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A

A-4 The original engineering designation for the **V-2**. See **V-2**.

ablation The erosion of a surface, usually of a spacecraft **heat shield** on **re-entry**, due to friction with the molecular constituents of the **atmosphere**. A surface designed to ablate in such circumstances is known as an 'ablative surface' or 'ablative coating'.

ABM An abbreviation for:

(i) **apogee boost motor** – see **apogee kick motor (AKM)**.

(ii) anti-ballistic missile, a missile designed to destroy another ballistic missile in flight and the subject of the 1972 ABM Treaty, designed to limit the development and deployment of ballistic missiles.

abort The termination of a space **flight** or **mission** (used both as a verb and a noun). As an illustration, the **Space Shuttle** has four abort alternatives which can be used during the launch phase in the event of a **Space Shuttle main engine** failure:

(i) Return To Launch Site (RTLS). Available from separation of the **solid rocket boosters (SRBs)** to the time when the next alternative (AOA) becomes available. The Shuttle flies on to burn the remaining **propellant**, turns back towards the **launch site**, jettisons the **external tank** and glides back to the launch site runway for a landing.

(ii) Abort Once Around (AOA). Available from about 2 minutes after SRB separation to when the next alternative (ATO) becomes available. The vehicle attains a **sub-orbital** trajectory, circles the Earth once and returns to the launch site.

(iii) Abort To Orbit (ATO). Available when the Shuttle has passed the AOA-point and can attain orbit. Although the orbit attained may be lower than originally intended, the **de-orbit**, **re-entry** and landing would be similar to a normal mission.

(iv) Transatlantic Landings (TAL). An additional abort alternative which overlaps the latter part of the RTLS option, added when emergency runways became available on the eastern side of the Atlantic.

absolute temperature Temperature measured on the 'absolute scale'. See **kelvin (K)**.

absolute zero The lowest temperature theoretically attainable; the temperature at which all molecular motion ceases (−273.15 °C). See **kelvin (K)**.

AC power A source of electrical power supplied with alternating current. See **power**. The great majority of spacecraft power systems use direct current (DC), AC being used only for special applications in scientific satellites and spacecraft payloads. The **Hubble Space Telescope**, for instance, uses a 20 kHz AC supply.

[See also **regulated power supply**]

acceleration due to gravity – see **gravity**

accelerometer A device for measuring acceleration.

[See also **inertial platform**]

access arm A projection from a launch vehicle **service structure** which can be rotated towards the vehicle for access, either for general maintenance or the loading of a **crew**. If the arm is swung away from the vehicle at the moment of **launch**, usually when it carries **umbilical**s for **propellant** or electrical services, it is also known as a **swing-arm**.

[See also **white room**]

access panel – see **closure panel**

access tower – see **service structure**

acoustic test chamber A ground-based test facility which simulates the acoustic environment experienced by a spacecraft during **launch**.

[See also **thermal-vacuum chamber**, **vibration facility**, **anechoic chamber**]

activated charcoal canister – see **environmental control and life support system (ECLSS)**

active A term applied to any device or system involved in mechanical or electrical action, or capable of a productive reaction to external stimuli; the opposite of **passive**. For example, an **amplifier** is an active device in a **communications system**, since it makes an active contribution to the input **signal**; a connector is a passive component. Similarly, a **heater** is an active device in a **thermal control subsystem**, while **thermal insulation** provides passive thermal control. While most spacecraft **sensor**s or remote sensing **payload**s are passive, the **synthetic aperture radar (SAR)** is an active device.

active satellite An archaic term for a satellite with an active payload, typically a **communications payload** (see, for comparison, **passive communications satellite**). The first satellite to carry an active radio repeater was Courier 1B – see **repeater**.

actuator Any device which produces a mechanical action or motion; a servomechanism that supplies the energy for the operation of other mechanisms.

Spacecraft actuators forming part of a spacecraft **attitude and orbital control system** include **reaction control thruster**s, **reaction wheel**s and **momentum wheel**s.

[See also **nutation damper**, **solar sailing**, **orbital control**, **attitude control**]

ADCS – see **attitude determination and control system**

aerial – see **antenna**

aerobraking Aerodynamic braking, an orbital **injection** technique which uses frictional forces generated within a planetary **atmosphere** to decelerate a **spacecraft**, thereby reducing the amount of **propellant** required. Aerobraking typically begins in the higher levels of the atmosphere and lowers the **apoapsis** in a gradual process (e.g. as performed by the Mars Global Surveyor spacecraft in 1997/98); the spacecraft may attain an **orbit** or conduct a **re-entry**. Contrast: **aerocapture**.

[See also **atmospheric drag**]

aerocapture Aerodynamic capture, an orbital **injection** technique which uses frictional forces within a planetary **atmosphere** to decelerate a **spacecraft** in a single pass (as opposed to **aerobraking**, which is a gradual process). In aerocapture, the spacecraft penetrates more deeply into the atmosphere and must be fitted with a **heat shield** to dissipate the higher levels of **aerodynamic heating**.

[See also **re-entry corridor**, **atmospheric drag**]

aerodynamic heating An increase in the **skin temperature** of a vehicle due to air friction, particularly at supersonic or hypersonic speeds [see **Mach number**]. Sometimes called 'kinetic heating', although this can be caused by other forms of friction due to motion.

[See also **re-entry**, **aerocapture**]

aerodynamic stress A generic term for the forces to which a **launch vehicle** or **spacecraft**, etc., is subjected during its passage through an **atmosphere** (during **launch**, **re-entry**, etc.). See **aerodynamics**.

aerodynamics The study of air flow over a body and the resultant aerodynamic forces. See **lift**, **drag**, **thrust**.

