

Success Factors in Human Space Programs - Why Did Apollo Succeed Better Than Later Programs?

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The Apollo Program reached the moon, but the Constellation Program (CxP) that planned to return to the moon and go on to Mars was cancelled. Apollo is NASA's greatest achievement but its success is poorly understood. The usual explanation is that President Kennedy announced we were going to the moon, the scientific community and the public strongly supported it, and Congress provided the necessary funding. This is partially incorrect and does not actually explain Apollo's success. The scientific community and the public did not support Apollo. Like Apollo, Constellation was announced by a president and funded by Congress, with elements that continued on even after it was cancelled. Two other factors account for Apollo's success. Initially, the surprise event of Uri Gagarin's first human space flight created political distress and a strong desire for the government to dramatically demonstrate American space capability. Options were considered and Apollo was found to be most effective and technically feasible. Political necessity overrode both the lack of popular and scientific support and the extremely high cost and risk. Other NASA human space programs were either canceled, such as the Space Exploration Initiative (SEI), repeatedly threatened with cancellation, such as International Space Station (ISS), or terminated while still operational, such as the space shuttle and even Apollo itself. Large crash programs such as Apollo are initiated and continued if and only if urgent political necessity produces the necessary political will. They succeed if and only if they are technically feasible within the provided resources. Future human space missions will probably require gradual step-by-step development in a more normal environment.

Nomenclature

CAIB	=	Columbia Accident Investigation Board
CEV	=	Crew Exploration Vehicle
CxP	=	Constellation Program
ISS	=	International Space Station
SEI	=	Space Exploration Initiative
SLS	=	Space Launch System
STEM	=	Science, Technology, Engineering, and Mathematics

I. Introduction

THIS analysis considers the factors that have contributed to success in NASA human space flight programs. The initial direct approach is simply to examine the reasons usually given for the success or failure of Apollo and other human space programs. Most of the usually mentioned factors are internal to the program and under its control, but the most crucial success factors are political and beyond the reach of the program. What factors lead to the initiation of a human space program and help it survive external challenges? What are the internal management, organization, staffing, and cultural factors that lead to success or failure?

The success factors apply to most programs and don't explain the unique aspects of Apollo, so the Apollo story is examined. Apollo succeeded far beyond all other human space missions. The challenge of the Soviet space race stimulated this success. The post-Apollo space era requires a more routine approach.

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II. Suggested reasons for the success of human space programs

The reasons for the success or failure of Apollo and other large, very visible government programs are often thought to be obvious and well known, but they are usually simplified to make a point. Hindsight makes some causes obvious and obscures complications. The so-called "halo effect" makes a successful project seem nearly perfect and the problems overcome are forgotten.

Table 1 provides a list of possible success factors for the Apollo program and other NASA human space flight programs.

Table 1. Possible success factors for Apollo and other human space programs.

Success factors	Program		Apollo	Shuttle	ISS	SEI	CxP
	Successful program?		+	o	+	-	o
	Important factor?	Necessary factor?	Factor present?				
Initiation							
Instigating event	Yes	No	+	-	-	+	+
Clear significant goal	Yes	Yes	+	+	+	-	-
Political support							
President	Yes	Yes	+, -	+, -	+	+, -	+, -, +
Congress	Yes	Yes	+, -	+, -	+	-	+
Science	No	No	-	-	-	-	-
Public	No	No	-, +, -	-	-	-	-
Limited oversight	Yes	No	+	-	-	-	-
Management							
Fixed requirements	Yes	No	+	-	-	-	-
Good plans and controls	Yes	No	+	-	-	-	-
Open communication	Yes	No	+	-	-		
Safety culture	Yes	Yes (if)	+	-	-		
Technical							
Feasible	Yes	Yes	+	+	+	-	-
Affordable	Yes	Yes	+	+	+	-	-
Direct benefits							
Prestige	Yes	Yes	+	+	+	+	+
Space technology	Yes	Yes	+	+	+	+	+
Exploration	Yes	No (but)	+	-	-	+	+
Defense	No	No	-	+	+	-	-
Science	No	No	+	+	+	+	+
Indirect benefits							
Technology	Yes	No	+	+	+	+	+
Jobs	Yes	No	+	+	+	+	+
STEM	Yes	No	+	+	+	+	+

The suggested success factors are listed down the leftmost column and are grouped in the categories initiation, political support, management, technical, direct benefits, and indirect benefits. The projects considered are Apollo, the space shuttle, the International Space Station (ISS), the Space Exploration Initiative (SEI), and the Constellation Program (CxP). Apollo and ISS are here judged to be successful (+), but the space shuttle seems only partially successful (o). SEI was quickly dropped and was unsuccessful (-). CxP carried on for some years and was then cancelled, but only partially. Its major efforts, the Space Launch System (SLS) and Crew Exploration Vehicle (CEV), were continued and will probably make CxP partly successful.

