**The Cause of Accident of Apollo 13:**

It was two months before NASA was satisfied that the causes of the accident were understood. As Lovell later wrote, the accident did not have a single cause but, rather, was the result of an "accumulation of human errors and technical anomalies that doomed...[the mission]." The accident began, in fact, in 1965 when the design engineers decided to change the spacecraft power supplies from 28 to 65 volts. Normally, of course, such a change would cause a cascade of other changes as designers adapted their particular components to the new operating environment. However, the people building the innards of the Service Module oxygen tanks somehow never became consciously aware of the change. Each of the tanks contained a stirring fan, a heating element, and a temperature-sensitive switch designed to shut everything off if the element got hotter than about 25 degrees centigrade (80 F) and none of these components was ever redesigned to accommodate the higher voltage. NASA might have gotten away with the design flaw (as it had on Apollos 7 through 12 ) if one of the oxygen tanks destined to fly on Apollo 13 hadn't been damaged in 1968. This particular tank had originally been installed in the Apollo 10 CSM but, prior to that mission, was removed for modification. At some point, the tank was dropped about 5 cm (two inches) and because of its very thin walls, suffered noticeable damage. Another tank was installed in Apollo 10 while the original was set aside for repair and eventual installation in the Apollo 13 spacecraft. Tests run on the tank after the repairs indicated proper functioning but, in the weeks preceding the Apollo 13 launch, ground crews experienced significant difficulties draining it. In hindsight, it was at this point that NASA should have taken a hard look at the health of the tank but instead, all of the cognizant individuals - the crew included - concluded that the problem was not serious. Replacement of the tank would have delayed the mission - by a month at least - and, at the time, it seemed acceptable to try emptying the tank by running the internal heater for several hours. No one imagined just how serious a problem the procedure would cause. As we now know, the temperature-sensitive switch was not designed to operate at 65 volts. During normal operations, the heater was on for only brief periods and the switch never opened. However, during what proved to be a lengthy process of emptying the tank using the internal heater, the switch opened but, then, was immediately welded shut again by an electric arc driven by the high voltage. Indications that the switch had closed were missed. Subsequently, whenever the CSM was powered up, the heaters went into operation without the protection normally provided by the switch; and, at some point during pre-launch activities, the whole assembly reached a temperature of over 500 degrees Centigrade (1000 F). This was a high enough temperature to cause severe damage to the Teflon insulation protecting the fan-motor wiring and, as the Apollo 13 Review Board later concluded, "from that time on the oxygen tank was in a hazardous condition when filled with oxygen and electrically powered." The stage was set for the accident.

Despite all the rattling that must have gone on during the launch and subsequent engine firings, nothing untoward happened inside the tank until fifty-five hours, fifty-five minutes into the mission. At that moment, at a quiet time and, undoubtedly as a result of something so simple as the start up of the fan, the wires arced and the insulation caught fire. It was the 1967 Apollo launch-pad fire all over again, only this time it was a fire fed by a superabundance of pure oxygen, a fire that wouldn't quickly go out. The heat of the fire began boiling the liquid oxygen that mostly filled the tank and the pressure began to rise. Within a half minute, the pressure was too high for the tank's thin walls and they burst. The explosion wreaked havoc throughout the innards of the Service Module, rupturing the other oxygen tank and blowing out the side of the spacecraft.