 2
1981S13	Pan	Saturn	Voyager 2
1981S14	Pallene	Saturn	Voyager 2
1981S15	Unconfirmed	Saturn	Voyager 2
1981S16	Unconfirmed	Saturn	Voyager 2
1981S17	Unconfirmed	Saturn	Voyager 2

1981S18	Unconfirmed	Saturn	Voyager 2
1981S19	Unconfirmed	Saturn	Voyager 2
1985U1	Puck	Uranus	Voyager 2
1986U1	Portia	Uranus	Voyager 2
1986U2	Juliet	Uranus	Voyager 2
1986U3	Cressida	Uranus	Voyager 2
1986U4	Rosalind	Uranus	Voyager 2
1986U5	Belinda	Uranus	Voyager 2
1986U6	Desdemona	Uranus	Voyager 2
1986U7	Cordelia	Uranus	Voyager 2
1986U8	Ophelia	Uranus	Voyager 2
1986U9	Bianca	Uranus	Voyager 2
1986U10	Perdita	Uranus	Voyager 2
1989N1	Proteus	Neptune	Voyager 2
1989N2	Larissa	Neptune	Voyager 2
1989N3	Despina	Neptune	Voyager 2
1989N4	Galatea	Neptune	Voyager 2
1989N5	Thalassa	Neptune	Voyager 2
1989N6	Naiad	Neptune	Voyager 2

An additional satellite of Uranus, 2003U1, Mab, is present in the Voyager images, but it was not recognized until a check was made following its discovery in 2003 by the Hubble Space Telescope.

Appendix 4

CHRONOLOGY OF SOLAR SYSTEM EXPLORATION 1952–1982

Date	Event
20 September 1952	Eric Burgess and Charles A. Cross present their "The Martian Probe" paper
4 October 1957	Sputnik 1, the first artificial satellite is launched
1 February 1958	Explorer 1, the first US satellite is launched
2 January 1959	Luna 1, the first "artificial planet" is launched
11 March 1960	Launch of Pioneer 5, the first interplanetary probe
10 October 1960	The first Mars probe is launched, but lost due to rocket failure
19 May 1961	Venera 1 passes Venus, but it had failed in February
14 December 1962	Mariner 2 passes Venus and returns data
19 June 1963	Mars 1 passes Mars, but it had failed in March
15 July 1965	Mariner 4 passes Mars and returns data
1 March 1966	Venera 3 impacts on Venus, two weeks after falling inert
22 August 1967	The Voyager Mars landing mission is canceled
18–19 October 1967	Venera 4 enters Venus's atmosphere and Mariner 5 passes the planet
31 July 1969	Mariner 6 passes Mars
5 August 1969	Mariner 7 passes Mars
15 December 1970	Venera 7 lands on Venus
14 November 1971	Mariner 9 enters orbit around Mars
2 December 1971	Mars 3 lands on Mars
4 December 1973	Pioneer 10 passes Jupiter
29 March 1974	Mariner 10 passes Mercury
15 March 1975	Helios 1 passes within 0.30 AU of the Sun
22 October 1975	Venera 9 lands on Venus and returns pictures
20 July 1976	Viking 1 lands on Mars
4 December 1978	Pioneer Venus Orbiter enters orbit around Venus
9 December 1978	The Pioneer Venus Multiprobes enter Venus's atmosphere

5 March 1979	Voyager 1 passes Jupiter
9 July 1979	Voyager 2 passes Jupiter
1 September 1979	Pioneer 11 passes Saturn
12 November 1980	Voyager 1 passes Saturn
26 August 1981	Voyager 2 passes Saturn
1 March 1982	Venera 13 lands on Venus and returns color pictures
Related milestones	
13 June 1983	Pioneer 10 crosses the orbit of Neptune
24 January 1986	Voyager 2 passes Uranus
25 August 1989	Voyager 2 passes Neptune
16 December 2004	Voyager 1 reaches the heliospheric termination shock

