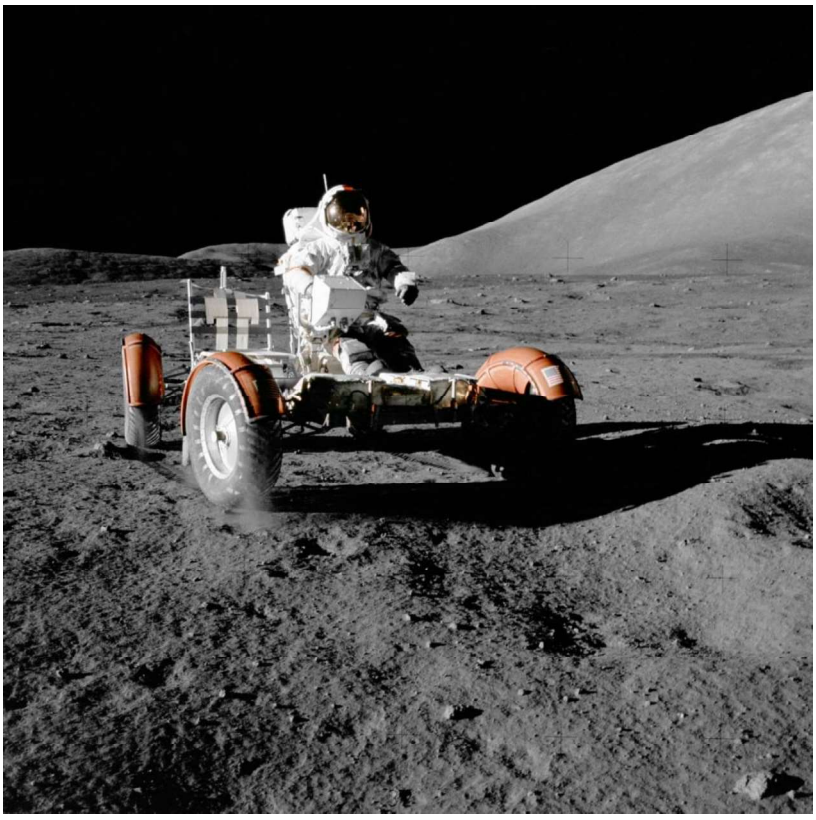
The Lunar Roving Vehicle (LRV): Technical Specifications and Performance Data

- **Prime Contractor: Boeing; Prime Subcontractor: General Motors (Delco Electronics);** developed under the aegis of the Marshall Space Flight Center in Huntsville, Alabama. [Original design concept was a General Motors idea.]
- **Lunar Rovers were carried to the Moon on the final three landing missions: Apollo 15, 16, and 17.** The LRV made the "extended stay" missions worthwhile, because of the distances the astronauts could now traverse.
- **Number Built: 3 flight articles for the Moon, & 7 training vehicles. [56 miles traversed on the Moon by 3 LRVs.]**
- **Size: 10 feet, 2 inches long.**
- **Portability:** the LRV had to fold up to fit in a triangular space in the LM Descent Stage that was only 5' tall, 5' wide, and 3' deep.
- **Weight: the LRV weighed 471 lbs. and could lift and transport 1,064 lbs.,** or over twice its weight. Its 1,064 lb. payload included about 400 lbs. for each astronaut in his space suit, along with 264 lbs. of tools, rock samples, and experiments.
- **Propulsion: four (4) sealed electrical drive motors,** one for each wheel; **.25 hp each, ran on 36 v D.C.**
- **Batteries: two (2) 27 kg. silver oxide-zinc batteries** mounted on the forward chassis; **36 v D.C. per battery.**
- **Steering:** Separate, independent **front and back steering.** (The front steering failed on Apollo 15's LRV, but the vehicle still operated satisfactorily using only the rear steering.)
- **Speed: on a level surface, about 8-12 kph;** upper limit of about 10 mph.
- **Maximum Range: 57 miles each (based on battery power);** far more distance than would ever be used, because of walk-back limits imposed for safety reasons.
- **Agility:** Because of its 32-inch diameter wheels, and 14 inch ground clearance, the LRV could cross crevasses 27" wide, and drive over obstacles almost a foot high. **It could climb hillsides as steep as 25 degrees.** The parking brake could hold the vehicle on a slope as steep as 30 degrees.
- **Stability:** its low center-of-gravity prevented the LRV from tipping over, even at pitch and roll angles of up to 45 degrees.
- **Wheels:** each of the four wheels was constructed of **see-through piano wire mesh, woven around a core of resilient titanium "bump-stop" bands.** The titanium bands came together in a "V" shape to provide traction.
- **Communications: high-gain S-band antenna for T.V. picture transmission** only when vehicle was stopped (because aiming the antenna toward Earth was critical and this had to be done manually, and remain stationary); a **low-gain antenna for audio comms with Earth** could be used when the vehicle was moving, to maintain voice contact with the astronauts while they were driving; **RCA color T.V. camera, controlled by the ground in MCC in Houston** (vacuum tube design with one imaging tube, using filter wheel with six color filters spinning at 10 rps, operating at 60 fps).
- **Control Panel:** was centerline, and the T-handle/joystick could be used by either astronaut.

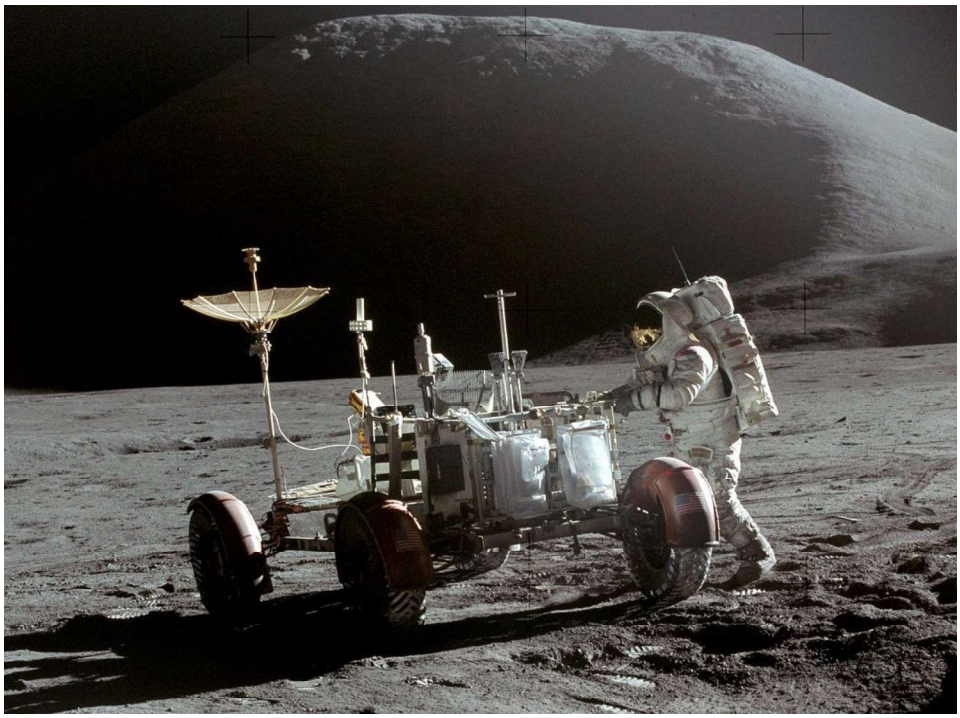
Lunar Roving Vehicle on the Moon at Taurus-Littrow

(Apollo 17 Commander Gene Cernan "in the driver's seat;" note that high-gain antenna for T.V. transmission, audio comm. low-gain antenna, 16 mm camera, and T.V. camera are not yet erected.)



