Development of Human Body Flight

by
Connor Bryce Kelsay

A THESIS

submitted to

Oregon State University

University Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Mechanical Engineering
(Honors Scholar)

Presented June 10, 2016
Commencement June 2016

AN ABSTRACT OF THE THESIS OF

Connor Bryce Kelsay for the degree of Honors Baccalaureate of Science in Mechanical Engineering presented on June 10, 2016. Title: Development of Human Body Flight.

Abstract approved: _____

Nancy Squires

Human body flight is a relatively young sport with a largely undocumented history. Human body flight is an umbrella term for any sport involving maneuvering one's body in a meaningful way through a column of relative wind. Human body flight includes skydiving, which was the origin of human body flight, as well as BASE jumping, wingsuiting, canopy flying, and indoor skydiving. The recent origin of skydiving as well as the fact that there are relatively few skydivers worldwide created a rich environment to write this thesis, which is likely the first attempt to record the recent history of sport skydiving and human body flight. The focus of this research was in-depth interviews with some of the most important skydivers to make contributions to the sport since its beginning in the 1950's. These sources were used to document the development of human body flight as a sport and lay the foundation for historical documentation of skydiving. This thesis details the origin of skydiving, the major equipment changes that allowed the sport to flourish, the introduction of tandem skydiving and its effect on business and sport diversification, wingsuiting, indoor skydiving, and the effect of advertising on human body flight.

Key Words: Skydiving, History, Wingsuiting, BASE Jumping, Vertical Wind Tunnel, Human Flight, Human Body Flight

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Honors Baccalaureate of Science in Mechanical Engineering project of Connor Kelsay presented on June 10, 2016.

APPROVED:

Nancy Squires, Mentor, representing Mechanical Engineering

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Jerry Baumchen, Committee Member, representing AeroSports USA

Toni Doolen, Dean, University Honors College

I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

Connor Bryce Kelsay, Author

ACKNOWLEDGEMENTS

I would like to thank my thesis mentor, Dr. Nancy Squires, for the unwavering commitment she shows to all of her students, myself included. Dr. Squires has been a constant beacon of motivation helping me discover and pursue my passion for space, aerospace, and human body flight. Without the direct and unparalleled support of Dr. Squires, this thesis would not have been possible.

Dean Toni Doolen inspired me to continue research on my thesis after a series of unfortunate events led my initial project to collapse. Her encouragement and commitment to my education was above and beyond what was required, and it is thanks to her that I was able to complete this thesis on time.

I would also like to thank Jerry Baumchen, who along with being a primary source for this thesis has also has aided in my understanding of parachute system design and mentored me in my parachute projects for the Oregon State University Rocket Team. He is a wealth of information and never hesitates to help students like myself learn and succeed. I am proud to have worked with Jerry and to call him my friend.

Dr. David Ullman inspired me to write this thesis on human body flight. He also supported my interest in parachute systems and aerospace by sharing his knowledge and allowing me to use his personal wind tunnel for testing my projects.

Lastly, I would like to thank Jay Gile, Rodney Holberton, and Luke Aikins for taking time to provide the interviews which were so critical to the success of this thesis. All three of these men are amazing skydivers committed to the idea of human body flight. They were all very helpful and learning their thoughts on the subject of human body flight was a pleasure.

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1 INTRODUCTION

As a new but rapidly growing array of individual sports, it is important that human body flight have a written history. Human body flight involves maneuvering one's body through a column of relative wind in a meaningful way. The most popular forms of human body flight are skydiving, BASE jumping, canopy flying, and indoor skydiving. The United States Parachute Association [1] estimates that in 2014 there were 36,770 active skydivers in the United States and that over 3.2 million skydives were made. The sport of skydiving, which developed in the late 1950s and 1960s, was the first form of human body flight. Parachuting was first and foremost used in the military. Parachutists were dropped by the thousands during WWII and the American military continued to promote parachuting through the creation of parachuting teams such as the Strategic Army Corps (STRAC) team in 1959 [3]. Excess military gear, mostly B-4 containers and C-9 round parachutes, became available to the civilian population after WWII and the Korean War. This rather inexpensive, surplus military parachute equipment is what lead a group of unique ex-military adventurers to create the sport skydiving, the foundation of human body flight. Recreational skydiving is a relatively new sport that was made possible through a unique set of circumstances. A series of major hardware equipment improvements and greater public exposure led to the slow growth of skydiving and in turn generated the diverse, individualistic, but tight knit community micro culture we see today [4].