III. Why are human space programs considered successful and others not?

Before we can consider what factors make a human space program successful or not, we need to establish which ones were successful. The above judgments on Apollo, the space shuttle, the International Space Station (ISS), the Space Exploration Initiative (SEI), and the Constellation Program (CxP) are discussed.

A. Apollo

Apollo 11 successfully landed men on the moon in 1969 and the Soviets were decisively beaten in the cold war space race. Five later missions also landed men on the moon and conducted geologic surveys.

The success of Apollo is clear, but there were also very significant problems. A fire in the Apollo 1 capsule on the launch pad killed three astronauts. Apollo 13 suffered an oxygen tank explosion on the way to the moon and the astronauts barely survived. The last three Apollo missions, 18, 19, and 20, were cancelled.

The obvious conclusion is that Apollo was very successful, even allowing for the problems of Apollo 1 and 13 and the cancellation of Apollo 18, 19, and 20. However some disagree, disparaging Apollo as a “flag and footprints” mission that did not lead the way or establish the infrastructure for future human space programs. Frustration in the current more limited era is understandable, but a program is not unsuccessful because it did not do something it never intended to do.

B. Shuttle

The space shuttle flew 135 missions from 1981 to 2011. It launched many satellites, planetary probes, the Hubble Space Telescope, and many modules of the ISS. It supported Hubble repair and transported astronauts to and from the ISS.

The shuttle suffered two major tragedies. The Challenger broke up during launch when an O-ring in the right solid rocket booster failed and allowed flame to reach the external fuel tank, destroying the shuttle and killing the crew. The high risk of the shuttle design had not been understood or mitigated. Investigators found that NASA had lost the safety culture that had prevailed in Apollo after Apollo 1. Many years later the Columbia astronauts died when the shuttle heat shield failed on reentry, and the investigators found that NASA had not repaired the deficiencies that led to Challenger.

That the shuttle program over-optimistically promised routine access to space with rapid turn around and lower launch costs could be forgivable, but not neglect of safety. Because of the human losses in Challenger and Columbia, the shuttle program can be considered only partially successful at best.

C. International Space Station (ISS)

The ISS first component was launched in 1998 and it has been continuously inhabited since 2000. It serves as a space and microgravity research laboratory and provides valuable experience in space systems operations. It will be useful in testing equipment for future human space missions.

The ISS is as much a Russian as a United States program. It grew out of the all-U.S. Space Station Freedom, which was scaled back by about half and joined to a roughly equivalent Russian space station design. The end of the cold war led to reduced U.S. space budgets and provided an opportunity for space cooperation. The ISS is not only a success, it embodies the cooperation in space after the U.S.-Soviet cold war.

D. Space Exploration Initiative (SEI)

In 1989, on the 20th anniversary of the Apollo 11 moon landing, President George H. W. Bush announced the Space Exploration Initiative (SEI). It included sustained human exploration of the solar system including the current planning for Space Station Freedom, a permanent moon base, and a Mars mission.

NASA conducted the 90-day study, which estimated the cost for SEI at 500 billion dollars spread over 20 to 30 years. The White House and Congress reacted very negatively to this high cost, and human exploration was soon dropped from the United States future plans. SEI was not just a failure in itself, it delayed future human space programs.

E. Constellation Program (CxP)

President George W. Bush in 2004 requested that NASA plan for manned exploration after completion of ISS and retirement of the shuttle. The Constellation Program (CxP) was developed in the Vision for Space Exploration and detailed in the Exploration Systems Architecture Study. It had three major goals, completing ISS, a moon base, and a human flight to Mars, as in SEI and earlier plans dating back to the Apollo era. Work began in 2006 on the Orion crew vehicle and the Aries I rocket.

The Augustine Committee reported in 2009 that the CxP could not be completed with the planned funding. In 2010 President Barack Obama proposed to provide no funding for CxP, but strong criticism and congressional pressure led to continued funding for two major elements of CxP, Orion as the Crew Exploration Vehicle (CEV) and Aries I transformed into the Space Launch System.

Since the CxP was similar to SEI and was also cancelled due to too high cost, CxP could also be judged a failure. However, the two major elements of the actual CxP continue and should be successful. CxP, like shuttle, can be considered partly successful despite greatly reduced goals.

IV. Discussion of the possible success factors

The twenty-one possible success factors of Table 1 are listed in the categories initiation, political support, management, technical, direct benefits, and indirect benefits.

A. Initiation

Two factors in program initiation are the occurrence of some instigating event and setting a clear and significant goal.

