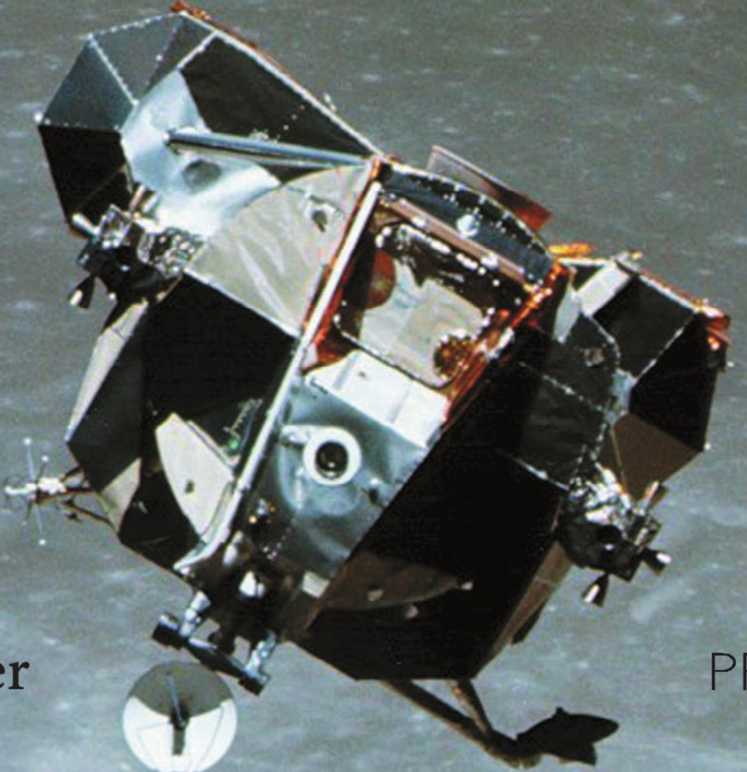
Apollo

The Definitive Sourcebook

Richard W. Orloff and David M. Harland



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Richard W. Orloff
Oakhurst
New Jersey
USA

David M. Harland
Space Historian
Kelvinbridge
Glasgow
UK

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"That the conquest of space is possible
must now be regarded as a matter beyond serious doubt"
Arthur C. Clarke, 1951

"... utter bilge"
Professor Richard van der Riet Woolley, Astronomer Royal,
commenting in 1956 on the prospects of space travel

"Beep, beep, beep ..."
Sputnik, 4 October 1957

"I believe that this nation should commit itself to achieving the goal, before this decade is out,
of landing a man on the Moon"
John F. Kennedy, 25 May 1961

"I think the most significant event that took place in the '50s was the launching of Sputnik"
John F. Kennedy, one week before his assassination in November 1963

"one giant leap for Mankind"
Neil Armstrong, as he stepped onto the lunar surface on 21 July 1969

"... America's challenge of tomorrow"
Gene Cernan as he departed the lunar surface on 14 December 1972

When Sir Arthur C. Clarke was asked in 2002 which event in the
twentieth century he would never have predicted, he replied,
"That we would have gone to the Moon and then stopped"
And, on reflection, he added,
"The space age hasn't begun yet"

This book is dedicated to
the 400,000 workers across America
who made Apollo a reality

A field geologist a long way from home.

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Authors' preface

The word 'epic' is woefully inadequate to describe the Apollo program of the 1960s and early 1970s, during which time the United States of America landed a total of 12 men on the Moon.* Although politically initiated as a 'space race' in the context of the Cold War with the Soviet Union, the program became a great feat of exploration. Innumerable texts have been produced, describing the program from many points of view, but few provide comparative statistical data.

The aim of this book is to provide a comprehensive reference for *facts* about Apollo. As numerous NASA centers and contractors created post-mission reports, there are often differences in certain reported measurements. Additionally, as time passed, typographical errors crept into some Apollo-related publications. To resolve such conflicts, we turned to original documents, some of which were previously unavailable to the public, but have now been made available through the US Freedom of Information Act. In addition to an introduction to the program and individual mission narratives that include comprehensive timelines from just prior to liftoff to just after the recovery of the crew and spacecraft, we have included a series of statistical tables in which much of this data is listed in a form designed to enable missions to be compared. Prelaunch and countdown events are given in local US Eastern time, in which missions were launched, but mission events are in either Greenwich Mean Time (GMT) or Ground Elapsed Time (GET), the latter measured from 'Range Zero', which is defined as the last integral second before liftoff. The 'T–' and 'T+' style is used for events during countdown and ascent to orbit, and the time is in seconds. In general, however, our notation uses colon separators, and in order to avoid confusion with 24-hour GMT the format for GET is hhh:mm:ss.sss (i.e. with three digits in the hour, with preceding zeroes early on). To remain within our assigned number of pages, we have focused on the origins and operational aspects of the program, at the expense of its vehicles and facilities. Having documented Apollo, we look forward to a renewal of human lunar exploration in a decade or so.

