



On March 1, 2013, Space Exploration Technologies (SpaceX) launched the Dragon Supply Capsule on a Falcon 9 booster. SpaceX 2 is the second commercial resupply mission to the International Space Station.

Dragon delivered about 1,268 pounds (575 kilograms) of supplies to support continuing space station research experiments and will return with about 2,668 pounds (1,210 kilograms) of science samples from human research, biology and biotechnology studies, physical science investigations, and education activities.

According to the launch video narration, while the first stage engines were operating before Main Engine Cut-Off (called MECO), the rocket position and speed were given by the values in the table below:

Time Min:Sec	Altitude (km)	Down Range (km)	Speed (km/s)
2:20	30	23	1.0
2:45	51	59	1.8

**Problem 1** - At what average speed was the altitude changing over this time interval?

**Problem 2** - At what average speed was the down-range distance changing over this time interval?

**Problem 3** - At what rate was the rocket accelerating over this time interval?

**Problem 4** - What was the distance from the launch pad to the rocket at each time?

**Problem 5** - At what average speed was the distance increasing over this time interval?

**Problem 1** - At what average speed was the altitude changing over this time interval?

Answer: Speed = distance/time. Time = 2:45-2:20 = 25 seconds. Distance = 51-30 = 21 km, so speed = 21 km/25 sec = **0.84 km/sec**.

**Problem 2** - At what average speed was the down-range distance changing over this time interval?

Answer: Time = 2:45-2:20 = 25 seconds. Distance = 59-23 = 36 km, so speed = 36 km/25 sec = **1.4 km/sec**.

**Problem 3** - At what rate was the rocket accelerating over this time interval?

Answer: Acceleration = speed change/time, so

$$\begin{aligned} A &= (1.8 \text{ km/s} - 1.0 \text{ km/s}) / (2:45 - 2:20) \\ &= + 0.8 \text{ km/s} / (25 \text{ sec}) \\ &= 0.032 \text{ km/sec/sec} \\ &\text{or } 32 \text{ m/sec}^2. \text{ This is about 3-Gs of acceleration felt by the astronauts.} \end{aligned}$$

**Problem 4** - What was the distance from the launch pad to the rocket at each time?

Answer: Use the Pythagorean Theorem

$$\text{At 2:20 } d = (30^2 + 23^2)^{1/2} = \mathbf{38 \text{ km}}$$

$$\text{At 2:45 } d = (51^2 + 59^2)^{1/2} = \mathbf{78 \text{ km}}$$

**Problem 5** - At what average speed was the distance increasing over this time interval?

Answer: From the distance calculation, speed = (78 - 38)/25 sec = **1.6 km/s**.