Interviews with some of the most prominent skydivers over the last 50 years, including Jerry Baumchen, Jay Gile, Rodney Holberton, and Luke Aikins were used as primary sources for this thesis.

Jerry Baumchen's knowledge of skydiving and skydiving equipment has been a valuable source for this thesis. He has been an active part of the skydiving community since its early years

and was a primary source for documenting skydiving equipment progression. He has made significant contributions both to skydiving as a sport and to design and development of parachuting equipment. Baumchen began jumping in 1964 and is a Master Parachute Rigger, which is the highest rating that can be obtained in parachute manufacturing. He is also the owner of AeroSports USA, which holds multiple TSOs for the production of certificated parachute equipment, both for sport use and pilot emergency systems. As the owner of this company, Baumchen has developed the MagBag and NoStoBag, which are both semi-stowless main parachute deployment bags used in skydiving. Baumchen also spent 20 years on the National TSO committee, which writes the standard for testing, development, and certification of parachute equipment. Baumchen also designed and developed the world's first automatic activation device for a piggyback container. The piggyback container is a skydiving container which has both the main and reserve parachutes mounted on the skydiver's back, one on top of the other. An automatic activation device deploys parachutes automatically at a specific altitude. While he admits his original device was rather crude, today's modern, electrical versions are now standard in most sport parachute systems and have saved many lives. Baumchen also was interrogated by the FBI in 1971 because he fit the profile for the infamous D.B. Cooper [2]. Baumchen has been an excellent source when researching the evolution of skydiving equipment because he has seen and often been a part of this evolution throughout his life

Jay Gile began skydiving in 1967, very soon after the introduction of sport skydiving and in his words, "was one of the first Pro-rated skydivers in Oregon." Gile is an accomplished skydiver with many awards and records to his name. These include one "Parachutists Over Phorty" and two "Skydivers Over Sixty" world records. He was also part of the first ever four person parachute formation at night. He has jumped in Italy, Namibia, the Dominican Republic, Belize, Nicaragua, and Costa Rica. While in the Dominican Republic, Gile was a guest of the

Dominican Air Force and helped them celebrate their 60th anniversary by building the number "60" with a 20 person formation over the ocean and presenting a photo to the Dominican President. Gile has been a valuable source when researching the early days of skydiving and investigating how the sport has evolved since its origin.

Rodney Holberton is an accomplished skydiver and pilot with an interesting history in human body flight. He made his first jump in 1975 and was a Wingwalker and Stuntman for the Great American Flying Circus in 1982 and 1983. Holberton was also the instructor of the first tandem skydive ever made in Oregon and has made over 40 skydives in a single day. Holberton has been a primary source when investigating how the culture of skydiving has changed over the years and offered unique insight into the development of tandem skydiving parachute systems.

Luke Aikins is a professional skydiver with over 16,000 jumps and more than two decades of experience. He has been an active force for progressing the sport of skydiving over the last 20 years. He is an expert in swooping, an extreme and precise discipline of skydiving and is one of the pioneers of speed riding, which combines parachuting with skis to fly down mountain sides. In addition, Aikins is a highly experienced airplane and wingsuit pilot with a great deal of experience BASE jumping. BASE jumping is a sport which involves parachuting off of fixed objects. BASE is an acronym which stands for the most common objects which are jumped; buildings, antennas, spans, and earth. Aikins uses all of these skills as a member of the Red Bull Air Force which is an elite team of skydivers, paragliders, and BASE jumpers dedicated to exploring and advocating for human body flight. Perhaps his most impressive feat to date is his role as a Skydiving Consultant on the Red Bull Stratos jump, a project which broke the record for highest freefall and marked the first time in history a person has broken the sound barrier exclusively with their body. Aikins currently plans to be the first person to survive a

skydive without using a parachute or wingsuit. This project, dubbed “Heaven Sent” will be carried out on July 30th, 2016 and will involve skydiving from 25,000 feet into a specially designed net. Aikins is at the center of human body flight and has been a powerful force in its development. Aikins was a primary source when gathering information about advertising through skydiving, Red Bull, the Stratos jump, and wingsuiting.

