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AEROSPACE MICRO-LESSON

Easily digestible Aerospace Principles revealed for K-12 Students and Educators. These lessons will be sent on a bi-weekly basis and allow grade-level focused learning. - AIAA STEM K-12 Committee.

THE SOVIET MOON PROGRAM

In the 1960s, the United States was not the only country that was trying to land someone on the Moon and bring him back to Earth safely. The Union of Soviet Socialist Republics, also called the Soviet Union, also had a manned lunar program. This lesson describes some of it.

Next Generation Science Standards (NGSS):

- Discipline: Engineering Design
- Crosscutting Concept: Systems and System Models
- Science & Engineering Practice: Constructing Explanations and Designing Solutions

GRADES K-2

K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

Have you ever been busy doing something when somebody challenges you to a race? If you decide to join the race—and it is usually up to you whether you join or not—you have to stop what you're doing, get up, and start racing. By the time you've gotten started, the other person is often halfway to the goal.

This is the sort of situation the Soviet Union found itself in when President Kennedy in 1961 announced that the United States would set a goal of landing a man on the Moon and returning him safely to the Earth before the end of the decade. The United States and the Soviet Union were competing in a "space race," each country trying to show that it could do better than the other. In October 1957, the Soviet Union had launched a satellite into orbit around the Earth before the Americans had; in September 1959, they had sent a spacecraft to the Moon before the Americans had; in April 1961, they had launched a person into space—and into orbit—before the Americans had. They were busy trying to figure out how to live and work in space and to send spacecraft to other planets when in May 1961 President Kennedy said, in essence, "Race you to the Moon!"

The Soviet rocket designers continued with their work. They would need larger rockets than they had if they were going to go to the Moon, but they would also need them to send

GRADES K-2 (CONTINUED)

spacecraft to other planets and to send living quarters into space at all. Nobody knew—including the Soviets themselves—whether they were going to join the Americans in their race to the Moon or whether they would pursue other goals in space. It was not until three years later in August 1964 that the Soviet leadership formally announced that they would also try to land a man on the Moon. By that time they had a lot of catching-up to do.

There is an old saying that "haste makes waste." Because of their late start, the people in the Soviet space program had to work quickly and this caused them to make mistakes. They designed and built the large rockets that they would need to send somebody to the Moon, but when they would test a rocket things often went wrong. Finally, in June 1969, a massive rocket exploded right after it launched, destroying the launch pad and ending the Soviet Union's efforts to land a person on the Moon.

Have you ever seen somebody who loses a race and then tries to pretend that he was never really racing to begin with? That is what the Soviet Union did. After the Americans landed two astronauts on the Moon in July 1969, the Soviet government denied that they had ever seriously tried to land a man on the Moon. They had kept their space program a secret and very few people knew about the things that had happened, so they managed to fool a lot of people for a long time. It was not until twenty years later that the Soviet government admitted that they had joined the race to the Moon and had lost it.

GRADES 3-5

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

Just as in a footrace, the race to the moon had moments when one team would pull ahead, and then they would seem to stumble and the other team would take the lead for a while. As mentioned above, the Soviets were the first to launch a satellite, a spacecraft, and a human into space. Those milestones made the American team try even harder to catch up and start earning some "firsts" of their own. The Americans had an advantage because their efforts were all coordinated through NASA, whereas the Soviets were not just competing with the United States, but also had to compete internally.

It may seem strange, but there were two very different designers in the Soviet Union who each ran a department that worked on a space program. The two designers, Sergei Korolev

GRADES 3-5 (CONTINUED)

and Vladimir N. Chelomei, had to compete with each other for funding, personnel, and official approval. Their departments developed different approaches for the types of fuel to be used (liquid hydrogen vs. hypergolic chemicals), the rocket engines, and even the construction of the rockets themselves. Of the two, Korolev was the better rocket designer, but one of Chelomei's employees was Sergei Khrushchev, son of Soviet Premier Nikita Khrushchev. This connection was very beneficial to Chelomei's group when competing for resources.

The Soviet government chose to use Korolev's N-1 launcher as the vehicle for the moon landing, while Chelomei's LK-1 was chosen to make the circumlunar journey. After Khrushchev was replaced as leader of the USSR in 1964, though, Chelomei lost most of his political clout and his circumlunar project was canceled. The two designers eventually worked together to use components from the plans of both departments to create a spacecraft for a newly assigned circumlunar project in 1965.

Despite all the problems and internal competition, the Soviet designers still managed to accomplish several more firsts. Their Luna 2 probe reached the moon (crashed into it, actually), and Luna 3 sent back the first photograph of the far side of the moon. (Do not underestimate the significance of the latter point: since the Moon always keeps the same side facing the Earth, this was the first time in history that people had gotten a look at the back side of the Moon. Scientists knew more about the interiors of distant stars than they did about the surface of the back side of the Moon.) Luna 9 landed successfully on the moon; then Luna 10 became the moon's first artificial satellite. Soviet cosmonaut Yuri Gagarin became the first man to orbit the Earth. And in September 1968 the Zond-5 spacecraft successfully orbited the moon and returned to Earth with the turtles and banana flies on board as biological specimens still alive.

Despite all the Soviet Union's firsts, NASA's Apollo program was still the first one to reach the Moon and have a successful landing on its surface and then bring the crew safely home again. After the race to the Moon was over, the Soviet Union and the United States started to cooperate more and compete less in space.

At the time, the Soviet Union kept its space program shrouded in secrecy, only announcing successful missions when they had finished. Nowadays there is much more information available on the internet. These web sites describe the Soviet project to land people on the Moon in some detail.

