European Commission

Mission-oriented R&I policies: In-depth case studies

Case Study Report

Apollo Project (US)

Eva Arrilucea

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Research and Innovation

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tecnalia Inspiring Business

2018 Directorate-General for Research and Innovation

Table of Contents

1 Summary of the case study

This document analyses the case study of mission-oriented R&I policy initiatives in the field of aerospace in U.S. The following table describes the main components of the case study:

	Apollo Program
Title:	Apollo Program
Country:	US
Thematic area:	Aerospace
Objective(s):	To land an American on the Moon and return safely to Earth.
Main Governing Body	National Aeronautics and Space Administration NASA
Timeline:	1961-1972
Budget:	USD 25.4 billion *(USD 163 billion inflation adjusted to 2008)*
Brief description of the case (250 words)	Apollo was a programme in the 1960s designed to land an American on the Moon and return safely to Earth. The Apollo Program was successfully accomplished on July 1969 when Apollo 11 Mission set foot on the surface of the Moon. Neil A. Armstrong and Edwin E. Aldrin-landed on the lunar surface while Michael Collins orbited overhead in the Apollo command module
Implementation and organisation	National Aeronautics and Space Administration NASA was the agency in charge of the Apollo Project.
Observed / expected outputs, outcomes, and impacts	• The Apollo Program consisted of 33 flights, 11 of which were manned. The 22 unmanned flights were conducted to qualify the launch vehicle and spacecraft for manned space flight. Four of the manned flights were conducted to man-rate the overall vehicle for lunar exploration. The final seven flights were conducted to explore the lunar environment and surface. • No major launch vehicle failure occurred to prevent a mission from being accomplished and only one inflight failure of a space craft (Apollo 13) prevented the intended mission from being accomplished. • These was a large amount of data and material collected as the result of the lunar missions. During each mission, the crew emplaced and activated a lunar geophysical observatory to be controlled and monitored from Earth, collected samples of lunar soil and rock, photographically documented the geologic features of the landing area and performed other exploration activities. • In 1961 two techniques, direct ascent and earth-orbit rendezvous were being considering for achieving a manned lunar landing. A third technique, lunar orbit rendezvous, was later determined to be more feasible and was adopted in July 1961. To make this decision, a preliminary programme for manned lunar landings was formulated.
	• Apollo project (mission 8) allowed the world to view the Earth for the first time in the history of mankind. • The operational and scientific success of the missions stimulated a vigorous interest in the solar system and established the study of the Moon as a modern interdisciplinary science. • There was an impressive range of results from the scientific experiments related to lunar orbital science and lunar orbital science. For example, mechanical devices and scientific instruments were developed so that certain instruments could be moved away from X-ray secondary radiation and the contamination cloud that surrounded the spacecraft, so that the desired photographic angles could be obtained. • The mission reports for 11 manned missions showed a continual improvement in fight crew performance. The increased complexity in the objectives of each mission was possible because new operational experience was used where appropriate to standardise and revise crew operations as each mission was flown, especially in the areas of pre-flight training, flight procedures and equipment operation. • Apollo 8's images of the Earth made people aware of the planet's fragility and helped to spur the green movement in the world.
	• The project established the technological pre-eminence of the US over other nations in space sector, so it accomplished the political goals for which it was created.

	• One of the main key success factors of the project was the management model, that was able to integrate complex technological and organisational dimensions. • About 30 000 photographs of the lunar surface were obtained from lunar orbit on the Apollo missions. The purpose was to obtain high-quality colour, panchromatic and multispectral photographs of selected land and ocean areas of the Earth and of clouds and other weather phenomena. • Some biomedical experiments were conducting during the Apollo series of space flights. Studies investigated the effects of space flight, including ambient radiation on one or more species of living organisms. • Inflight demonstrations were small carry-on experiments operated by several crews during translunar or trans-earth coast. The purpose was to demonstrate the effects of near-zero gravity on various phenomena and processes. • 382 kg of lunar rocks and soil were returned during the Project, contributing to the understanding of the Moon's composition and geological history. • Apollo spurred advances in medicine, food, geology, manned spaceflight, avionics, telecommunications, computing, maths, astronomy, physics, bioscience and other several areas of technological and scientific interest. • Apollo set the foundations for other projects such as Skylab, Apollo-Soyuz, Space Shuttle and International Space Station • Even today, Mission Control operates on the principles founded in the Apollo era. • 409 000 labourers were employed by the Project either directly by NASA or contracted workers. • Apollo led to over 1800 spinoff products as of 2015. Physical products that would not have been possible, a variety of breakthroughs from early breast cancer detection to the accelerated development of integrated circuits were birthed by the Apollo programme.

Main elements of mission-oriented R&I initiative[1]	
Directionality (links to societal challenges, industry transformation):	**Yes.** The Apollo Project gave a big boost to American industry technological level, and not only in the aerospace sector.
Intentionality (specific, well-articulated targets):	**Yes.** Apollo Project has a perfectly defined structure with objectives, sub-projects, goals, schedules, timelines and budgets. The Project also had an innovative management process to control the milestones with clear functions and responsibilities.
Clearly set timeline and milestones:	
Mobilises public and private investments:	**No.** Apollo Project was mainly a publicly-funded project.
Focused on new knowledge creation (basic research, TRLs 1-4):	**Yes.** The project had both components: knowledge creation and knowledge application. There were various communities within NASA that differed over priorities and competed for resources. The two most identifiable groups were engineers and the scientists. Engineers usually worked in teams to build hardware that could carry the mission to success. Their primary goal involved building vehicles that would function reliably within the fiscal resources allocated to the project. On the other hand, space scientists engaged in pure research were more concerned with designing experiments that would expand scientific knowledge.
Focused on knowledge application (applied research, TRLs 5-9):	
Demand articulation (involves instruments for inducing demand):	**Yes.** Apollo Project developed a huge programme of public procurement with national industry.
Multi-disciplinary (inter-disciplinary and/or trans-disciplinary)	**Yes.** Aerospace, but also food, medicine, computation, materials, biology, microbiology, geology, electronics, and communications were some of the areas involved in the Apollo Project,
Joint coordination (multi-level and/or horizontal governance of	**Yes.** The Project developed an ad-hoc management system to coordinate all the areas**,** inside NASA and also with other stakeholders such as universities and contractors.

[1] Assessment: Yes, To certain degree, No or Not known).

policies/finance):	
Reflexivity (flexible policy design, timely monitoring):	**Yes.** Planning and management system had a high degree of flexibility to adapt the milestones to the real situation. The continuous evaluation process allowed the adaptation of the Project to the main targets
Openness (connected to international agenda and networks):	**No.** Apollo project was defined, designed and implemented by the US federal agency NASA. There were contacts with other nations to attract talent and other issues, but openness was not one of the main characteristics of the Project.
Involvement of citizens:	**No.** Even the Project is often considered as a “national pride”, citizens were not involved at all in the decision, design and implementation of the initiative, and the relationship between the Project and citizens was unidirectional, with merely informative purposes.

2 Context and objectives of the initiative

This Chapter contains the description of the Apollo Program as well as its strategic and operative objectives and milestones.

2.1 Contextual factors and origins of the initiative[2]

Apollo was a programme in the 1960s designed to land an American on the Moon and return safely to Earth. It was announced by President John F. Kennedy on May 1961 in a speech on Urgent National Needs billed as a second State of the Union message. He said: "*I believe this Nation should commitment itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish*".[3]

In addition to the Apollo Program, NASA inserted additional programmes to strengthen the scientific and technological return on the investment to go to the Moon. NASA proposed and accelerated and integrated national space effort incorporating both scientific and commercial components.[4]

The Apollo Program was successfully accomplished on July 1969 when Apollo 11 Mission set foot on the surface of the Moon. Neil A. Armstrong and Edwin E. Aldrin-landed on the lunar surface while Michael Collins orbited overhead in the Apollo command module. After checkout, Armstrong set foot on the surface, telling that it was "*one small step for a man, one giant leap for mankind*".[5]

There have been several Apollo Missions with different purposes:[6]

- Apollo 7, 1968, with confident building purposes and CSM manned flight demonstration;
- Apollo 8, 1968, when the first human being was in the Earth orbit with the purpose of CSM manned flight demonstration;
- Apollo 9, 1969, lunar module manned flight demonstration;
- ;Apollo 10, 1969, lunar module manned flight demonstration,
- Apollo 11, 1969, the first mission with safe return of a human being with manned lunar landing demonstration;
- Apollo 12, 1969, an exercise of precision targeting, precision manned lunar landing demonstration and systematic lunar exploration;
- Apollo 13, 1970, suffered a mayor crisis and succeeded in bringing the crew back safely. The purpose was precision manned lunar landing demonstration and systematic lunar exploration;

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[2] Launius R (2004). "Apollo. A retrospective Analysis". Monographs in Aerospace History Number 3. NASA SP-2004-4503. NASA History Office. Office of External Relations. NASA Headquarters.

[3] Kennedy J.F (1961). "Urgent National Needs". Congressional Record House (25 May 1961). p. 8276; text of speech, speech files, NASA Historical Reference Collection, NASA History Office, Washington DC

[4] Launius R (2004). Op.Cit.

[5] Idem.

[6] Orloff R (2000). "Apollo by the numbers. A Statistical Reference". NASA History Division. Office of Policy and Plans. NASA Headquarters, Washington D.C. NASA SP-2000-4029.