This thesis also details the major advancements in parachuting hardware which greatly improved the safety and availability of skydiving. Each advancement has had a significant contribution to the progression of human body flight. The effect of tandem skydiving on the business of human body flight reflects advancement in both expertise and hardware. In addition, wingsuiting, a new form of human body flight which has improved significantly over the last 15 years, is explored in detail. The recent boom in vertical wind tunnels for indoor skydiving and its effect on increasing public exposure to human body flight is explored. Lastly, the effect of skydiving in advertising is explored, along with major stunts that pushed scientific and athletic boundaries such as the Red Bull Stratos jump.

2 THE FIRST SKYDIVERS

The first sport skydivers of the 1950s and 1960s and were nearly 100% ex-military veterans of WWII and the Korean War. They had been trained in static-line parachuting during their military service and found it thrilling enough to continue after their service. The creation of this base of avid parachutists coincided with the downsizing of the U.S. military after the Korean War. Jay Gile, an active skydiver since 1967, even mentioned that much of this surplus military gear was simply given away free of charge. The college club where Gile began skydiving used donated military surplus gear [5].

During the early years, skydivers were a small, tight knit, and homogenous group of people. As Gile puts it, “These guys were wild men, very hardcore, and did not cover the wide range of socioeconomic classes skydiving does today” [5]. They jumped non maneuverable round parachutes, and hit the ground hard on every jump. They learned without instruction during freefall, and had extensive training similar to military-style ground courses before their first skydives. They also all followed Static Line Progression as their method of learning. Static Line Progression is the most traditional method of training skydivers which the early skydivers developed. A line attached to the airplane deploys the parachute immediately after jumping. Freefall time is then incrementally increased until student learns to stay stable while in freefall.

During the 60’s and early 70’s, there were almost no laws governing skydiving whatsoever, and no central agency to provide safety recommendations. Even the local organization was makeshift. Jerry Baumchen, a professional parachute rigger who has been skydiving since 1964, stated that

> [skydiving] was very crude compared to today. 7-day/week drop zones were virtually unheard of. Where I started (at an airport in Vancouver, WA) no one jumped anything

> but military surplus gear. The ‘clubhouse’ was a lean-to nailed to the side of another building with a dirt floor. The drop zone was about 10 miles away. You usually could only get in one jump per day; unless you were very eager. The airplane was unreliable; some days it might show up and other days we sat around till late afternoon and then went for beers [2].

Over time, skydiving gear improved and became customized for sport skydiving as discussed in Section 3. This, coupled with greater public exposure and the advent of smaller cameras, changed the culture and demographic of the skydiving community to be more individualistic and diverse. As of 2014, skydivers are a relatively even spread of ages ranging from 16 to well over 70 years old and include people of many professions [1]. Currently, only 11% of recreational skydivers are military by occupation [1].

3 EQUIPMENT EVOLUTION

The evolution of human body flight is strongly tied to technical improvements made in parachute systems over the last century. Each major advancement in equipment has led to large changes in the sport of skydiving. For that reason, a major focus of this thesis is the evolution of sport parachuting equipment and the effect that each improvement has had on human body flight.

At the origin of sport skydiving, all skydivers used modified military gear and sported round parachutes made out of uncoated rip-stop nylon. Reserve parachutes, if used at all, were "belly mounted" and simply thrown into the relative wind by the skydiver if anything went wrong with the main parachute. The round parachutes were packed into surplus military containers and attached to the skydiver with a harness. In a quotation, Mike Horan explains,

> In the 1950s and '60s, military B-4 containers, C-9 round canopies, 24-foot twill reserve canopies, pilot chutes, ripcords, helmets and boots saw heavy use at drop zones around the nation. Many jumpers didn't particularly like military surplus equipment because it was bulky and uncomfortable, so a few started designing new equipment just for recreational skydivers. The equipment revolution began diminishing every aspect of military influence and changed skydiving forever [6].

