**The Beresheet spacecraft crash report**

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**Background and history**

The spacecraft was developed by the SpaceIL association

On February 22, 2019 the Beresheet spacecraft Launch - the Israeli spacecraft that was about to make history and land on the moon. The mission was to make Israel the fourth country to land a spacecraft on the moon and be the first spacecraft that was privately funded to land on the moon, the smallest and cheapest spacecraft to send to the moon as a "hitchhiker" in another launch.

The spacecraft made the way to the moon in an increasing elliptical orbit around Earth, with the transition between each orbit being maneuvered for a short time - a few minutes at the longest.

On April 4 the spacecraft performed the most complicated maneuver except for the landing itself, starting the engine to slow down and entering the course around the moon. A week later and a few slowdown maneuvers, the landing itself began, in which the engine was switched on again to allow it to land softly on the Mare Serenitatis part of the moon.

**The original landing plans**

The moon landing program was autonomously operated by the spacecraft by these steps

When the spacecraft receives a command, it will begin to perform a system checks as well as some maneuver to get started. If the control panel finds a problem at this point, the landing will be cancelled. if it does not find any problem the landing will begin, which is the no-return point.

About 850,000 meters from the landing point and at an altitude of 25,000 meters, the spacecraft will begin the maneuver so that it will eventually align its engines in the direction of landing in order to use them to slow down.

The landing process will take between 15-21 minutes when the spacecraft control computer will run its engines according to the data and slow the spacecraft to a total stop at 5 meters above the moon's surface. from this height, the spacecraft will free fall to the moon, this fall will take about 2.5 seconds.

**The causes of the crash**

At first everything went well, but in the last ten minutes before landing a series of glitches began, leading to the engine being shut down and eventually to the crash of the spacecraft on the moon.

The crash of Beresheet have a series of failures starting with the spacecraft design itself which was very small and built with only 100 million $ budget to human errors.

Research lately published by the Davidson institute revealed the following:

On launch night a problem was discovered with the star-trackers which is a pair of cameras designed to capture the sky and detect certain stars and determine the angle of the spacecraft in space, It seems that during the separation from the launch missile dust particles landed on the dark shields that was supposed to protect the star-trackers from direct sunlight and returned light which blinded the cameras.

The first few attempts to work around the problem with new software instructions were unsuccessful and instead the engineers found creative solutions to tilt the spacecraft sideways while maneuvering and using accelerometers instead of the star-trackers in the maneuvers where sunlight could not be avoided. These changes forced the team to put in a lot of work, and made it difficult to locate the spacecraft, as any bias could slightly shift the course.

A few days after launch, the spacecraft unexpectedly rebooted itself and delayed a planned maneuver. The boot problem continued all the way to the moon, probably due to a malfunction in the electronics box that connected between the computer and the spacecraft system, it was built specifically for Beresheet and was never tested in space and due to intense radiation exposure in space worked poorly.

In addition, there was only one computer on the spacecraft so the software extensions that were designed to overcome problems were not burned into the computer's memory and was only written on the RAM memory, so they were deleted every time the computer was booted and had to be uploaded repeatedly in a command file.

In the midst of landing while the engine was running, the accelerometer, called the Inertial Measurement Unit (IMU) turns off, the spacecraft had two IMU’s and functioned well with only one while trying to run the one who’s not working again, but due to the spacecraft's design, re-activating the first IMU blocked the transfer of information from the second for less than a second which during that time the computer did not receive acceleration data and declared a navigation failure which caused a reboot that took less than two seconds but the computer returned to activity without the software extensions, which according to the command file should be recharged every minute, as a result the computer rebooted itself over and over again and only after about five times the expansions were received.

The computer reboots turned off the spacecraft's main engine, which at this point was supposed to run all the time to slow down the landing, the computer was supposed to start the engine immediately but to restart the engine it had to receive voltage from two sources and after the rebut only one worked so the main engine did not turn on. The spacecraft continued falling toward the moon in high speed, with only the small directional engines continue operating and maintaining the proper direction.

It hit the moon at the speed of more than 3,000 mph and probably crashed to small pieces.

**My project- Simulation**

In my project I took the basic data of the spacecraft and the moon and the starting point data of the landing and slowly rotated the spacecraft to face down so it can land safely and then caused it to slow down each time to a different speed determined by its height from the moon, so, after encountering a number of bugs of fuel and lack of fuel and landing in high speed and in fact crashing the spacecraft I realized there was a need to slow the landing even further at higher altitudes so that it would slow down and not crash and all this by using as little engine use as possible so that it won’t run out of fuel and crash

**Simulation results**

In this schema see how much fuel we have in each point of time

In this schema see how the Horizontal speed and vertical speed in each point of time