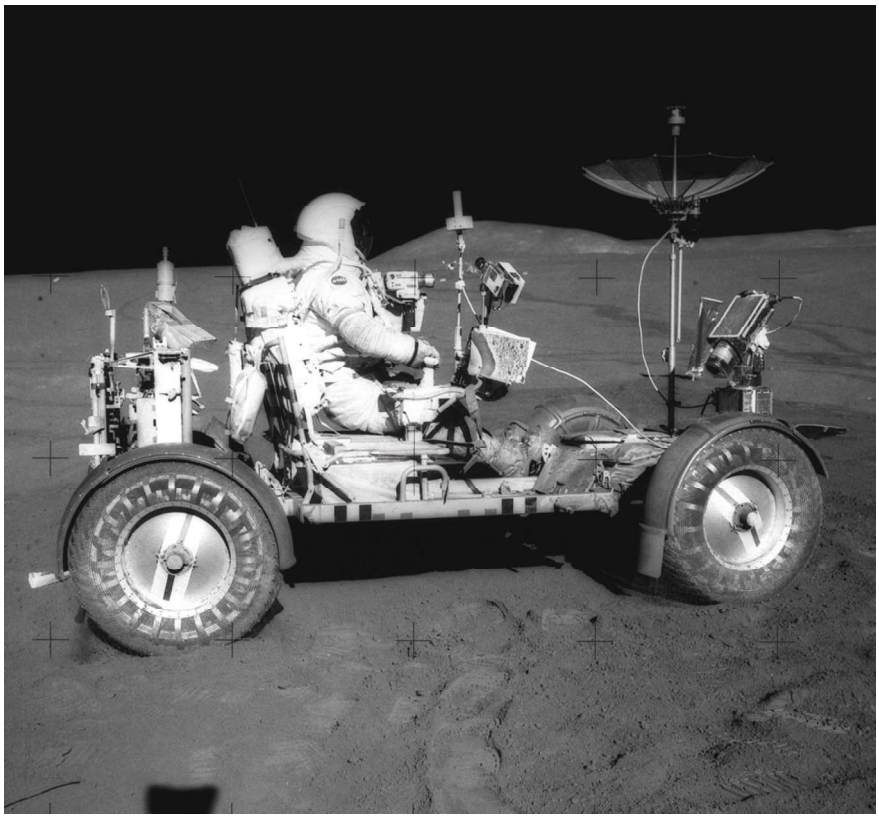
The Lunar Rover at Hadley-Apennine (Apollo 15)

(LMP Jim Irwin provides scale; note high gain antenna for T.V. uplink; low-gain antenna for audio comms; and behind it, the T.V. camera wrapped in gold Mylar.)



B&W Image of Apollo 15's Lunar Roving Vehicle on the Moon at Hadley-Apennine

(Note, left-to-right: CDR Dave Scott; audio low-gain antenna; 16 mm movie camera; high-gain antenna used for T.V. transmission; and T.V. camera.)

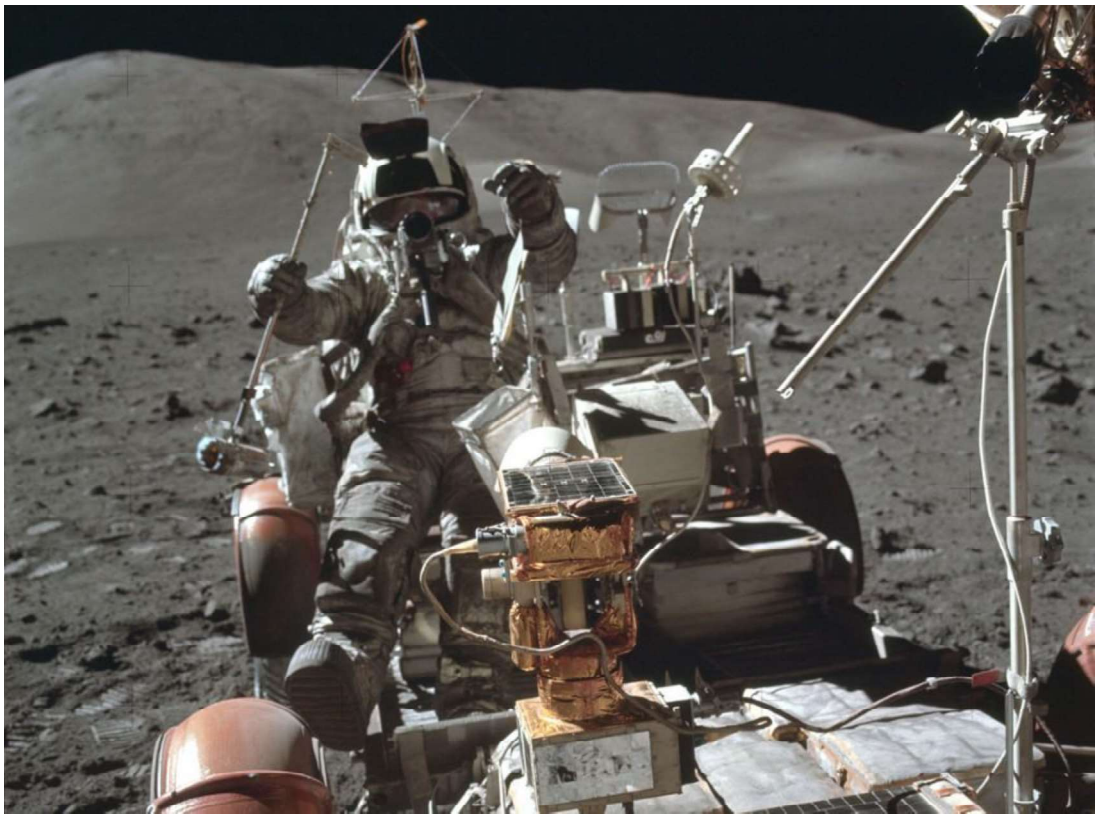


The Lunar Rover at Taurus-Littrow

(Note T.V. camera, battery compartments, and high-gain antenna at front of LRV; and white low-gain comm. antenna at center of LRV)