- Apollo 14, 1971, with the purpose of precision manned lunar landing demonstration and systematic lunar exploration;

- Apollo 15, 1971, the first of the longer lunar landing missions with the purpose of extensive scientific investigation of Moon on lunar surface and from lunar orbit;

- Apollo 16, 1972, in which astronauts returned with the largest single rock with 11.34 kilograms; and

- Apollo 17, 1972, with the purpose of extensive scientific investigation of Moon on the lunar surface and from lunar orbit and that ended the Apollo lunar program.[7]

The following table summarises main external drivers and barriers for facing and managing the Apollo Program:

	Drivers	Barriers
Political	• The public commitment with the Space Race was oriented and fostered to maintain the balance of power and spheres of influence in American/ Soviet relations, and gain "national prestige". In a press conference in 21 April 1961 the President said: "*If we can get to the Moon before the Russians, then we should*". • The debacle of Bay of Pigs[8] in April 1961 eroded the US' credibility and the Space Race was considered as a measure of Kennedy's to restore national dignity. • Before launching the Program, considerable political support was secured, and the support of relevant business men and representatives from the aerospace industry and other government agencies was also guaranteed.[9]	
Technological	• In the 60s, the US had not demonstrated technical equality with the Soviet Union (the first man in Space had been the Soviet Yuri Gagarin in 1961) and these apparent disparities in technical competence had to be addressed to re-establish the nation's credibility.	

[7] To know more technical details about the different missions, please consult "Apollo Missions" on the NASA website: https://www.nasa.gov/mission_pages/apollo/missions/index.html

8 The Bay of Pigs invasion begins in 1961 when a CIA-financed and -trained group of Cuban refugees lands in Cuba and attempts to topple the communist government of Fidel Castro: https://history.state.gov/milestones/1961-1968/bay-of-pigs

[9] Divine R (1987). "Lyndon B. Johnson and the Politics of Space" in "The Johnson Years: Vietnam, the Environment and Science". University Press of Kansas, pp.231.33

	• The programme emphasised the importance of non-military applications of space technology (communications, mapping, weather satellites), and national security applications (reconnaissance satellites and ICBM-Intercontinental Ballistic Missile). • NASA provided a space policy planning[10] to ensure that science and technology development were going to be the main objective of the programme. This document had the lunar landing as its centrepiece but attached several items to enhance the programme's scientific value (spacecraft and boosters for the human flight to the Moon, scientific satellite probes, nuclear rocket, satellites for global communications, satellites for weather observation and scientific projects for Apollo landings). • Previous projects such as Mercury[11] and Gemini[12] set the foundations for Apollo Program.	

2.2 Strategic and operative objectives and milestones of the initiative

Project Apollo's goals went beyond landing Americans on the moon and returning them safely to Earth. They included:

- Establishing the technology to meet other national interests in space;
- Achieving pre-eminence in space for the United States;
- Carrying out a programme of scientific exploration of the Moon;
- Developing man's capability to work in the lunar environment.

Six of the missions (Apollos 11, 12, 14, 15, 16, and 17) achieved this goal. Apollos 7 and 9 were Earth orbiting missions to test the Command and Lunar Modules, and did not return lunar data. Apollos 8 and 10 tested various components while orbiting the Moon, and returned photography of the lunar surface. Apollo 13 did not land on the Moon due to a malfunction, but also returned photographs. The six missions that landed on the Moon returned a wealth of scientific data and almost 400 kilograms of lunar samples. Experiments included soil mechanics, meteoroids, seismic, heat flow, lunar ranging, magnetic fields and solar wind experiments.

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[10] James E. Webb and Robert S. McNamara to John F. Kennedy, May 8,1961, John F. Kennedy Library.

[11] Initiated in 1958 and completed in 1963, Project Mercury was the United States' first man-in-space program. https://www.nasa.gov/mission_pages/mercury/missions/program-toc.html

[12] Gemini was an early NASA human spaceflight program. The Gemini missions were flown in 1965 and 1966. They flew between the Mercury and Apollo programs: https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-was-gemini-program-58.html

3 Resources and management

Next section contains the Apollo Program governance model as well as the financial model and the key actors, key technologies and main platforms involved in the initiative.

3.1 Governance and management model

National Aeronautics and Space Administration NASA was the agency in charge of the Apollo Project. The organisational chart can be seen in Figures 1 and 2:

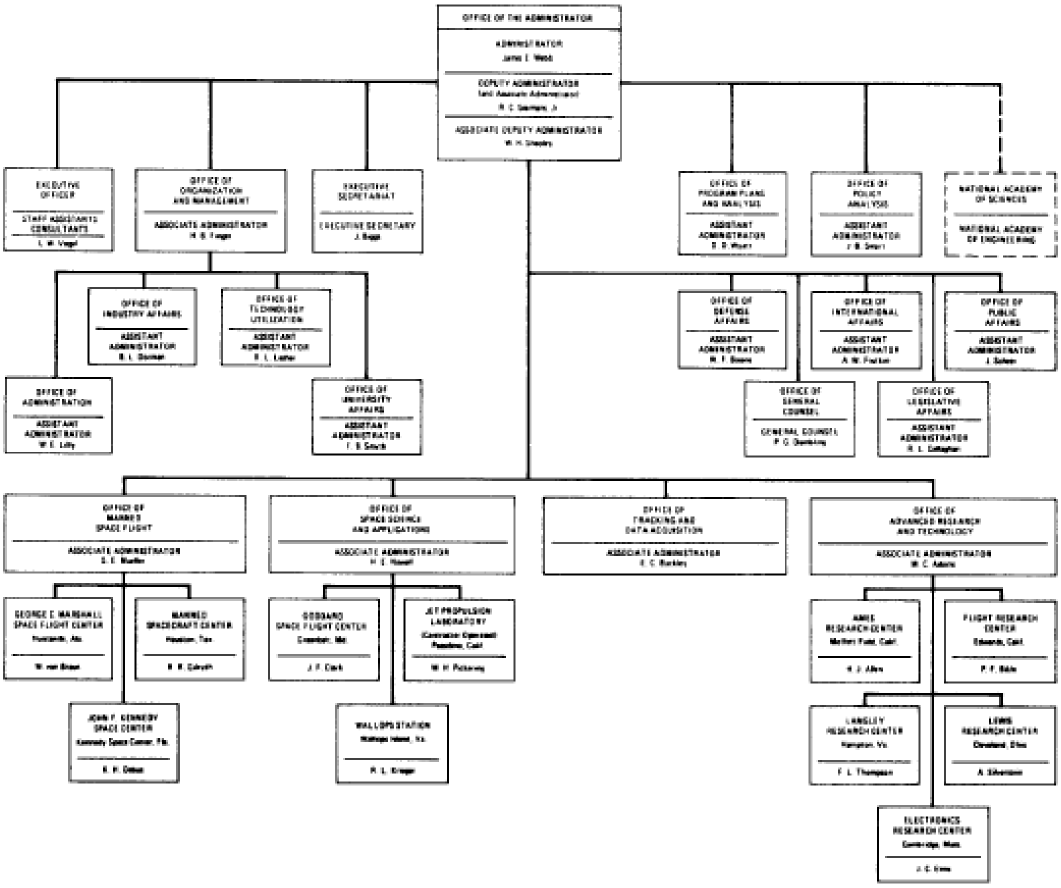

Figure 1: NASA Organizational Chart (February 1973). Source. The Apollo Spacecraft. A chronology (1974)[13]

[13] Ertel I, Newkirk R, Brooks C (1974). "The Apollo Spacecraft". Vol 4. Scientific and Technological Information Office. NASA, Washington D.C.

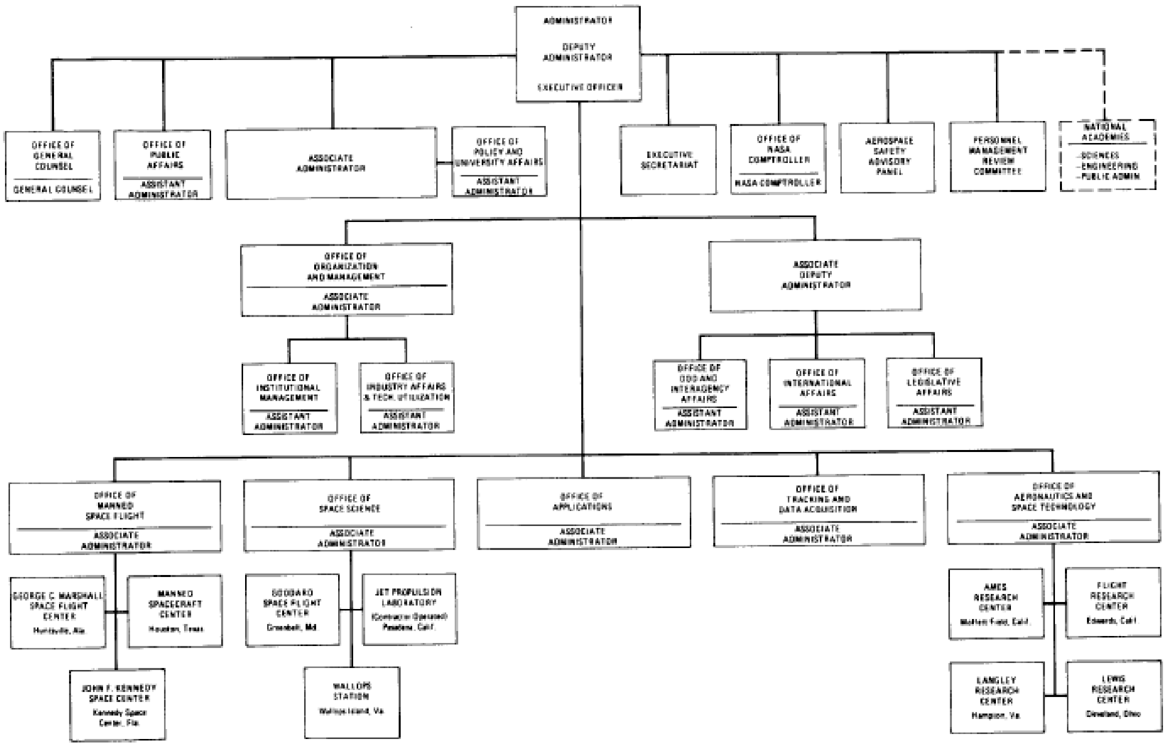

Figure 2: NASA Organizational Chart (February 1973). Source. The Apollo Spacecraft. A chronology (1974)[14]

Each stakeholder involved in the project had differing perspectives on how to go about the task of accomplishing Apollo. To manage all of them, NASA expanded the "program management" concept borrowed by T. Keith Glennan in the late 1950s from the military/ industrial complex, bringing in military managers to oversee Apollo.[15] Thus, a programme office was created with centralised authority over design, engineering, procurement, testing, construction, manufacturing, spare parts, logistic, training and operations (see Figure 3).