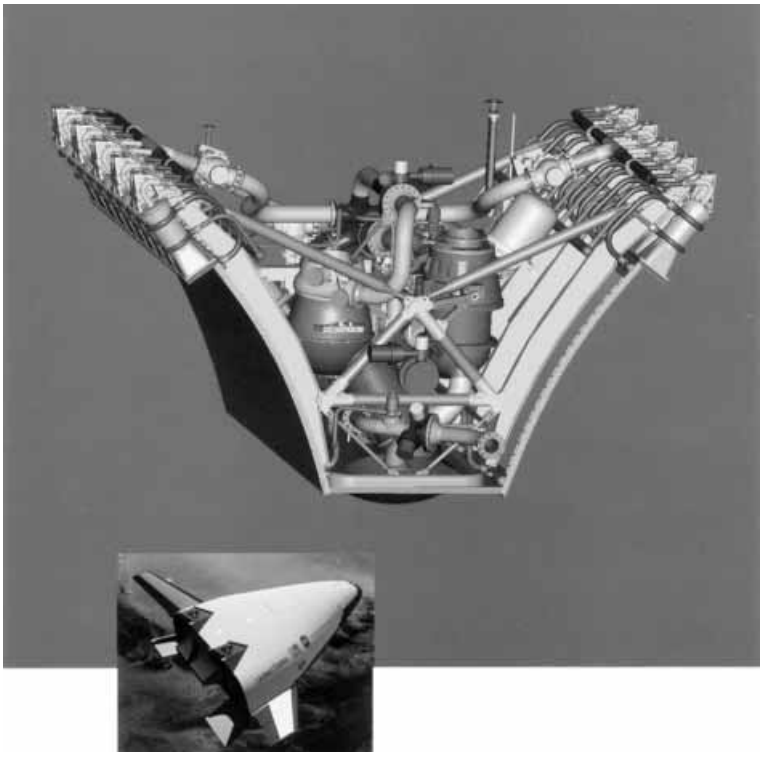
[See also **aerospace vehicle**, **lifting body**, **lifting surface**, **fairing**, **dynamic pressure**]

aerospace A modifier describing a relevance to both air and **space**: e.g. aerospace industry, **aerospace vehicle**.

aerospace vehicle A term used for a space vehicle which, as part of its **launch** or **re-entry** phase, is also capable of flight in the **atmosphere** using a **lifting surface** (namely a wing) as well as conventional rocket propulsion. [See also **spacecraft**, **single stage to orbit**, **reusable launch vehicle (RLV)**, **Hotol**]

aerospike A system of shock-waves (an 'aerodynamic spike') formed in the stream of exhaust gases from a **rocket engine** using a **plug nozzle**, as opposed to a bell-shaped **exit cone**. An abbreviated name for the engine itself: see **aerospike engine**.

aerospike engine An alternative to the bell-shaped **exit cone** used in the **nozzle**s of contemporary **rocket engine**s, whereby a number of small **combustion chamber**s, with accompanying **nozzle** outlets, discharge combustion gases



A1: XRS-2200 linear **aerospike engine** designed for the **X-33** technology demonstrator. [Boeing]

against the outer surface of a truncated wedge or cone [see figure A1]. The system of shock-waves formed below the engine is known as an **aerospike**. In the case of the wedge (or ramp) design, the nozzle-outlets are arranged in a line and the device is known as a linear aerospike engine; in the conical design, where the nozzles are arranged in a ring, it is termed a plug nozzle or annular nozzle.

The aerospike engine is more efficient than the conventional bell nozzle in that it offers an automatic adjustment to the variation in atmospheric pressure between ground level and the upper **atmosphere** [see **plug nozzle**]. The linear engine design formed the basis for **NASA**'s **X-33** programme to develop the technology for a **reusable launch vehicle (RLV)**.

aerozine-50 A **liquid propellant** comprising 50% **hydrazine** and 50% **UDMH** (unsymmetrical dimethylhydrazine).
[See also **liquid propellant**]

Agena A rocket **stage** used with the **Thor**, **Titan** and Atlas **launch vehicle**s. See **Atlas**.

AI An abbreviation for **artificial intelligence**.

airborne support equipment (ASE) Equipment flown on a **spacecraft** or **launch vehicle** to support a **payload** (physically or in terms of electrical supplies, etc.); for example, a **cradle** (and its associated systems) designed to support a spacecraft in the **payload bay** of the **Space Shuttle**, or a Spacelab **pallet**.
[See also **flight hardware**, **ground support equipment (GSE)**]

air-breathing rocket – see **combined cycle engine**

airframe The supporting structure and aerodynamic components of a **launch vehicle** or **aerospace vehicle**. The term, borrowed from aviation technology, tends to be applied only to space vehicles which have some contact with the Earth's **atmosphere** during their launch phase, and not to **satellite**s and other similar **spacecraft**.
[See also **thrust structure**, **inter-tank structure**, **inter-stage**, **fairing**, **fin**, **skin**, **longeron**, **stringer**, **ogive**, **skirt**, **shroud**, **SYLDA**, **SPELDA**, **SPELTRA**]

airlock An airtight chamber which allows **astronaut**s and/or equipment to leave and/or enter a **spacecraft** without depressurising the entire vehicle. Most early space **capsule**s were far too small to include a separate airlock so any **extra-vehicular activity (EVA)** required all crewmembers to don their **spacesuit**s before the capsule was depressurised. However, the Space Shuttle **orbiter** has a removable airlock which can be installed in one of three

different positions dependent on the mission: inside the crew compartment, allowing maximum use of the **payload bay**; inside the payload bay attached to the aft cabin bulkhead; or on top of the pressurised 'tunnel adapter' which links a **Spacelab** payload to the orbiter **cabin**. Two spacesuits are stored in the airlock and, during EVA, it can supply oxygen, cooling water, electrical power and communications services to the suited astronauts.

AIT – see **assembly, integration & test**

AKM – see **apogee kick motor**

albedo The ratio of the intensity of light reflected from a body to that received from the Sun (in the 'visible **spectrum**' unless otherwise specified).

The fraction of the incident solar radiation returned to space by reflection from a planetary surface (solid or gaseous) is called 'planetary albedo', the average value of which for Earth, for example, is 0.34. In contrast, the thermal energy re-radiated by the Earth is known as 'earthshine'. Although important to the thermal design of spacecraft in **low Earth orbit**s, albedo and earthshine are only significant for geostationary spacecraft carrying devices at **cryogenic** temperatures.

[See also **thermal control subsystem**, **geostationary orbit**]

Alcantara The location of a Brazilian **launch site** (at approximately 2° S, 44° W), used mainly for its domestic small satellite launcher, **VLS** (Veiculo Lancador de Satellites).

ALH84001 The designation of a **meteorite** found in the Allan Hills region of Antarctica but believed to originate from Mars. In 1996, NASA announced that the 'Martian meteorite' appeared to contain fossilised lifeforms, thereby suggesting that there was once life on Mars. Less well known is the 'lunar meteorite' designated ALH81005, which, among others, is believed to have reached Antarctica from the **Moon**.

Alpha A former designation of the **International Space Station (ISS)**.

ALSEP An acronym for Apollo Lunar Surface Experiments Package. The ALSEP, carried on all **Apollo** landing missions except Apollo 11, was stored in the **descent stage** of the lunar module and powered by a plutonium-238 **radioisotope thermoelectric generator (RTG)**, designated **SNAP**-27 (an acronym for systems of nuclear auxiliary power). The package contained **seismometer**s, a **magnetometer**, and **solar wind** and lunar heat flow experiments.

altimeter An instrument designed to measure **altitude** (sense (i)).