The gear improvements made since the 1960s have revolutionized parachuting and led to massive demographic and culture changes within the sport. Skydiving gear has become safer and the equipment lighter and more comfortable due to the major advances detailed below. This has made skydiving accessible to a wide variety of individuals interested in skydiving, which is an essential part of the current skydiving micro-culture.

3.1 *The Piggyback Container*

The first major advancement in the evolution of skydiving equipment was the development of the “piggyback” parachute system in which both the main and reserve parachutes rested on the jumper’s back. In the spring of 1964, Security Parachute Company marketed the first system of this type and named it the CrossBow harness and container system [6]. These CrossBow systems (shown in Figure 1) were safer and far more comfortable, allowing jumpers to put them on more conveniently and move more easily in freefall. With the increased maneuverability of CrossBow systems, relative work, a skydiving discipline where formations are made by groups of skydivers who fall in a belly-to-earth orientation, was enhanced. The CrossBow came in a variety of bright colors and left room for individualism and self-expression. By the late 1970s, nearly every skydiver used a piggyback style parachute system, and today they are the only certified type of sport parachute system on the market.

Figure 1: The CrossBow harness and container system

3.2 *The Para-Commander*

The CrossBow was quickly followed by a semi-maneuverable round parachute that had the ability to drive forward in the sky rather than simply getting pushed by the wind. The Para-Commander was the first widely used parachute of this type (Figure 2). The Para-Commander featured a pulled down apex which forced air through vents at the back of the canopy. The resulting reaction force allowed for a forward speed of about 10-12 mph [6]. This created a revolution in parachute accuracy, and significantly reduced the impact experienced when landing. Over just a few years, Para-Commanders began to dominate the market and "accuracy competitions began to be measured in centimeters rather than meters" [5]. The canopies were also built for the exact purpose of sport skydiving, and color patterns could be customized. This became one of the first steps towards the creation of a highly individualistic skydiving micro-culture.

Figure 2: The Para-Commander

3.3 *The Three-Ring Release*

Of all the advances made in sport parachuting equipment, the three-ring release system did the most to improve safety (Figure 3). In the event of a parachute malfunction, it is important that the parachutist has the ability to detach or "cutaway" their main parachute and separate from it before deploying their reserve

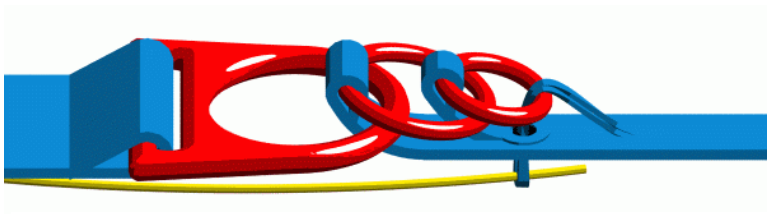

Figure 3: Three-ring release system

parachute. If the jumper fails to cutaway cleanly prior to reserve parachute deployment, the result is often two entangled parachutes. Prior to the three-ring system, the Capewell canopy release system was used [6]. The Capewell canopy release system was functional, but required the parachutist to pull two cables using both hands at exactly the same time [5]. If the jumper failed to do this, only one side of the parachute would release, causing a "streamer malfunction," where parachute fabric is trailing behind the skydiver but the parachute is unable to inflate. The three-ring system was far simpler and more effective; it used only one handle to release both sides of the parachute and used mechanical advantage to greatly reduce the pull force to release the parachute. It was also lighter and relatively inexpensive compared to the all metal Capewell canopy release system. The three-ring system quickly became popular among skydivers and nearly every skydiver used it by the early 1980s [6]. Being able to safely release a malfunctioning main parachute greatly improved the safety of the sport and the reduction in pull force allowed people with less arm strength to safely skydive for the first time.