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[14] Ertel I, Newkirk R, Brooks C (1974).Op.Cit.

[15] McCurdy H (1993). "Inside NASA: High Technology and Organizational Change in the U.S. Space Program". Baltimore, MD: Johns Hopkins University Press, 1993.

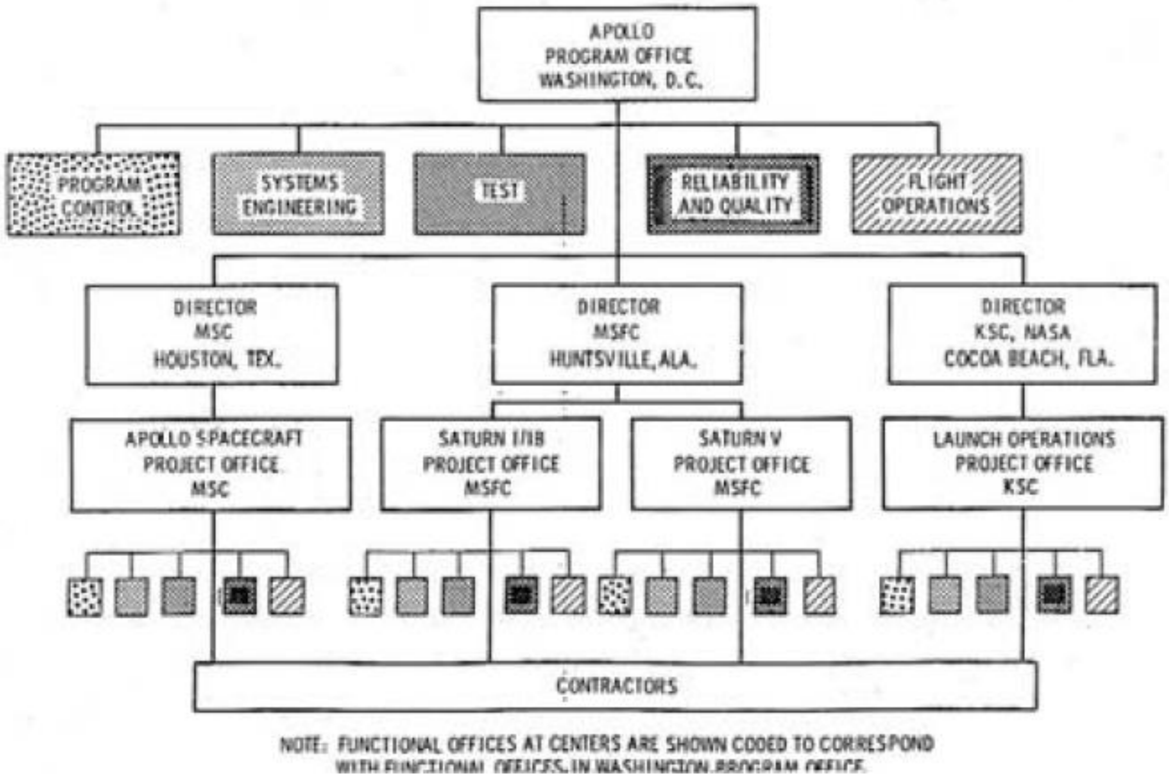

Figure 3: Management Organization for the Apollo Program. (1964). Source: Glennan (1961).[16]

George E. Mueller headed the Office of Manned Space Flight from 1963 to 1969. The main characteristic of the programme management was that the critical factors (cost, schedule and reliability) were interrelated and had to be managed as a group. To do this, Mueller reorganised the Apollo Program Office, creating a five-box structure and a Headquarters and field centre (see Figure 4).

[16] Glennan T (1961) "Authorized Development Projects," 19 January 1961 memorandum, Robert Channing Seamans, Jr., papers, MC 247, Institute Archives and Special Collections, MIT Libraries, Cambridge, MA.

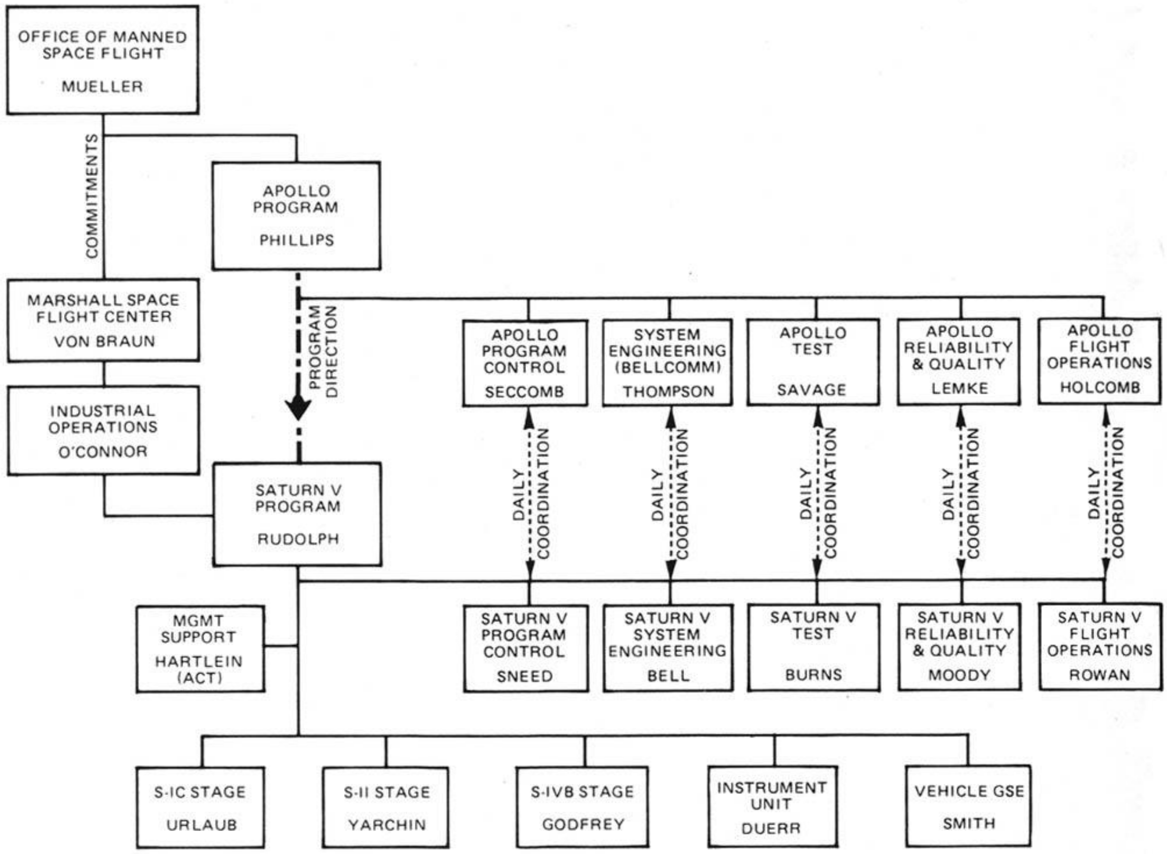

Figure 4: Apollo Program Office (1965). Source NASA.gov.

The five functions, programme control, systems engineering, testing, reliability and quality, and flight operations, permitted NASA to have centralised management at Headquarters for overall control of the Apollo Program. The key part of the idea was that inside these boxes, managers and engineers communicated directly with their functional counterparts in NASA Headquarters, bypassing all of the chain of command and bureaucracy.

This structure replicated Mueller's concept of system management and provided far better programme overview. The three major Centers in Houston, Huntsville and at the Cape reported directly to him. The project directors were in the Centers and each programme director had five staff officers, as did the project directors. These were responsible for programme control, systems engineering, test, reliability and quality and flight operations.[17]

The management of Apollo was clearly disciplined and distributed. There was no large central authority issuing detailed instructions, but interface documents that were continually updated to correspond with developments at the Centers. Final development cannot take place without the interfaces, and interfaces require knowledge of the developed hardware. Progress can only take place in an iterative fashion with strong Center participation.

To manage the Project, several committees were organised. Some of them were:

[17] Seamans R (2007). "Project Apollo. The Tough Decisions". Monographs in Aerospace History number 37. NASA. Office of External Relations. History Division. Washington, DC.

- Special Committee on Space Technology (1958), with working groups on Space Research Objectives, Vehicular Program, Re-entry, Range, Launch and Tracking Facilities, Instrumentation, Space Surveillance, Human Factors and Training;
- Working group on Lunar Exploration (1959);
- DOD-NASA Saturn Ad Hoc Committee (1959);
- Research Steering Committee on Manned Space Flight (1959);
- Booster Evaluation Committee (1959);
- New Projects Panel of the Space Task Group (1959);
- Saturn Vehicle Team – Silverstein Committee (1959);
- Space Exploration Program Council (1960);
- Advanced Vehicle Team (1960);
- Apollo Technical Liaison Groups (1960) with following groups: Configurations and Aerodynamics, Guidance and Control, Group on Heating, Human Factors, Instrumentation and Communications, Mechanical Systems, Onboard Propulsion, Structures and Materials and Trajectory Analysis;
- Manned Lunar Landing Task Group (1961);
- Ad Hoc Committee on Space – Wiesner Committee (1961);
- Ad Hoc Task Group for a Manned Lunar Landing Study – Fleming Committee (1961) with groups on spacecraft, launch vehicles, facilities, life sciences, advanced technology, and space sciences;
- Lundin Committee (1961);
- Ad Hoc Task Group for Study of Manned Lunar Landing by Rendezvous techniques-Heaton Committee (1961) with sub-groups on launch vehicle performance and logistics, guidance and control, orbital launch operations and advanced technology;
- Manned Lunar Landing Coordination Group (1961);
- DOD-NASA Large Launch Vehicle Planning Group (1961);
- Source evaluation board for evaluation of contractor's proposals for the Apollo spacecraft (1961) with subpanels of systems integration, propulsion, flight mechanics, structures, materials and heating, human factors, instrumentation and communications, onboard systems, ground operational support systems and operations, technical development plan, reliability, and manufacturing;
- Business subcommittee (1961) with following panels: organisation and management, logistics, subcontract administration and cost;
- Apollo Saturn Coordination panels (1961) with groups on electrical system integration panel, instrumentation and communication, mechanical integration, flight mechanics, dynamics, guidance and control panel, launch operations panel, mission control operations panel and crew safety panel;
- MSFC-MSC Advanced Program Coordination Board (1961);
- Rosen Working Group (1961);

- Manned space Flight Management Council (1961).