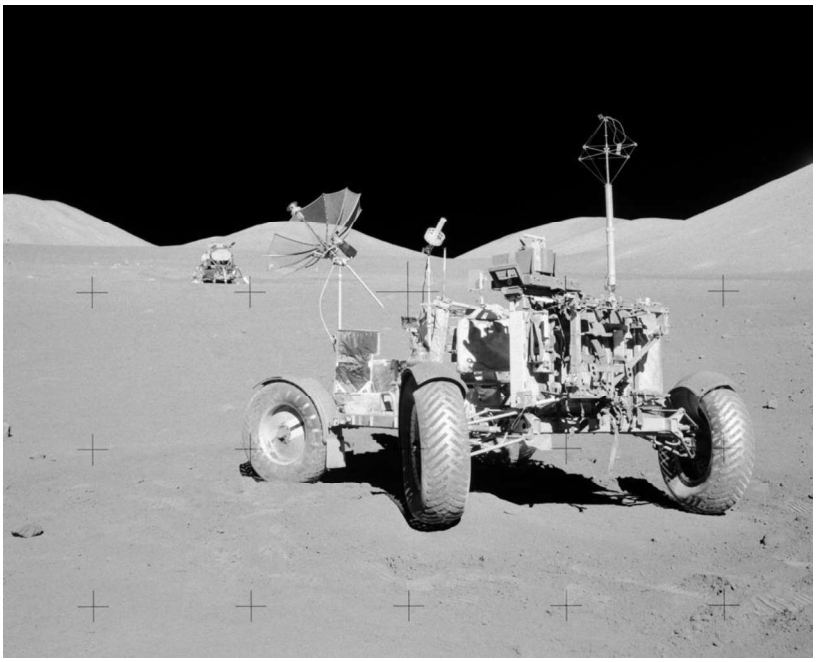
Sitting in the Lunar Roving Vehicle Could Be Awkward (At Best)

(Even the improved pressure suits for the "J" missions were still quite stiff.)



Apollo 17's Lunar Rover at Taurus-Littrow

(Note structure of wheels; see next slide for close-up at NASM.)

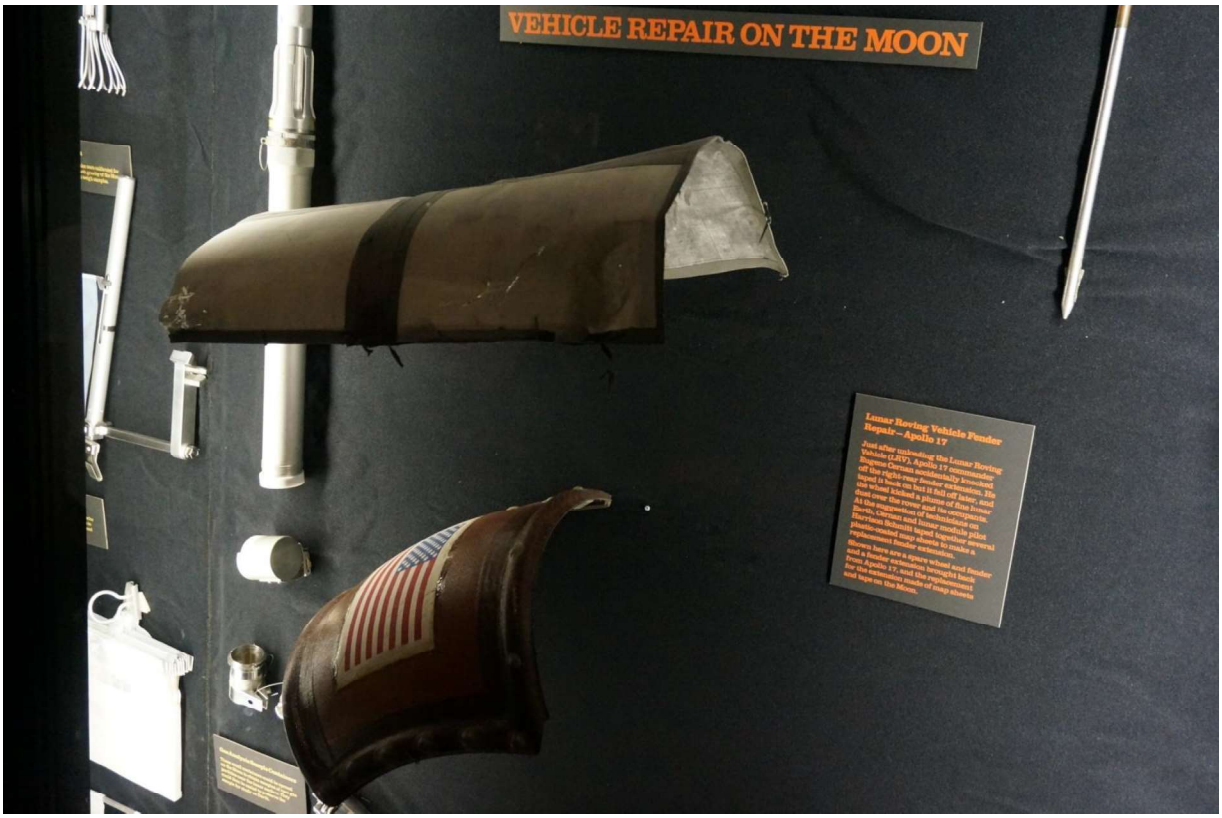


Close-Up of Lunar Rover Wheel and Fender [NASM]

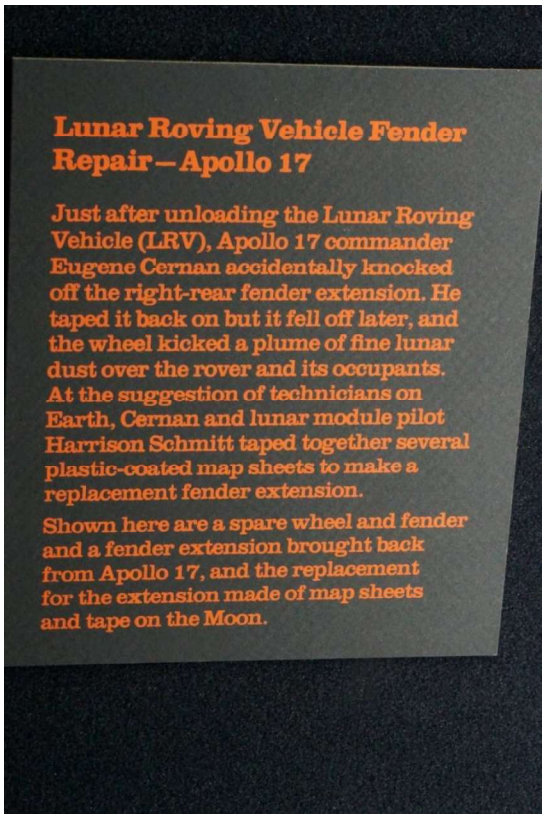
(The last 3 Apollo landing missions [the "J" missions]---Apollo 15, 16 and 17---took a Lunar Roving Vehicle (LRV) to the Moon; this greatly extended the exploration capability on the lunar surface. Note the resilient titanium bands and flexible "piano-wire" construction on each hollow wheel.)