1. Instigating event

All the U.S. space programs began with a presidential decision and new program announcement, but the causal events differed for each. A crucial challenge called for Apollo. Uri Gagarin became the first man in space in 1961, and the U.S. was faced with a further proof of Soviet technical and space superiority. The cold war competition in space exploration required the U.S. to show it could do something spectacular and Apollo was found to be suitable.

However the shuttle and ISS were initiated and succeeded after Apollo without a crucial event or fear of falling behind. A prompting trigger event can be important but is not necessary.

The trigger for SEI was the 20th anniversary of Apollo 11. CxP followed the Columbia tragedy and the decision to retire shuttle. These notable instigating events were not critical challenges to the U.S. and did not provide enough motivation to prevent the cancellation of SEI and CxP. Shuttle and ISS show that a strong driving event is not necessary, but Apollo shows that one can be very important.

2. Clear significant goal

Apollo had a clear significant goal. In 1961 President John F. Kennedy set the goal of "landing a man on the moon by the end of the decade and returning him safely to earth." The shuttle was to be a "space truck" and provide rapid turnaround inexpensive launch to low Earth orbit. The ISS itself is probably the most impressive and expensive engineering project ever accomplished.

Both SEI and CxP had the same three goals, space station, moon base, and Mars, and both SEI and CxP were cancelled. A single, simple, clear, attainable goal seems necessary for success. It defines the meaning of success and acts to unify and guide the program. An unfunded, unplanned Mars mission always 15 or 20 years in the future is not a sufficient goal.

B. Political support

Political support is needed from the president and Congress and desired from the scientific community and the public. An indirect effect of political support is protection from critical oversight.

1. President

Presidents have supported all of the U.S. human space programs considered here. The announcements by Presidents J. F. Kennedy, G. H. W. Bush, and G. W. Bush were mentioned above. President Ronald Regan announced Space Station Freedom in 1984. President Richard Nixon supported only the space shuttle but not the space station, moon base, and Mars visit suggested as post-Apollo programs. Clearly, presidential support is necessary for program initiation but not sufficient to ensure success through subsequent administrations.

But more significantly, the loss of presidential support is usually the end of human space programs. Nixon cancelled the last three Apollo missions. G. H. W. Bush lost enthusiasm for his own SEI. President William J. "Bill" Clinton downsized Regan's SSF to ISS after the collapse of the Soviet Union. G. W. Bush initiated the plan to retire the shuttle. President Barack Obama initially proposed to completely cancel CxP but under congressional pressure, supported the restoration of the SLS and CEV. Only ISS has not so far lost presidential support.

2. Congress

Since Congress controls the federal budget, no human space program starts or continues without specific congressional approval. Only SEI was denied all funding, but the ISS survived many close votes. Congressional pressure led to the restoration of the SLS and CEV elements of the cancelled CxP.

3. Science

In general, the science community did not support Apollo. An editorial in *Science* assessed the scientific return as practically none and suggested that more practical return could be obtained for much less investment. Robotic space exploration was preferred. (Compton and Benson, 2011) A *Science* poll of 113 scientists found that all but three of them thought there was no reason to rush a man to the moon. (Etzioni, 1964) (Madrigal, 2012)

4. *Public*

Space historian Roger Launius found, "(M)any people believe that Project Apollo was popular … but the polls do not support a contention that Americans embraced the lunar landing mission. Consistently throughout the 1960s a majority of Americans did not believe Apollo was worth the cost, with the one exception to this a poll taken at the time of the Apollo 11 lunar landing." (Madrigal, 2012)

It is doubtful that the existing low level of existing public support is very helpful to human space programs, or that greatly increased public support would result in large new efforts. The federal budget is a complicated political compromise and very popular programs often have difficulty getting funding.

5. *Limited oversight*

It can be argued that, rather than requiring strict control, system development organizations are more productive if they can be shielded from bureaucracy, second guessing, and external political distractions. This is the "skunk works" theory. NASA was severely criticized after the Apollo 1 fire, but the NASA administrator was allowed to establish an all government, largely NASA staffed, review board that blocked outsiders' access to information. (Benson and Faherty, 1978)

Later programs were not so shielded from criticism. The shuttle tragedies, Challenger and Columbia, were investigated by highly critical commissions. The negative Augustine Commission report led directly to the cancellation of CxP.

C. Management

A program's goal is usually understood to be to complete the mission as planned, on schedule, and within budget. Management methods have been developed to accomplish this, including planning, organizing, staffing, scheduling, and budgeting. Yet very few efforts are completed within the original scope, time, or cost. Many programs are cancelled or fail, and many are successful despite reduced scope, extended schedule, or overrun budget. The fundamental criterion of success is simply customer satisfaction. This means that success often can be achieved without providing what looks like good management or meeting the original goals for performance, time, and cost.