At an operational level, the whole project was divided in phases and milestones, with schedules in several levels to determine the final outcome. The charts showed in detail the sequencing of the many work packages that had to be completed (see Figure 5):

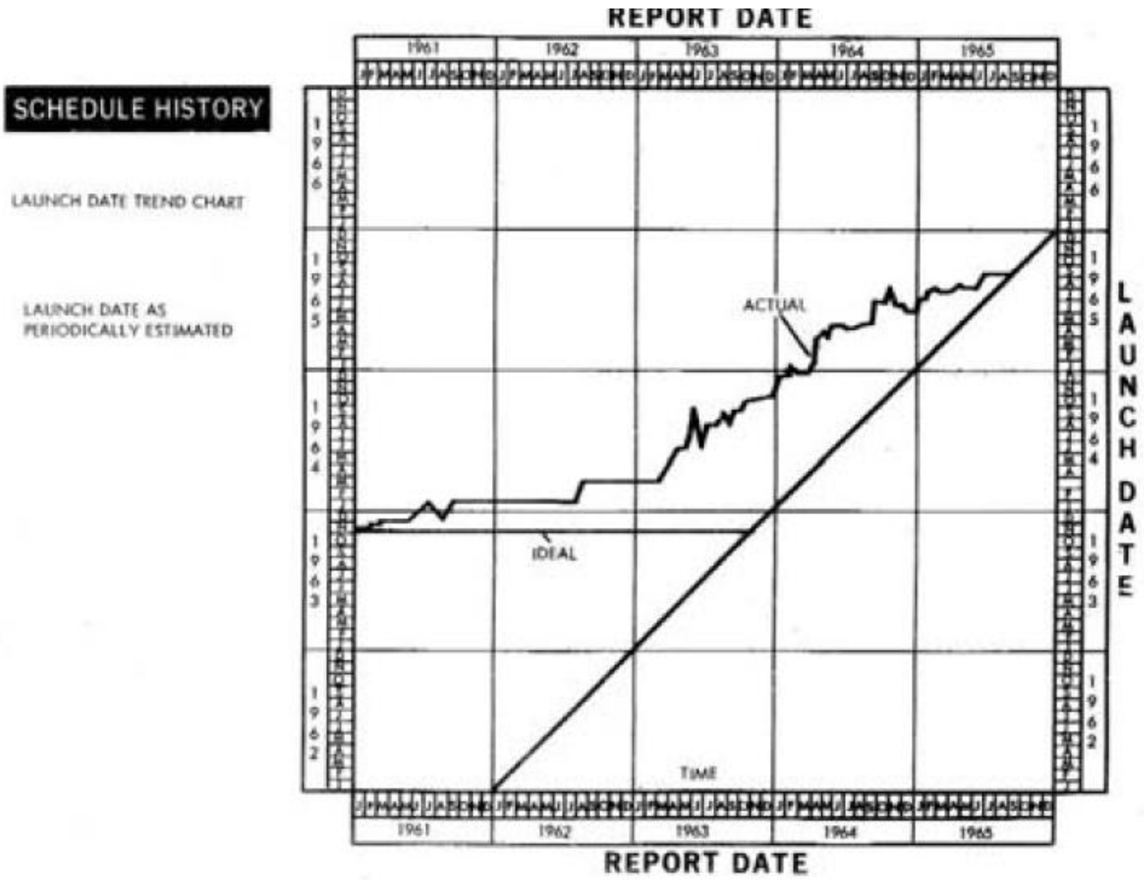

Figure 5: A hypothetical mission experiencing major delay. This type of chart was used to focus management on unfavourable project trends. Source: Glennan (1961).[18]

Each of the sub-projects had a Project Approval Document (PAD) to control the definition, purpose, budget and, in general, the details related to each milestone (see Figure 6). The PADs were the basis for the monthly status reviews held with each of the Program Director, that included an updating of costs, schedules and performance with emphasis in areas where deficiencies existed. There was a control group in each Program Office. For their part, all the PADs were structured to configure the next level of project (see Figure 7).

[18] Glennan T (1961). Op.Cit.

December 18, 1961

<u>Project Number</u>: 32-0304

<u>Program</u>: Apollo

<u>Project</u>: Apollo Spacecraft

<u>Purpose</u>: Development of a three man spacecraft capable of achieving manned lunar landing through direct ascent or orbital rendezvous techniques utilizing a modular concept.

<u>Estimated Level of Effort</u>:

a.	FY 1961	$ --	
b.	FY 1962 Budget:	$52,000	
c.	FY 1962 Approval:	Command and Service Module	$42,500
		Instrumentation and Scientific Eq.	$ 2,100
		Operational Support	$ 1,500
		Supporting Development	$ 1,675
		Guidance and Navigation	$ 4,500
		Total	$52,275 *

<u>Project Stipulations</u>:

a. Project Management: Manned Spacecraft Center
b. Program Management: Office of Manned Space Flight
c. Scope and content of Project Apollo shall be consistent with PPDP with amendments of October 23, and November 1, 1961, submitted by the Office of Manned Space Flight less the exclusions noted under (e).
d. Utilization of NASA-PERT and the NASA Financial Management Reporting System for Cost Type contracts will be utilized. PERT events and Financial Management Reporting System cost reporting categories shall be selected in a manner which will permit integrated time/cost management control and reporting.
*e. Funds are not approved for the high-energy abort and lunar take-off propulsion development included under Supporting Development ($925) pending recommendation on management of this work.
*f. Funds are not approved for lunar landing propulsion development.

<u>Project as specified above approved</u>

CONCUR ____________

APPROVED R.C. Seamans, Jr.

*Indicates change

Figure 6: Project Approval Document (PAD) for the Apollo Spacecraft (1961). Source: Glennan (1961).[19]

[19] Glennan T (1961). Op.Cit.

ATTACHMENT I
4/21/67

APOLLO PAD CHRONOLOGY
(Items marked with * are summarized on Chart)

Date	Title	Date	Title
*7-20-61	Saturn C-1 Development	6-7-62	Advanced Saturn
*7-20-61	J-2 Engine Development	6-19-62	Advanced Saturn
*7-20-61	F-1 Engine Development	7-27-62	Apollo Spacecraft
8-1-61	Apollo-Adv. Tech.	*9-4-62	Saturn C-IB
*8-9-61	Apollo Spacecraft G&N	9-21-62	F-1 Engine
*9-26-61	Saturn C-3	9-21-62	J-2 Engine
10-18-61	Saturn C-1	9-21-62	Vehicle Procurement
10-25-61	J-2 Engine	9-21-62	Saturn C-5
*11-3-61	Apollo Spacecraft	9-21-62	Saturn C-1
11-3-61	Apollo-Adv. Tech.	9-21-62	Apollo Spacecraft
11-7-61	Saturn C-1	11-13-62	Saturn C-5
11-16-61	Apollo-Manned	11-13-62	Vehicle Procurement
	18 orbit mission	11-28-62	Vehicle Procurement
*12-18-61	J-2 Engine	12-11-62	Vehicle Procurement
*12-18-61	Apollo Spacecraft	1-14-63	Apollo Spacecraft
12-22-61	Advanced Saturn	2-28-63	Apollo Spacecraft
*1-2-62	J-2 Engine	3-12-63	Vehicle Procurement
1-2-62	Advanced Saturn	4-4-63	Integration & Checkout
*1-25-62	Advanced Saturn	4-4-63	Aerospace Medicine
1-26-62	Apollo Spacecraft	4-4-63	Systems Engineering
*1-29-62	Apollo Spacecraft	*6-30-63	Apollo Spacecraft
3-13-62	Advanced Saturn	*6-30-63	Vehicle Procurement
3-13-62	Apollo Spacecraft	*6-30-63	RL 10 Engine
*3-21-62	Saturn C-1	*6-30-63	H-1 Engine
3-29-62	Apollo Spacecraft	*6-30-63	F-1 Engine
3-30-62	Saturn C-1	*6-30-63	Launch Operations Suppor
4-9-62	Advanced Saturn	*6-30-63	Launch Instrumentation
4-25-62	F-1 Engine	*6-30-63	Systems Engineering
4-25-62	J-2 Engine	7-10-63	J-2 Engine
4-26-62	Advanced Saturn	9-10-63	L/V Supp. Tech.
4-26-62	Saturn C-1	9-10-63	Propulsion Supp. Tech.
*4-27-62	Apollo Spacecraft	9-10-63	Launch Ops. Supp. Tech.
*4-27-62	Vehicle Procurement	*6-3-64	Apollo Total
5-2-62	Advanced Saturn	*8-28-64	Apollo Total
5-21-62	Saturn C-1	*12-16-64	Apollo Total
6-4-62	Apollo Spacecraft	*8-18-65	Apollo Total
6-7-62	Saturn C-1		

