Lecture 13 Engineering the LEM
by Joe Gavin

American vs. Soviet programs:
- open vs. secret
- LOR decision
- Kennedy’s firm decision to go to the Moon

Naysayers claimed that there was a 10-foot layer of dust on the surface of the Moon that would present problems for landing; engineers chose not to believe that conclusion.

No flight tests were done on the crafts, but a whole series of different kinds of tests were devised. On top of that, measures were in place to ensure that each test was testing the system/component/procedure they *thought* they were testing.

Revelation: this machine only has to make one landing, which is an unusual concept to aircraft engineers.

NASA’s competition for the LM designer was: We have 20 questions; answer them to the best of your ability, and show that your answers are better than all other conceivable answers. [Image of “paper clip model” of LM.]

[Series of photos of the actual LM.]

Landing gear was over-designed; they wanted to make sure that the whole endeavor wasn’t ruined by the LM tipping over upon landing, since they’d never designed something to land vertically before.

Concerned that dimensional stability and other distortions would mess up the electronics; got NASA to allow them to perform a drop test with the electronics on board. Almost everything worked just fine; there was only one minor problem.

The fire of Apollo 1 caused them to realize they needed better protection measures for the capsule and exposed wiring in the O2 environment.

Ascent stage:
Fuel tanks were proportionally thinner than eggshells. They arbitrarily decided that the tanks had not undergone enough pressurizations to become dangerously close to fracturing; they were made of a titanium alloy, and machined carefully both inside and out.

Cockpit design: held as little inside as possible, more weight outside (backwards from airplane cockpits).

Astronomers advised that micrometeors would be present around the moon, so the LM skin (over the "birdcage" that surrounded the cockpit) was designed to hopefully deflect these.

Since there is no atmosphere on the moon, there would be nothing to help slow a craft down as it descends. This idea was very counterintuitive for aircraft engineers.

More than in any previous engineering project, they kept pedigrees of every component used on the craft. The craft was built in a clean room; workers had to wear protective clothing (gowns, caps).

One day, one of the windows dissolved into little pieces all by itself. They'd been using what they thought was the best glass around, so this caused a panic and sparked an investigation into glass itself (as a material).

Descent stage:
Gauged the plumbing where ever they could, since they tried to minimize mechanical connections (since they leak).

Insulated the descent stage from the take-off engines on the ascent stage, in case there was any fuel remaining in this stage that might ignite. The insulation ended up melting when the ascent stage took off.

[chart of Grumman organization]
"This chart changed from day and day, and no one paid any attention to it anyway."
It was an unusual company; anyone could talk to anyone, conversations were informal.
The task at hand was the priority, not the personal hierarchy.

"There's no such thing as a random failure." If all the elements have been understood correctly, it should not "just fail" from time to time. This was something Northrup Grumman believed, which lead to a few conclusions, such as running the cost of the project up since they ran more tests. In addition, "we had our priorities right;" priorities were 1. safety/performance, 2. schedule, and lastly, cost. Thus, they didn't earn their incentive fees until the actual lunar landings, when the LM worked perfectly every time. (they also earned it for Apollo 13, since despite no landing, the LM served as a lifeboat).

Lesson: Take nothing for granted. For example: inside the cockpit, standard military toggle switches were used, the same ones that had been used in military planes for the past 10-15 years. One of the junior electrical engineers wondered what happened inside the electrical casing, and found that in about a third of them, there was a free ball of solder that was rattling around. In zero gravity, the ball might be floating around inside that space – doing what? This could be bad. So they designed a test to determine which switches had the free ball rolling around, and discarded them (since they didn't have time to design whole new switches).

Q: What was the most valuable thing you learned in college (at MIT) that prepared you for your career?
A: Well… I was in the last aeronautical engineering class that looked at a biplane, and the last one that was required to take Industrial Stoichiometry, and the less said about that, the better. But, I'd say it would be that if you're going to defy gravity, you'd better be careful.

Q: How did you decide which projects to pursue?
A: At that time, new, primary projects were hotly pursued by younger engineers with less business sense. We wanted to build things that went higher, faster, further… and then we'd dig ourselves out of the hole. Enough of the senior management were supportive that they didn't just prevent us from pursuing these projects.

Gavin is not so supportive of going back to the moon; there aren't any compelling reasons *why*. He's more in favor of robotic exploration to determine if Mars is interesting, and then if it is, we could send a more permanent human colony there.

There were people at NASA who figured "we've hired these engineers, they'll do what we tell them." But Grumman knew that their reputation was on the line, and depended on the LM working properly, so they never made any design decisions that they felt weren't the best idea. And NASA listened to them.