Appendix 5

PLANETARY LAUNCHES 1960–1981

Launch Date	Name	Main Target	Launcher	Nation
11 March 1960	Pioneer 5	Solar orbit	Thor–Able IV	USA
10 October 1960	(1M No.1)	Mars	8K78 Molniya	USSR
14 October 1960	(1M No.2)	Mars	8K78 Molniya	USSR
4 February 1961	(1VA No.1)	Venus	8K78 Molniya	USSR
12 February 1961	(Venera 1)	Venus	8K78 Molniya	USSR
22 July 1962	(Mariner 1)	Venus	Atlas–Agena B	USA
25 August 1962	(2MV-1 No.1)	Venus	8K78 Molniya	USSR
27 August 1962	Mariner 2	Venus	Atlas–Agena B	USA
1 September 1962	(2MV-1 No.2)	Venus	8K78 Molniya	USSR
12 September 1962	(2MV-2 No.1)	Venus	8K78 Molniya	USSR
24 October 1962	(2MV-4 No.1)	Mars	8K78 Molniya	USSR
1 November 1962	(Mars 1)	Mars	8K78 Molniya	USSR
4 November 1962	(2MV-3 No.1)	Mars	8K78 Molniya	USSR
19 February 1964	(3MV-1A No.4A)	Venus	8K78 Molniya	USSR
27 March 1964	(3MV-1 No.5)	Venus	8K78 Molniya	USSR
2 April 1964	(Zond 1)	Venus	8K78 Molniya	USSR
5 November 1964	(Mariner 3)	Mars	Atlas–Agena D	USA
28 November 1964	Mariner 4	Mars	Atlas–Agena D	USA
30 November 1964	(Zond 2)	Mars	8K78 Molniya	USSR
18 July 1965	Zond 3	Lunar flyby	8K78 Molniya	USSR
12 November 1965	(Venera 2)	Venus	8K78M Molniya	USSR
16 November 1965	(Venera-3)	Venus	8K78M Molniya	USSR
23 November 1965	(3MV-4 No.6)	Venus	8K78M Molniya	USSR
16 December 1965	Pioneer 6	Solar orbit	Thor–Delta E	USA
17 August 1966	Pioneer 7	Solar orbit	Thor–Delta E1	USA
12 June 1967	Venera 4	Venus	8K78M Molniya	USSR
14 June 1967	Mariner 5	Venus	Atlas–Agena D	USA

17 June 1967	(1V No.311)	Venus	8K78M Molniya	USSR
13 December 1967	Pioneer 8	Solar orbit	Thor–Delta E1	USA
8 November 1968	Pioneer 9	Solar orbit	Thor–Delta E1	USA
5 January 1969	Venera 5	Venus	8K78M Molniya	USSR
10 January 1969	Venera 6	Venus	8K78M Molniya	USSR
25 February 1969	Mariner 6	Mars	Atlas–Centaur	USA
27 March 1969	(2M No.521)	Mars	8K82K Proton-K/D	USSR
27 March 1969	Mariner 7	Mars	Atlas–Centaur	USA
2 April 1969	(2M No.522)	Mars	8K82K Proton-K/D	USSR
27 August 1969	(Pioneer E)	Solar orbit	Thor–Delta L	USA
17 August 1970	Venera 7	Venus	8K78M Molniya	USSR
22 August 1970	(3V No.631)	Venus	8K78M Molniya	USSR
9 May 1971	(Mariner 8)	Mars	Atlas–Centaur	USA
10 May 1971	(3MS No.170)	Mars	8K82K Proton-K/D	USSR
19 May 1971	Mars 2	Mars	8K82K Proton-K/D	USSR
28 May 1971	Mars 3	Mars	8K82K Proton-K/D	USSR
30 May 1971	Mariner 9	Mars	Atlas–Centaur	USA
3 March 1972	Pioneer 10	Jupiter	Atlas–Centaur	USA
27 March 1972	Venera 8	Venus	8K78M Molniya	USSR
31 March 1972	(3V No.671)	Venus	8K78M Molniya	USSR
6 April 1973	Pioneer 11	Jupiter	Atlas–Centaur	USA
21 July 1973	(Mars 4)	Mars	8K82K Proton-K/D	USSR
25 July 1973	Mars 5	Mars	8K82K Proton-K/D	USSR
5 August 1973	(Mars 6)	Mars	8K82K Proton-K/D	USSR
9 August 1973	(Mars 7)	Mars	8K82K Proton-K/D	USSR
3 November 1973	Mariner 10	Mercury	Atlas–Centaur	USA
10 December 1974	Helios 1	Solar orbit	Titan IIIE–Centaur	USA/FRG
8 June 1975	Venera 9	Venus	8K82K Proton-K/D	USSR
14 June 1975	Venera 10	Venus	8K82K Proton-K/D	USSR
20 August 1975	Viking 1	Mars	Titan IIIE–Centaur	USA
9 September 1975	Viking 2	Mars	Titan IIIE–Centaur	USA
15 January 1976	Helios 2	Solar orbit	Titan IIIE–Centaur	USA/FRG
20 August 1977	Voyager 2	Jupiter	Titan IIIE–Centaur	USA
5 September 1977	Voyager 1	Jupiter	Titan IIIE–Centaur	USA
20 May 1978	Pioneer Venus Orbiter	Venus	Atlas–Centaur	USA
8 August 1978	Pioneer Venus Multiprobe	Venus	Atlas–Centaur	USA
12 August 1978	International Cometary Explorer*	P/Giacobini –Zinner	Delta 2914	USA
9 September 1978	Venera 11	Venus	8K82K Proton-K/D-1	USSR
14 September 1978	Venera 12	Venus	8K82K Proton-K/D-1	USSR
30 October 1981	Venera 13	Venus	8K82K Proton-K/D-1	USSR
4 November 1981	Venera 14	Venus	8K82K Proton-K/D-1	USSR

* Will be covered in a later volume.
Missions in parentheses are missions that failed, but the status of Mars 2, 3 and 5 is disputed.

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