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Research Paper

MAXIMUM ALTITUDE FOR A SUCCESSFUL SPACE DIVE

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ABSTRACT

In this paper, we attempt to find the maximum altitude from sea level from which a person could successfully and safely descend to the surface of the Earth. We also analyse and highlight the challenges and dangers in such a descent which is also a proof of how only a handful of people have ever tried doing this pragmatically, notably Felix Baumgartner in 2012 and Alan Eustace in 2014. With a range of variables, conditions, and velocities, we investigate the problem using a density-barometric perspective and one solely based upon forces and using simple one-dimensional motion equations to analyse the scenario. We use Newton's second laws to determine the maximum velocity a skydiver can achieve which would be when the resultant forces acting on it must be 0. Then we analyse the different drag forces the skydiver goes through before reaching this velocity and found the relative acceleration. Equating this into the motion equations gave the displacement and thereby the maximum altitude possible for the skydiver. In the barometric approach, we formulate a relation between the terminal velocity at different heights (terminal velocities change due to the changing drag forces due to different air densities of regions in atmospheres) and the density of those heights. Then we formulated an equation for the maximum height which involved scale height, a logarithmic equation of the terminal constants and some constants. From these methods we find that the maximum altitude for a skydiver to descend from and reach the ground safely is 45,818m, whereas the true value must be somewhere between 41,261m and 45,818m.

Keywords: space diving, terminal velocity, barometric formula, aerodynamic drag, supersonic descent

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1 Introduction and Problem Restatement

Humans can be crazy. That is what makes our species so special. Testing out the limits of our physical and mental capabilities and expanding on them has helped us achieve where we are at the status quo. To further this, a very natural, yet physically complicated question emerges: from how high up in the sky can we jump to land safely and successfully? Recently, this has been tried and done in 2012 by Felix Baumgartner in the Red Bull Stratos mission (from a height of 39,970 meters from sea level) and in 2014 by Alan Eustace (from a height of 41,420 meters from sea level) [1]. In this paper, we aim to find the maximum height a skydiver can descend from and land safely on the surface of the Earth. This paper first lists out assumptions, then devises a list of physical constants that play a critical role in the free fall of the diver and finally assesses the situation using Force - Newton's Laws of Motions, and the Work-Energy Theorem. We will then discuss the plausibility of our results, referencing existing space dive world records. Throughout the paper, we will elucidate the challenges and dangers a potential space diver may face during his descent.

2. Assumptions and Risk Assessment

2.1 Assumptions

1. The space diver is trained and will not make any errors. This includesdeparting the rocket with zero initial velocity and no non-vertical component to their velocity (purely vertical jump).
2. The force of gravity is constant and equals 9.81m/s2.
3. The rotation of the Earth does not have any relative effect on theskydiver because they are assumed to still be in the atmosphere.
4. We assume that the space diver does not experience spin (any spin iscorrected by a device such as a G-Whiz or Drogue chute). Additionally, though the diver is assumed not to spin, we assume that their drag coefficients are the same as the ones used for Felix Baumgartner in the 2012 Red Bull Stratos jump[2].
5. The space suit has the necessary and modern technology and materials to withstand their rapid descent, pressure changes, and extreme temperatures.
6. The diver has an oxygen tank, which is included in his given totalmass of 190 kg and with enough oxygen reserves to last throughout the duration of descent and ascent to the drop off point (thus, he can jump from greater heights where he cannot naturally survive).
7. The diver can survive the G forces felt during parachute deployment.
8. The space jumper is wearing an A7-LB[3], which we will use to calculatetheir cross-sectional body area in Section 5.3.
9. The jump conditions are close to ideal; wind speed (especially for highaltitude winds) is negligible. The horizontal displacement does not play a role in the vertical displacement and motion of the diver.
10. The space diver is assumed to always fall horizontally in an orientationwhere the area of the cross-section of the spacesuit perpendicular to the direction of motion is the maximum, “belly up.”
11. Upwards is considered positive, and the problem has been simplified toa one-dimensional problem assuming that the skydiver only undergoes vertical motion. The origin is set such that $y = h = 0$ m. at ground level.