Apollo 17's Broken LRV Fender Extension, and Improvised Fender Extension (Made from Lunar Mapsheets) [NASM]

(These are the actual items, returned from the Moon by the Apollo 17 crew.)



Legend for Vehicle Repair Exhibit [NASM]



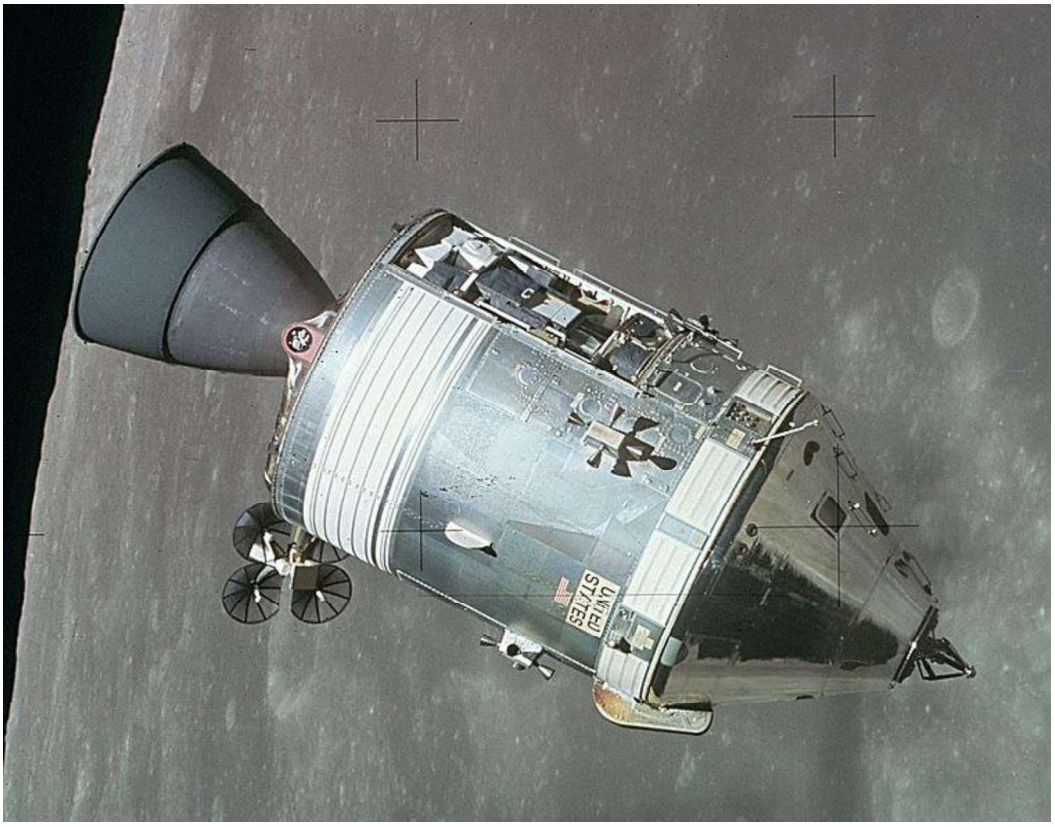
Close-Up of Improvised Fender Repair on Apollo 17 LRV [NASM]

Apollo 17 Lunar Rover Fender Repair on the Moon

(Note temporary fender made of plastic maps, affixed to right rear fender of LRV.)

Apollo 17 "SIM Bay"

(The Scientific Instrument Module Bay was operated in lunar orbit on all three "J" missions)



On Each "J" Mission, Two "SIM Bay" Film Canisters Were Retrieved by the Command Module Pilot, via Space Walk, During the "Trans-Earth Coast," on Day # 2 of the Return to Earth

Apollo Manned Mission Flight Summaries (1 of 4)

Mission and Dates	Crew	Spacecraft Names	Mission Objectives/Highlights
Apollo 1 (AS-204) (Never flew---spacecraft destroyed by the Apollo One Fire during CDDT on January 27, 1967)	Virgil I. Grissom (CDR) Edward White II Roger Chaffee	Not Named	Was to have been first manned Apollo flight---an Earth-orbital test of the early "Block I" Apollo CM. The flight crew expired.
Apollo 7 (AS-205) October 11-21, 1968 163 orbits; 10 days, 20 hours	Walter M. Shirra, Jr. (CDR) Don F. Eisele, Jr. Walter Cunningham	Not Named	First piloted CM mission (in Earth orbit) of redesigned "Block II" CM, and first 3-man American flight crew. "Shakedown" of all CSM systems, including SM fuel cells, SPS engine, CM inertial guidance system, CSM rendezvous capability, and first manned re-entry of CM.
Apollo 8 (AS-503) December 21-27, 1968 6 days, 3 hours, 42 sec.	Frank Borman (CDR) William A. Anders James A. Lovell, Jr.	Not Named	This was the first piloted, human circumnavigation of the Moon. This mission also demonstrated cislunar navigation capability, and NASA's deep-space communications network. Also demonstrated was the first trans-lunar injection (TLI); the first lunar orbit insertion (LOI); the first trans-earth injection (TEI); and the first crewed re-entry into the Earth's atmosphere at the trans-lunar return speed of 25,000 mph (i.e., 7 miles per second, vice the 5 miles per second velocity of Earth-orbital missions.)

Apollo Manned Mission Flight Summaries (2 of 4)

Mission and Dates	Crew	Spacecraft Names	Mission Objectives/Highlights
Apollo 9 (AS-504) March 3-13, 1969 10 days, 1 hour	James A. McDivitt (CDR) David R. Scott (CMP) Russell L. Schweickart (LMP)	CM "Gumdrop" LM "Spider"	Demonstrate full Lunar Module flight capabilities, in concert with the CSM, in Earth orbit: including docking (TD&E), crew transfer, undocking, DPS engine, abort staging, APS engine, LM guidance systems (PGNS and AGS), rendezvous, re-docking with CSM, undocking from the CSM, and full communications capability between CSM, LM, and the MCC.
Apollo 10 (AS-505) May 18-26, 1969 8 days, 3 min., 23 sec.	Thomas P. Stafford (CDR) John W. Young (CMP) Eugene A. Cernan (LMP)	CM "Charlie Brown" LM "Snoopy"	Full "dress rehearsal" flight for a manned lunar landing. For the first time, a Lunar Module flew to the Moon with a Command and Service Module; the LM executed the DOI burn, and then descended to an altitude of only 50,000 ft. above the lunar surface (but did not execute the PDI burn, or powered descent). All LM systems (guidance, communications, propulsion) were demonstrated for the first time in the lunar environment.