On the other hand, good management obviously increases the chance of success and should increase customer satisfaction. Four management issues that are important to the success of human space programs are fixed requirements, good plans and controls, open communication, and a safety culture.

1. *Fixed requirements*

Apollo had Kennedy's announced goal of "landing a man on the moon by the end of the decade and returning him safely to earth." This was clear and this was done. Fortunately budget was not mentioned then or constrained later. Shuttle and ISS had scope changes. Shuttle was initially to perform all government space launches but, except for Hubble, was limited to completing ISS after Challenger. It was very far from meeting the originally projected launch costs, which were based on much higher launch rates than achieved. The ISS was a reduced, Russian enabled down-scoped version of Space Station Freedom. Both SEI and CxP had broad and vague requirements including space station, the moon, Mars, and even "beyond" for CxP. This vagueness resulted in a lack of focus and frighteningly large projected total costs.

2. *Good plans and controls*

The decision to go to the moon followed a consideration of alternatives and advanced planning that guided Apollo. The space shuttle and space station were envisioned in Apollo era planning, but they were developed in a more contentious environment with multiple military and political stakeholders. The plans for both SEI and CxP were developed quickly in response to a presidential call, by small teams, and not published in detail or peer reviewed. The poor quality of SEI and CxP planning, their astronomical budgets and unresolved technical issues, at least foreshadowed if not directly caused their cancellation.

3. *Open communication*

A flat organization with open communication is considered better at innovation and problem solving than a steep hierarchical bureaucracy with rigid reporting rules. After the tragic Apollo 1 fire, safety was made central by an engineering culture that encouraged an environment of open communications, attention to detail, and ability to challenge technical assumptions. A post Challenger analysis found that NASA had changed to emphasize frequent flights, efficiency, obeying orders, and following rules rather than problem solving. "Structural secrecy," prevented effective action. (Vaughan, 1996) The Columbia Accident Investigation Board (CAIB, 2003) also emphasized the organizational barriers that prevent communication.

4. *Safety culture*

Open communication is generally helpful but it has been most mentioned as part of a good safety culture. The Apollo 1 fire review board recommended that NASA make safety more important than schedule. (Benson and

Faherty, 1978) Safety was made central in the Apollo engineering culture. "Reliability was a concern at all levels." (Oberhettinger, 2007) NASA had a good safety culture during Apollo but it was lost before shuttle, as noted by the Challenger and Columbia investigations. (Vaughan, 1996) (CAIB, 2003) These two tragedies that were due to insufficient attention to safety in design and operation make shuttle appear only partly successful.

ISS is considered successful even though it was developed in the post Apollo era of an inadequate safety culture. ISS itself does not experience the high risk launch or reentry with a crew aboard. Other hazards have been successfully avoided.

D. Technical

Two technical factors that are required to make a human space program a success are that it be feasible and affordable to accomplish.

1. Feasible

Before the Apollo program was announced, it was judged feasible. After Apollo, the shuttle and space station and even a moon base were clearly technically feasible. A Mars mission has not been shown to be technically feasible. We do not have a good plan or design, we have not solved problems such as the radiation and microgravity effects on health, and we have not demonstrated much of the needed technology. This provided an important reason for cancelling SEI and CxP and having NASA develop the needed capabilities instead.

2. Affordable

Apollo, shuttle, and ISS all had astonishingly high costs, far higher than anticipated. But regardless of how high they were, the costs were accepted and paid, they were actually afforded. But both SEI and CxP had estimated costs on the order of 500 billion dollars, which was clearly not considered affordable. Insufficient funds were provided for CxP and very little for SEI. This provided another important reason for cancelling SEI and CxP.

E. Direct benefits

Business invests money in facilities and projects that are expected to produce a financial return. Satellites for communications, weather, mapping, and positioning do pay for their development, launch, and operation. Human space missions provide other direct benefits, including prestige, space technology, exploration, defense, and science.

1. Prestige

The success of Apollo provided unequalled national prestige and universal approval. Shuttle provided less prestige because of the tragedies and perception of reduced NASA capability, while ISS substantially relied on Russian technology paid for by U.S. funding. SEI and CxP ended as embarrassments. A possible gain in prestige if successful is important in initiating human space programs.

2. Space technology

Testing and demonstrations in microgravity are necessary to advance space technology. ISS provides a very valuable platform for developing systems needed for transit to Mars. All human space programs advance space technology, even if they have other primary goals, and developing technology to expand into space is an important goal in itself.