2.2 Risk Assessment

Jumping from high altitudes poses several physical and biological threats to the human body which can easily prove fatal if overlooked in a real-life scenario. Following are some of the risks and the analysis of them:

1. Ultraviolet Radiation: As the atmosphere gets thinner, the exposureto UV radiation increases. Not only is this potent for the human skin but it can also have intense effects on the outer layer of the spacesuit.
2. Lack of Atmosphere: Not only does the thinning of atmosphere create the obvious problem of less air for the skydiver to breathe, there would be less aerodynamic drag due to a decreased air density, thereby creating large velocities.
3. Extreme Conditions: The outer layers of the atmosphere are very cold,reaching approximately -51°C [4]. Without proper insulation, the skydiver can freeze to death. The low air pressures and extreme temperatures can cause health complications and lead to unconsciousness, seizures, and death.

4. Lack of Oxygen: Skydivers have a limited amount of oxygen in theirgas tanks which, if depleted, will lead to hypoxia (oxygen starvation).
5. Biological Considerations: Depending on the velocity at which thespace diver is falling, they may experience a large number of G forces upon deploying their parachute. Sustained exposure to such high forces might cause biological problems and complications for the skydiver. Additionally, the space diver must have a landing velocity small enough that they are not injured.
6. Re-entry Heating: Unlike spacecraft and capsules, which are heatshielded for atmosphere re-entry and subsequent vehicle heating, spacesuits are not equipped for this. The space diver cannot jump from a height where their velocity would result in large friction forces on their suit, leading to the material burning up.
7. Entering a flat spin during the descent: This problem was seen with Felix Baumgartner's Red Bull Stratos Jump, during which Baumgartner began to spin uncontrollably [4]. Because the laminar and turbulent flow are not always even, a slight deviation at such high velocities can cause potentially fatal spin. To prevent this, engineers have come up with solutions like the G-Whiz and drogue chutes, but we assume that the diver experiences no spin.
8. Breaking the Sound Barrier: We assume our diver breaks the soundbarrier because Felix Baumgartner reached Mach 1.25 [4]. The skydiver in our scenario will be jumping from a higher point and subsequently should reach even higher speeds, where risk of internal injury increases[5].
9. Imperfect Suit and Rogue Debris: Any breach or break in the suitwould cause serious issues to the air pressure, spacesuit temperature, oxygen supply, and sensitivity to the skin. Also, at such high velocities, collision between the diver and a particle with a small mass would have a very high momentum transfer creating chances for lethal damage.
10. Accidental Deployment of a Parachute: If the parachute is deployed ina region where the air density is not high enough to provide enough drag for the parachute to extend and deploy properly, the speed of the skydiver would not be able to reduce significantly before they reach the ground. Early deployment of the parachute also means that the fall time of the skydiver increases, and they require more oxygen, which the suit may not be equipped to provide.

3. Notations

Symbol	Meaning	Values (As Appropriate)
F_g	Force due to Gravity	Calculated as per the equation mg = 1864N
F_d	Force due to Aerodynamic Drag	Calculated as per the equation $\frac{1}{2}C_D(v)\rho(h)v^2A$
$C_D(v)$	Coefficient of Drag as a function of the velocity	Refer to 5.3.2 for the Drag Coefficients Formulas
m	Mass of the skydiver, spacesuit, and parachute	190 kg
$\rho(h)$	Air density as a function of height	Refer to 5.2 for the equation of $\rho(h)$
$A_\perp$	Cross-sectional Area of the Skydiver	$1.328m^2$ when horizontal and $0.2807m^2$ when vertical
s	Displacement	Refer to 5.4.3

v_T	Terminal Velocity	Variable
h_s	Scale Height	8434.2725m
K	Boltzmann's Constant	$1.380649 \times 10^{-23} m^2 kg s^{-2} K^{-1}$
T_a	Average Temperature of the Atmosphere	288K
M	Molecular Mass of Dry Air	$4.81063 \times 10^{-26} g$

