Apollo 11 Took Plastics to the Moon 50 Years Ago!

Written by Don Rosato

The 20th century will be remembered 500 years from now as the century when humans began the exploration of space. The Apollo 11 space mission launched from the Kennedy Space Center, Florida, USA July 16, 1969, with the first humans, U.S. astronauts Neil Armstrong and Buzz Aldrin, to walk on the moon July 20, 1969, and safely returned to earth July 24, 1969. The Apollo 11 program was breathtaking in scope, and the result of 10,000 solutions to challenges laid before it in the 1961 to 1969 time period. These challenges were solved by the technological might of all the advanced industrialized democratic countries of the world. Let's take a brief tour of Apollo 11 from a plastic application's perspective.

Space Suits and Gear

Union Carbide (now Dow) and Amoco (now Solvay) materials were on board the Apollo 11 mission. Udel Polysulfone (PSU) polymer was developed in 1965, just in time to be used to make the exterior helmet visors on Buzz Aldrin and Neil Armstrong's space suits as they set foot on the moon in July 1969. Udel PSU was the material of choice thanks to it being a tough and transparent plastic that can resist extremely high temperatures. A GE Plastics (now SABIC) Lexan 100 UV stabilized polycarbonate (PC) grade was molded by Swedlow Plastics (now Pilkington Brothers/Japan's NSG owned) for the inner core helmet. Within the core PC helmet there is a white Temper (soon to be Tempur Pedic, as in current day mattress use) open-cell polyurethane-silicon plastic foam cushioning that takes the shape of impressed objects but returns to its original shape even after 90 percent compression. This foam was developed in the 1960s by NASA's (National Aeronautics & Space Administration) Ames Research Center and refined by Swedish researchers.

Extra-Vehicular Polysulfone Visor Assembly (L); Polycarbonate Pressure Helmet with White Temper Polyurethane Silicon Foam Cushioning (C); Neil Armstrong Moonwalking July 20, 1969 (R)

Apollo 11 Pressurized Space Suit

The lunar spacesuits were designed to provide a life-sustaining environment for the astronaut during periods of extra vehicular activity or during unpressurized spacecraft operation. They permitted maximum mobility and were designed to be worn with relative comfort for up to 115 hours in conjunction with the liquid cooling garment. If necessary, they were also capable of being worn for 14 days in an unpressurized mode. Because Apollo astronauts had to walk on the moon as well as fly in space, a single space suit was developed that had add-ons for moonwalking.

The Apollo 11 suit consisted of the following:

- A water-cooled DuPont (now Invista, Koch Industries) nylon fiber undergarment;
- A multi-layered pressure suit: inside layer - lightweight DuPont (now Invista) nylon with fabric vents; middle layer – DuPont neoprene-coated nylon fabric to hold pressure; outer layer – DuPont (now Invista) nylon fabric to restrain the pressurized layers beneath;
- Five layers of aluminized DuPont (Teijin) polyethylene terephthalate (PET) Mylar film interwoven with four layers of DuPont (now Invista) Dacron polyester fiber for heat protection;
- Two layers of DuPont Kapton polyimide film for additional heat protection;
- A layer of DuPont polytetrafluoroethylene (PTFE) Teflon-coated cloth (nonflammable) for protection from scrapes;
- A layer of white DuPont Teflon cloth (nonflammable).

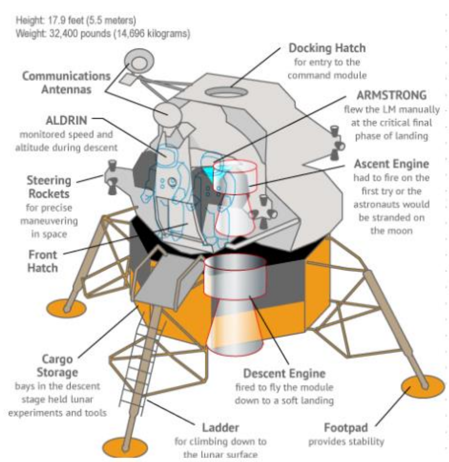
The suit had boots, gloves, a communications cap and a clear plastic helmet. During liftoff, the suit's oxygen and cooling water were supplied by the ship.

For walking on the moon, the space suit was supplemented with a pair of protective overboots, gloves with rubber fingertips, a set of filters/visors worn over the helmet for protection from sunlight, and a portable life support backpack that contained oxygen, carbon-dioxide removal equipment, and cooling water. The space suit and backpack weighed 180 pounds on Earth, but only 30 pounds on the Moon.

<u>Lunar Excursion Module (LEM)</u>

The Lunar Excursion Module (LEM) was the transport vehicle used in the Apollo program to ferry two astronauts between the Command Module in lunar orbit and the surface of the Moon. The lunar-orbit rendezvous eliminated the need to land the entire Apollo spacecraft on the Moon on a direct ascent flight path from Earth orbit, and thus made possible a lighter load of fuel. Nine LEMs were flown during the Apollo program, and six landed on the Moon.