[See also **radar altimeter**]

altitude

(i) The vertical height of a body above the surface of a planet (typically above sea level for Earth).

(ii) In astronomy, navigation, etc., a measure of the angle above the horizon. See **elevation** (**angle**).

altitude-azimuth mount A structure for the support and guidance of an astronomical telescope or a satellite **earth station** which uses the 'horizon system' of celestial coordinates – see **azimuth**. In satellite applications it is referred to as an **elevation**-over-azimuth mount if its lower axis is perpendicular to the ground, and '*X*–*Y*' if its lower axis is parallel to the ground. The term 'Az-El mount' is also sometimes heard. The major alternative to the 'Alt-Az' mount for telescopes is the **equatorial mount**, known as a **polar mount** for earth stations.

[See also **kinetheodolite**]

aluminium (Al) A low-density metal, widely used (when alloyed with other metals) in the aerospace industry. Historically, aluminium was alloyed with only a few elements close to it in the periodic table: magnesium, zinc, copper, silicon, manganese and lithium. However, later techniques, including rapid solidification technology, have trebled this number. Typical applications: spacecraft body-panel **face-skins**, mounting-brackets and fittings (machined), launch vehicle **adapter ring**s (forged).

[See also **honeycomb panel**, **materials**]

AM – see **amplitude modulation**

Ames Research Center – see **NASA**

AMF – see **apogee motor firing**

ammonium perchlorate (NH_4ClO_4) A solid **oxidiser** used in **rocket motor**s. See **solid propellant**.

amplifier An electrical device which increases the strength of an input signal and presents a magnified replica of the signal at the output.

[See also **amplifier chain**, **HPA**, **LNA**, **SSPA**, **TWTA**, **linearity**]

amplifier chain A general term for a number of amplifiers, and associated hardware, linked together in series. In a practical amplification device (for instance a spacecraft **communications payload**) a number of discrete, specialised amplifiers (e.g. pre-amplifiers, **low noise amplifier**s and **IF amplifier**s) are commonly linked together to form a chain. Within the communications payload one finds equipment divided, by function, into a **receive chain** and a **transmit chain**.

amplitude modulation (AM) A transmission method using a modulated **carrier** wave, whereby the **amplitude** of the carrier is varied in accordance with the amplitude of the input signal; the **frequency** of the carrier remains unchanged.
[See also **modulation**, **frequency modulation (FM)**, **phase modulation (PM)**, **pulse code modulation** (**PCM**), **delta modulation** (**DM**)]

Andoya The location the Andoya Rocket Range (at approximately 69° N, 16° E), a Norwegian **launch site** used mainly for **sounding rocket**s.

anechoic chamber A ground-based test-facility for the evaluation of **radio frequency (RF)** equipment on a spacecraft, which simulates the RF propagation characteristics of **free space**. The walls and all service equipment and mounts are covered with RF absorbing material to reduce reflections (or 'echoes') to a minimum [see figure A2]. The larger chambers admit the whole spacecraft, but it is quite common to test only the **communications payload** (**antenna**s and **transponder**s) at an earlier stage in the design process.
[See also **thermal-vacuum chamber**, **acoustic test chamber**, **vibration facility**]

Angara A Russian **launch vehicle** developed in the late 1990s, in a number of variants, to replace the **Zenit** and **Proton**. Its smallest version was designed to lift about 2200 kg to **low Earth orbit (LEO)**, while medium and heavy-lift versions had approximate payload capabilities of 14 and 24.5 tonnes, respectively, to LEO (2.5 and 6.8 tonnes to **geostationary transfer orbit**).

angle modulation – see **modulation**

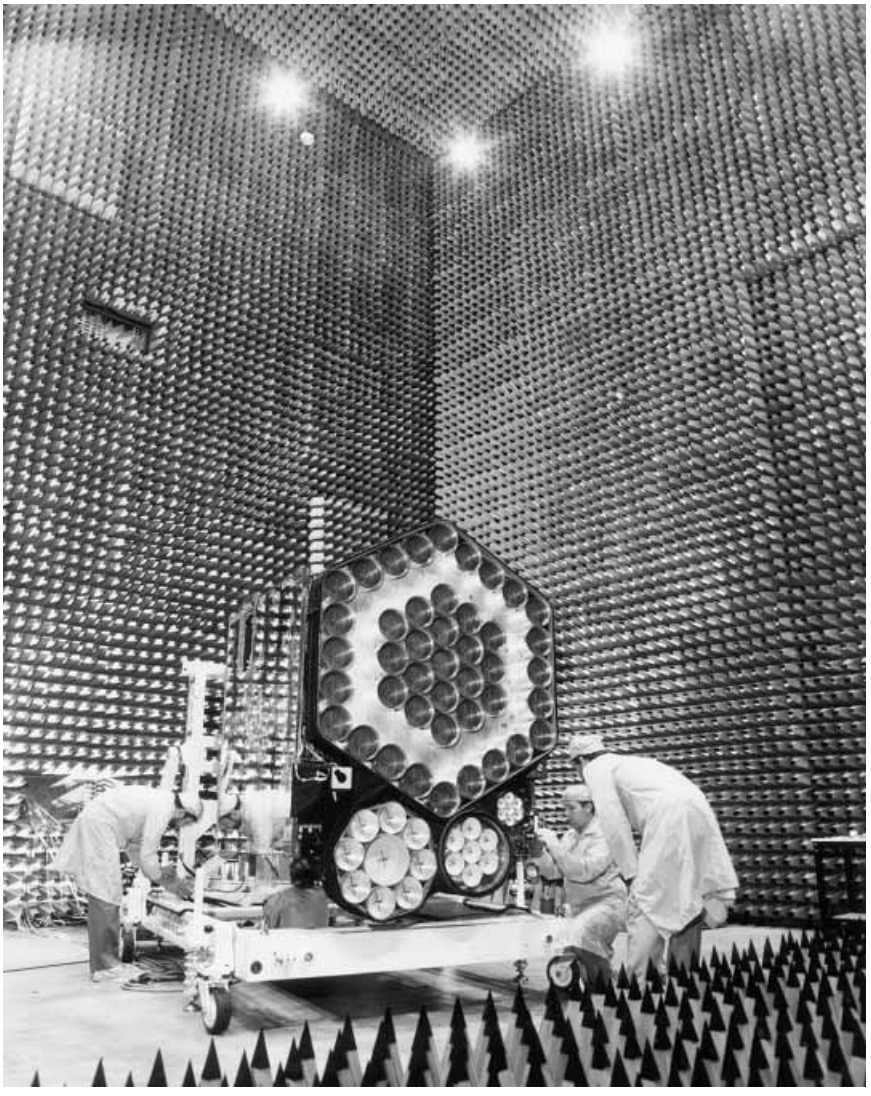
announcement of opportunity – see **AO**

annular nozzle – see **plug nozzle**

anoxia A lack of oxygen. See **hypoxia**.

