



Project Apollo Lights the Way for Acquisition Success

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It has been just over 40 years since the fulfillment of President John F. Kennedy's goal of "landing a man on the moon and returning him safely to the earth." As we reflect on this technological triumph, we find numerous examples of acquisition best practices and lessons learned, many of which are manifest in our current DoD acquisition management system. From its earliest stages, the U.S. space program pioneered and implemented many innovative ideas and best practices—often out of necessity—and many of those ideas have evolved and are now common tenets of today's defense acquisition practices.

Project Apollo

In the early days of the space race, a new program, named Project Apollo, emerged as America's way to the moon. A developmental effort from the boosters up, Project Apollo initially had two major manned sub-systems—the Command and Lunar modules—and eventually gained a third sub-system called the Lunar Roving Vehicle, or Lunar Rover for short.

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The Command Module was designed to carry a crew of three astronauts into orbit, then eventually return them safely through a fiery reentry and splashdown in the ocean. Prior to being launched, it sat atop a huge three-stage rocket that stood nearly at 363 feet—58 feet taller than the 305-foot Statue of Liberty—and had a diameter of 33 feet. The Lunar Module was located two stages below the Command Module on the rocket. It was a relatively fragile ship, with a cabin barely larger than the combined volume of two telephone booths. It provided adequate room for two pressure-suited astronauts, and no more. Its walls were about as thick as several layers of aluminum foil, and it was incapable of withstanding reentry into Earth's atmosphere.

Non-Developmental Items

The creation of the Command and Lunar modules and the Lunar Rover began with the Soviets' successful launch of Sputnik, the world's first manmade satellite. The National Aeronautics and Space Administration was desperate to respond to that achievement, and as a result, the organization resorted to what today we would call a non-developmental item. NASA started the Mercury and Gemini programs, which were the United States' first tentative flights into space, using existing inter-continental ballistic missile boosters and technologies from the Redstone, Atlas, and Titan missile programs. NASA engineers made reliability and safety modifications to the missiles so human life wouldn't be endangered by their use.

The nation's reputation as a world power was riding on this non-developmental but still cutting-edge technology. That same cutting-edge technology provided the foundation for the United States' early research, testing, and demonstration procedures and processes, such as ensuring a spaceship could rendezvous and dock—necessary steps in the United States' quest to win the race to the moon.

Cost and Risk

Today, we routinely cite cost as an independent variable while concurrently trying to balance schedule and performance as dependent variables; and NASA found balancing independent and dependent variables equally as difficult as we do today. President Kennedy set a schedule of "this decade" [*the 1960s*] as the independent variable. NASA soon came to realize the hard way—what we, in many cases, have yet to recognize today—that there is a fundamental law of acquisition: Program cost, schedule, and performance risks are inversely proportional to the respective weighted relative importance of those same variables. Therefore, if an accurate program estimate exceeds the set limit for the independent variable, then the risks for one or both of the other two dependent variables will be elevated beyond established acceptable limits.

The prime example of that fundamental law in the Apollo program was the tragic launchpad fire of Apollo 1, killing astronauts Gus Grissom, Ed White, and Roger Chaffee. Fol-

lowing that tragedy, NASA coined the term "go fever" to describe what happens when schedule is permitted to reign supreme at all costs. Echoing that same sentiment, we say these days, "If you want it bad, you get it bad."

In the Apollo program's rush to meet schedule, acceptable performance risks were exceeded. Then, as now, the response was the necessary redesign and rebaselining of the program. Following that loss of three lives, NASA spent two years and millions of additional dollars to get back on a course for the moon with a totally redesigned Apollo capsule.

Managing the Pace of Change

Another initiative evident in Project Apollo that applies to today's acquisitions is the idea of design freeze to stem requirements creep—and that happened with the Lunar Module. NASA engineers correctly recognized that effective manufacturing planning and implementation could not be achieved with a constantly changing configuration; however, some design modifications were still necessary after the design was frozen. Those changes required rigorous reviews and prudent control. The risks associated with the delicate balance of making design modifications became apparent in the fifth Lunar Module manned flight, when it was discovered the onboard carbon dioxide scrubbers were not standardized with those onboard the Command Module. That almost became a fatal oversight, but was fortunately identified and overcome by creativity and ingenuity. The idea of design freeze and configuration control was clearly an early precursor to what today we call configuration steering boards.

Expanding Our Capabilities

One well-known but seldom-studied system from Project Apollo is the Lunar Rover. Taking some literary license, we can see how the evolution of that system best illustrates the logic and utility of our current defense acquisition management system.