Figure 7: Project Approval Documents for the Apollo Program. Glennan (1961).[20]

The programme management of Apollo combined centralised planning and a hierarchical organisation with decentralised and flexible technology development processes. Centralised bureaucratic processes overlaid technical accountability systems characterised by project management and systems engineering methods. This allowed for organisational accountability. NASA integrated the relatively autonomous technical

[20] Glennan T (1961). Op.Cit.

cultures within its field centres through a centralised management structure that applied the formal controls of systems and configuration management.[21]

3.2 Financing model

Initial NASA estimates of the costs of Project Apollo were about USD 20 billion through the end of the decade. Accordingly, the NASA's annual budget increased from USD 500 million in 1960 to a high point of USD 5.2 billion in 1965.[22]

Out of the budgets appropriated for NASA each year, approximately 50% went directly for human spaceflight, and the vast majority of that went directly toward Apollo. Between 1959 and 1973 NASA spent more than USD 25 billion on human spaceflight, exclusive of infrastructure and support, of which nearly USD 20 billion was for Apollo.[23]

Moreover, during the early 1960s, NASA expanded its physical capacity to accomplish the Apollo Program. The cost of this expansion was more than USD 2.2 billion, with 90% of it expended before 1966.[24]

NASA's official budget appropriations for the entire organisation from 1960 to 1973, including work after the final Apollo mission, was USD 56.6 billion (USD 363 billion adjusted for inflation to 2008). The Apollo Project total cost has been estimated in USD 25.4 billion. The detailed fiscal budget appropriation for NASA and for Apollo Project is reflected in the following table (Table 1).

Table 1: Fiscal budget appropriation (thousand dollars). Source: F.B. Hopson, Administrative and Program Support Directorate, NASA.

Year	NASA (USD 1,000)	Apollo (USD 1,000)
1960	USD 523,575	USD 0
1961	USD 964,000	USD 0
1962	USD 1,671,750	USD 160,000
1963	USD 3,674,115	USD 617,164
1964	USD 3,974,979	USD 2,272,952
1965	USD 4,270,695	USD 2,614,619
1966	USD 4,511,644	USD 2,967,385
1967	USD 4,175,100	USD 2,916,200
1968	USD 3,970,600	USD 2,556,000
1969	USD 3,193,559	USD 2,025,000
1970	USD 3,113,765	USD 1,686,145
1971	USD 2,555,000	USD 913,669

21 Sadeth E (2006). "Societal impacts of the Apollo Program". Department of Space Studies. University of North Dakota, 20

22 Aeronautics and Space Report of the President, 1988 Activities (Washington, DC: NASA Annual Report, 1990), p. 185.

23 Ezell. NASA Historical Data Book, Vol II, 2:122-32.

24 Launius R (2004). op.cit.

1972	USD 2,507,700	USD 601,200
1973	USD 2,509,900	USD 76,700

3.3 Key actors and key technologies and platforms involved in the initiative

By 1966, the agency's civil service rolls had grown to 36 000 people from the 10 000 employed at NASA in 1960. Additionally, contractor employees working on the programme increased by a factor of 10, from 36 500 in 1960 to 376 700 in 1965. Private industry, research institutions, and universities provided the majority of personnel working on Apollo[25]

NASA

The National Aeronautics and Space Administration is an independent agency of the executive branch of the U.S federal government responsible for the civilian space programme, as well as aeronautics and aerospace research. The Agency's vision is to reach for new heights and reveal the unknown for the benefit of humankind.

President Eisenhower established NASA in 1958 with a distinctly civilian orientation encouraging peaceful applications in space science. The National Aeronautics and Space Act was passed on 29 July 1958, disestablishing NASA's predecessor, the National Advisory Committee for Aeronautics (NACA). The new agency became operational on 1 October 1958.

Since its inception NASA has accomplished many great scientific and technological feats in air and space. Most US space exploration efforts have been led by NASA, including the Apollo Moon landing missions, the Skylab space station, and later the Space Shuttle. NASA technology also has been adapted for many non-aerospace uses by the private sector. NASA remains a leading force in scientific research and in stimulating public interest in aerospace exploration, as well as science and technology in general. Its exploration of space has taught us to view Earth, mankind, and the universe in a new way.

Current missions are focused on Earth, humans in space, solar system and universe. NASA supports the International Space Station and is overseeing the development of the Orion Multi-Purpose Crew Vehicle, the Space Launch System and Commercial Crew vehicles. The agency is also responsible for the Launch Services Program (LSP) which provides oversight of launch operations and countdown management for unmanned NASA launches.

NASA science is focused on better understanding Earth through the Earth Observing System, advancing heliophysics through the efforts of the Science Mission Directorate's Heliophysics Research Program, exploring bodies throughout the Solar System with advanced robotic spacecraft missions such as New Horizons, and researching astrophysics topics, such as the Big Bang, through the Great Observatories and associated programmes. NASA shares data with various national and international organisations such as from the Greenhouse Gases Observing Satellite

3.4 Monitoring system and evaluation of the initiatives

From a technological point of view, each Apollo project passes through a review and approval process making its way through definition, design, manufacture and flight

[25] Levine A (1982). "*Managing NASA in the Apollo Era".* Washington, DC: NASA SP-4102, 1982), Chapter 4.

operations. The key reviews were design certification and flight-readiness. If some items were outstanding, they would have to be cleared before the time of the launch.[26]

The mission evaluation was provided by an organisational team of engineering specialists who resolved technical problems associated with the spacecraft systems. This team provide direct support to the Kennedy Space Center during prelaunch testing and to the light control organisation in the Mission Control Center during mission operations. Each of the missions had its own assessments of mission objectives. [27]

In addition, the Apollo Project had several reports to President Kennedy informed about the results. The first one was in 1961, signed by Vice-President Lyndon B. Johnson, and contained some general conclusions of the preliminary evaluation.[28]

- Largely due to their concentrated efforts and their earlier emphasis upon the development of large rocket engines, the Soviets were ahead of the United States in world prestige attained through impressive technological accomplishment in space.
- The US had greater resources than the USSR for attaining space leadership but had failed to make the necessary hard decisions and to use the resources to achieve such leadership.
- US should be realistic and recognise that other nations will tend to align themselves with the country which they believe will be the world leader. Dramatic accomplishments in space are identified as a major indicator or world leadership.
- In certain areas, such as communications, navigation, weather and mapping, the US can and should exploit its advanced position.
- Even in the areas in which the Soviets are in first position, the US should make an aggressive effort to gain leadership.
- Manned exploration of the Moon is essential as an objective. The US cannot expect the Russians to transfer the benefits of their experience.
- The American public should be given the facts as to how the Project stands in the space race and advised of the importance of such leadership to the future for the country.
- More resources and more effort need to be put into the space programme.

Also, other reviews were considering, such as one in 1961 from Wernher von Braun[29] who led the development of the V-2 rocket for Germany during World War II. There was also an evaluation in 1967[30] when a fire engulfed the Apollo 204 capsule and killed three astronauts.

3.5 Level and type of citizen engagement in the initiative

An estimated one quarter of the population of the world saw the Apollo 8 transmission during the ninth orbit of the Moon[31] and one fifth of the population watched the live transmission of the Apollo 11 moonwalk.

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[26] Seamans R (2007). Op.Cit.

[27] Al the mission technical reviews can be consulted here: https://www.hq.nasa.gov/alsj/alsj-mrs.html

[28] Johnson L. B (1961). Memoradum for the President. "Evaluation of Space Program" 28 April 1961, NASA Historical Reference Collection, NASA Headquarters, Washington D.C.

[29] Biography available at: https://www.nasa.gov/centers/marshall/history/vonbraun/bio.html

[30] "Report of Apollo 204 Review Board to the Administrator, National Aeronautics and Space Administration". 5 April 1967, Apollo Files, NASA Historical Reference Collection, NASA Headquarters, Washington, D.C.

31 "Apollo 8: Christmas at the Moon". NASA. Retrieved July 20, 2016 available at https://www.nasa.gov/topics/history/features/apollo_8.html

Even the Project is often considered as a “national pride”, citizens were not involved at all in the decision, design or implementation of the initiative, and the relationship between the Project and the citizens was unidirectional, with merely informative purposes.

Despite this, there was a clear allusion to the citizens in the President Kennedy’s speech for the joint session of Congress on 25 May 1961: “*I believe we should go to the Moon. But I think every citizen of this country as well as the Members of Congress should consider the matter carefully in making their judgment, to which we have given attention over many weeks and months, because it is a heavy burden, and there is no sense in agreeing or desiring that the United States take an affirmative position in outer space, unless we are prepared to do the work and bear the burden to make it successful*”[32].

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[32] Kennedy J.F (1961). “Urgent National Needs” Op.Cit.

4 Policy instruments and wider policy mix used for implementing the initiative.

4.1 Description of the R&I policy instruments used for implementing of the initiative

Public Procurement

Once NASA received the mandate for the lunar landing, it expanded its workforce and started to contract with industry. In fact, many functions in Project Apollo were performed through contracts with external stakeholders. In general, NASA projects were managed at the Field Centers following the process reflected in Figure 8.