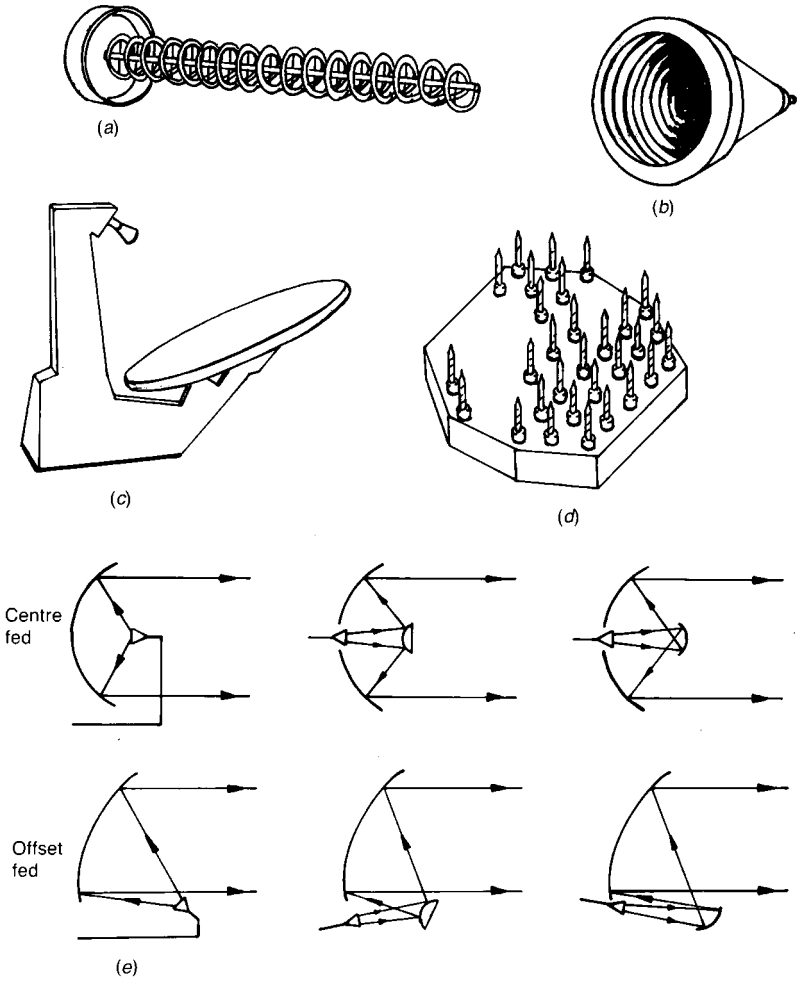
antenna The part of a radio system that enables a radio signal to be transmitted and/or received; the 'interface' between the radio equipment and the environment, between a '**free space**' RF wave and a guided wave. A radio **transmitter** 'excites' electric currents in the conductive surface layers of an antenna leading to the propagation of an electromagnetic wave; conversely, an incident radio wave 'excites' similar currents which are conducted to the **receiver**.

There are many different types of antenna, but using one method of categorisation four main types can be identified: wire, horn, reflector and array antennas [see figures A3, A4]. For spacecraft applications, wire antennas operate chiefly at VHF and UHF frequencies, often taking the form of a helix, conical spiral or simple dipole. The other types operate mainly at **microwave**



A2: Inmarsat-2 **communications satellite** in an **anechoic chamber**. Note the cupped dipole array **antenna**s. [British Aerospace]

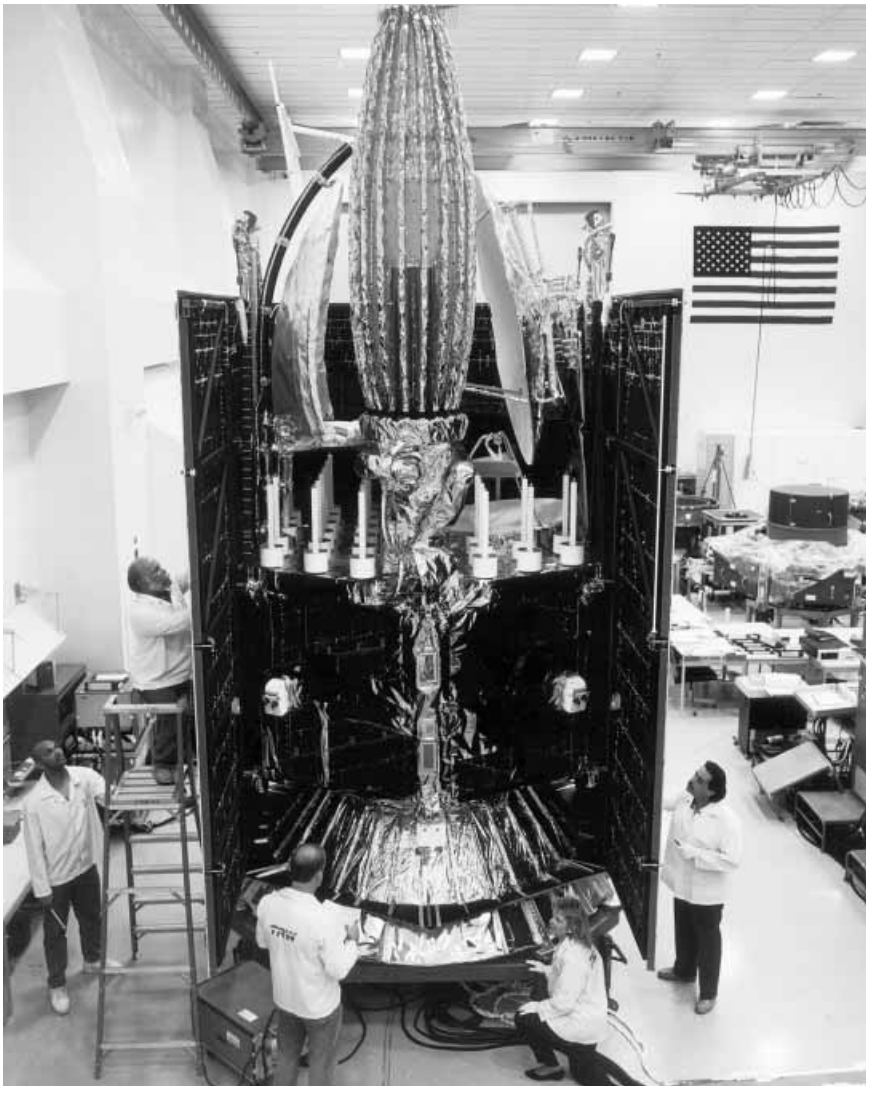
frequencies. Horn antennas are used by themselves on spacecraft to provide wide coverage of the Earth [see **global beam**], and as **feedhorn**s to illuminate reflector antennas. Both horns and reflectors are known as 'aperture antennas'. Another type of aperture antenna is the microwave lens, or 'dielectric lens', which, like an optical lens, can be designed to convert a