4. Failed Approaches

4.1 Work-Energy Theorem

An intuitive approach may be to employ energy equations. At the maximum height, the space diver will have a certain potential energy, all of which is converted into kinetic energy at the bottom of the jump and thermal energy lost from friction. There are quite a few problems with this approach, which are enumerated below:

1. $\int_a^b F(x)dx \neq 0$ which means that non-conservative forces act on the object (it is path dependent). Therefore, it becomes crucial to know the path the diver travels, which varies based on factors such as wind condition.
2. The vagueness involved in calculating the thermal energy gained by the object also complicates the situation. The factors to consider are the velocity of the skydiver, the air density at that velocity, and the cross sectional area of the skydiver perpendicular to the direction of motion which faces air resistance. On further research, we tried finding out the specific heat capacity of GORE-TEX, a popular material through which spacesuits are made, to see the energy change if it was allowed to fluctuate over large temperatures.
3. Another issue is the atmospheric conditions. Temperature, pressure, air density, and humidity all change with height. Temperature changes unpredictably with height, such that it cannot be modelled with high accuracy.

For these reasons, this approach was discarded.

4.2 Forces on a Parachute

With this approach, we aimed to find the maximum drag force of a parachute with a general cross-sectional area. After finding the maximum drag force, we calculated the terminal velocity of the diver with the parachute. Greater tensions can break the diver's bones or tear their limbs from their body. We found the the maximum survivable force and thus the maximum height the diver can survive. However, this approach was discarded because:

1. The dynamics and the dimensions of a parachute meeting space jumping standards are not available. For future research, easy and accurate access to data from previous high-altitude skydives could allow further progress with this approach.
2. This problem deals with biophysics and the structural strength of muscles and bones. This would depend on numerous factors such as height, weight, and where the force is applied. Our assumptions for these factors create a highly simplified scenario that neglects the complexity involved in this problem.

5. Physical Constants and Parameters as Functions

5.1 Air Density as a Function of Height

We employed numerical analysis and graphed data from the U.S. Standard Atmosphere Air Properties to find a curve of best fit, which was extrapolated to fit the data range we are considering: 0m to 100,000m. Descending from any height above this would be highly unfeasible, as UV radiation, atmospheric temperatures, and the thermal energy generated from friction would be too high for existing space suits to withstand. The data was plotted on LoggerPro:

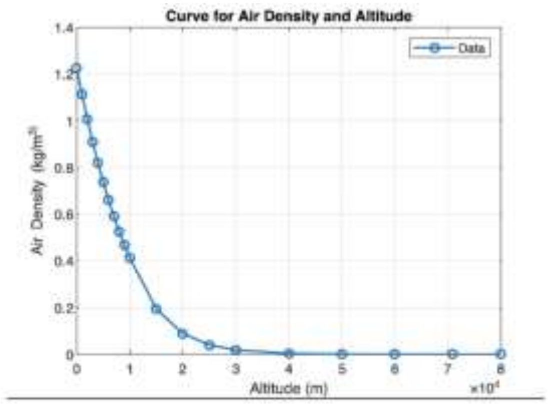

Figure 1: Data Plotted For Air Density vs Altitude

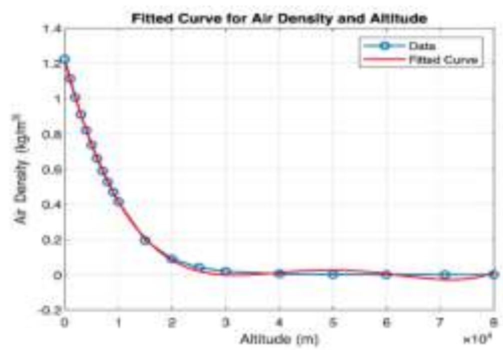

Figure 2:Line of Best Fit Generated by MATLAB

and the equation for air density as a function of height was a Gaussian Function

$$3.627e^{((height+2.395_*104)2(2.291_*101)2} + 0.0007524$$

with a correlation of 1. We used a simplified model with a correlation of 0.9988:

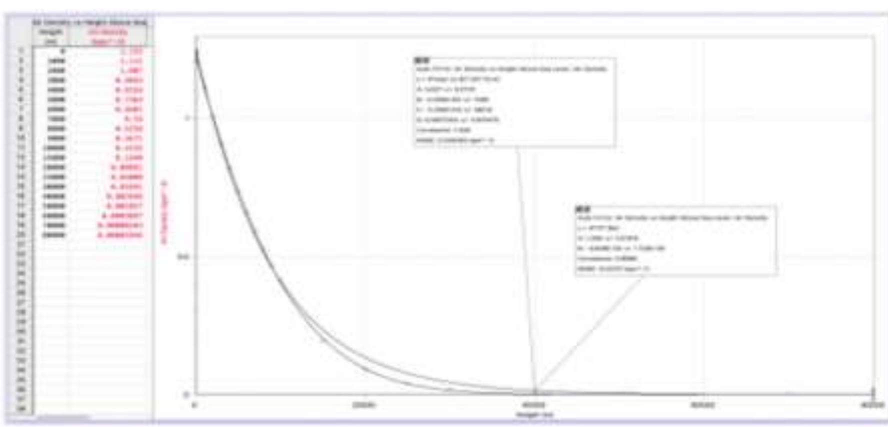

Figure 3: Line of Best Fit Generated by LoggerPro

The equation was

$$(2.4585*10^{-19})x^4-(5.02*10^{-14})x^3+(3.652*10^{-9})x^2-(0.0001114)x+1.213.$$

We considered the first three terms (x^4, x^3 and x^2, negligible, giving us a linear fit for air density versus height.

5.2 Physical Dimensions of the Skydiver

The physical dimensions of the skydiver play an important role in determining the force and energy changes that take place. The dimensions of the space dive suit were assumed to be roughly similar to that of the A7-LB's, or 1.803m × 0.737m × 0.381m [3]. These yield the following values:

Cross-sectional Area when vertical: $0.2807m^2$ Cross-sectional Area when horizontal: $1.328m^2$

5.3 Calculating the Maximum Height using Forces

5.3.1 Maximum Speed Reached during Free Fall

The maximum speed during a free fall without a parachute would be when the time derivative of velocity, $\dot{v}$, would be equal to 0m/s, which occurs when the acceleration of the system is $0m/s^2$. Taking down to be the negative direction and applying Newton's Second Laws of Motion:

$$-F_g + F_D = m\vec{a}$$

$$-mg + \frac{1}{2}C_D\rho v^2 A_\perp = 0mg$$

$$\frac{1}{2}C_D\rho v^2 A\perp = mg$$

Note that because this is a theoretical maximum, we will be considering the maximum capabilities of a human inside a space suit. The lowest density a person can survive is $0.0601\frac{kg}{m^3}$ typically occurring around 5950 meters above ground level [4]. The drag coefficient of humans is 0.7 [0], and the crosssectional area is the lowest when the human is oriented vertically. Inputting all these values gives a value of approximately 89.8m/s.

This is the case when the human does not have any protective space suit that balances out the air density, ignoring the thermal energy and heat generated. With a spacesuit, this value should be much larger. The minimum density a spacesuit might have to experience in our scenario is $0.00008283\frac{kg}{m^3}$ which is the air density at 80,000 meters. Using this as our density value would yield a very large number because realistically, the skydiver reaches their maximum speed at an altitude lower than that. Using Felix Baumgartner's jump as a reference, he reached his maximum speed at around 28000 meters when the air density was around $0.01841\frac{kg}{m^3}$ [2]. Taking the simplified assumption that the drag coefficient of the suit is 0.65 and setting the air density as $0.01841\frac{kg}{m^3}$ we get the maximum possible velocity to be 484m/s. This result seems plausible because Felix Baumgartner has a record speed of 376.9m/s at 28,000 m above the ground. We did not consider Alan Eustace's skydive because he used a drogue parachute [6]. The maximum velocity is obtained during free fall, and upon reaching this speed, the diver's velocity decreases because the drag force increases due to the increasing air density. We can also assume that our maximum velocity is achieved at 28000 meters to simplify the further arguments which aim to find the height at which we have to descend to reach this maximum velocity.