Apollo Manned Mission Flight Summaries (3 of 4)

Mission and Dates	Crew	Spacecraft Names	Mission Objectives/Highlights
Apollo 11 (AS-506) July 16-24, 1969 8 days, 3 hours, 18 min., 35 sec.	Neil A. Armstrong (CDR) Michael Collins (CMP) Edwin E. Aldrin, Jr. (LMP)	CM "Columbia" LM "Eagle"	Perform first manned lunar landing and return safely to the Earth; this was the goal established by JFK. (Sea of Tranquility)
Apollo 12 (AS-507) November 14-24, 1969 10 days, four hours, 36 min.	Charles Conrad, Jr. (CDR) Richard F. Gordon (CMP) Alan L. Bean (LMP)	CM "Yankee Clipper" LM "Intrepid"	Goals included a more precise landing and collection of hardware from the *Surveyor 3* robotic lander. (Ocean of Storms)
Apollo 13 (AS-508) April 11-17, 1970 5 days, 22 hours, 54 min.	James A. Lovell, Jr. (CDR) John L. Swigert, Jr. (CMP) Fred W. Haise, Jr. (LMP)	CM "Odyssey" LM "Aquarius"	Original goal was to land in lunar highlands at Fra Mauro; oxygen tank explosion in SM caused mission abort. Crew did not land on moon, but did return to Earth safely.
Apollo 14 (AS-509) Jan. 31-Feb. 9, 1971 9 days	Alan B. Shepard, Jr. (CDR) Stuart A. Roosa (CMP) Edgar D. Mitchell (LMP)	CM "Kitty Hawk" LM "Antares"	Land at Fra Mauro (the Apollo 13 landing site); "saved" the Apollo Program, and in doing so, made the 3 subsequent "J" missions possible.

Apollo Manned Mission Flight Summaries (4 of 4)

(Chart does not include the 3 Skylab ferry missions, or the Apollo-Soyuz flight)

Mission and Dates	Crew	Spacecraft Names	Mission Objectives/Highlights
Apollo 15 (AS-510) July 26-August 7, 1971 12 days, 17 hours, 12 min.	David R. Scott (CDR) Alfred M. Worden (CMP) James B. Irwin (LMP)	CM "Endeavour" LM "Falcon"	Land at Hadley-Apennine, adjacent to Hadley Rille (a large volcanic channel). Took first Lunar Rover to the Moon. First "extended stay" mission; performed three (3) EVAs, and spent 66.9 hrs. on lunar surface. The LRV traversed 17 miles.
Apollo 16 (AS-511) April 16-27, 1972 11 days, 1 hour, 51 min.	John W. Young (CDR) Thomas K. Mattingly II (CMP) Charles M. Duke, Jr. (LMP)	CM "Caspar" LM "Orion"	Land at Descartes Highlands, and search for evidence of craters formed by lunar volcanism. Took second LRV to the Moon. Second of three "extended stay" missions (71 hrs. on lunar surface); 3 EVAs.
Apollo 17 (AS-512) December 7-19, 1972 12 days, 13 hours, 52 min.	Eugene A. Cernan (CDR) Ronald E. Evans (CMP) Harrison H. Schmitt (LMP)	CM "America" LM "Challenger"	Land at the Taurus-Littrow highlands and valley area; perform geological surveying and sampling of materials at pre-selected sites. Took third LRV to the Moon. Third and final "extended stay" mission (75 hrs. on lunar surface); 3 EVAs.

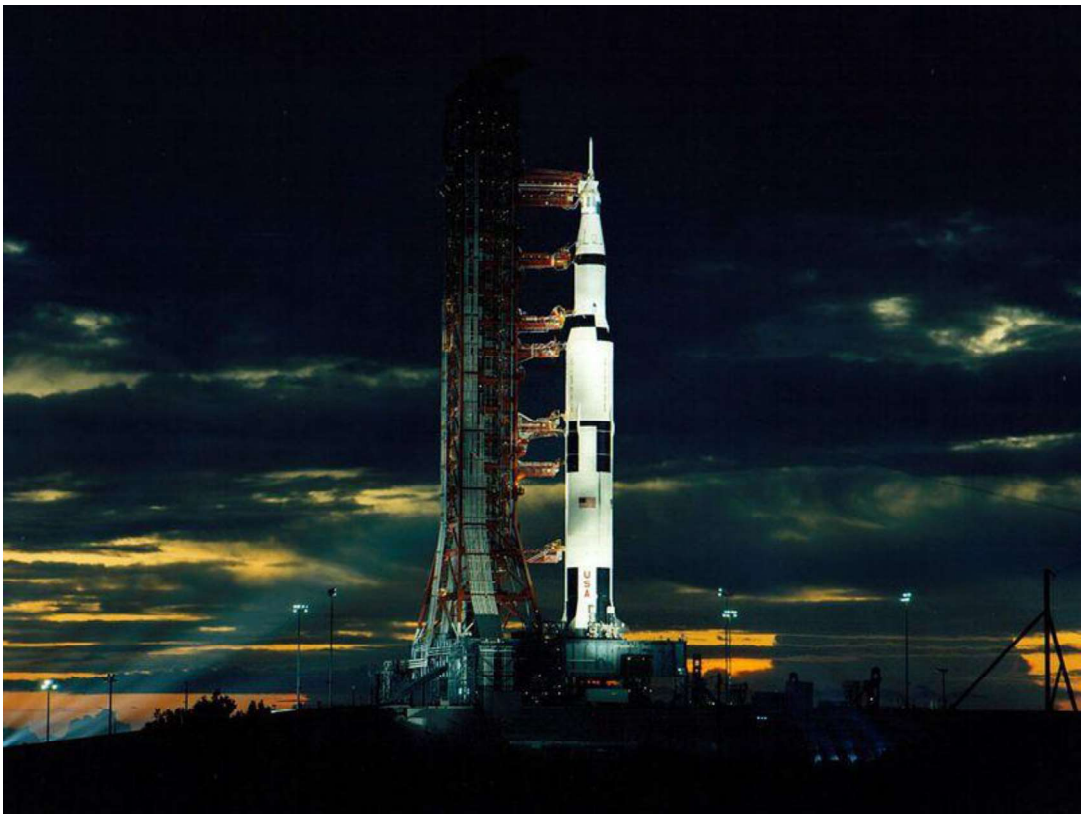
RETROSPECTIVE

(Photo of Earth taken by the outbound Apollo 17 crew about 5 hours after the TLI burn, during the trans-lunar "coast" phase.)

The Last Moonshot:

The Apollo 17 Space Vehicle Sits on Pad 39A Awaiting Launch

(Apollo 17 was the only night launch of the Apollo Program, on December 7, 1972.)



Apollo 17 Panorama

(This computer "wallpaper" panorama of the Apollo 17 landing site at the Taurus-Littrow Valley was created using Photoshop.)

The Last Man on the Moon

(Apollo 17 Commander Gene Cernan, in LM "Challenger" on the Lunar Surface.)