Early on in the Apollo program, Director of NASA's Marshall Space Flight Center Dr. Werner von Braun and NASA engineers and scientists knew they wanted to be able to explore the lunar surface beyond the immediate landing sites—there were limitations as to how far an astronaut could explore on foot. Just as the Joint Requirements Oversight Council now validates DoD requirements, NASA implemented a process to study and evaluate the capabilities necessary to meet their requirements. This work was similar to what we in DoD now refer to as a capabilities-based assessment. Von Braun and his staff were convinced of the practicality of the idea and developed a plan to pursue a materiel solution; and in today's terms, an initial capabilities document was born. With the equivalent of an approved initial capabilities document in hand, a materiel development decision was also approved and an initial materiel solution analysis was begun.

Evaluating the Options

A primary activity during the materiel solution analysis phase is to conduct an analysis of alternatives, which analyzes operational effectiveness, suitability, and life cycle costs of the alternatives that satisfy the established capability needs. However, the decision to begin the materiel solution analysis phase does not mean that a new acquisition program has been initiated.

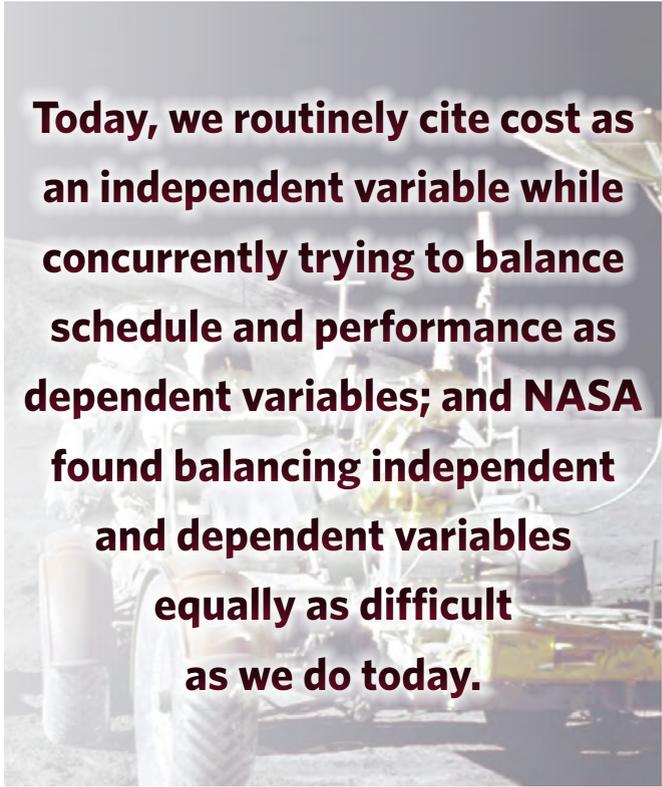
Because of the lack of understanding of what kind of terrain a lunar vehicle would encounter on the moon, many types of locomotion were considered, including an Archimedean screw device, a wide range of wheel types, and track designs. After the 1962-3 unmanned lunar probes provided more detailed data about the moon's surface, scientists and engineers were able to make some design decisions.

NASA's initial concept for the Lunar Rover vehicle was a self-contained version that could transport two or three astronauts and provide sufficient living space for up to a two-week excursion on the moon. It soon became evident that a vehicle for such a mission would weigh approximately 8,000 pounds and would require a dedicated Saturn launch rocket (meaning it couldn't travel with the Command and Lunar modules). NASA quickly realized that the cost and complexity of that plan were not acceptable, and subsequently revised their plans.

As previously stated, the intent of the material solution analysis phase is to determine what solutions should be pursued or developed, if any. In the case of the initial Lunar Rover program, the materiel solution analysis process worked as expected, eliminating unfeasible options. In fact, none of the technologies investigated warranted further pursuit because of mission constraints. In particular, the alternatives considered were not realistically achievable because the costs associated with transport to the moon were too high in terms of tradeoffs and actual dollars.

One of the primary participants considered in the initial analysis was General Motors, and the company was determined that if there was to be a car on the moon, they were going to make it. They were willing to invest corporate funds to realize that vision, and their dedicated and innovative engineering team began to ask questions. What could be transported on the existing Lunar Module? What size? What weight? They learned there was a wedge-shaped bay onboard the Lunar Module that was available to carry a small Lunar Rover.

The allotted cubic space and weight restriction would be critical design factors for the vehicle. Such a vehicle would not support the two-week excursion originally envisioned by NASA, but it would allow the astronauts to venture beyond their limited walking range. After two General Motors engineers demonstrated an ingenious prototype to von Braun, NASA decided to proceed once more with developments for a Lunar Rover. In a classic example of capability tradeoffs,



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NASA reduced the requirements for the Lunar Rover from a vehicle that could transport two or three astronauts for a two-week journey to one that could simply extend the astronauts' range on the moon and could be transported on the Lunar Module.