5.3.2 Drag Coefficients

We found that the drag coefficients of the spacesuit were highly dependent upon the speed at which the skydiver is descending in the atmosphere. We obtained the following empirical equations used by the Red Bull Stratos team [2]

Table 1: Table showing the different drag coefficients as a function of velocity in Mach numbers

Using these drag coefficients:

Drag Coefficient (C_D)	**Range**
$C_{D1} = 0.65$	for $Ma \leq 0.6$
$C_{D2} = 0.50 + 1.23(Ma - 0.25)^2$	for $0.6 \leq Ma \leq 1.1$
$C_{D3} = 1.38 - 0.30(Ma - 1.1)$	for $1.1 \leq Ma$

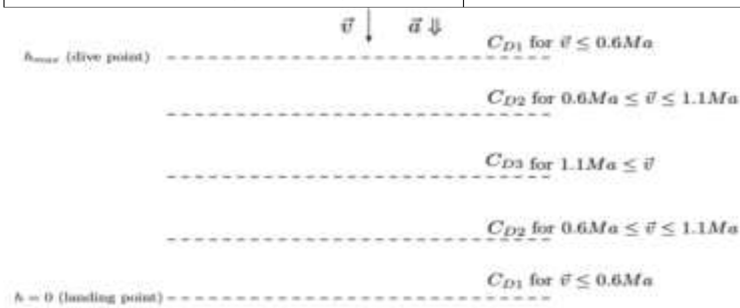

Figure 4: Different regions of Drag Coefficients

As seen by the drag coefficient formulas, we can create three different regions that would have different drag forces and thereby different accelerations for the system. These regions are distinguished by the speed of the object: speeds lesser than 0.6Ma, speeds in between 0.6Ma and 1.1Ma, and speeds greater than 1.1Ma. Note that the speed would eventually go below 1.1Ma and subsequently 0.6Ma. The maximum speed is achieved in region 3 where the speed is 1.41Ma. Below that speed, the distance travelled is equal to the height obtained in 5.4, which is 28,000m.

5.3.3 The Distance from Descent Point to Reach Maximum Velocity

The next step is to find the distances traveled in Region 1 and Region 2, and the brief moment the diver is in Region 3 until they reach maximum velocity. The values for the speed are 0.6Ma, 1.1Ma, and 1.41Ma, and in meters per second respectively: $205.8\frac{m}{s}$, $377.3\frac{m}{s}$ and $484\frac{m}{s}$

$$\frac{dv}{dt} = \frac{F}{m}$$

$$s = v_0 t + \frac{1}{2}at^2$$

To find the displacement we have to find the time spent and the acceleration undergone in each region. We can call these t_1, t_2, t_3 and a_1, a_2 and a_3. The displacement can be s_1, s_2, s_3 respectively. For simplification, we assumed two things: the air density changes in the orders of magnitudes of 10^{-2} and therefore has little effect on the final result, as it stays nearly constant over the regions. This is assumed to be 1. The velocities also change in the region which causes the drag force acting on the object to change. This is simplified to assume that the average drag force acting on the object is $\frac{Fdmax \pm Fdmin}{2}$ which is dependent upon the maximum and the minimum velocity of the regions. v_1, v_2, v_3 represent the average velocities of the respective regions which are as follows: $102.9\frac{m}{s}$, $291.55\frac{m}{s}$ and $430.65\frac{m}{s}$