A3: **Antenna** types and reflector-antenna configurations: (a) wire antenna (helix); (b) horn antenna (conical corrugated); (c) reflector antenna (offset fed); (d) array antenna (phased array helices); (e) reflector antennas (from left to right): single reflector, **Cassegrain reflector**, **Gregorian reflector**.

spherical wave to a plane wave, thereby improving **directivity** [see **lens antenna**].

The limited **gain** and relatively wide **beamwidth** of horn antennas has led to the widespread use of reflector antennas, particularly on **communications satellites** where high gain and narrow **spot beams** have become increasingly desirable. Array antennas consist of a number of radiating elements designed



A4: TDRS-F tracking and data relay satellite [see **TDRSS**] showing **unfurlable antenna** (in furled position), two **deployable antenna**s and helix array **antenna**. [TRW]

to act together to form a particular **beam**. The array may comprise a number of slots in the wall of a **waveguide** (a 'slot-array antenna'), a number of **dipole**s, helices, horns or reflectors, depending on the frequency, required beamwidth, etc. See **phased array antenna**.

The word 'aerial' is still used in the space industry (mainly by veteran

British engineers), but is gradually being replaced by 'antenna'. Recommended plurals are 'antennas' for radio equipment, 'antennae' for insects.

[See also **frequency bands**, **communications payload**, **boresight**, **footprint**, '**pointing**', **peak**, **axial ratio**, ***f*/*D* ratio**, **Cassegrain reflector**, **subreflector**, **antenna pointing mechanism**, **antenna radiation pattern**, **antenna platform**, **deployable antenna**, **unfurlable antenna**, **steerable antenna**, **elliptical antenna**, **parabolic antenna**, **shaped antenna**, **beam-forming network**, **isotropic antenna**, **omnidirectional antenna**, **TT&C antenna**]

antenna array An assembly of **antenna**s, not necessarily electrically coupled as they are in an **array antenna**.

[See also **antenna farm**, **antenna platform**, **antenna module**]

antenna beam The geometric distribution of **radio frequency** radiation formed by a **spacecraft** communications **antenna**.

antenna efficiency – see **aperture efficiency**

antenna farm A collective term for a number of **antenna**s. When applied to **space segment** hardware, it usually refers to an orbiting **platform** carrying an assembly of communications antennas, although it is sometimes extended to the **antenna platform** of a much smaller **satellite**. When applied to **earth segment** hardware, it refers to a collection of antennas at an **earth station** (sense (ii)).

[See also **antenna module**, **antenna array**]

antenna feed – see **feedhorn**

antenna gain The ratio of the signal power at the **output** of an **antenna** to that received at the **input**, usually measured in decibels (dB). The majority of antennas used in **satellite communications** are parabolic dishes which when used on the input side increase the gain of the signal passed to the **receiver**, and when on the output side increase the gain of the signal transmitted through space. This definition views the antenna as a gain-producing component in a **transmit chain** or **receive chain**; considering the antenna in a more theoretical sense, as an independent entity, the word 'gain' refers to an increase in signal-power over and above that which would be available from an **isotropic antenna**.

Two 'rule-of-thumb' expressions commonly used to calculate antenna gain are given below:

Peak gain: $10 \log_{10} \eta(\pi D/\lambda)^2$

where η is antenna efficiency (%); D is diameter (m); λ is wavelength (m); and

Half-power gain: $10 \log_{10} \eta(27{,}800/\theta{\cdot}\phi)$

where η is antenna efficiency (%); θ and ϕ are the orthogonal **half-power beamwidths** in degrees. Alternative values for the constant may be found in other texts, where a distinction is made between antennas of different types. [See also **equivalent isotropic radiated power (EIRP)**, **power flux density (PFD)**, **directivity**, **decibel (dB)**]

antenna module A self-contained section of a modular spacecraft containing the communications **antenna** subsystem.
[See also **payload module**, **service module**]

antenna platform
(i) The panel of a satellite's body, usually the Earth-pointing face, which supports the fixed **antennas**. Note, however, that antennas can also be mounted on other faces of the spacecraft [see **deployable antenna**].
(ii) Another name for **antenna farm**.
[See also **space platform**, **antenna module**, **antenna array**]

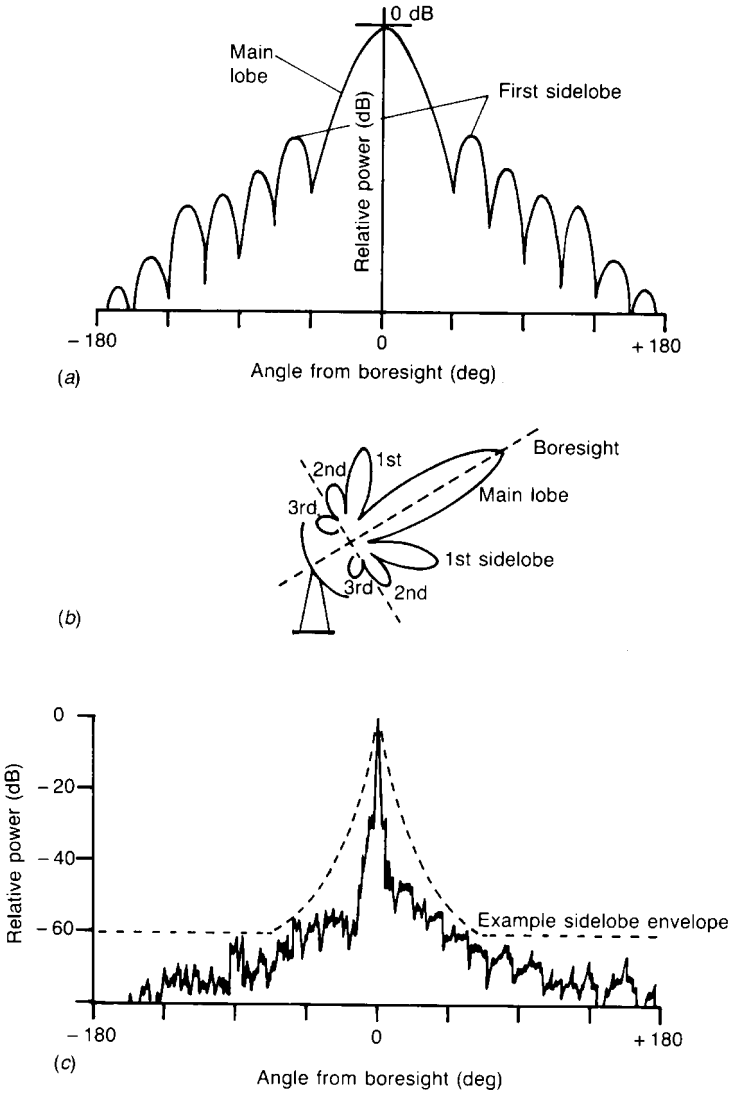
antenna pointing mechanism (APM) A device which gives a spacecraft **antenna** a finer degree of **pointing** control than that offered by the body of the spacecraft itself, particularly important for **spot beam** antennas.
[See also **attitude control**, **phased array antenna**]