3. Exploration

Human space programs provide new worlds to explore, the Moon for Apollo and Mars for the future. Shuttle and ISS did their work close to home. Exploration is sufficient to justify human space missions but is not always necessary.

4. Defense

NASA missions are civilian, but some have an intentional defense benefit. Space shuttle was partly designed to meet military requirements. The military currently operates a smaller size robotic version of shuttle. The ISS provides an observation platform and has conducted military experiments.

5. Science

Apollo provided lunar planetary science and shuttle and ISS support microgravity investigations. Science is the driver on robotic missions but has always taken a back seat on human missions.

F. Indirect benefits

Any large high technology program would produce advances in technology, jobs and economic stimulus, and interest in science, technology, engineering, and mathematics (STEM). It seems that human space programs lead to more advanced technology, more interesting jobs, and stronger public interest in STEM. The perceived urgency of stimulating these varies with the economic and political situation.

1. *Technology*

Space technology investment since Apollo has produced technology and even consumer spin-offs. A strong argument against spin-offs is that the resources spent in space would produce much greater progress if they were applied directly to solving current problems. This misses the point. Even though most research is usefully and practically dedicated to incrementally improving existing systems, only far out research on new concepts can produce radically new breakthroughs. We can not predict the path of future technology. Big steps make fast progress.

2. *Jobs*

Cold war military and space expenditures were deliberately used to stimulate the economy during recessions, but not Apollo, since it coincided with a boom and competed with Vietnam, the start of medicare, and the war on poverty. Existing large programs are difficult to cancel because they provide jobs and votes. The continuation of SLS and CEV has been disparaged as "a jobs program" by some with other priorities that would produce different but not yet voting jobs.

3. *Science, technology, engineering, and math (STEM)*

After Sputnik, and frequently since, the U.S. has wanted to stimulate interest and education in science, technology, engineering, and mathematics (STEM). Capability in these fields supports high technology business and defense efforts. The space program stimulates interest in STEM, and any human space program is more effective than robotic science, military, and commercial efforts.

The indirect benefits of technology, jobs, and STEM are important but not strictly necessary for two reasons. First, they are unavoidable, since any human space program will produce them. Second, they are poor justifications for any particular human space program, since any human space program or other large high technology program will produce them. The political conflict between programs is partly motivated by the different technologies they develop and jobs they produce.

G. What factors are necessary for success?

The necessary factors for success in human space programs are clear and they are indicated in Table 1. For a human space program to be successful, it must have a goal that is clear and significant, and also feasible and affordable. To be initiated and continued, it must have the support of the president and Congress. A successful program must have a strong safety culture if it presents significant risk to human life and it must provide direct benefits. The benefits of human space programs, if successful, always include prestige and advancing space technology. The benefit of exploration is not always present and is not necessary, but when present is a major justification and motivation.

Viewed negatively, the direct causes of failure are loss of political support, neglect of safety, and lack of a feasible and affordable approach. Public support, good management, advancing science, and the indirect benefits of technology, jobs and support for STEM, however estimable, are inessential and either dispensable or unavoidable.

The Apollo program can be taken as the archetype, the perfect example, of a successful human space program. It has the all the eight necessary success factors plus exploration and, of the twenty-one important factors, it lacks only political support from science and the public and a direct military defense benefit. The also successful ISS has the seven of the eight necessary and important factors, lacking only a safety culture, and has twelve of the twenty-one listed. The marginally successful shuttle has the same seven of the necessary and important factors, more significantly lacking a safety culture, and the same twelve of the twenty-one factors. Shuttle is less successful than ISS because in shuttle the lack of the necessary safety culture in a high risk launch and reentry mission resulted in the tragic deaths of astronauts. The many other differences between Apollo and the shuttle and ISS include the latter's lack of an instigating event, of good management, and of a major exploration mission. These are important but apparently not necessary success factors.

The SEI had only three of the eight necessary factors plus exploration, and eight of the twenty-one total. The CxP had four of the eight necessary factors plus exploration, and ten of the twenty-one total important factors. Both had but later lost presidential support, a fatal lack for SEI but reversed for CxP. CxP always retained a necessary success factor, congressional support, but this powerful factor has preserved the two key parts of the CxP, the launch vehicle and crew capsule. SEI always lacked congressional support and went nowhere. The most notable deficiencies of both SEI and CxP were the lack of technical feasibility and affordable cost. The CxP also suffered from a lack of goal clarity and a low prestige initial mission to return to the moon but may well be successful in achieving its revised limited goals.

The eight necessary success factors for a human space fight program are a clear significant goal, political support from the president and Congress, a safety culture if needed, technical feasibility, affordable cost, and the direct benefits of prestige and space technology. Exploration is an important motivating goal, especially if it is clear, significant, and relatively soon, as in Apollo.