Richard W. Orloff and David M. Harland
December 2005

* Throughout the Apollo era all US astronauts were male, and the terminology (which we unashamedly retain) reflected this.

Acknowledgments

The information contained in our mission logs was derived primarily from uncopyrighted NASA and contractor reports (see the Bibliography) and, in some cases, is used verbatim without attribution. In addition, we must acknowledge the following copyrighted works:

- The source for some of the astronaut biographical data is the excellent *Who's Who In Space: The International Space Year Edition*, by Michael Cassutt, although most information was derived from NASA biographies.
- The primary source for descriptions of the mission insignias is the official NASA text that accompanied each emblem, but additional information was obtained from *Space Patches from Mercury to the Space Shuttle*, by Judith Kaplan and Robert Muniz, 1986, and *"All we did was fly to the Moon": Astronaut Insignias and Callsigns* by Richard L. Lattimer, 1985.
- The COSPAR designations for spacecraft and launch vehicle stages assigned once in space are from *R.A.E. Table of Earth Satellites 1957–1986*, a compilation of installments originally issued by the Royal Aircraft Establishment in England.
- Artwork of the planned lunar traverses is courtesy NASA.
- The Apollo lunar surface traverse maps are courtesy the US Geological Survey.
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Introduction

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

On 4 October 1957, to mark the International Geophysical Year, which ran from mid-1957 to the end of 1958, the Soviet Union launched the world's first artificial satellite, naming it 'Sputnik' for 'fellow traveler'. The United States, which had expected this technological milestone to be achieved by its own Vanguard project, was shocked. Worse was to come. The attempt to launch Vanguard on 6 December from Cape Canaveral on Florida's Atlantic coast was a disaster. The vehicle rose several feet, lost thrust, fell back and exploded. In an effort to recover from this humiliation, Wernher von Braun of the Army Ballistic Missile Agency (ABMA) at the Redstone Arsenal in Huntsville, Alabama, drew from storage a Redstone missile fitted with 14 solid rockets – 11 in the outer ring serving as the second stage and three in the center serving as the third stage. This variant, known as the Jupiter-C, had been developed to accelerate a payload into the atmosphere from the top of a ballistic arc in order to test a thermal shield for the warhead of the Jupiter missile. With a fourth stage formed from yet another solid rocket, the Jupiter-C was capable of putting a payload into orbit. This was done on 31 January 1958. The satellite, named Explorer, was supplied by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology in Pasadena, which had developed the Sergeant rockets that formed the upper stages.[1] The payload, supplied by James van Allen of the University of Iowa, was integrated into the final stage and the whole thing went into orbit. In detecting the presence of energetic charged particles trapped in Earth's magnetic field, this instrument made the first significant discovery of the Space Age.

[1] In 1938 Caltech's Daniel Guggenheim Aeronautical Laboratory was contracted by the Army Air Corps to develop 'jet-assisted take-off' rockets for heavy bombers. In 1942 laboratory leader Theodore von Kármán set up the Aerojet Engineering Corporation to manufacture such 'JATO' rockets. By 1943, when the program was expanded to include the development of ballistic missiles, the name 'Jet Propulsion Laboratory' had been adopted even though, strictly speaking, it was not involved in research into jet engines. In quick succession, it created a series of solid-fuel missiles named Private, Corporal and Sergeant.