antenna radiation pattern A measure of the directional sensitivity of an **antenna**; graphically, a plot of the radiated field-strength against the angle from **boresight** [see figure A5]. The pattern is important since it determines the **beamwidth** and **directivity** of the antenna. According to the reciprocity theorem, the transmitting and receiving patterns of an antenna are identical at a given **wavelength**.

Sensitivity in a direction outside the main **beam** or main 'lobe' of the pattern is known as a 'side lobe'. This represents a detrimental attribute of an antenna, because it indicates that some of the power radiated from the antenna will not be contained within the main beam which, apart from being wasteful, could lead to **interference** with other systems. Equally, a signal received from the side-lobe direction could interfere with the system in question.

antenna taper The variation in electric field produced by a **feed** across an **antenna** surface. For a theoretical uniform illumination, the electric field is constant and the aperture taper efficiency is 1. However, most practical

antenna taper



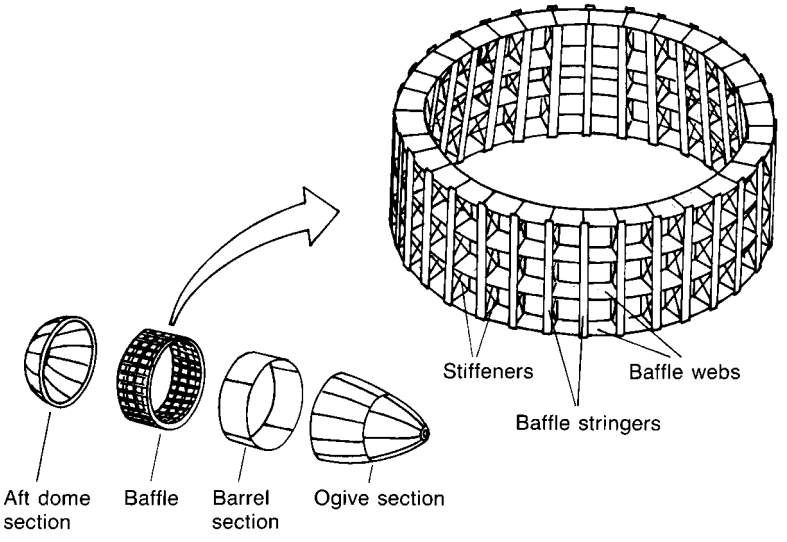
A5: **Antenna radiation patterns**: (a) conventional linear plot (simplified); (b) pattern in polar coordinates; (c) example pattern for a 3 m **earth station**.

antenna feeds produce a highly tapered distribution which decreases the electric field with distance from the centre: this increases the power in the main lobe and increases the beam efficiency of the antenna.
[See also **antenna radiation pattern**]

anti-Earth face The face of a **three-axis stabilised** spacecraft (defined as the minus-*z* face) which faces directly away from the Earth. See **spacecraft axes**.

anti-jam – see **jamming**

anti-slosh baffle A structure in a **liquid propellant** tank which damps out the motion of the liquid known as '**sloshing**', which can disturb a vehicle's flight dynamics [see figure A6]. Various different structures are used (e.g. vanes, rings, truncated cones, etc.). Some tanks also have anti-vortex baffles, which minimise the propellant's tendency to swirl as it flows out of the tank (like water down a plug-hole). Vortices can produce bubbles of gas which would otherwise pass to the **engine**(s) producing uneven combustion.



A6: **Anti-slosh baffle** in a **propellant tank**.

AO An abbreviation for announcement of opportunity (e.g. as in 'AO payload'). In space technology, the term refers mainly to payloads of science or **Earth observation** spacecraft and indicates the existence of an opportunity to propose, manufacture and fly a payload on that spacecraft.

AOCS – see **attitude and orbital control system**

AOS An abbreviation for acquisition of signal. Typically used to denote the moment that a tracking **earth station** acquires a **spacecraft**'s **telemetry** signal during **launch** and **transfer orbit** phases. Also used when a **communications** link with a spacecraft has been re-established after a period

of 'radio silence' (e.g. following blockage by a **planetary body**, a period of radio **interference** or during **re-entry** [see **S-band blackout**]). The opposite of 'loss of signal' (LOS).

[See also **signal**, **carrier**]

AP An abbreviation for **ammonium perchlorate (NH_4ClO_4)**.

aperture antenna A 'horn antenna' or a 'reflector antenna'. See **antenna**.

[See also **synthetic aperture radar (SAR)**]

aperture blockage The reduction in the effective area of an **antenna** reflector by obstructions in the aperture, such as a **feed** or **subreflector** and its supports. Blockage decreases the **aperture efficiency** and degrades the **side lobe** performance owing to diffraction.

aperture efficiency The efficiency of an '**aperture antenna**'; a term used in the calculation of **antenna gain**, etc., which quantifies how effectively the antenna uses the **RF power** transmitted or received.

This can include 'illumination efficiency' or 'aperture taper efficiency' (the efficiency with which the power is distributed over the surface of an antenna reflector by the **feed**); the degree of **spillover**; the degree of **aperture blockage**; diffraction effects; phase errors; and **polarisation** and 'mismatch' losses.

aperture taper – see **antenna taper**

aphelion The furthest point from the Sun in an elliptical solar orbit (from the Greek for 'away from the sun'); the opposite of **perihelion**.