The two-stage LEM was designed and built by the Grumman Aircraft Engineering Corporation under a $1.6 billion ($19 billion in today's US dollars) contract with NASA. Because little was known about the lunar surface when construction began in 1962, engineers designed the cantilever landing gear — consisting of four sets of legs, each ending in a dish-shaped pod — so that the vehicle could land safely and remain upright on a variety of surfaces.



Moon Landing LEM Machine (Lunar Module (LM, T), Lunar Lander Base with Struts (B)

Parts of the LEM were wrapped in a multi-layer blanket of aluminized DuPont Kapton polyimide film. Depending on where it was used, the outer layer might be yellow, silver, or amber in color, and generally had a “gold foil” appearance. The reason for this insulation is that at the Earth’s distance from the sun, the principle thermal control issue for a spacecraft is to prevent overheating. Without insulation, an object will heat up to about 250°F in sunlight and chill down to about -250°F in the shade. The insulation rejected much of the sun’s heat, and to a lesser extent, slowed the loss of heat to space. This let the spacecraft control temperature by adjusting a water sublimator to eliminate heat generated by the onboard equipment—no heat required. The insulation was intentionally crumpled by hand to minimize contact points that could leak between the layers. Like all LEM components, weight reduction was a big feature—the film blanket was much lighter than more solid types of heat shields. Also, critically important, this insulation was used to protect against radiation penetration and meteor impact. The plastic insulation technology for the LEM is very similar to components of the space suit insulation.

DuPont Kapton Polyimide (PI) Film External Insulated LEM (L); Internal LEM PI Insulation (C);PI Film Insulation Layering (R)

The four lunar module struts were fabricated by Grumman and the Hercules Powder Company (now Ashland) using boron fiber (AVCO Specialty Materials), carbon fiber (Union Carbide, Dow Chemical, now Turkish based AKSA Fibers), Courtaulds (now Hong Kong based PD Enterprise Ltd.) reinforcements, and epoxy resin from Ciba Geigy (now Huntsman). The composites were designed in the late 1960s as Lunar Lander Base leg inserts to decrease weight while maintaining high strength that was far superior to aluminum, titanium, or steel.

Due to the catastrophic January 27, 1967 LEM fire where three astronauts died, aluminum struts with aluminum honeycomb crush chambers were used on Apollo 11, as design returned to heavier, but safer metal alternatives versus outgassing composites that were deemed flammability threats. These boron/graphite epoxy composites show up later as lightweighting leg strut inserts on the Apollo 14-17 final Moon flights. These cylindrical inserts were fabricated by pressurizing a nylon bag inside a metal tubular female mold using filament wound cross plies and longitudinal tape layers. The preceding cylindrical composite tube infusion process, still in use today, was invented by PPA member Don Rosato under the direction of George Lubin, legendary composites engineer and chief materials scientist of Grumman Aerospace Corporation.

Command Module Ablation Shielding

Command Module (CM) Ablative Shield Rendering

After jettisoning the Lunar Module, the Apollo spacecraft was ready to return home with a controlled descent into the Pacific Ocean. The temperature on the CM's surface climbed up to 5,000 degrees Fahrenheit, but the heat shields protected the inner structure of the CM. The heat shield was ablative, which means that it was designed to melt and erode away from the CM as it heated up. From the ground, it would look as if the CM had caught on fire during its descent. In reality, the ablative covering is what kept the astronauts inside the CM safe -- the material diverted heat away as it vaporized. Approximately 1,000 pounds of reinforced asbestos phenolic and glass phenolic composites (AVCO Specialty Materials, now Textron Systems; American Cyanamide, now Solvay) was carefully layer laminated with a fancy caulking gun on the CM reentry surface. The late PPA member Tony Mack was instrumental in developing CM ablative shield technology at AVCO.

In conclusion, the Moon landing left several lasting legacies still present today – namely: (1) the birth of the digital, portable computer and software revolution. NASA was the primary purchaser of semiconductor chips, hardware, and related software that birthed this industry in the 1960s; (2) the age of light weight, advanced materials was born such as high heat thermoplastics and thermosets, composites, light weight metals (aluminum, titanium), and most importantly; (3) it accelerated the age of technology where the impartial use of science and engineering aided modern civilization in advancing our standard of living.

The moon landing, although centered in the USA, was a global enterprise that became a metaphor for technological teamwork. It inspired a whole generation of scientists and engineers still alive to this day. The further successful exploration of space in utilizing the moon as a launch pad to Mars and beyond will require the best efforts of all the technologically advanced countries of Earth.