The Only Scientist to Land on the Moon

(Apollo 17 LMP Harrison Schmitt in the LM "Challenger"---
Schmitt was a PhD Geologist Who Also Helped Train the Apollo Astronauts.)

JFK's Cold War Response to USSR Space Achievements Sent Humans to the Moon <u>One or Two Generations Earlier</u> Than We Would Otherwise Have Gone, *When It Was Barely Possible.* The Benefit Has Been An Unparalleled Enrichment of the Human Spirit, and Human Potential.

Quoting author David West Reynolds, in *Apollo, The Epic Journey to the Moon:*

"The challenge [to land on the Moon before the end of the decade] <u>was undertaken as a political gamble</u>, *but would embark mankind upon an odyssey of the spirit."* [pg. 14] [emphasis added]

"President John F. Kennedy had not launched Apollo in a spirit of exploration. The race to the Moon was for superpower prestige in the arena of geopolitics. As disgruntled scientists came to learn, science was secondary at best in the early Apollo missions. *Yet a spirit of exploration had grown within the program.*

Apollo 11 had commanded a unique kind of awe: *No matter what its origins, the mission itself was exploration of the most extraordinary kind and a compelling beacon for the human spirit.* When the race was won, and Kennedy's goal had been accomplished, Apollo's overall purpose became much less clear, **<u>and it was in the context of this uncertainty that scientific exploration came to fill the void</u>.**

A unique opportunity in history presented itself: A great power was at hand to be harnessed, and *for a brief and wondrous interval, the spirit of exploration took up the reins of this power and drove Apollo to its greatest and most spectacular heights."* [pg. 165] [emphasis added]

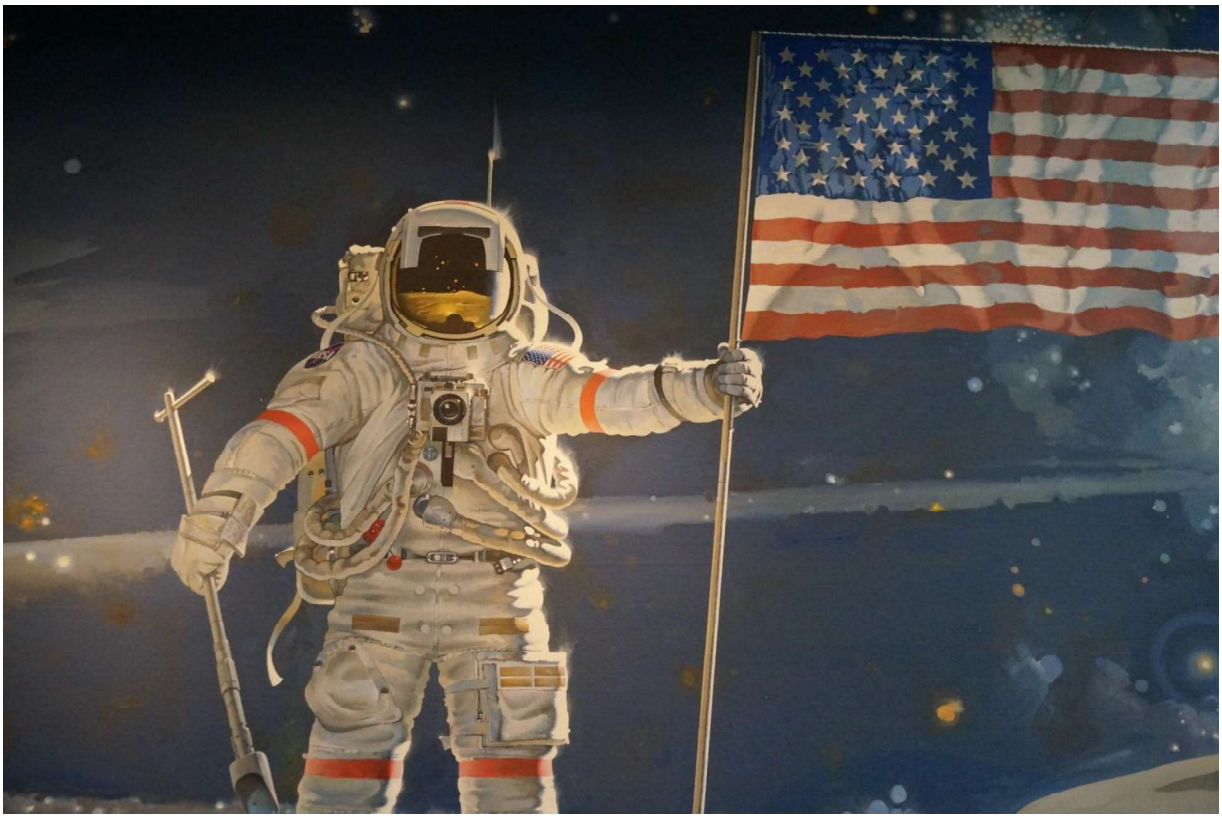
IN SUMMARY, a geopolitical technological competition advanced America's (and thereby humanity's) technology base without war, and more importantly, exalted the human spirit. ***Apollo was about leaving, as Michael Collins has sagely observed---about leaving Earth for the first time.*** By doing so, all of humanity has become privy to the priceless Apollo images of a beautiful and fragile earth, drifting in the vast emptiness and blackness of space. As a result we all have a profound motivation for taking better care of our home. *Because of the Apollo Program, humanity has also experienced the spiritual uplift provided by exploring new vistas, and visiting as-yet unexplored destinations in the cosmos---a journey which has just begun, and which promises unlimited expansion of our collective sense of wonder.* Exploring the cosmos beyond the Earth is a journey which is consistent with our evolution as a species---always questing to find out what is beyond the next horizon. Journeying to the Moon was tantamount to dipping our toe into the ocean of space; we have decided we like the water, and are now ready to wade into that sea and embark upon countless new voyages that will enrich the human spirit, and will inevitably ensure our immortality as a species. ***In the post-Apollo era, we are gradually establishing a spacefaring civilization which will guarantee our future survival,*** once we take the next steps and establish self-sustaining human settlements on Mars, the moons of the outer planets, and in the asteroid belt. **We will forever owe those who made the Apollo Program possible---the politicians, engineers, technicians, mathematicians, computer programmers, and astronauts---a debt of gratitude; one day the first starship will leave our solar system to explore and colonize another star system, and when that happens, we will all thank Apollo for taking humanity's first step into the cosmos.**

In Praise of the Engineers of Project Apollo…

"Apollo was a grand attempt to reach beyond the world of mundane life and to transcend the ordinary limits of human existence through accomplishment of the miraculous. Above all it was a story of engineers who tried to reach the heavens."