Maturing and Prototyping the Technology

With the benefit of hindsight, we would now say that NASA was entering what the defense acquisition community calls the technology development phase. The Lunar Rover had already made a long journey up to this point—but the journey was only just beginning. Although General Motors had developed an innovative and promising design, that did not guarantee them the contract award. NASA conducted full and open competition for the Lunar Rover contract.

Grumman Aircraft Engineering Corporation, the builder of the Lunar Module, entered a prototype that was a strong contender. It was a close competition, and Grumman very nearly won the bid with a design featuring conical wheels that could be removed and stowed together to save space. Grumman's design also had the capability to be remotely operated from Mission Control, even after the astronauts had returned safely home. But in the end, the ease of deployability was the deciding factor, and General Motors (partnered as a major subcontractor under Boeing), won the bid. Like a detachable Murphy bed with wheels, the General Motors design featured spring-loaded hinges that allowed for minimal exertion of the astronauts' energy and time—it literally sprang out of the cargo hold. Although the Grumman design featured somewhat more robust performance characteris-

tics, it also required a substantial amount of time and energy to assemble—resources that were just not available based on the limited supply of consumables.

Once the competitive prototypes were evaluated, a contract was awarded to the General Motors Defense Research Labs—although Boeing was the prime contractor, the design was General Motor’s baby. What we today call the engineering manufacturing and development phase began. The hard part was yet to come—actually building a vehicle that would fit onboard the Lunar Module and operate on the lunar surface once it arrived. Engineers faced the task of reducing technology risk through the maturing of critical technology elements. Additionally, the team had a very aggressive schedule of delivering the Lunar Rover—it had to be delivered in just 17 months if it was to be incorporated into Apollo 15.

From the onset of the program, deployability and weight were the two attributes of the Lunar Rover considered critical to the operation of the system. Today, we would call them the key performance parameters for the system. If the Lunar Rover could not be stored in the 5x5x5-foot wedge-shaped space in the Lunar Module, then it would not get to the moon. Furthermore, if the astronauts were not able to easily deploy the Rover once they arrived on the moon’s surface, it would be of little value.

Because the Lunar Module hovered over the moon’s surface looking for a spot to land, weight of the vehicle was critical. Every ounce of additional weight carried meant a decrease in the available hover time for the Lunar Module pilot to find a suitable spot to land. Therefore, the Lunar Rover’s maximum weight, or threshold, was set at 400 pounds. Of course, there were other key system attributes that had to be considered, such as reliability.

Some of the technology development efforts General Motors undertook included developing a battery that both weighed less than 10 pounds and could dissipate heat during operation, capitalizing on the properties of wax to ab-

sorb the heat while in operation and then cool and dissipate that same heat when the Rover was not running. Another technology issue was that the dust on the moon adhered to everything it touched, so the engineers and scientists had to develop a wheel capable of shedding dust so it wouldn’t build up on and around the hub and brakes. Their successful approach to that challenge resulted in a wheel constructed of woven piano wire.

The Rover in Action

The engineering manufacturing and development phase ended on schedule after 17 months, with delivery of the first Lunar Rover to NASA on March 10, 1971. The Lunar Rover was first used on July 31, 1971, during the Apollo 15 mission. The mission wasn’t without problems, however. Once deployed on the moon, the Apollo 15 crew experienced problems with the front-wheel steering. Fortunately, the Lunar Rover also had rear steering, so the mission could continue. Thus, as that experience proves, even if significant developmental testing and operational assessments are done on a system, problems still can occur during operational testing on a deployed vehicle.

During the Apollo 15, 16, and 17 missions, the Lunar Rover traversed approximately 56 miles, allowing the astronauts to explore the moon’s surface to an extent never before achieved.

Learning From the Past

The significance of the achievements and innovations of the Apollo program, and more specifically, the Lunar Rover program, is not lost over time. Even though the NASA engineers at that time didn’t have the structured DoD acquisition management system to guide them as we do now, they still used a very systematic approach to acquiring the Lunar Rover and other Apollo systems. That systematic approach, when applied deliberately, led to great programmatic success for Project Apollo, as the Lunar Rover success demonstrates.

However, as expressed in a recent interview with current U.S. astronaut Heidemarie Stefanyshyn-Piper (captain, U.S. Navy), who flew on space missions STS-115 and STS-126, “The biggest change has been our acquisition strategy. We are no longer in a space race, and cost is a far greater concern.”

The same disciplined approaches of the Apollo team members are as valid today, if not more so, than they were 40 years ago. The lessons and principles still apply in the strategic and tactical execution of programs, whether in support of a mission to the moon or providing for the daily support and protection of our troops.

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