THE OSO-7 MISSION

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OSO-7, the Orbiting Solar Observatory-7, was the seventh in a series, as the name implies. It was the most challenging of the original series; its mission objective is shown in Figure 1.

The payload for OSO-7, which was composed of six experiments, had a total weight of 204 kilograms (450 lb). Early in the program it was obvious to many of us that we had great incompatibility between the existing spacecraft and the selected payload. Recognizing that the science to be accomplished was challenging and that it was unreasonable to expect this science from a lesser payload, we had to make some changes in the spacecraft. The required changes to the basic spacecraft amounted to roughly doubling its physical parameters.

That sounds like a big deal, but it really wasn't.

We used the system approach here of using fully the launch vehicle. We had plenty of launch vehicle capability. We didn't impose weight constraints. We just let it happen to a great extent and this saved considerable money.

We added a gyro and a star sensor to the wheel section, to provide a nighttime pointing capability for the three experimenters who needed night reference.

And for the first time this payload forced us to think clean, build it clean, and keep it clean through injection. This imposed several system requirements on the launch vehicle people since, for the first time, they had to really clean everything up, get rid of all the particles and they did a terrific job in this regard.

MISSION OBJECTIVE:

- TO OBTAIN HIGH-RESOLUTION SOLAR-CORONA DATA IN THE XUV AND VISIBLE SPECTRAL REGIONS

CHANGES REQUIRED TO DO MISSION:

- PHYSICAL PARAMETER OF S/C DOUBLED
- GYRO AND STAR SENSOR ADDED
- BUILD THRU LAUNCH-CLASS 10,000 CLEAN

Figure 1. OSO-7 mission objectives and spacecraft compatibility.

I will show you the reference launch trajectory in Figure 2. In this standard Delta launch trajectory, about half way up you see the fairing jettison. When that happened, we caused the sail portion to rotate by a motor which is in the wheel. The wheel is the bottom part and the sail is the upper part. When the shroud came off, the motor caused the sail to spin up with respect to the wheel, thus storing momentum in the sail.

The launch vehicle control system easily accommodated this torque until we separated. At the time of separation the plan was that the momentum stored in the sail would be transferred to the wheel to provide a stable momentum vector about the spin axis. We, of course, did all of the regular things with regard to the mission planning in preparation for this launch. We made sure the data links were correct; the data processing plan was viable; that the spacecraft and experiment were built and tested properly; the format for experimenter data was proper; and the ground stations and control center support was properly planned. At that point we had, in the classical sense, met all the requirements; except as it transpired, the mission would have been a failure. And in Figure 3 you see what we like to think of as the first principle of system engineering stated rather simply. "If you can't afford to lose your pants, wear your belt and suspenders, too."