V. Apollo is different

The process of identifying the success factors in NASA human space programs began by identifying similarities and common factors as if all successful space programs were basically alike. Comparing Apollo, space shuttle, ISS, SEI, and CxP showed significant differences. Apollo, SEI, and CxP had an instigating event and the goal of exploration, but only Apollo was successful. Shuttle and ISS did not have a destination and timeline but were started more because something had to be done and they were the obvious next steps. SEI and CxP can be viewed as failed attempts to start another Apollo program with Mars as the goal. Table 1 tells us that Apollo had the all the eight necessary success factors plus exploration, while SEI and CxP lacked a clear goal, sufficient political support, technical feasibility, and affordable cost. Despite their similarities, Apollo was significantly different from SEI and CxP in an aspect that can be called political will. Sufficient determination produced Apollo with a clear goal, feasible approach, and very substantial funding. Insufficient political will failed to do so for SEI and CxP. Although Shuttle and ISS were tremendous efforts, they were less extraordinary than Apollo and had much more political difficulty.

Of all the human space programs, the Apollo program has the most interesting, inspiring, and often fabulous history. The Apollo 11 landing the moon will forever be a landmark in human history, even though we hope it will not be the farthest milestone ever reached. Hindsight looking back nearly fifty years and the halo of glorious success make Apollo seem nearly perfect. Later human space programs, however impressive, have barely escaped Earth's atmosphere. Both literally and metaphorically, shuttle and ISS fall far short of Apollo.

Apollo raises interesting questions. Does everyone understand what happened? Will a Mars mission be like Apollo? The answers seem to be "No."

A. The Apollo romance

The Apollo story usually describes President John F. Kennedy as a strong and decisive leader, tragically fallen, whose vision of sending a man to the moon within the decade was carried out by his worthy successor Lyndon B. Johnson, who was the equally dedicated co-deviser of the Apollo program. Congress and the people strongly supported Apollo. A lavishly-funded crash effort of more than 400,000 exceptional, dedicated people carried on through high risk and tragic loss to achieve an unparalleled success, watched and applauded around the world, destined to be famous forever.

Then came Richard M. Nixon, a tragically flawed president, who stopped Apollo flights to the moon and disapproved the plans and disappointed the hopes for a space station, moon base, and Mars mission. He left only the space shuttle, cursed with an unsafe design and destined to be operated by a deteriorating organization with tragic results. Since Apollo, no one has gone beyond low Earth orbit.

All this is basically true, but the events are explained as due to decisive leadership and forceful execution, to right choices and wrong choices freely made. The role of the Soviet Union is often unmentioned. Where in this story are the Soviet space milestones, the first satellite, dog, man, pair, and woman in space, the first space walk? The cold war led to much more than Apollo, including military buildup, a missile race, the Vietnam war, and the extensive educational, social, and political reforms of the 1960's. People bought guns, build bomb shelters, and learned Russian. We forget that we did not just get an isolated inspiration to do Apollo, it was characteristic of the times. The Apollo era was the 1960's, more vivid and intense, more progressive and hopeful than any time since.

The fundamental error in the Apollo romance is that it is wrong to believe that all it takes is a good, strong, right thinking leader to implement our vision of space exploration. This view has been recently asserted and rebutted. "Logsdon calls for John F. Kennedy-style leadership to serve as a catalyzing mechanism capable of ushering in a new era of U.S. human spaceflight." But the author objects that "JFK-style leadership during successive presidencies … led to distinctly different results." (Perrino, 2014)

B. The Apollo reality

Apollo started with Kennedy's announcement and culminated with the moon landings. But repeated presidential announcements of new programs have shown that an announcement is not enough. And the problem is not that the follow-up to the later program announcements was insufficient, it's that the other necessary conditions for a successful program were not met. In space programs as in everyday life, what people do depends more on the motivating circumstances than on their desires and resolutions. The U.S.-Soviet cold war, the world-wide geopolitical struggle between capitalism and communism, the dramatic sequence of Soviet space successes, motivated Kennedy and the U.S. government to make many risky, costly countermoves including the Apollo program. The Apollo story unfolded as it did because of the urgency, intensity, and endurance of the initial motivation. The key success factor is not a willful commitment by political leaders but international political necessity.

The role of the cold war in motivating space efforts is clear. Human space program expenditures followed changes in cold war tensions. Kennedy initiated Apollo after Gagarin became the first man is space, but, hoping to reduce tensions and costs in 1993, he proposed U.S.-Soviet cooperation in space. (NASA SP-4209) Nixon pursued detente and reduced space plans and expenditures. The Apollo-Soyuz joint 1975 U.S.-Soviet flight symbolized better relations and the end of the space race. Clinton de-scoped Space Station Freedom into the U.S.-Russian International Space Station after the collapse of the Soviet Union. Current tensions with Russia over Crimea and Ukraine are producing suggestions for more U.S. investment and independence in space.