$$\frac{dv}{dt} = \frac{F(v)}{m}$$

$$\frac{dv}{F(v)} = \frac{dt}{m}$$

$$\frac{1}{mg-\frac{C_d(v)A_{\perp}v^2\rho}{2}}dv=\frac{dt}{m}$$

$$\int_0^{484}\frac{1}{mg-\frac{C_d(v)A_{\perp}v^2\rho}{2}}\mathrm{dv}=\int_{v_i}^{t}\frac{dt}{m}$$

$$\int_{377.3}^{484}\frac{1}{mg-\frac{(1.38-0.30)(1.41-1.11)A_{\perp}v^2}{2}}dv+\int_{205.8}^{377.3}\frac{1}{mg-\frac{(0.50+1.23)(0.85-0.25)^2)A_{\perp}v^2}{2}}dv+$$

$$\int_0^{205.8}\frac{1}{mg-\frac{0.65}{A_{\perp}}v^2}dv=\frac{t}{m} \qquad (1)$$

$$0.099+0.1328+0.1148=\frac{t}{190}$$

t_1=21.83s, t_2=25.63s, t_3=18.81s=⇒t_{total}=18.81+25.63+21.83=66.23s

Finding acceleration using

$$\vec{a}=\frac{\Delta v}{\Delta t}$$

$$a_1^*=\frac{205.8-0}{t_1}=9.43\,\frac{m}{s^2}$$

$$a_2^*=\frac{377.3-205.8}{t_2}=6.69\frac{m}{s^2}$$

$$a_3^*=\frac{484-377.3}{t_3}=5.67\frac{m}{s^2}$$

The values obtained for acceleration make sense and match the physical understanding of the world. As the skydiver descends, they are going to experience a higher drag force and thereby the resultant force acting on them would be lower, which suggests a lower acceleration. In this derivation, the average acceleration in the regions progressively decreases which suggests that as an object goes from Region 1 to Region 2 and Region 2 to Region 3, it accelerates at a decreasing rate until the acceleration reaches 0m/s^2 and the object reaches its maximum velocity. Through this average acceleration, we would try to find the displacement in each of these regions. We note that these regions are unlike physical regions, rather they specify boundaries for the specific velocities concerned to the drag coefficient equations in 5.5.

We know that s=$v_0t+\frac{1}{2}at^2$,thus

$$s_1=(0)(21.83)+\frac{1}{2}(9.43)(21.83^2)=2246\text{m}$$

$$s_2=(205.8)(25.63)+\frac{1}{2}(6.69)(25.63^2)=7472\text{m}$$

$$s_3=(377.3)(18.81)+\frac{1}{2}(5.67)(18.81^2)=8100\text{m}$$

$$s=s_1+s_2+s_3=17818\text{m}$$

Maximum height above the surface = 17818 + 28000 = 45,818 m

The maximum possible altitude from which a person could successfully descend to the surface was calculated to be 45,818 meters above ground level. This is slightly higher than the highest-ever jump made by Alan Eustace which was from a height of 41,420 metres.

5.4 Calculating the Maximum Height using Barometric Formula

5.4.1 Terminal Velocity

Terminal velocity is the maximum speed an object reaches during free fall, where the downward gravitational force on the object by the Earth equals the upward aerodynamic drag from the atmosphere. It is calculated using the following derivation, adapted with the concept of the skydiver at rest in a non-inertial reference frame:

$$\sum \vec{F}=0$$

$$F_g=F_d$$

$$mg=\frac{1}{2}C_D pA \perp v_T^2$$

$$v_T=\sqrt{\frac{2mg}{pA\perp c_D}}$$

Through this we can observe that the terminal velocity and the density have an inverse relationship, wherein the square of the terminal velocity is proportional to the inverse of the density. This can be denoted by $v_r \propto \sqrt{\frac{1}{p}}$

$$\frac{v_r(h)}{v_k} \approx \sqrt{\frac{p_0}{p(h)}}$$

5.4.2 Barometric Formula

The Barometric Formula is as follows [9]:

$$p(h)=p_0 e^{\left(\frac{-h}{g}\right)}$$

Where h_s (Scale height) is given by $\frac{KT_a}{Mg}$

$$=\frac{(1.380649x10^{-23})(288)}{(4.81063x10^{-26})(9.8)}$$

$$=8434.2725m$$

Substituting this into the equation of the terminal velocity and making h the subject of the equation we get

$$h = 2ln\frac{(v_T)(h)}{v_{T*}}h_s$$

If we take the terminal velocity to be the speed at which the diver initiates the parachute, we divide the height h_{max} into two components. [Assume $v_T = v_{max}$].

