RELAY

An Early Communications Satellite
Launched December 13, 1962
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INTRODUCTION

Without satellites, world-wide communications was slow. In 1941, the final warning from Washington DC to Pearl Harbor of the Japanese attack was delivered by bicycle. My parents' letters to me, from Brazil to the United States took months, and expensive telegrams took several days.

Early developments to get to SPACE included: Werner von Braun developed V-2 rockets (max 3,600 mph) to bomb Britain. The U.S. and Britain developed RADAR (using microwaves) to detect German bombers and submarines. And Bell Laboratories invented the transistor, which led to digital circuits & computers. The rockets accelerate the satellites to the necessary speed (7 miles/sec), the microwaves provide the communications between the satellites and the earth stations, and the solid state devices made possible small and light communications equipment.

The Russians were first in space launching SPUTNIK on Oct 4, 1957. The Americans followed in four months, launching EXPLORER 1 on Jan 31 1958. The first communications satellite was project SCORE (**S**ignal **C**ommunications by **O**rbiting **R**elay **E**quipment), launched on Dec 18, 1958. President Eisenhower's message was recorded and then transmitted many times to the entire world – as SCORE circled the world.

THE FIRST ACTIVE COMMUNICATIONS SATELLITES – TELSTAR and RELAY

The first active communications satellite was TELSTAR, built and launched on July 10, 1962 by AT&T. The spherical shape was dictated by the thermal design. It received the same amount of solar radiation, regardless of the orientation. The spherical shape also provided structural strength with minimum weight. Most of the components were inside the shell, and well insulated from the outside surface.

The next active communications satellite was RELAY, built by RCA, and paid for by NASA. It was launched on December 13, 1962. I was working for RCA, and I was in charge of the RELAY's thermal design. I accepted a configuration chosen by the structures group, that maximized the solar cell power. The satellite was partly cone-shaped to maximize the solar array and still fit inside the rocket shell that protected the satellite during launch. The structure was not as rigid as a sphere, and had to be modified a few times before it passed the vibration test.

To improve the temperature control on the inside components, I suggested a flat, circular louver, with two circular tin-foil disks with alternate holes. When the inside temperature increased, the louvers would turn so that the holes matched, and thermal radiation went to the colder bottom. When the inside temperature decreased, the louvers would turn so radiation was blocked. After the satellite was built, tests showed that the louvers did open and close, but the effect on the inside temperature was very small. Tests and the launch showed the louvers were not needed.

The satellite was built to receive a signal from an earth station, increase the power of the signal, and transmit it to another earth station. The high power output was provided by a traveling wave tube, with a function similar to the vacuum tubes used in radios in those days, but with a different geometry. For redundancy there were two separate circuits: two receivers, two amplifiers, and two traveling wave tubes. As explained later, it was good that there was redundancy in the satellite function.

TESTING SATELLITES IN A VACCUUM CHAMBER – Traveling wave tubes

All satellites are subject to two difficult environments: the vacuum in outer space and the vibration during launch. To make sure the satellite will work after it is launched, these two tests (vacuum and vibrations) are made both on satellite components and on the final assembled satellite.

When testing a traveling wave tube amplifier (TWTA) for the satellite, it appeared to work OK, but the technician noticed some noisy ticks. Since most of the TWTA is an evacuated tube, he assumed the ticks originated in the test equipment. He tried to find the source, but failed. After a week or two he called this to the attention of the engineer in charge. The engineer also thought it must be in the test equipment, and spent another week or two trying to find the problem. More time was spent after the engineer reported the problem to his supervisor.

The delays were holding up the entire satellite schedule. The TWTAs were manufactured at an RCA plant in Harrison, NJ, 45 miles from the RCA Space Center in Hightstown, NJ. On a Friday morning some experts from Hightstown (including me) travelled to Harrison for a discussion with all the RCA experts that might have useful suggestions. With all these suggestions a new TWTA was built and tested. Monday morning the results were sent to us in Hightstown. The clicks were still there.

In desperation the two TWTAs were put inside of sealed, pressurized containers. The problem was “solved” by brute force. But weeks had been lost. In retrospect, the sealed evacuated container could have been built sooner, and the launch not delayed by several weeks.

TESTING SATELLITES – Simulating the sun

To test the complete satellite, we used a large vacuum chamber. To simulate the incident radiation from the sun and the earth, we had metal plates heated or cooled by a circulating fluid. We planned to orient the satellite so the sun would shine more on the “top” of the satellite. So the metal plates facing the top were at a higher temperature than the plates facing the bottom. We called this a “thermal gradient test.” The temperatures were carefully controlled so that the actual thermal radiation absorbed by the satellite in the test chamber, was equal to the calculated solar radiation absorbed by the satellite in space.

We had experience with this simulation method, having experience using it on the TIROS weather satellite. However, the RELAY satellite project manager from NASA was not convinced. He thought simulation of the solar radiation with carbon arcs would be better. He insisted on a test with carbon arcs (used in many theater movie projectors). Since NASA was paying the bills, we had to satisfy the NASA project manager. So, we did a test using carbon arcs. After both tests had been completed, the project manager admitted that for the RELAY satellite the thermal gradient test was better. I admired a manager that would admit that he had been wrong!

LAUNCH AND IN ORBIT TESTING

After completing all the ground tests, the first RELAY satellite was launched. When it achieved its desired orbit, it was time to turn on TWTA #1. This was done with a remotely controlled solid state switch, which included power to the receiver, amplifiers, and the TWTA. When the satellite was being designed, there was some concern that the switch would get too hot. During construction I was asked to specify the coldest place for the switch. I replied that this would be the external surface on the bottom (away from the sun) of the satellite. A command was sent to turn on TWTA #1, with the corresponding receiver and transmitter. Signals were sent and received. Performance was excellent. Then the TWTA#1 was turned off.

RELAY was designed to use either TWTA#1 or TWTA#2, but not both at the same time. So after completing the tests on the first system, TWTA#2 was turned on, along with the corresponding equipment. Again the tests were performed, and the receiver and amplifiers worked well. But – the command to turn off the second system didn't work, – and the switch stayed on !!! The solar power could not maintain system 2 on, so the batteries furnished the rest of the power. And when the battery power was gone, the whole system died!