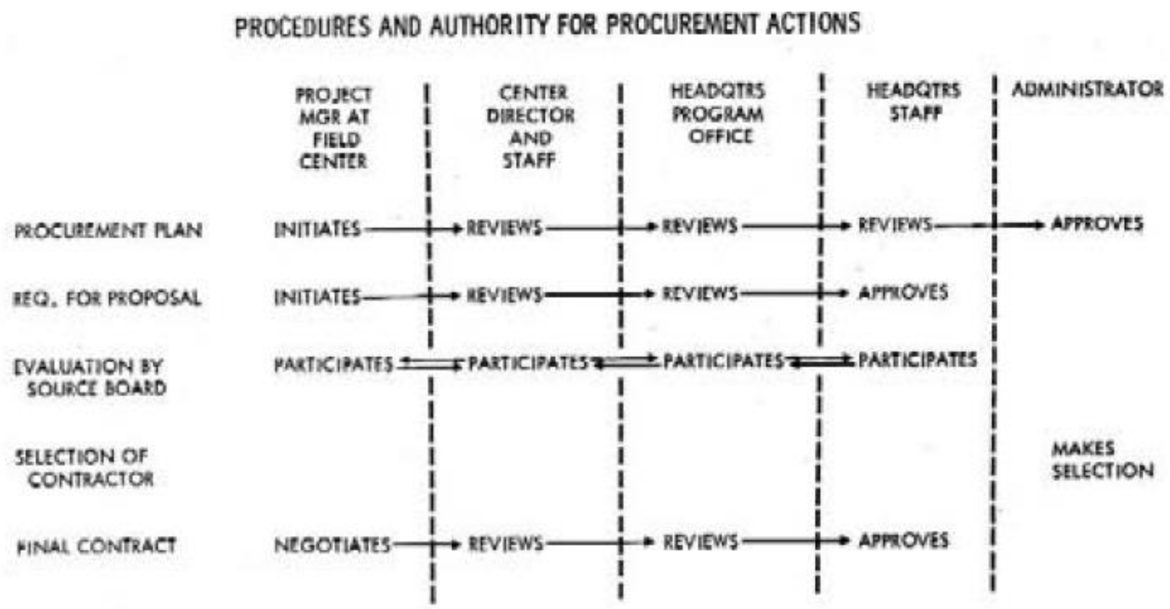

Figure 8: NASA Procurement Procedures. Source: Glennan (1961).[33]

The Project Manager prepared the procurement plan, which passed through the Center Director and the Program Director, before a review by the Procurement Officer at Headquarters. From 1966 on, approval was given by the Office of the Administrator. Once the plan was approved, the Project Manager prepared a Request for Proposal (RFP) that was released by the Headquarters Procurement Office. The source evaluation board name in the procurement plan had both line and staff members who participated in the evaluation. Prior to the submission of proposals, the board had to establish the basis for scoring them and during the process, strict rules were enforced regarding communication with the contractors. Also, there was a process defined to avoid hidden interests in the procurement for the benefit of any contractor.

When NASA procured buildings and other facilities, the contractors were provided with specifications and designs in the Request for Quotation (RFQ). Also, NASA started with incentive and award fees: when the incentive was tied to cost, the contractor shared the cost of overruns with the Government, but if cost savings occurred, the contractor's fee was increased in proportion. Incentives were related to schedules and performance as well as to cost. A large percentage of NASA's Apollo business was conducted on either an incentive or an award-fee basis.[34]

In Figure 9 there is a list of major spacecrafts component manufacturers:

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[33] Glennan T (1961). Op.Cit.
[34] Seamans R (2007). Op.Cit.

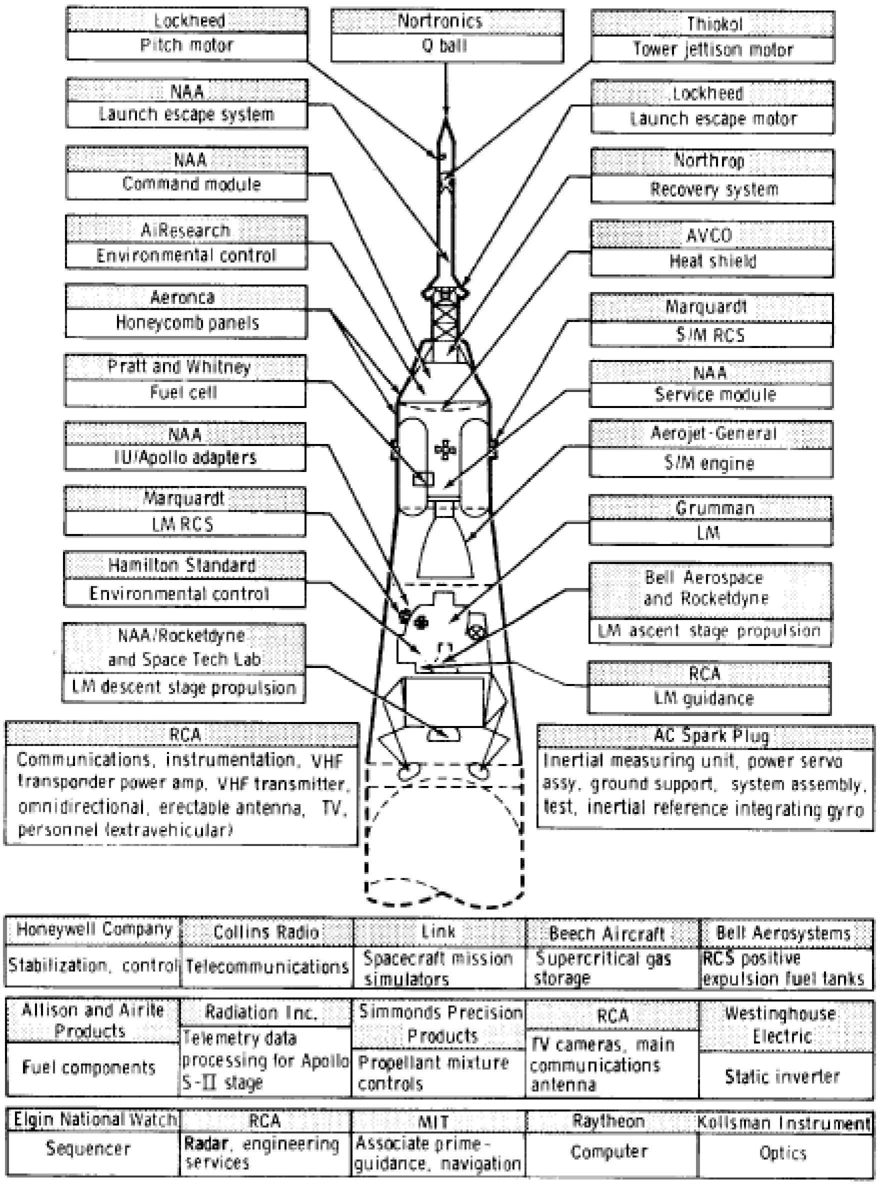

Figure 9: Major Spacecrafts Component Manufacturers. Source: Ertel and Newkirk (1974).[35]

4.2 Connection with other initiatives and policies

Project MERCURY

Initiated in 1958, completed in 1963, Project Mercury was the United States' first man-in-space programme. The objectives of the Mercury Project, as stated at the time of project go-ahead, were as follows:

- Place a manned spacecraft in orbital flight around the earth;
- Investigate man's performance capabilities and his ability to function in the environment of space;
- Recover the man and the spacecraft safely.

After the objectives were established for the project, many guidelines were established to ensure that the most expedient and safest approach for attainment of the objectives was followed. The basic guidelines that were established were as follows:

[35] Ertel I, Newkirk R, Brooks C (1974). Op.Cit

- Existing technology and off-the-shelf equipment should be used wherever practical;
- The simplest and most reliable approach to system design would be followed;
- An existing launch vehicle would be employed to place the spacecraft into orbit;
- A progressive and logical test programme would be conducted.

More detailed requirements for the spacecraft were established as follows (see Figure 10):

- The spacecraft must be fitted with a reliable launch-escape system to separate the spacecraft and its crew from the launch vehicle in case of impending failure;
- The pilot must be given the capability of manually controlling spacecraft attitude;
- The spacecraft must carry a retrorocket system capable of reliably providing the necessary impulse to bring the spacecraft out of orbit;
- A zero-lift body utilising drag braking would be used for re-entry;
- The spacecraft design must satisfy the requirements for a water landing.