$$h_{para} = 2ln\frac{v_{max}}{v_{T*}}h_s$$

The maximum velocity in an assumed vacuum:

$$v_f^2=v_i^2+2gh$$

$$h_{max}-h_{para}=\frac{v_{max}^2}{2g}$$

5.4.3 Derivation of the Maximum Height using Barometric Method

We have derived an equation for the height at which the parachute is deployed and the difference between the maximum height and the height at which parachute is deployed. These can be used in one to find the maximum height which is the aim of this research paper.

$$hmax = hpara + (hmax - hpara)$$

$$= 2ln\frac{v_{max}}{v_{T1}}h_s + \frac{v_{max}^2}{2g}$$

$$= 2ln\frac{484}{v_{T1}} \text{ x } 8434.2725 + 5556.1224$$

$$\text{where} v_{T1} = \sqrt{\frac{2mg_i}{p_i A_{\perp} C_D}}$$

Assuming (any C_D from figures) = C_D, and (any $A_{\perp}$ of person) = $A_{\perp}$. The skydiver has mass of 190 kg, and g_i = 9.8 m/s^2 while ρ_i = 1.222 kgm$^{-3.}$ We naturally take the coefficient of drag recorded from region 1, since $v_{T1} << 0.6$Ma. The cross-sectional area of the skydiver is taken to be a value of 1.328 m^2. Thus:

$$v_{T1} = 58.37 ms^{-1}$$

Solving for $h_{max} = 2ln\frac{484}{58.37} \text{ x } 8434.2725 + 5556.1224 = 41261m$

6. Strengths and Shortcomings

6.1 Strengths

1. Our calculations take into account that factors such as air density andthe force of gravity vary as a function of height from the ground, which gives a more accurate result than assuming constants for these factors.
2. We have taken into account the biophysics of a situation that he "successfully descends," meaning that he survives the descent. This is on the order of calculating compressive strengths of bone to counteract the forces generated by the impact of the skydiver on the ground, plus the upward impulse directed when the straps become taut in the parachute upon initiation of the parachute at v_{max}.
3. We had assumed that when approaching speeds close to the speed of sound, that the drag coefficient itself would change throughout the descent, which improved accuracy with the concepts of supersonic motion.
4. Another strength is the formulations of our work were built upon previous knowledge and improving upon it. This allowed us to deeply consider the physics and helped eliminate models which were highly complicated or lead to erroneous results.

6.2 Shortcomings

1. Though we attempted to integrate as many factors as possible, we were unable to take into account every factor affecting the space diver and space-diver-parachute system. For example, we did not comprehensively take into account the changing temperatures in Earth's atmospheric layers, which affect the air density. Also, the heights in this problem suggest that the force of gravitational attraction would vary as the distances involved cannot be regarded as "near earth" situations, so the force of gravity is not always 9.81m/s^2 throughout the fall.
2. One of the biggest risks to space divers is spin, which experimentally is inevitable due to body asymmetry without stabilization devices and can become uncontrollable or even

fatal. Spin can happen in three dimensions, and our calculations do not take these into account.

3. In addition to the previous shortcoming, our models assume that the space diver does not experience life-threatening spin; realistically, the diver would have a drogue chute that stabilizes them but changes velocities in all three dimensions unpredictably.
4. Our calculations do not account for some real-world conditions like wind speed and ground type (springy versus hard land, which affects the impulse experienced by the diver upon landing).
5. The drag coefficients we used assume that the shape of the diver is that of a rotating cube. Realistically, the diver is not, and we also assume that they do not spin.
6. Reynolds number not considered.

