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# The Miraculous Survival of Nicholas Alkemade

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**Abstract**
This paper discusses the fall of Flight Sergeant Nicholas Alkemade from a height of 18,000ft during the Second World War. It uses simple mechanical models to see whether such a fall was in fact possible and comes to the surprising conclusion that it may have been possible to survive the fall. However this conclusion depends on the analysis of what happened when the airman hit the trees, where certain values i.e. the spring constant of a pine tree branch, are uncertain.

**Introduction**
In 1944 Flight Sergeant Nicholas Alkemade is reported to have fallen from 18000ft (5,500m) from his Lancaster bomber, whilst flying on a mission over Germany [1]. It is reported that, despite the fact that he fell without a parachute, he survived the fall with only a sprained leg. It is thought that this is because he fell into pine trees and soft snow. Evidence for his story is that after being taken as prisoner of war he was given a certificate by the Germans to support his claim. However the job of this paper is not to attempt to prove the truth of a certain historical episode but to see whether, using simple mechanics, surviving such a fall is possible.

It is known that the leading cause of mortality in free fall is cerebral damage and haemorrhage from intra-abdominal and intra-thoracic organs [2]. The damage to the internal organs is thought to be caused by the effects of deceleration on impact. The total number of *g*'s in terms of deceleration a human can withstand are not clear. However at least two sources cite 100*g* as being the absolute maximum a human can withstand, although this is with some injury [3, 4]. Moreover [4] is for racing track car drivers in full body protection. However 100*g* will be taken as the upper limit.

**Reaching Terminal Velocity**
If the airman begins his fall from 18000 ft he will reach terminal velocity before reaching the ground or hitting the trees. His terminal velocity may be calculated by the equation:

$$v_t = \sqrt{\frac{2mg}{C\rho A}},$$

where $v_t$ is the terminal velocity, $m$ is the mass of airman, $g$ is gravity (9.8 $ms^{-2}$), $C$ is the drag coefficient which depends on the falling object, $\rho$ is the density of air (1.2$kgm^{-3}$) and $A$ is the surface area of the falling object (0.7$m^2$) [5]. The drag coefficient is calculated by assuming the airman is falling lying flat and so may be modelled as a cylinder on the flat, which has a drag coefficient of 1.2 [6].

When this calculation is normally done it is often assumed that the airman has a mass of 75 kg. This would give a terminal velocity of 38 $ms^{-1}$ or 85 mph. However, this is wartime and he may not have been eating well! He may therefore have weighed as little as 7st or 45kg. This would give a terminal velocity of 29.5 $ms^{-1}$ or 66 mph.

**The Pine Trees**
Now suppose that falling through the air he has the good fortune to hit pine trees. The interaction may be modelled in the following way. Each branch the airman strikes absorbs some of his kinetic energy and, rather like a spring, transforms it to elastic potential energy. Ignoring the negligible change in gravitational potential energy this gives:

$$\Delta(\text{Kinetic Energy}) = \Delta(\text{Elastic Potential Energy})$$

$$\frac{1}{2}mu^2 = \frac{1}{2}kx^2$$

$$v = \sqrt{\frac{2}{m}\left(\frac{1}{2}mu^2 - \frac{1}{2}kx^2\right)}$$

Where *u* is the initial velocity, *v* is the final velocity, *k* is the spring constant and *x* is the distance the branch bends.

Some educated guesses must now be made. It can be estimated that the branch bends by 0.25m. Spring constants vary widely from 50000 $Nm^{-1}$ [7] for a car suspension to 88 $Nm^{-1}$ [8] for a rubber band. This means the decrease in velocity could vary from 28.3 $ms^{-1}$ to 29.49 $ms^{-1}$. This means that at a very best estimate the airman's velocity will decrease by only 1.2 $ms^{-1}$ every time he hits a branch. If it is supposed that he hits 10 branches on the way down, then his speed will decrease by 12 $ms^{-1}$. This would bring his speed down to 17.5 $ms^{-1}$ or 39.2 mph.

**Falling in to Snow**

It is assumed that the airman fell into a snow drift. The depth of the snow drift may be taken to be 2 m. Snow fall greater than this has been recorded in Germany and in drifts the snow will be deeper than usual. The situation during the impact may be modelled as follows, where $F_g$ is the work done by the snow on the airman and $\Delta h$ is the depth of the snow.

$$\Delta KE + \Delta GPE = F_g \Delta h$$

$$\frac{1}{2}mv_t^2 + mg\Delta h = F_g \Delta h$$

$$F_g = \frac{{}^1/_2\, mv_t^2 + mg\Delta h}{\Delta h}$$

$$F_g = \frac{m}{\Delta h}\left(\frac{1}{2}v_t^2 + g\right)$$

The best estimate for the number of *g*'s acting on the airman with a mass of 45 kg and velocity that is now 17.5 $ms^{-1}$ is 3666 N. This gives a deceleration (*F/m*) of 81.5 $ms^{-2}$ or 8.3*g*. However, with the less generous estimate for the spring constant for the pine tree branches and therefore a speed of 29.5 $ms^{-1}$ the force will be $1x10^5$ N and the deceleration will be 226.5*g*. This is clearly not survivable.

**Conclusion**

If we use values for our calculations that take the airman as an outlier, which he must be, for example his weight and the values for the spring constant for the pine tree branches, then it does seem possible for the airman to survive his fall. However, whether he survives or not seems to depend strongly on the how much energy is absorbed by striking the tree branches. Too low a value for the spring constant and the airman does not survive his fall.

**References**


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