[See also **apoapsis**]

APM – see **antenna pointing mechanism**

apoapsis The point in an **orbit** furthest from the centre of gravitational attraction; the opposite of **periapsis**. From this general term, specific terms relating to a given **planetary body** can be derived: e.g. **apogee** for Earth, **aphelion** for Sun, apolune for Moon, apojove for Jupiter, etc.

apogee The point at which a body orbiting the Earth, in an **elliptical orbit**, is at its greatest distance from the Earth [see figure G1]; the opposite of **perigee**. The word is derived from the Greek 'apogaios': the prefix 'ap' meaning 'away from'; the suffix 'gee' referring to 'Earth'.

[See also **apoapsis**, **orbit**, **apogee kick motor**]

apogee boost motor (ABM) – see **apogee kick motor (AKM)**

apogee engine – see **liquid apogee engine**

apogee engine firing The **ignition** of a **liquid apogee engine (LAE)**, designed to transfer a satellite from a **geostationary transfer orbit (GTO)** to

geostationary orbit (GEO) in several stages [see **parasitic station acquisition**]; the equivalent, for a solid propellant system, of an apogee motor firing.
[See also **propellant**, **rocket motor**]

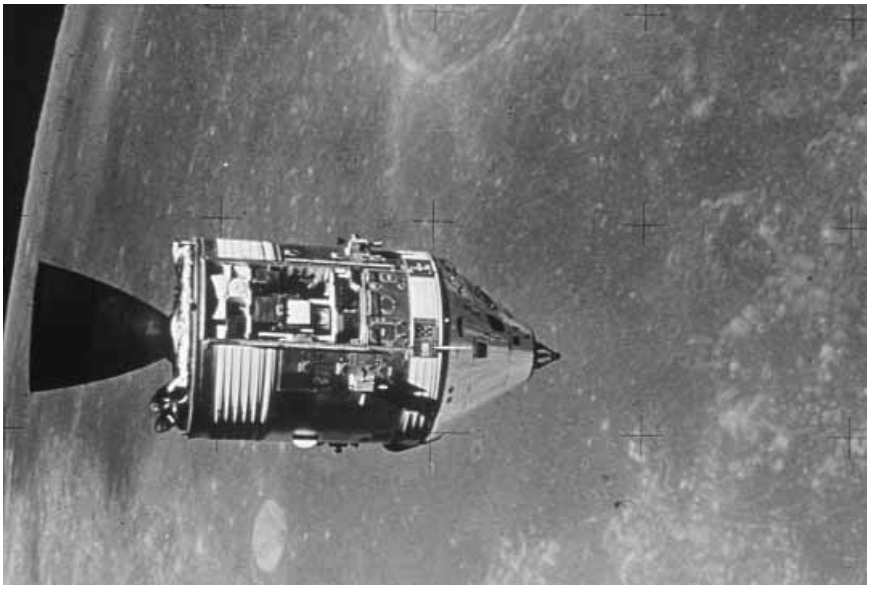
apogee kick motor (AKM) A **rocket motor** used to transfer a satellite from **geostationary transfer orbit (GTO)** to **geostationary orbit (GEO)** [see figure R7]. Alternatively called an apogee boost motor (ABM) and sometimes called an apogee stage.

An AKM is fired when a spacecraft reaches the point in the GTO ellipse furthest from the Earth, the **apogee**. This type of **solid propellant** motor was an integral part of most early geostationary satellites and was usually installed inside a central thrust cylinder or other **thrust structure**. The majority of geostationary satellites now use a liquid bipropellant system which combines the functions of the AKM and the **reaction control system** – see **combined** (**bipropellant**) **propulsion system**. In a **liquid propellant** system, the equivalent device is known as a **liquid apogee engine (LAE)**.
[See also **rocket engine**, **perigee kick motor (PKM)**, **inertial upper stage (IUS)**]

apogee motor firing (AMF) The **ignition** of an **apogee kick motor (AKM)** – a solid propellant **rocket motor** – which occurs at the **apogee** of a **geostationary transfer orbit (GTO)**; the equivalent, for a liquid propellant system, of an apogee engine firing.
[See also **propellant**, **rocket engine**]

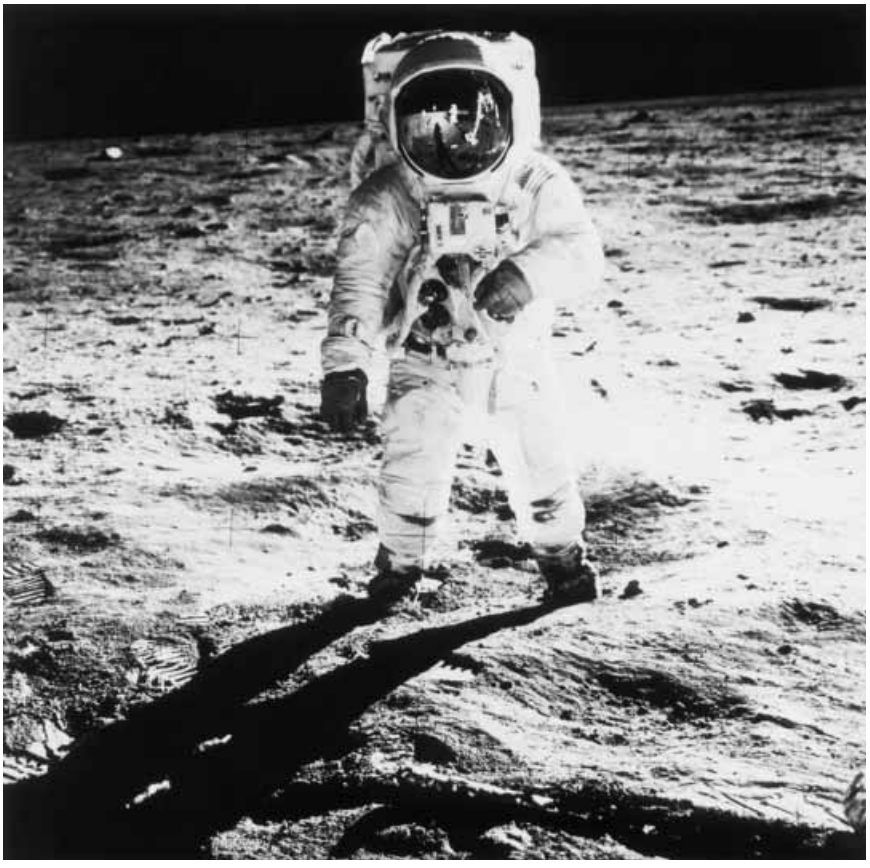
apogee stage A **launch vehicle** stage which injects a spacecraft into **geostationary orbit** by firing its **engine**(s) at the **apogee** of the **transfer orbit**. Sometimes used as an alternative term for **apogee kick motor**.
[See also **stage**]