3.4 *The Ram-Air Parachute and Slider*

Another important step in sport parachuting came with the adoption of the ram-air canopy and slider. Ram-air parachutes are designed completely differently than round parachutes. They are approximately rectangular in shape and have two layers of fabric (one on top and one on bottom) which are connected by airfoil shaped fabric ribs to form cells (Figure 4). The cells fill with air

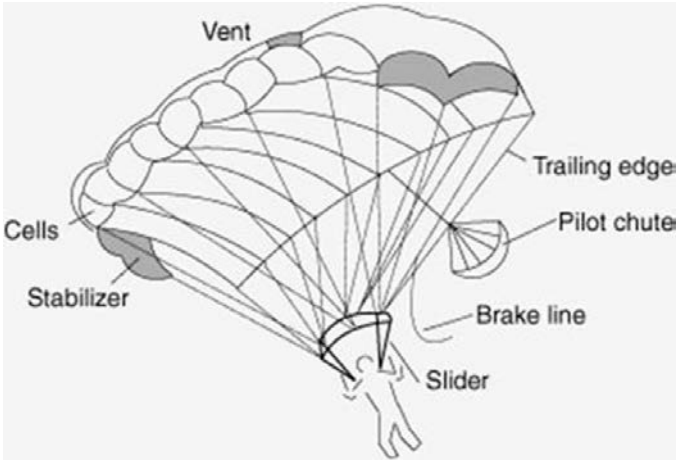

Figure 4: Ram-air parachute

using vents placed at the leading edge of the parachute and inflate to create an airfoil shape [7]. Once inflated, these parachutes provide substantial forward speed and are highly maneuverable. Depending on a number of factors including wing loading and aerodynamic design, ram-air parachutes can maintain glide ratios of up to 4 [8]. Glide ratio is distance traveled horizontally divided by vertical distance lost. Jerry Baumchen pointed out that although people were experimenting with 'wing' canopies in the 1960s, it was not until the early 1970s that ram air parachutes came on the market as a commercial product [2]. Domina Jalbert, considered the father of ram-air parafoils and paragliding, first spoke of his invention June 10th, 1963 in an issue of the Sun Sentinel Newspaper. He believed that this inflatable wing technology had many applications, and the design went through many transitions before it was successfully flown in 1964 and patented November 15th of 1966 [9]. Early designs for skydiving use, such as the Para-Foil, created by Jalbert Aerology Laboratory, had high forward speed and great maneuverability but had harsh opening characteristics which limited their popularity [6, 5].

The development of the slider reefing system from Pioneer Parachute Company allowed ran air parachutes to become the standard in the industry. A reefing system is any device used to slow the opening of a parachute. A slider is a type of reefing mechanism made up of a rectangular piece of fabric with grommets at each corner. During parachute deployment, the slider slides down the parachute lines and is slowed by air resistance. The slider reduces the rate that the lines can expand, and therefore the speed at which the parachute can inflate. Using a slider system on ram-air parachutes drastically reduced "opening shock" and led ram-air parachutes to become "popular beyond compare" [6]. Opening shock is the force experienced by the skydiver during parachute deployment. High opening shocks can cause injury or death. The ram-air parachute and slider were a significant advancement because they allowed the parachutist to control of their landing location. Parachutists could now fight a headwind, glide

miles to a safe landing area if the aircraft “spot” was off, and land gently on their feet by flaring the parachute. In parachuting, the “spot” is the area which skydivers jump over. The spot must be adjusted based on wind speed and aircraft velocity to ensure parachutists open their parachutes over the desired landing area. All of the accuracy and landing improvements made skydiving a safer sport and allowed skydiving to take place in a greater variety of weather conditions and landing areas. Instead of waiting for winds to be under 5 miles per hour, skydivers could jump in winds exceeding 15 miles per hour. Parachutists no longer required a large landing area, so drop zones could be introduced in locations previously deemed dangerous such as near oceans, forests, and towns. Additionally, ram air parachutes can be stalled or “flared” to provide very soft landings. Round parachute jumps had notoriously high impact landings and could easily cause injury if the jumper was not physically capable of taking the impact. With the introduction of ram air parachutes, skydiving was no longer restricted to strong young men; a more diverse group of people, including elderly and individuals with lower physical strength or medical conditions could now skydive. This led to the demographic diversification which has occurred over time.