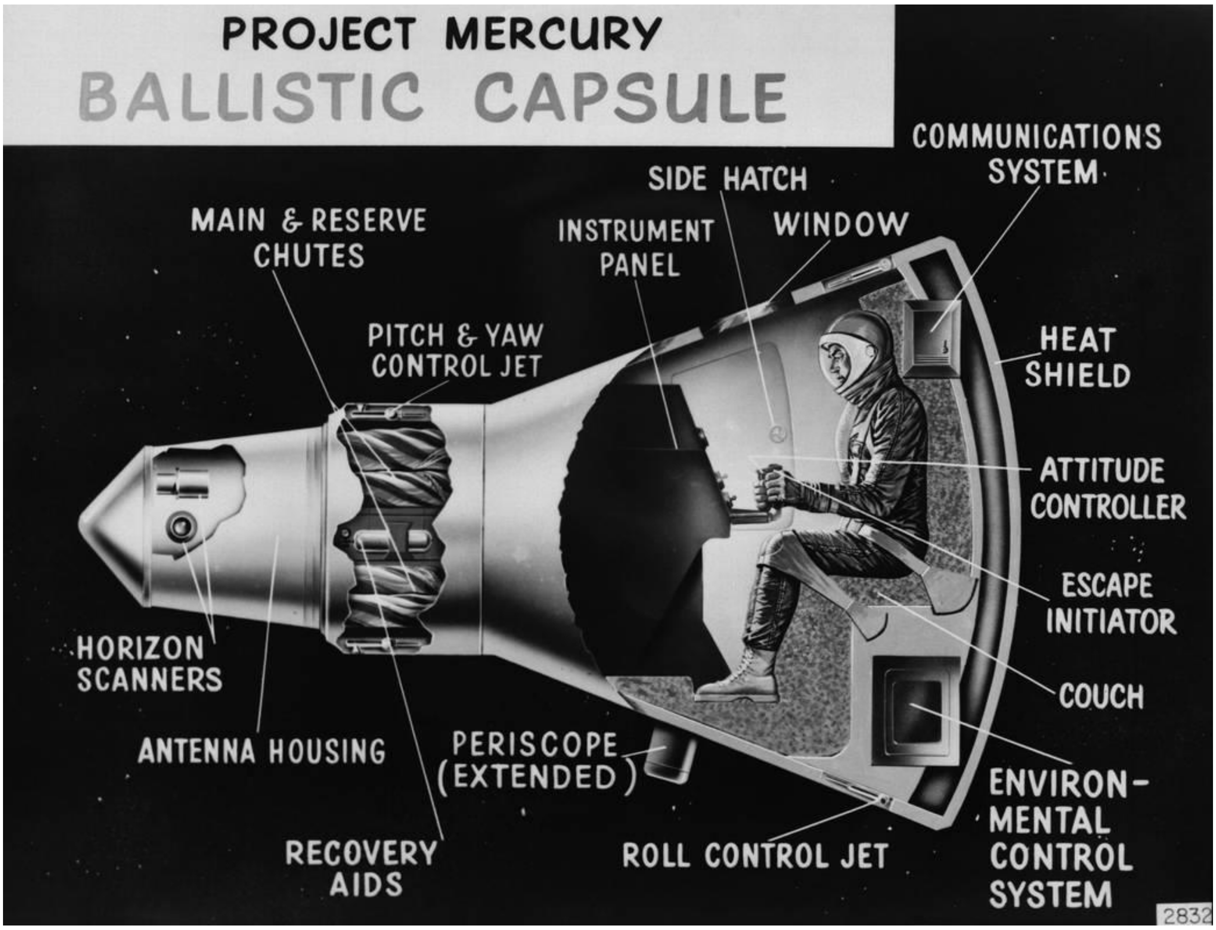

Figure 10: This cutaway drawing of the Mercury capsule was used by the Space Task Group at the first NASA inspection, on Oct. 24, 1959. Source: NASA.gov

The United States' first manned space flight project was successfully accomplished in a 4 2/3-year period of dynamic activity which saw more than 2 000 000 people from many major government agencies and much of the aerospace industry combine their skills, initiative, and experience into a national effort.

In this period, six manned space flights were accomplished as part of a 25-flight programme. These manned space flights were accomplished with complete pilot safety and without change to the basic Mercury concepts. It was shown that man can function ably as a pilot-engineer-experimenter without undesirable reactions or deteriorations of normal body functions for periods up to 34 hours of weightless flight.

The cost of Project Mercury was USD 142 800 000[36]

Project GEMINI

Project Gemini was the United States' second manned space flight programme, a bridge between the pioneering achievement of Project Mercury and the yet-to-be realised lunar mission of Project Apollo.

The Gemini programme defined and tested the skills NASA would need to go to the Moon in the 1960s and 1970s. Gemini had four main goals: to test an astronaut's ability to fly long-duration missions (up to two weeks in space); to understand how spacecraft could rendezvous and dock in orbit around the Earth and the moon; to perfect re-entry and landing methods; and to further understand the effects of longer space flights on astronauts. Gemini was one of the early pioneering efforts in the developing the space capability of this nation.

The most significant achievements of Gemini involved precision manoeuvring in orbit and a major extension of the duration of manned space flights. These included the first rendezvous in orbit of one spacecraft with another and the docking of two spacecraft together. The docking operation allowed the use of a large propulsion system to carry men to greater heights above Earth than had been previously possible, thereby enabling the astronauts to view and photograph Earth over extensive areas. Precision manoeuvring was also employed during the very high-speed re-entry back to the surface of Earth, enabling accurate landings to be made

The Gemini spacecraft (Figure 11) was designed to carry two astronauts into Earth orbit to test long-duration flight, rendezvous and docking and other techniques needed for journeys to the Moon.

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[36] Swenson L, Grinwood J, Alezander Ch (1989). "This new ocean: a history of Project Mercury". NASA Special Publicaion – 4201 in the NASA History Series.

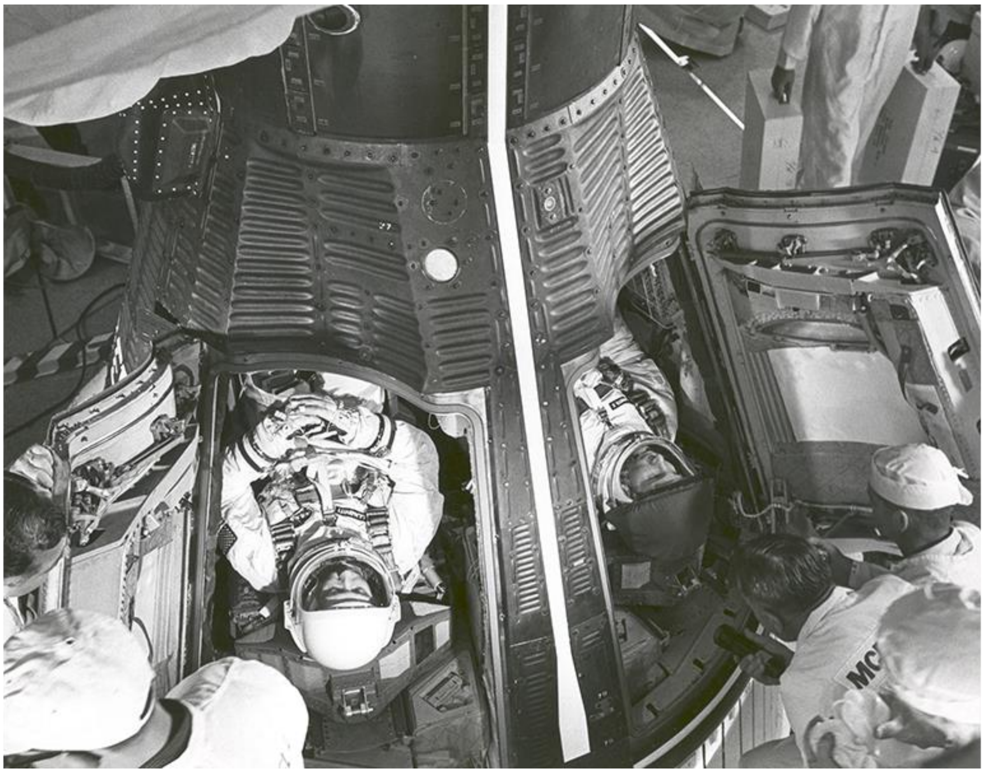

Figure 11: Gemini Spacecraft. Source NASA.gov

Astronauts Gus Grissom and John Young flew the first manned mission, Gemini III, which launched 23 March 1965. On 3 June 1965, Gemini IV astronaut Edward H. White II became the first American to step outside his spacecraft and let go, effectively setting himself adrift in the zero gravity of space. For 23 minutes White floated around the spacecraft, logging 6500 miles during his orbital stroll. The programme ended with Gemini XII's splashdown on 15 November 1966, and NASA moved on to Apollo.

From 1962 to 1967, the total cost of Gemini Program was USD 1.2 billion.[37]

4.3 Key turning points of the initiative and policy adaptation measures

The following table shows the major changes and turning points of Apollo Project, as well as a description of the main flexibility mechanisms and policy adaptation measures.

Major changes / turning points of the initiative	**Description of the flexibility mechanism / policy adaptation measures**
Apollo project involved a great amount of private and public stakeholders and almost each of them had differing perspectives on how to go about the task of accomplishing Apollo.	To manage all stakeholders, NASA expanded the "program management" concept borrowed by T. Keith Glennan in the late 1950s from the military/ industrial complex, bringing in military managers to oversee Apollo. Thus, a programme office was created with centralised authority over design, engineering, procurement, testing, construction, manufacturing, spare parts, logistic, training and operations
When Mercury Project finished, NASA	Project Gemini was developed to gain experience

[37] Grimwood J, Hacker B (1968). "Project GEMINI, Technology and Operations. A Chonology". NASA Special Publication – 4002

program managers still perceived a huge gap in the capability for human spaceflight between that acquired by Mercury and what would be needed for a lunar landing	in three main areas, all of them needed to reach the main goal of Apollo Project. The areas were: the ability in space to locate, manoeuvre toward and rendezvous and dock with another spacecraft; the ability of astronauts to work outside a spacecraft; and to collect more sophisticated physiological data about the human response to extended spaceflight.
During a test for what was to be the first Apollo mission, a fire killed the three-person crew	Mission Control established the philosophy "tough and competent" for all the team: to be accountable for what they do and never to stop learning. This changed the entire team's attitude. There were no manned flights for 20 months after the fire and it was a period of stepping back and reflection. Then, 20 months later, Apollo 7 tested the redesigned Command Module. Without the leadership of the managers and the change of attitude, all those involved in the Apollo Project recognise that they would never have achieved the final success.[38]

[38] "Mission Control: The Unsung Heroes of Apollo" (2017). USA. Director: David Fairhead. Available online here: http://gravitasventures.com/mission-control/

5 Realised or expected outputs, outcomes and impacts

This Section is focused on the outputs, outcomes and impacts resulted from the whole initiative.

5.1 Outputs and New Instruments

- The Apollo program consisted of 33 flights, 11 of which were manned. The 22 unmanned flights were conducted to qualify the launch vehicle and spacecraft for manned space flight. Four of the manned flights were conducted to man-rate the overall vehicle for lunar exploration. The final seven flights were conducted to explore the lunar environment and surface.[39]
- No major launch vehicle failure occurred to prevent a mission from being accomplished and only one inflight failure of a space craft (Apollo 13) prevented the intended mission from being accomplished.
- These was a large amount of data and material collected as the result of the lunar missions. For example, during each mission, the crew emplaced and activated a lunar geophysical observatory to be controlled and monitored from Earth, collected samples of lunar soil and rock, photographically documented the geologic features of the landing area and performed other exploration activities.
- In 1961 two techniques, direct ascent and earth-orbit rendezvous were being considering for achieving a manned lunar landing. A third technique, lunar orbit rendezvous, was later determined to be more feasible and was adopted in July 1961. To make this decision, a preliminary programme for manned lunar landings was formulated.