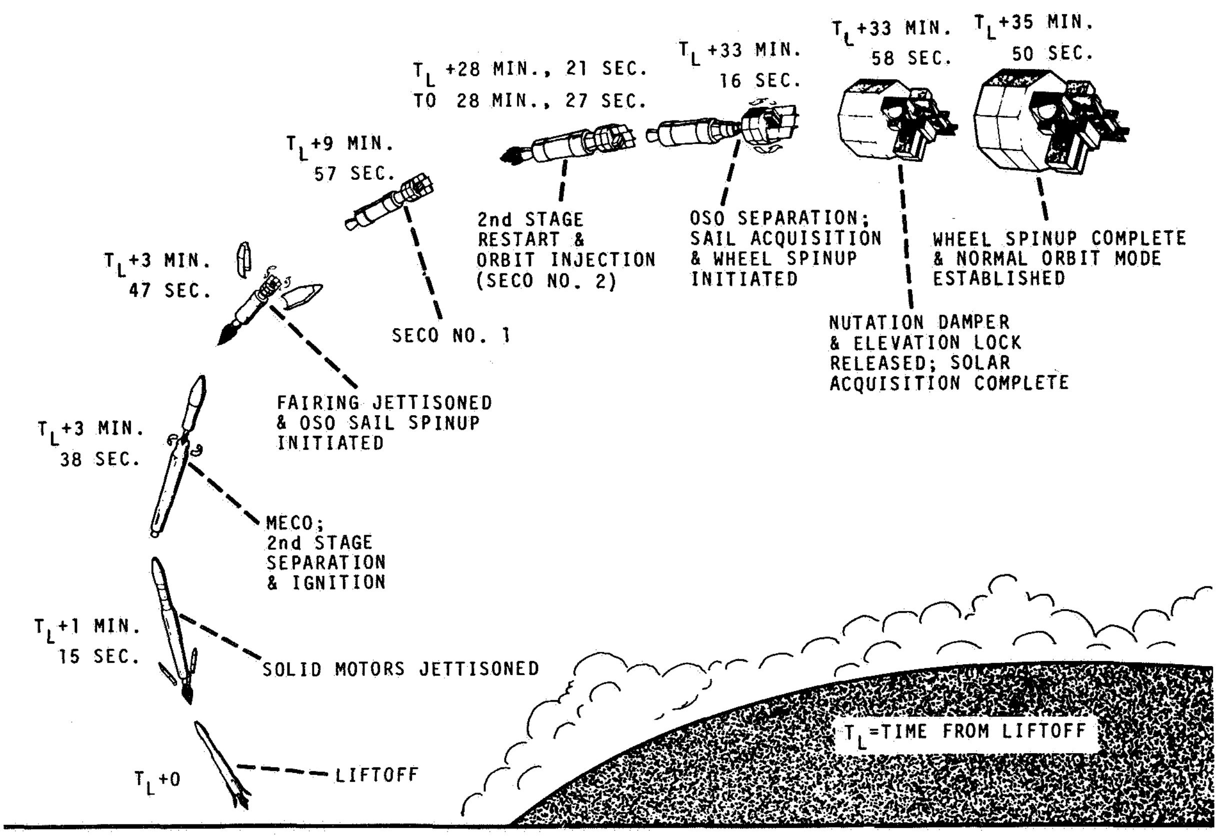

Figure 2. OSO-H launch sequence.

FIRST PRINCIPLE OF SYSTEM ENGINEERING:

"IF YOU CAN'T AFFORD TO LOSE YOUR PANTS,

WEAR YOUR BELT AND SUSPENDERS, TOO."

CONSEQUENCE OF THIS TO OSO-7:

- ADD 3-MINUTE SPINUP TIMER
- LARGE-ANGLE SUN SENSOR
- SHORTED-CELL MONITOR
- CONTINGENCY PLAN

Figure 3. OSO-7 system engineering.

What this means is that after you have got the original configuration pretty well tied down, it is necessary to really take a look at the whole mission from end to end, and try to ferret out those particularly sensitive points and put in functional redundancy where you can.

In the case of OSO-7 we added four things. They are shown on the bottom of the figure – none of these are very cosmic – we added a three-minute timer, which would dump gas in a spinup direction for three minutes after separation. This would be quite important in the event that the transfer of momentum that was indicated in the previous figure did not really come off as programmed.

We added a large-angle sun sensor. We had flown this mission six times before without this sun sensor. This time, because of the importance of the mission, the fact that it cost $36 million, and some other things which I don't have the time to go into, we put one on. This device gave us the capability of determining the angle between the sun line and the spin axis within plus or minus 90 degrees and backed up the standard sun sensor which had only a plus or minus 15 degree field of view. We never had a shorted-cell monitor before, but in this particular case we were flying batteries that were five or six years old, and we wanted the capability of being able to determine if we were going to generate gas and perhaps blow the side off the spacecraft. We really needed this device later in the mission.

We always had a contingency plan before, but we never really had a contingency plan like this one. The OSO-7 contingency plan tied together the ground stations, the control center, the engineers, everybody had rehearsed this launch until it was coming out of their ears.

We did this because, if we had trouble, we had to have people that were skilled, that really knew what they were going to do. The day of launch arrived, and to be quite frank about it, I really felt that it would be a routine launch, and there wouldn't really be any trouble.

I figured that I would never have to tell anybody that we spent $135,000 for those last four items. And those are the only four we added, and the contractor really didn't like them because they were a pain to him, and he felt they weren't really necessary and a "waste of taxpayers' money." And I figured that we would never have to tell anybody about how we "wasted the taxpayers' money," but we put them in and didn't need them at all until September 29, 1972, the day of launch, when we had a launch vehicle anomaly.

This anomaly put the combined OSO spacecraft and launch vehicle into a flat spin at 60 rpm. It killed off the spin momentum we had stored in the spacecraft, and meant that when we came off the delta launch vehicle, we were spinning about the wrong (transverse) axis at 60 rpm.

All our instrumentation was set up for spinning about the correct axis. When we saw the telemetry data in the control center, we saw nothing but zeros for about two minutes. Then we began to see some data that made sense. The spacecraft was actually starting to nutate and three minutes after separation it had erected about the right axis. This nutation and subsequent erection was caused by the three minute timer functioning as described above. In this condition we had some chance of bailing out the mission by using the other features listed in Figure 2. So, the inclusion of those last four items, which were sort of the second-effort functional redundancy, meant we were able to successfully get OSO-7 straightened out 8 hours and 29 minutes after liftoff. Because of this successful spacecraft recovery the scientific mission of OSO-7 was a success, and some of its scientific firsts which you heard about yesterday, are recapped in Figure 4.

- THE DISCOVERY OF GAMMA-RAY EMISSION LINES, WHICH DEMONSTRATE THE OCCURRENCE OF NUCLEAR REACTIONS ON THE SURFACE OF THE SUN, WERE OBSERVED BY THE UNIVERSITY OF NEW HAMPSHIRE EXPERIMENT.
- THE EJECTION OF LARGE PLASMA CLOUDS FROM THE OUTER CORONA (IN RESPONSE TO SOLAR FLARES AT LOWER LEVELS IN THE SOLAR ATMOSPHERE) AS OBSERVED BY THE NAVAL RESEARCH LABORATORY WHITE-LIGHT CORONAGRAPH EXPERIMENT.
- THE OBSERVATION BY THE GSFC (NEUPERT) EXPERIMENT OF THE 262-SECOND OSCILLATION OF EXTREME ULTRAVIOLET EMISSION LINES WHICH GIVES VALUABLE INFORMATION ON THE HEATING OF THE CORONA.

Figure 4. Major OSO-7 scientific results.