4 TANDEM SKYDIVING

Nothing has done more to increase public exposure for skydiving than the advent of tandem skydiving in 1984 [10]. Tandem skydiving involves an experienced skydive instructor using a large parachute system and a specialized harness attached to a passenger on the front of their body. Tandem skydiving greatly reduces training time and offers people the experience of freefall with the security of a knowledgeable and experienced instructor. Prior to tandem skydiving, Static Line Progression or Accelerated Freefall training programs were required to engage in skydiving. Static Line Progression is the traditional method of training skydivers and is outlined in Section 2. The Accelerated Freefall (AFF) program is the most common form of student training today. The student jumps from 9,000-13,000 feet and is stabilized by instructors who also provide hand signals to improve technique and body position. These programs require days of preparation and training on the ground to prepare the student to control themselves during freefall, fly their parachute correctly, resolve any parachute malfunctions, and land safely. With a tandem parachute jump, a 15 minute mini-course is all that is needed before boarding the airplane. Approximately 500,000 people make their first tandem skydive every year [11].

Figure 5: Tandem skydiving

Initially, tandem “rigs” were just oversized sport parachute systems. A “rig” is a complete skydiving parachute system, which includes a container, main parachute, reserve parachute, and often an automatic activation device. Tandem parachutes were large to accommodate the weight of two people (typically around 500 square feet). However, the high terminal velocity of tandem pairs caused problems for these early systems. Single skydivers usually fall at a rate of 110-120 mph. This is called their terminal velocity and it is caused when drag force (F_d) equals the weight of the freefalling object (F_g) as shown in Figure 6. When two skydivers are put together, their weight effectively doubles, but their surface area stays about the same as a single skydiver. This causes the tandem pair to fall at a much greater terminal velocity (180-200 mph). At this speed, parachutes open very quickly and cause hard openings that are uncomfortable or can cause injury. To fix this problem, tandem systems began using drogue parachutes which trail behind the pair while in freefall. This drogue parachute slows freefall speeds to the ideal 120 mph. Additional improvements have been made to systems since then which have led to additional improvements in safety, reliability, and comfort of tandem skydives. In particular, United Parachute Technologies LLC completely redesigned the tandem parachute system and added a safety pin which eliminates the chance of the main parachute being deployed before the drogue is deployed [12]. This eliminated “out-of-sequence deployments”, which were the most common cause of tandem accidents. An out of sequence deployment occurs when a tandem pair deploys the main parachute before deploying the drogue. The resulting parachute malfunction caused several fatal accidents. The harness was also redesigned to improve student comfort by forcing the student’s legs forward and upward once the parachute is opened. This reduced the common complaint that blood was cut off from the student’s legs [13].

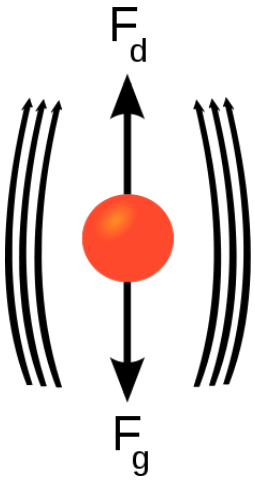

Figure 6: Force balance at terminal velocity

Tandem skydiving has also had a tremendous impact on the business side of skydiving. Before tandem skydiving, it was not feasible to form a functioning business out of skydiving. The number of routine sport skydivers in the world has always been too low and these jumpers were not willing to pay prices high enough to support a profitable, sustainable business. However, tandem jumpers are far more numerous and are willing to pay far higher prices for a skydive. The high demand for tandem skydives coupled with short training time made tandem skydives the most lucrative part of the skydiving business. Drop zones could now be profitable, which led to huge growth in the skydiving industry. As Baumchen pointed out,

Figure 7: Freeflying skydivers

Figure 8: Freestyle is an artistic form of skydiving resembling ballet.

> The business effect has been unbelievable. If not for tandems, you would not have turbine aircraft [drop zones]. You would not have people actually making a living in jumping. The change truly cannot be measured, it has been so amazing [2].