Apollo A series of American **manned spacecraft** designed to take three **astronaut**s to lunar **orbit** and land two of them on the **Moon**. Apollo comprised two spacecraft: a command and service module (CSM) and a lunar module (LM), formerly called the LEM (for lunar excursion module) [see figures A7, A8]. After the third (S-IVB) **stage** of the **Saturn V** launch vehicle had injected the Apollo combination onto a lunar trajectory [**trans-lunar injection (TLI)**], the CSM separated and withdrew the LM from its launch **fairing** on top of the S-IVB stage. The service module's main engine was used to place the spacecraft in lunar orbit, to return it to Earth and for major **mid-course correction**s. It used the **propellants UDMH** and **nitrogen tetroxide (N_2O_4)** which were also employed by its four sets of RCS [**reaction control**



A7: **Apollo** 15 command and service module in lunar orbit, 30 July 1971. Note the **docking probe** on top of the command module. [NASA]

A8: **Apollo** 15 lunar module and **lunar roving vehicle** at the Hadley Rille landing site, 31 July 1971. **Astronaut** James Irwin salutes the Stars and Stripes. [NASA]



A9: **Astronaut** Edwin 'Buzz' Aldrin photographed by Neil Armstrong, the first man to set foot on the Moon, during the **Apollo** 11 mission, 16–24 July 1969. Note Armstrong and a leg of the Lunar Module 'Eagle' reflected in Aldrin's visor. [NASA]

system] thrusters, used for **rendezvous** and **dock**ing, minor **manoeuvre**s and as **ullage rocket**s.

The command module, the only part of the whole vehicle to return to Earth, was the crew **cabin** for the outward and return journeys as well as the **re-entry** vehicle: it had an ablative **heat shield** made from an epoxy resin bonded to a stainless steel honeycomb. A tunnel in the nose gave access to the lunar module, which comprised a **descent stage** and an **ascent stage**.

Following a number of unmanned launches of Apollo hardware, the first manned mission, Apollo 7, was launched by a **Saturn 1B** to test the CSM in

Earth orbit; Apollo 8, which was launched by a Saturn V without a LM, made ten orbits of the Moon; Apollo 9, which conducted **dock**ing tests in Earth orbit, was the first manned flight with a complete Apollo spacecraft; the Apollo 10 LM descended to within 15,240 m of the lunar surface in a 'dress rehearsal' for the landing; Apollo 11 made the first lunar landing in the Sea of Tranquillity (0° 41′ N, 23° 26′ E) at 8:17 pm GMT 20 July 1969, the first foot being placed on the surface at 2:56 am GMT 21 July (21.8 kg rock returned) [figure A9]. Apollos 12, 14, 15, 16 and 17 also made lunar landings, the latter three carrying a **lunar roving vehicle (LRV)** to extend their coverage of the surface [see figure A8]. Apollo 13 suffered an explosion of an oxygen tank in its service module en route to the Moon and failed to make a landing.

In summary of the Apollo missions, 12 men spent 160 man-hours on the Moon, collected over 2000 rock samples totalling 380 kg, and took over 30,000 photographs; 60 major experiments were placed on the lunar surface [see **ALSEP**] and 30 were carried out from lunar orbit.

[See also **extra-vehicular activity (EVA)**, **space insurance**]

Apollo–Soyuz Test Project (ASTP) A docking mission between an American **Apollo** and a Soviet **Soyuz** spacecraft which developed from a political agreement between President Nixon and Premier Kosygin. The spacecraft docked on 17 July 1975, Apollo 18 carrying three **astronaut**s, and Soyuz 19 carrying two **cosmonaut**s (launched 2 days earlier).

[See also **docking module**]

application The field of research or commerce for which a **satellite** or **spacecraft** is designed. The term is widely used in the space industry to differentiate between spacecraft designed, among others, for **communications**, meteorology, **remote sensing, space science**, **microgravity** research and **manned spacecraft** applications.

[See also **Earth observation**, **Earth resources satellite**, **navigation satellite**, **technology demonstrator**]

applications satellite An archaic term for a **satellite** with a particular application (e.g. **communications**, meteorology, **remote sensing**), as opposed to one carrying a scientific payload.

approach and landing test (ALT) A series of test flights conducted by the Space Shuttle **Enterprise** in 1977 in order to determine the **orbiter**'s aerodynamic characteristics.

APU – see **auxiliary power unit**

arcjet thruster A propulsive device that uses an electric arc to superheat **hydrazine** propellant, approximately doubling its efficiency [see **specific impulse**]; a type of **reaction control thruster**.
[See also **hydrazine thruster**, **hiphet thruster**]

area expansion ratio – see **expansion ratio**

arean Martian; of or pertaining to Mars (from Ares, the Greek counterpart to the Roman god of war, Mars).

areocentric Centred on Mars (e.g. an **areostationary orbit**).

areostationary orbit A **stationary orbit** around Mars.
[See also **geostationary orbit (GEO)**]

Ariane A series of European **launch vehicle**s developed under the auspices of the **European Space Agency (ESA)**. The Ariane programme was proposed by the French space agency after the cancellation of the **Europa** launch vehicle and was given the 'go-ahead' in 1973. The first flight, from the launch site at the **Guiana Space Centre**, was in December 1979. The majority of its payloads are commercial **communications satellite**s placed in **geostationary orbit**, although it can also launch spacecraft into **low Earth orbit** and **sun-synchronous orbit**.

The Ariane family has evolved through several versions, leading to the Ariane 4, which itself is available in six **variant**s with different **payload** capabilities. Ariane 1, 2, 3 and 4 deliver(ed) up to 1850 kg, 2175 kg, 2700 kg and 4460 kg, respectively, to **geostationary transfer orbit (GTO)**, the most common delivery orbit for commercial satellites. Ariane 1 used the propellants **nitrogen tetroxide** and **UDMH** in its first and second stage Viking engines (UDMH being replaced by **UH25** from Ariane 2 onwards), and all variants used **liquid oxygen**/**liquid hydrogen** in the third stage HM7/7B engines. Ariane 1, 2 and 3 used the same first and second stages; 2 and 3 had a 'stretched' third stage; and 3 used two **strap-on** solid rocket boosters to augment the first stage **thrust**. Ariane 4 [see figure G6] has a stretched first stage, but uses the same second and third stages, although strengthened to withstand increased launch **load**s. A number of solid and liquid **propellant** strap-ons can be added to form the six different configurations: no boosters (Ariane 40); 2 solids (42P); 4 solids (44P); 2 liquids (42L); 2 solids and 2 liquids (44LP); and 4 liquids (44L).

In the 1990s, the entirely new Ariane 5 launch vehicle was developed and, following three demonstration launches, entered commercial operation in