Although national honor had been restored, the Department of Defense was deeply concerned that the Soviet rocket was so much more powerful than its own. On 7 February President Dwight David 'Ike' Eisenhower created the Advanced Research Projects Agency (ARPA) to develop national goals and coordinate (although not conduct) the necessary research. On 1 April Roy W. Johnson was appointed director, reporting directly to the Secretary of Defense. On the recommendation of James Rhyne Killian, Eisenhower's special assistant for science and technology, an executive order on 2 April established the National Aeronautics and Space Administration (NASA) to manage a national civilian space program. Eisenhower also set up the National Aeronautics and Space Board to advise on policy. In June the National Academy of Sciences – which had been established in 1863 as a private institution to promote the advancement of science and, on being requested, advise the government on scientific matters – created a Space Science Board to advise on the scientific exploration of space. The National Aeronautics and Space Act was passed by Congress on 16 July and was signed into law on 29 July. Simultaneously, the National Advisory Committee for Aeronautics (NACA), created in 1915 to undertake basic research in aerodynamics, was wound up and its facilities transferred over to its successor: the Langley Aeronautical Laboratory at Langley Field, which was established in Hampton, Virginia, in 1917, together with its Pilotless Aircraft Research Station at Wallops Island; the Ames Aeronautical Laboratory at Moffett Field, which was established in 1939 in Mountain View, California; the Lewis Flight Propulsion Laboratory, which was established in 1941 in Cleveland, Ohio; and the High-Speed Flight Station, which was established in 1949 at Muroc Field in California, which was renamed Edwards Air Force Base in 1950.[2] Langley was pursuing aerodynamic studies related to manned spaceflight, Lewis was developing a rocket engine that burned hydrogen as its fuel, and Edwards was developing the X-15 rocket-powered aircraft capable of flying on a ballistic arc up to the 'fringe' of space. Although NASA's remit was significantly broader than that of its predecessor, it did *not* immediately gain control of either the rocketry expertise at ABMA or of JPL.[3] On 8 August Thomas Keith Glennan, president of the Case Institute of Technology in Cleveland, Ohio, was nominated as administrator, and Hugh Latimer Dryden, who for the past decade had been NACA director, was retained as Glennan's deputy, and their appointments were confirmed within days.

A MANNED SATELLITE

Six weeks after Explorer was launched, Maxime A. Faget at Langley started to write the aerodynamic specifications for a recoverable satellite. Contrary to the prevailing belief that a spacecraft would be a derivative of the ever-higher ever-faster trend in aircraft, he

[2] On their transfer to NASA, Langley became the Langley Research Center and Ames became the Ames Research Center.

[3] On 3 December 1958 Eisenhower ordered that JPL be transferred to NASA, and in September 1959 the Department of Defense voluntarily yielded ABMA.

decided to design a 'capsule' that would be launched vertically on a rocket. In space, its orientation (its 'attitude') would be controlled by thrusters firing cold gas. On leaving orbit, it would make a ballistic re-entry and land by parachute. The main prerequisites were a rocket with sufficient thrust to achieve orbital speed, and a thermal shield to protect the capsule during re-entry. Although powerful rockets were already under development, the thermal problem posed a technological challenge. Faget decided on a conical capsule that would enter the atmosphere 'blunt end forward'. The blunt shape would compress the air and generate a shock wave that would prevent most of the heat from impinging on the capsule, and the base would be protected by an ablative shield that would flake off into the slipstream to prevent heat from penetrating the capsule. As the capsule would create no aerodynamic lift, it would follow a ballistic trajectory. This outline was presented to an aerodynamics conference at Ames on 18 March in a paper entitled *Preliminary studies of manned satellites – wingless configuration, non-lifting*.

In September 1958 Glennan and Johnson (of ARPA) agreed to cooperate in the development of a "manned satellite". On 7 October Robert Rowe Gilruth formed an informal group at Langley to explore how to achieve "at the earliest practicable date, orbital flight and successful recovery, of a manned satellite". Left unsaid but understood, was that this must be achieved ahead of any Soviet effort to send a man into space. On 5 November this working party was formalized as the Space Task Group. NASA promptly invited concept proposals from industry for a spacecraft, and set out to recruit 'astronauts' to fly it. On 17 December Glennan announced that the project had been named 'Mercury'. Eleven companies submitted bids, and on 12 January 1959 the contract was awarded to the McDonnell Aircraft Company in St Louis, Missouri.

On 9 April 1959 Glennan announced to a packed press conference the names of the seven military test pilots who had been selected to be astronauts. They were Lieutenant Commander Alan Bartlett Shepard Jr, Lieutenant Malcolm Scott Carpenter and Lieutenant Commander Walter Marty Schirra Jr from the Navy; Lieutenant Colonel John Herschel Glenn Jr from the Marines; and Captain Virgil Ivan 'Gus' Grissom, Captain Donald Kent 'Deke' Slayton and Captain Leroy Gordon Cooper Jr from the Air Force.

THE SATURN LAUNCH VEHICLE

Following World War II, North American Aviation re-engineered the engine of the German V-2 missile, and ABMA incorporated it into the Redstone medium-range missile. When the company developed a more powerful engine, ABMA used it to substantially upgrade the Redstone to create the Jupiter intermediate-range missile. In 1955 North American Aviation created its Rocketdyne division in the West San Fernando Valley in California to design and manufacture engines. For the Atlas intercontinental-range missile for the Air Force, it devised a power plant with three engines that delivered a total of between 360,000 and 380,000 pounds of thrust. In parallel, the company assessed the feasibility of developing a single engine that would produce 1 million pounds of thrust. In April 1957 ABMA initiated a design study for an advanced rocket (dubbed the Super Jupiter) that would be powered by a cluster of E-1 engines, then being considered by