The profits brought by tandem skydivers allowed skydiving businesses to buy much larger aircraft which could carry more skydivers to altitude faster. It also meant that most skydiving centers could operate nearly year round rather than mirroring the sporadic availability of a few club jumpers. All this meant that for the first time, skydivers could make

Figure 9: Skysurfing is a discipline popular in the 1990s.

enough money to make skydive instruction a full time job. Tandem instructors typically get paid $20-$40 per jump, and depending on a number of factors can make more than 1000 jumps per year and can expect to make around $20,000 to $40,000 per year.

Figure 10: Wingsuits convert vertical velocity into horizontal velocity.

Full-time professional skydivers brought about by tandem skydiving were able to use their experience to master freefall techniques and experiment with the sport in ways previously impossible. They created many new forms of skydiving which greatly increased the diversity and appeal of skydiving: Freeflying, a very difficult and nontraditional skydiving discipline involving high speed head-down and head-up body positioning (Figure 7) was invented in the late 1980's [14]. Likewise, freestyle (Figure 8), skysurfing (Figure 9), wingsuiting (Figure 10), and canopy swooping (Figure 11), were developed in part due to increased financial revenue from tandem jumpers. The various sub disciplines of skydiving, each requiring years of training to master, transformed skydiving from a simple act of falling straight and parachuting to the ground into a multifaceted art form.

Figure 11: Swooping involves building up high speed through low altitude turns. This speed is then used to travel great distances close to the ground during landing.

5 WINGSUITS

Wingsuiting is a sport aligned with human desire to spread their arms and fly. As defined by the World Wingsuit League,

> Wingsuits are a special kind of jumpsuit with ram-air inflated wings between the arms and legs that enable human beings to fly their bodies like gliders. They can't sustain level flight, but can glide more than three feet forward for every foot they go down – and they can go up for brief periods by flaring after a steep dive [15].

The first attempts at wingsuiting occurred during the 1930s when parachutists affixed wings made of canvas, wood, silk, steel, and even whale bone to their bodies in an attempt to increase horizontal movement (Figure 13). These early "batwing" designs were not effective or reliable and killed more than 70 percent of the jumpers who attempted to fly them [15]. Wingsuits quickly became unpopular and experimentation with horizontal body flight all but ceased until the mid-1990s when French skydiver Patrick de Gayardon (Figure 12) invented the first safe-to-fly wingsuit using the same inflation technology used by ram-air parachutes. In his design, air entered vents at the top of the arm and leg wings and allowed the suit to inflate and become rigid just like a ram-air parachute. Also like a ram-air parachute, this rigidity allowed the suit to assume an airfoil shape and glide forward at great speeds. This design was far superior to

Figure 13: 1937 "batwing" design

Figure 12: Patrick de Gayardon wearing the first modern wingsuit design

the early batwing designs because it had no rigid components; this meant the parachutist could still maneuver their body and could easily collapse the arm and leg wings if necessary. In 1999, Jari Kuosma of Finland and Obert Pecnic of Croatia created the company Bird-Man International, the first company to produce wingsuits commercially. Other companies have since entered the market and the resulting competition has improved wingsuit performance incrementally ever since as explained in Section 5.2. With these improvements and accessibility, a new skydiving discipline, and indeed, an entirely new sport was born.

5.1 *Proximity Flying*

Wingsuiting has captured the public imagination over the last 20 years, mainly due to viral YouTube videos depicting “proximity flying”. Proximity flying is a very technical and dangerous form of wingsuit flying which involves either skydiving over steep terrain or BASE jumping a large cliff using a wingsuit. BASE jumping is an extreme form of skydiving that involves jumping off fixed objects with only one parachute designed to open rapidly. The proximity fliers’ goal is to glide very close to the ground, sometimes as close as a few feet, before increasing glide ratio and gaining separation from the ground to deploy their parachute (Figure 14). Although proximity flying is a relatively uncommon form of wingsuit flying, its ability to capture the attention of the public has made it a target of advertising. In addition, the

Figure 14: Proximity wingsuit flying

lessons learned from such experimental wingsuit flying has been used by wingsuit manufacturers to technically improve their designs.