VI. Challenge and response

The Apollo narrative can be told as a sequence of challenge and response. In Apollo, the Soviet threat inspired the Apollo vision, and the Apollo 1 fire tragedy focused the Apollo program on safety and reliability. We needed the political challenge of Soviet space success to inspire the vision and the technical challenge of a tragic failure to focus the development. The Soviet challenge was faced successfully on all fronts, not just the space race.

Challenge and response is a well known theory of history. It explains much in space history and suggests one possible future.

A. The theory of challenge and response

Arnold J. Toynbee was once a widely read historian whose twelve volume "Study of History" explained the rise and fall of 28 human civilizations using his theory of challenge and response. Civilizations are created in response to some difficult challenge, by making social changes to implement a creative solution to the problem. Civilizations fall when they are unable to cope with internal or external challenges. This theory is extensively illustrated with historical detail, but in its most simplified form it is obvious. Existing organizations survive in current conditions, but changes continually occur. The organization either successfully adapts to change or it fails. Organizational adaptation and growth is a successful response to some internal or external change. (Wikipedia, Arnold J. Toynbee)

Any nation faced with an existential threat will respond as strongly as it can. The Soviets launched Sputnik and the U.S. established NASA, they launched Gagarin and the U.S. responded with Apollo. The success of the Apollo moon landing was made possible by U.S. political, technical, and economic superiority. This overwhelming capability was itself produced by an open, free democratic society based on markets, corporations, and government agencies. The cold war and space race were a dramatic but limited contest between opposed social systems. The Soviets finally lost hope of winning and fear of loosing and just gave up.

Many large high technology government programs can be explained by the theory of challenge and response. These include the development of atomic and hydrogen bombs, nuclear submarines, intercontinental ballistic missiles, and the "Star Wars" missile defense initiative. The nature of the adversary and the form of the challenge determine the mode of the response. The Soviets had a modern ideology and a rational, scientific, technical orientation that inspired a symmetrical response, a competitive race to the same goal. The U.S. response to the terrorist attacks of 9/11 increased government spending, created jobs, and led to the development of new technological systems, but did not increase interest in and support of STEM. The new anti-terror technologies such as surveillance by cameras and drones, monitoring telephone and internet communications, and metadata analysis are not especially inspiring. The terrorists' beliefs are anti-modern and attractive to few. But even radically different societies in conflict can exchange ideas and methods, such as modern cell phones and barbaric methods. The Soviets were much more dangerous, much more inspiring. Apollo was a major part of a "Clash of Civilizations."

On a lesser scale, within ourselves and our projects and our organizations, the formula for success is facing reality, choosing the right goal, and then doing what must be done to achieve it. But usually we face a disturbing reality and take strong action only when forced to by a disturbing event. And the reality we must face is never of our own choosing. A good challenge is one that inspires our highest vision, that our best efforts can overcome, that leads us in a new creative path. Such was Apollo.

B. Challenge and response in U. S. space programs

The unequalled challenge of the Soviet missile build up and space successes threatened global domination and destruction. It was sufficient to motivate the space race and the Apollo program. During the Apollo era, it inspired future plans to build a space shuttle, space station, and moon base and go to Mars. But Nixon's conciliatory foreign policy did not require these plans, and he believed the public did not want them and the country could not afford them. Space programs lost their high priority and had to compete on an equal basis with other discretionary programs. (Logsdon, 2015) The challenge of the space race produced the success of Apollo and continuing hopes and plans for a moon base and Mars mission.

The shuttle and space station were responses to the lesser challenge of our own expectations, the question of "Now what?" These completed developments continued the Apollo era vision. But after them, the SEI and CxP initiatives were unsuccessful responses to the "What next?" challenge of expectations. If we believe that we just spontaneously chose to go to the moon and to explore space of our own free will, then we naturally expect to continue in the same way. But if we recognize instead that we established Apollo at a particular time to regain lost prestige, to demonstrate technological power, and to display economic strength by unmatchable expenditure, then we can accept that the priority of human space programs must decline when these motivations disappeared.

Each human space program has its own external and internal challenges and responses. Budget cuts and de-scoping severely affected shuttle and ISS and eliminated SEI and the future elements of CxP. The safety challenge of Apollo 1 was successfully dealt with, but that of Challenger was not.