GRADES 6-8

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

In an engineering design problem, there is no single right answer and no completely wrong answers. There are better answers and there are worse answers. The question being addressed is "How do we solve this problem?" or "How do we accomplish this goal?" A good answer will solve the problem or accomplish the goal; a better answer will do this with less trouble and expense; a bad answer will fail to solve the problem or accomplish the goal. But the idea of absolutely right answers and absolutely wrong answers does not apply here.

The Soviet programs to send people to the Moon illustrate this idea of there not being an absolutely right or absolutely wrong solution to a problem, only better and worse (and sometimes much worse!) solutions. The first thing a mission to the Moon needs is a rocket that can lift the entire assemblage of itself and the spacecraft off the ground. The United States solved this problem by building the S-1C (the first stage of the Saturn V), with its five massive F-1 rocket engines. The Soviets, however, did not know how to build a rocket engine as powerful as the F-1, so they solved the problem by building their N-1 first-stage rocket with 26 separate NK-15 engines. (Other designs called for 30 engines.) If everything had gone well, this would have worked. Unfortunately, everything did not go well; each rocket engine is a complicated thing with its own chance of going wrong, and with 26 engines the chance of one of them going wrong gets pretty large. All four of the N-1 rocket's launch tests ended in failure.

You can illustrate the problem of more rocket engines making more opportunities to fail by rolling a pair of dice. One roll of the dice corresponds to one rocket engine firing; getting a pair of ones corresponds to something going wrong while any other combination corresponds to the rocket engine working properly. If you roll the dice five times, you have about one chance in seven of something going wrong. If you roll the dice 26 times, something will go wrong more than half the time.

With some imagination, one can think of other solutions to engineering problems that are not obvious right away. (Indeed, imagination is one of the more important things an engineer can have.) Another way to launch a rocket to the Moon if you don't have

GRADES 6-8 (CONTINUED)

powerful enough engines is to launch the rocket into orbit around the Earth, launch another rocket with more fuel, and use the extra fuel from the second rocket to refuel the first one for its trip to the Moon. The Soviet space planners considered doing this (with two refueling rockets instead of just one) but decided not to. While it would have let them use smaller rockets for their launches, it would have required a lot of complicated processing in space to move fuel from one spacecraft to another. In the end it was not a wrong answer, it was simply harder than other answers that were available.

GRADES 9-12

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Americans tend to speak of a "space program" as a unified effort. In the United States, NASA provided such a unified space program—after the Army, Navy, and Air Force missile programs in the 1940s and 1950s were assembled under its aegis. In the Soviet Union, however, the separation of the space program into separate departments continued through the 1960s and hampered their efforts badly.

The early 1960s saw three separate Soviet efforts to send a manned spacecraft to the Moon. These three efforts were headed by Sergei Korolev leading the OKB-1 bureau, Vladimir Chelomei leading the OKB-52 bureau, and Mikhail Yangel leading the OKB-586 bureau. While Yangel tried to have his efforts complement those of the other two, Korolev and Chelomei openly competed with each other. This competition created much duplication of effort and wasted many resources. In 1962, Chelomei told Nikita Khrushchev, the Soviet premier, that he would have a Moon rocket ready within three years; the other two, being more honest, demurred from making such a promise. The result was that Chelomei's project was funded while the other two were cancelled. When it became obvious that Chelomei would not meet his deadline, the other two programs were restored, the lost time and resources could not be brought back.

Soviet efforts were hampered further by a series of unfortunate accidents. The worst, called the Nedelin disaster after the Soviet general in charge of the project, happened on October 24, 1960 when a fully-fueled rocket exploded on the launch pad during a test, killing several dozen people including Nedelin. (Yangel survived only because he had

GRADES 9-12 (CONTINUED)

stepped out to smoke a cigarette when the explosion happened.) On April 24, 1967, cosmonaut Vladimir Komarov died on the Soyuz 1 mission when the parachutes on the capsule failed to open after re-entry. Finally, on July 3, 1969, an N-1 rocket exploded on lift-off, destroying the launch facilities and ending Soviet hopes of landing a person on the Moon before the United States did. (Thankfully nobody was killed in this last accident.)

The secretive nature of the Soviet space program prevented the rest of the world—meaning, at that time, mostly the Americans—from learning from mistakes that the Soviets made. One example of this was the question of what gases to use in the atmosphere inside a spacecraft. Both the Soviets and the Americans tried to use atmospheres with larger concentrations of oxygen than the Earth's atmosphere; this would let them make the total atmospheric pressure lower while still giving the astronauts the same amount of oxygen to breathe. This in turn would allow the rocket designers to send nitrogen up with the spacecraft, saving weight. But a higher concentration of oxygen in the air causes things to burn more easily and makes things burn that do not usually burn. Both space programs suffered catastrophic accidents because of the enriched oxygen atmospheres. Soviet cosmonaut Valentin Bondarenko died in a fire in 1961 during a fifteen-day test in a low-pressure chamber; six years later the three Apollo 1 astronauts died in a fire caused by the enriched oxygen atmosphere in their space capsule. While one can never be sure of what might have been, if NASA had known about Bondarenko's death they might have been more careful about the flammability problems caused by excess oxygen in the air.

Sixty Years Ago in the Space Race:

August 7, 1959: The American Explorer 6 was launched into orbit and transmitted the first pictures of Earth from orbit.

August 13, 1959: The American Discoverer 5 reconnaissance satellite was successfully launched into orbit. However, its load of exposed film was lost on reentry.