J. Bainbridge
Spaceflight Revolution

Apollo: A Magnificent Achievement

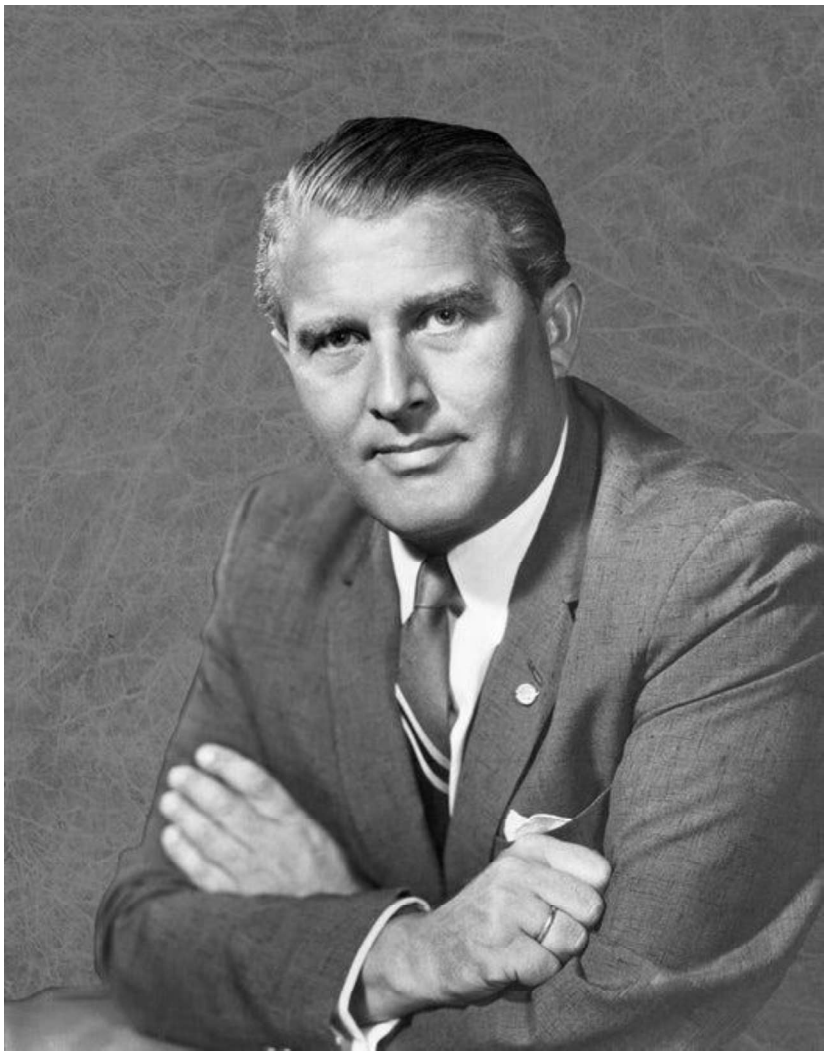


Wernher von Braun: "The Columbus of Space"

During the 1950s, the German rocket engineer who developed the A-4 (V-2) rocket for Hitler's regime during the Second World War transformed himself into America's foremost proponent of Space Travel.

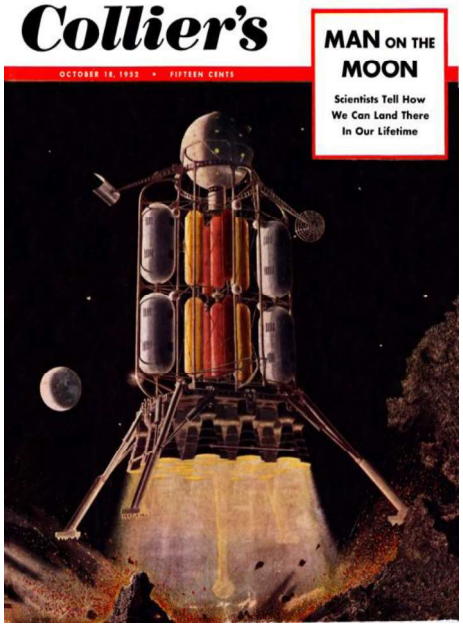
Through a series of thoughtful and brilliantly illustrated articles in Collier's magazine from 1952-1954, and three televised Walt Disney episodes in 1955 and 1957, Wernher von Braun "sold" the idea of manned space travel to the American public. This vital public relations work laid the foundation for the large space budgets of the 1960s, and widespread public support for NASA once the space agency was established in 1958.

Von Braun and his engineering team at MSFC in Huntsville, Alabama went on to design and oversee the construction of the giant Saturn V launch vehicle that sent America to the Moon. He was a great engineer, an impressive manager, an inspirational leader, and perhaps the world's best salesman. When von Braun spoke, Congress responded.



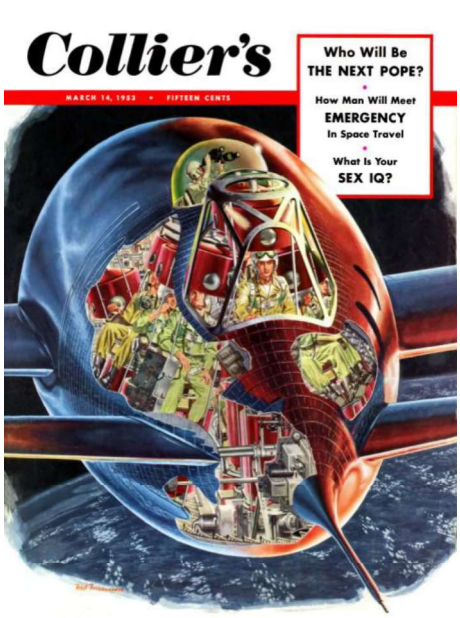
The *Collier's* Magazine Articles (1 of 2):

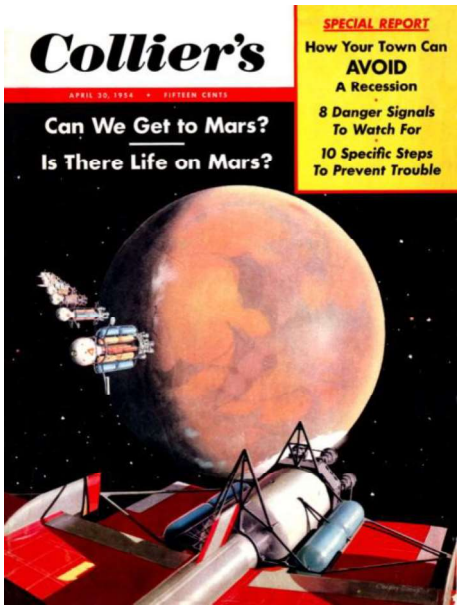
Eight Issues Promoting Manned Space Flight Were Published Between 1952 and 1954, and Five Key Articles Were Written By Wernher von Braun. *They Were Brilliantly Illustrated by Chesley Bonestell, Rolf Klep, and Fred Freeman.*



The *Collier's* Magazine Articles (2 of 2):