VII. After Apollo, slow steps to Mars

Since Apollo, developing space technology capabilities has been the primary goal of human space programs. First the shuttle was developed, then the station, and even CxP focused on SLS and CEV. Going back to the moon and on to Mars have been postponed to the future. Some space enthusiasts want another mission like Apollo, but the president and Congress have seen no need for such a program. There has been no great necessity to set aside everyday priorities. A new challenge similar to the cold war threat is not expected. Regardless of all the visions and plans since Apollo, the actual, operative, funded space policy has always been to develop capabilities.

A. Developing technological capabilities and using stepping stones

The challenge for U.S. human space programs has been the same since Apollo, "What next?" The vision of the Apollo era planning, SEI, and CxP has been shuttle, station, moon base, and Mars, but this sequence of destinations was directly repudiated with the cancellation of CxP. President Barack Obama explained the administration position.

> "Now, I understand that some believe that we should attempt a return to the surface of the Moon first, as previously planned. But I just have to say pretty bluntly here: We've been there before. Buzz has been there. There's a lot more of space to explore, and a lot more to learn when we do. So I believe it's more important to ramp up our capabilities to reach -- and operate at -- a series of increasingly demanding targets, while advancing our technological capabilities with each step forward." (Obama, 2010)

This approach has been continually strongly endorsed by Congress.

> "The NASA Authorization Act of 2015… continues the consistent guidance Congress has given to NASA for nearly a decade by reaffirming a stepping stone approach to exploration." (Cowing, 2015)

Developing capabilities and using stepping stones has its difficulties. Without a defined mission to a particular destination, it is difficult to identify and prioritize the capabilities to be developed. This has led to a search for destinations that can be reached with the SLS and CEV that are being developed. Earth-moon libration points and a near-Earth asteroid are reasonable but unconvincing candidates. There is nothing at the libration points and the near-Earth asteroids are too far away. A solution to this is to bring a near-Earth asteroid to a libration point.

The ultimate goal remains Mars. The solar system provides only one stepping stone on the way to Mars, Earth's moon. But the moon that was too distracting during CxP is now considered too boring.

B. Post Apollo NASA

An organizational sociologist claimed that during Apollo NASA came close to being "a perfect place," the best possible organization to accomplish its particular goal. But its clarity, support, and technical ability "are gone and will probably never occur again." (Logsdon, 2011)

After Apollo NASA became a less exceptional government agency, and had to compete with defense, scientific, and social programs for its share of the discretionary budget. NASA's challenges were no longer geopolitical and technical, but locally political within the government and the space industry. In this different less nurturing environment, additional political skills are required for success. In the competition for funding, it is expedient to exaggerate benefits, minimize costs, and downplay reliability and safety issues that hint at risk of failure or injury. These less admirable capabilities of post Apollo NASA are those of a typical government bureaucracy. They are surprising only in contrast to the above-the-fray purity of Apollo era NASA.

C. How will we get to Mars?

If a high cost crash program like Apollo is never repeated, how will humans get to Mars? The approach of developing capabilities and using stepping stones has been established. We need to produce a technology development plan and implement it to develop the capabilities needed. Some elements needed for a Mars mission, the SLS and CEV are under development now. The deep space habitat, lander, surface habitat, rover, and ascent vehicle are deferred to the future. The human habitat systems must operate reliably for many months and will require long testing to identify problems, make redesigns, and verify them. Some plan is needed to guide system development in a logical and efficient way. Developing the Mars mission technology will take hard work and a long time. If a surprise need arises for a high priority Mars mission similar to Apollo, we will be better prepared. If not, our slow and steady efforts to develop technology and the general growth in technology and the economy will get us to Mars eventually.

VIII. Conclusion

A list of suggested success factors for human space projects was developed. Apollo, the space shuttle, the International Space Station (ISS), the Space Exploration Initiative (SEI), and the Constellation Program (CxP) were judged as successes, partial successes, or failures. The presence or absence of the suggested success factors was evaluated for each project. For a human space project to be successful, it must have a clear significant goal, political support from the president and Congress, a safety culture if significant human risk is involved, technical feasibility, affordable cost, and also provide prestige and advance space technology. In the case of Apollo, exploration of the moon was an important motivating factor, but the space shuttle and ISS did no exploration.

Apollo is fundamentally different from the other space programs, even though it shared the same success factors, because all the success factors were present in much greater intensity. The clarity of the goal, the amount of political support, the safety culture, the funding provided, and the prestige gained were far beyond all other human space programs. The political will to go to the moon was so great because it was a response to the challenge of the Soviets, the cold war, missile race, and space race.

Since Apollo, NASA has focused on developing space technology capabilities, such as the shuttle, space station, and now a rocket and crew capsule. With no expectation of an Apollo-like Mars mission, NASA should be improving technical feasibility and reducing cost for Mars. A stepping stone approach will be followed to demonstrate capabilities.

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