5.2 Outcomes

- Apollo project (mission 8) allowed the world to view the Earth for the first time in the history of mankind.
- The operational and scientific success of the missions stimulated a vigorous interest in the solar system and established the study of the Moon as a modern interdisciplinary science.
- There was an impressive range of results from the scientific experiments related to lunar orbital science and lunar orbital science. For example, mechanical devices and scientific instruments were developed so that certain instruments could be moved away from X-ray secondary radiation and the contamination cloud that surrounded the spacecraft, so that the desired photographic angles could be obtained.
- The mission reports for 11 manned missions showed a continual improvement in fight crew performance. The increased complexity in the objectives of each mission was possible because new operational experience was used where appropriate to standardise and revise crew operations as each mission was flown, especially in the areas of pre-flight training, flight procedures and equipment operation.
- Apollo 8’s images of the Earth made people aware of the planet’s fragility and helped to spur the green movement in the world. [40]

5.3 Impacts

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[39] Johnson L B (1975). “Apollo Program Summary Report”. National Aeronautics and Space Administration. Houston, Texas.

[40] Lexington, ed. (2011). "Apollo plus 50". The Economist. London: The Economist Newspaper Limited. p. 36 available at: http://www.economist.com/node/18712369

- The project established the technological pre-eminence of the US over other nations in space sector, so it accomplished the political goals for which it was created.[41]
- One if the main key success factors of the project was the management model, that was able to integrate complex technological and organisational dimensions.[42]
- About 30 000 photographs of the lunar surface were obtained from lunar orbit on the Apollo missions. The purpose was to obtain high-quality colour, panchromatic and multispectral photographs of selected land and ocean areas of the Earth and of clouds and other weather phenomena.
- Some biomedical experiments were conducting during the Apollo series of space flights. Studies investigated the effects of space flight, including ambient radiation on one or more species of living organisms.
- Inflight demonstrations were small carry-on experiments operated by several crews during translunar or trans-earth coast. The purpose was to demonstrate the effects of near-zero gravity on various phenomena and processes.
- 382 kg of lunar rocks and soil were returned during the Project, contributing to the understanding of the Moon's composition and geological history.
- Apollo spurred advances in medicine, food, geology, manned spaceflight, avionics, telecommunications, computing, maths, astronomy, physics, bioscience and other several areas of technological and scientific interest.
- Apollo set the foundations for other projects such as Skylab[43], Apollo-Soyuz[44], Space Shuttle[45] and International Space Station[46]. Even today, Mission Control operates on the principles founded in the Apollo era.
- 409 000 labourers were employed by the Project either directly by NASA or contracted workers.
- Apollo led to over 1800 spinoff products as of 2015.[47] Physical products that would not have been possible, a variety of breakthroughs from early breast cancer detection to the accelerated development of integrated circuits were birthed by the Apollo programme.

5.4 Summary of the key indicators

Next table shows the main indicators related to Apollo Project:

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[41] Launius R (2004). op.cit.

[42] Levine A (1982). Op.Cit. Fries S (1992), "NASA Engineers and the Age of Apollo". Washington, DC: NASA SP-4104.

[43] Skylab was the United States' first and only space station, orbiting Earth from 1973 to 1979. Much of the hardware developed during the Apollo era was used in our first space station, Skylab. Skylab produced many valuable results based on its solar observatory and various experiments performed onboard, none of which would have been possible without the Apollo program. More info available at: https://www.nasa.gov/mission_pages/skylab

[44] The Apollo–Soyuz Test Project (ASTP) conducted in July 1975, was the first joint U.S.–Soviet space flight, as a symbol of the policy of détente that the two superpowers were pursuing at the time. More info available here: https://www.nasa.gov/mission_pages/apollo-soyuz/astp_mission.html

45 The Space Shuttle was a low Earth orbital spacecraft system operated by the NASA, as part of the Space Shuttle program. It was taken from a 1969 plan for a system of reusable spacecraft of which it was the only item funded for development. More info available here: https://www.nasa.gov/mission_pages/shuttle/main/index.html

[46] The International Space Station (ISS) is a space station, or a habitable artificial satellite, in low Earth orbit. Its first component launched into orbit in 1998, the last pressurised module was fitted in 2011, and the station is expected to be used until 2028. More info available her: https://www.nasa.gov/mission_pages/station/main/index.html

47 NASA Spinoff Database, available at: https://spinoff.nasa.gov/spinoff/database/

Key indicators	
Timeline:	1961-1972
Objective and targets:	To land an American on the Moon and return safely to Earth.
Total budget:	USA 25.4 billion *(USA 163 billion inflation adjusted to 2008)*
Annual budget:	(see table below)
Share of budget, public funding:	100% public budget
Share of budget, private investment:	
Leverage effect (additional public/private investments the initiative has triggered):	N.A.
Key (official/public) indicators applied for monitoring the progress towards the targets:	From a technological point of view, each Apollo project passes through a review and approval process making its way through definition, design, manufacture and flight operations. The key reviews were**:** • Trajectory: launch, earth orbit, entry; • Launch vehicle performance; • Command and service module performance: structures, aerodynamics, thermal control, thermal protection, earth landing, mechanical systems, electrical power distribution, fuel cells and batteries, cryogenics, pyrotechnic devices, launch escape, emergency detection, communications, instrumentation, guidance, navigation and control systems, reaction control systems, service propulsion, crew systems, crew station and consumables; • Flight crew performance and flight crew report;

Annual budget:

Year	Apollo (USD 1,000)
1960	USD 0
1961	USD 0
1962	USD 160 000
1963	USD 617 164
1964	USD 2 272 952
1965	USD 2 614 619
1966	USD 2 967 385
1967	USD 2 916 200
1968	USD 2 556 000
1969	USD 2 025 000
1970	USD 1 686 145
1971	USD 913 669
1972	USD 601,200
1973	USD 76 700

	• Biomedical evaluation: inflight, physical examinations; • Mission support performance: flight control, network, recovery operations; • Experiments; • Assessment of mission objectives; • Anomaly summary.
Other key indicators (e.g. outputs/outcomes/impacts):	• Jobs created • Number of spinoffs and products • Patents

6 Conclusions and lessons learned

6.1 Identification and assessment of key strengths and weaknesses of the initiative

Strengths	Weaknesses
• In 1960s whatever money NASA needed was made available. Resources for the first landing were a priority for the US Government. • The technical requirements of Apollo Project included a very high level of reliability because the political cost of failure of the Project was unacceptably high.[48] • To manage the Project, vast public resources were mobilised within a centralised bureaucracy under government direction. • Apollo Project had technologies such as the silicon chip, oxygen-hydrogen engines, system-testing technology and the large engine F-1, that were not available for the Soviets, which allowed US to take the lead in the Space Race. • Research and technology development had a main role in Apollo Project. As they could not afford to develop hardware for every approach, they selected the ones that showed the greatest promise of payoff toward the objectives.[49] • The National Space Program international activity opened channels for the introduction of new instrumentation and experiments attracting the talent of foreign scientists from 35 different nations.[50] • Although the first mission Apollo 1 or AS-204 failed, the team learned from the mistakes and restructured the entire project to launch the next mission 20 months later. To learn from the mistakes was constant in the Project and part of its philosophy.	• The high cost come the Project to a fast end, closing the door to potential future developments (in 1965 the annual cost of Apollo was 0.8% of U.S GDP).[51] • The main reason to develop the Apollo Project was to win the Space Race against the USSR. When this incentive disappeared because the Space Race was definitely won, the Project become less interesting for political leaders. • Since Government was accountable for the expenditure, functions such as procurement (including second and first TIER contracts), launch and flight operations should remain under direct NASA control. When delays and problems occurred with some contracts, the Government did not have enough room to manoeuvre for solving problems. [52]

6.2 Lessons learned and key messages for European R&I policy

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[48] Mindell D (2008). "Digital Apollo: human and machine in spaceflight". Cambridge, Massachusetts: The MIT Press

[49] James E Webb's (NASA Administrator) letter to President Kennedy of 30 November 1962.

[50] James E. Webb. Op.Cit.

[51] Jones E (2010). "When might we go back to the Moon?". Apollo Lunar Surface Journal. 1995, rev 13, August 2010.

[52] Seamans R (2007). Op.Cit.

- A confluence of political necessity, personal commitment and activism, scientific and technological ability, economic prosperity, and public mood made the Apollo Mission possible.[53]

- The reliance on the private sector was a key success factor for the project, attracting talent and resources from the emerging aerospace industry and the country's leading research universities.[54]

- The programme management concept was recognised as a critical factor of Apollo Project's success by Science magazine in November 1968.[55] In fact, understanding the management of complex structures for the successful completion of different political and technological tasks was an important outgrowth of the Apollo project.

- Everyone on the Project team (more than 400 000 people were directly involved) seemed to share a common vision, no matter the function they had to perform. The documents point to a pride of belonging: "*Somehow or other, when we came together, we were greater than the sum of our parts. We became capable of doing what in most cases, would be considered impossible. We were better than we ever expected to be. We were more successful than we were expected to be. And really, with the exception of a bad accident on the launch pad, we brought every crewman home*"[56]

[53] Launius R (2004). op.cit.

[54] Kraemer S (1995). "Organizing for Exploration," in John M. Logsdon, editor. Exploring the Unknown: Selected Documents in the History of the US. Civil Space Program, Volume I, Organizing for Exploration (Washington, DC: NASA SP-4407,1995), chapter 4.

55 Wolfe D (1968), Executive Officer, American Association for the Advancement of Science, editorial for Science, 15 November 1968.

[56] "Mission Control: The Unsung Heroes of Apollo" (2017).

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This is one of a series of case studies developed to support mission-oriented research and innovation policy at EU level.

Apollo was a program in the 1960s designed to land an American on the Moon and return safely to Earth. It was announced by President John F. Kennedy on May 1961 in a speech on Urgent National Needs billed as a second State of the Union message. He said: "*I believe this Nation should commitment itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish*".