7. Conclusion

We had successfully modelled the extreme scenarios associated with approaching supersonic velocity, which enabled a list of several new factors to consider in the safety of a human as they approach a certain value. The term "successful descent" simply doesn't mean reaching the surface. It means being able to accurately measure for the risk and hazards of this nature - on a realistic magnitude. This is what we modelled - taking into account human environmental conditions, such as pressure (assumed constant for suit), force on re-entry, both on release of the parachute and on contact with the ground. We also accounted for the moment that a parachute should be deployed where we do not risk unnecessary danger to the pilot by allowing terminal velocity to be the velocity at which the parachute should automatically be deployed. Of course, we cannot account for all factors and in any scenario, there are unpredictable events that can take place in the experiment itself which is where we learn of the chaos associated with reaching extreme levels of physics.

Acknowledgments

We would like to thank our mentors and institutions for their support in this research project.

8. Appendix

```
clear all
% Define the x and y values
x_values = [0, 1000, 2000, 3000, 4000, 5000, 6000, 7009, 8000, 9000, 10000,
    15000, 20000, 25000, 30000, 40009, 50000, 60000, 70900, 80000];
y_values = [1.225, 1.112, 1.007, 0.9093, 0.8194, 0.7364, 0.6601, 0.59,
    0.5258, 0.4671, 0.4135, 0.1948, 0.08891, 0.04008, 0.01841, 0.003996,
    0.001027, 0.0003097, 0.00008283, 0.00001846];

% Fit a polynomial curve of a specified degree
degree = 4;  % Adjust the degree as needed
coefficients = polyfit(x_values, y_values, degree);

% Generate the fitted curve
x_fit = min(x_values):100:max(x_values);  |
y_fit = polyval(coefficients, x_fit);

% Create the plot
plot(x_values, y_values, '-o', 'LineWidth', 1.5, 'DisplayName', 'Data');
hold on;
plot(x_fit, y_fit, 'r', 'LineWidth', 1.5, 'DisplayName', 'Fitted Curve');
xlabel('Altitude (m)');
ylabel('Air Density (kg/m^3)');
title('Fitted Curve for Air Density and Altitude');
legend('Location', 'NorthEast');
grid on;
% Display the equation for the fitted curve
eq = '';
for i = 1:length(coefficients)
 eq = [eq num2str(coefficients(i), '%.4f') 'x^' num2str(degree - i) ' + '];
end
eq = [eq num2str(coefficients(end), '%.4f')];
disp(['Equation for the curve of best fit: y = ' eq]);
```

Figure 5: Code for MATLAB

References

[1] Wikipedia Contributors. (2023). Space diving. Retrieved from https://en.wikipedia.org/wiki/Space diving

[2] Clark, J. B., & Damron, D. (2017). High altitude physiology and the Red Bull Stratos project. PLOS ONE, 12(11). https://doi.org/10.1371/journal.pone.0187798

[3] National Air and Space Museum. (2023). Space suit specifications. Smithsonian Institution. Retrieved from https://airandspace.si.edu

[4] National Oceanic and Atmospheric Administration. (2023). Layers of atmosphere. Retrieved from https://www.noaa.gov/jetstream/atmosphere/layers-of-atmosphere

[5] Kittinger, J., & Baumgartner, F. (2012). Felix Baumgartner skydive: Breaking the sound barrier. National Geographic. Retrieved from https://www.nationalgeographic.com/science/article/121005-felixbaumgartner-skydive-science

[6] Wikipedia Contributors. (2023). Alan Eustace. Retrieved from https://en.wikipedia.org/wiki/Alan Eustace

[7] Echemi. (2023). Chemical properties database. Retrieved from https://www.echemi.com

[8] GigaCalculator. (2023). Scientific calculator tools. Retrieved from https://www.gigacalculator.com

[9] Wikipedia Contributors. (2023). Barometric formula. Retrieved from https://en.wikipedia.org/wiki/Barometric formula