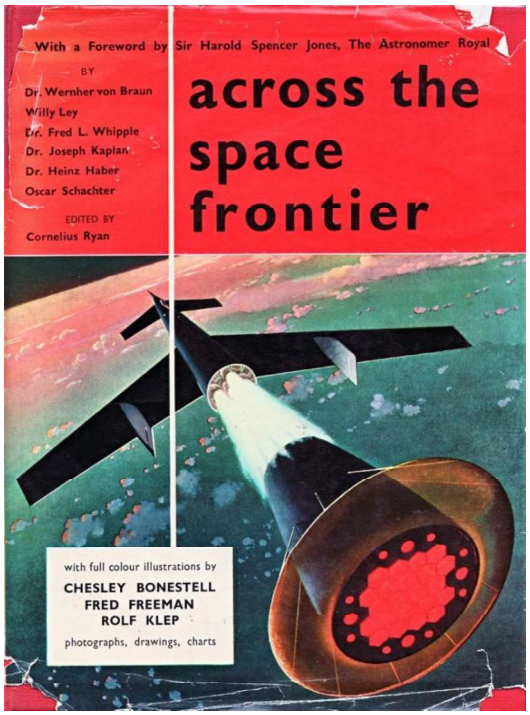
The cover art sold the magazines, and was backed up by sound engineering and a persuasive optimism about the future.



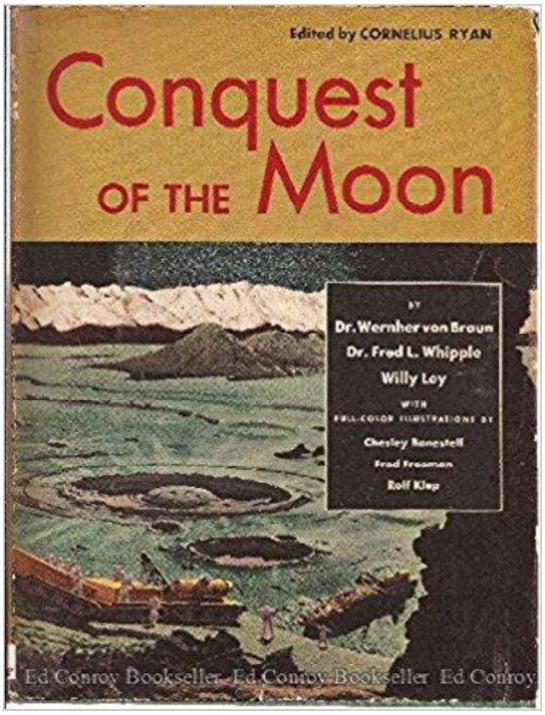


Collier's Assistant Editor Cornelius Ryan Was the Driving Force Behind the Magazine Articles, and Also Edited Two Spinoff Books (Heavily Featuring von Braun's Ideas), That Expanded Upon the *Collier's* Magazine Series

Published in 1952

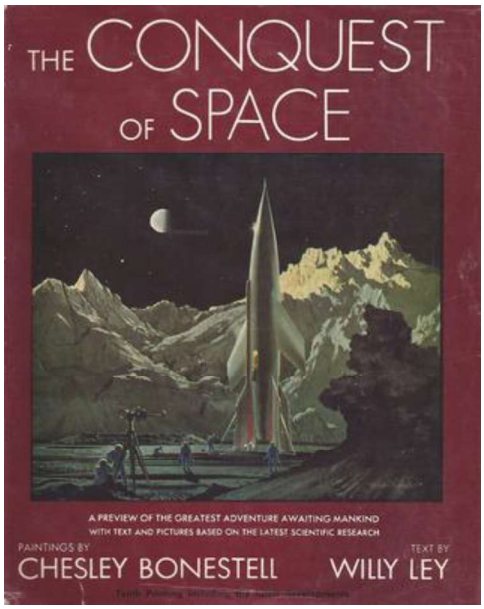


Published in 1953

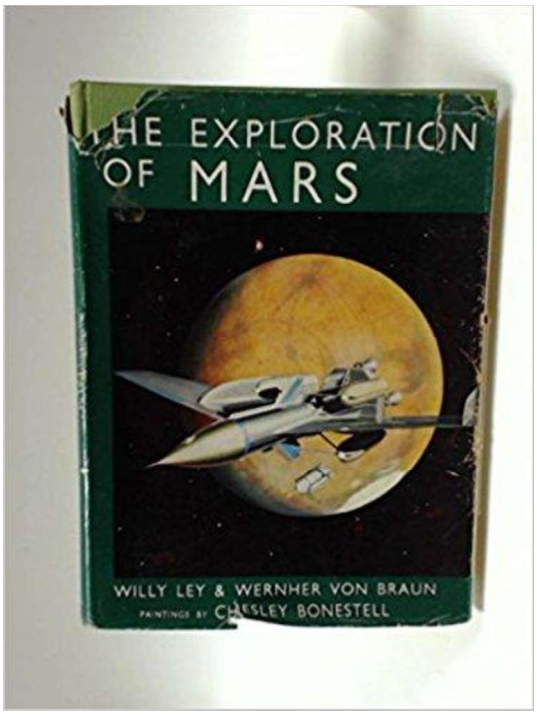


Willey Ley, One of the Key Founding Members of the German "Society for Space Travel" (VfR) in 1927, Emigrated to the United States in 1935. Although not a rocket engineer, Ley was instrumental in popularizing and promoting space travel in the United States from the late 1940s, throughout the 1950s, and into the 1960s. (In 1954, it was Willey Ley who insisted that Walt Disney utilize Wernher von Braun in his forthcoming television series on manned space flight; von Braun quickly became the star of the first two programs, in 1955---reaching a much bigger audience than *Collier's* did.)

Willey Ley and Space Artist Chesley Bonestell Collaborated on This Book, Published in 1949



Willey Ley and Wernher von Braun Co-Authored This Book, Published in 1956. (It, too, was lavishly illustrated by Chesley Bonestell).



An Ideal Collaboration: Wernher von Braun and Walt Disney, Two Avowed "Futurists"

In 1955, Disney aired two programs about manned space flight which prominently featured Wernher von Braun:

---"Man in Space" (featuring a huge 4-stage booster that launched a reusable space shuttle with wings and wheels); and

---"Man and the Moon" (featuring von Braun's concept for a lunar circumnavigation mission launched from an orbiting Earth space station).

In 1957, shortly after the launch of Earth's first artificial satellite--- Sputnik---by the Soviet Union, Disney aired the third program featuring von Braun, titled: "Mars and Beyond" (about a manned expedition to the planet Mars).

Von Braun's hold on the public imagination was instrumental in helping JFK to persuade Congress to land an American on the Moon by the end of the 1960s. After all, von Braun had not only built the Redstone and Jupiter missiles for the U.S. Army, but he had launched America's first artificial satellite, Explorer 1, early in 1958. His visionary persuasion, combined with his engineering and managerial competence, made it possible for JFK to "sell" the Apollo Program.