5.2 *Wingsuit Improvements*

Since the 1990s, improvements in wingsuit performance have occurred which have greatly improved the appeal and accessibility of wingsuit flying to skydivers. “The suits athletes wear started out as tiny flaps attached to skintight suits, but have since morphed into huge wings that span the entire length of a wearer’s outstretched arms” [16]. Wingsuits have improved in speed, maneuverability, and range. This allows wingsuiters to make formation skydives, BASE jump previously inaccessible cliffs, easily fly over three miles horizontally, perform graceful aerobatics, and routinely stay airborne for upwards of 5 minutes before deploying their parachutes [18]. Luke Aikins, a world renowned skydiver, wingsuiter, and aerial consultant, believes that material and wing profile improvements have been the major contributors to these performance gains [18]. The new materials used for wingsuits inflate more quickly and stay more rigid, improving aerodynamics. Improvements in wing profile allow better stability, maneuverability, and control, which in turn allows a wingsuiter to fly larger surface area suits more safely. As veteran Canadian wingsuit pilot Jason Moledzki put it,

> When I made my first wingsuit jump 15 years ago, the suits were horrid. If you could jump off and stay away from the cliff, it was a miracle of flight. Now you step off a cliff and you are flying instantly…At no point do you ever fall straight downwards, you’re immediately moving forward. When you nail it, you’re flying straight away, moving forward with excellent control. No one dreamed that was possible 15 years ago [16].

Advanced wingsuits today are now much larger and have dramatically improved performance

compared to the first Bird-Man suits (Figure 15). Matt Gerdes, founder of the modern wingsuit company “Squirrel” explains “as [wingsuits] have increased in surface area, we have made steps forward in reducing drag and increasing efficiency” [16]. Improving the aerodynamic profile of the leading edge of the suits and increasing rigidity of that leading edge is often credited with improving wingsuit speed, which in turn allows for more lift and more control over altitude. Squirrel made these improvements by adding semi-rigid foam inserts into the leading edges of their suits and adding larger and more efficient air inlets to allow the suit to inflate quickly and assume a rigid airfoil shape that increases lift. They also added Mylar to the surfaces just above and below the leading edge of the suits to reduce drag and improve efficiency [17].

Figure 15: Late 1990s “Bird-Man” brand wingsuit (left) versus modern “Squirrel” brand wingsuit (right)

5.3 *Wingsuit Competitions*

The improvement in wingsuit performance along with the rising popularity of wingsuiting within the skydiving community has led to the relatively recent development of wingsuit competitions. The first large-scale wingsuit competition was Red Bull Aces, a four-cross slalom wingsuit event which debut in 2014 (Figure 16). Luke Aikins was the Race Director and organized much of the event, which he hopes will "let the guys who do amazing things in the mountains [proximity flying] showcase their skills without the same level of danger" [18]. The competition allows the best wingsuit athletes from all over the world to compete with each other and use the same diving, flaring, and precision turns that they use while proximity flying but under far safer conditions. When asked about the future of wingsuiting, Aikins said he believes that a small group of athletes will always proximity fly, but that the danger and high mortality rates will keep that group small. He believes competitions like Aces "have the same kind of energy as proximity flying" but are a better outlet and will make high performance wingsuiting a more sustainable and enjoyable sport [18]."

Figure 16: Red Bull Aces athletes competing in the four-cross slalom event

6 VERTICAL WIND TUNNELS

Vertical wind tunnels have been in use since the end of the 19th century for use in aerodynamic testing, but since the late 1960s they have been used for skydiving simulation or "indoor skydiving". The advent of indoor skydiving brought the sensation of human body flight to the public in a way similar to tandem skydiving. However, tandem skydiving still has its own risks, age limits, and requires the passenger to willingly exit an airplane. The beauty of indoor skydiving is that nearly *anyone* can experience what it feels like to freefall and maneuver in high speed wind. Children's camps are common, with a minimum age of only three years old. Since 2005, the number of indoor skydiving locations has increased from 17 to 162 [20]. Events like family outings, birthday parties, dates, and even corporate events are commonplace at wind tunnels due to the wide ranges of ages allowed to fly [21].

Figure 17: A young indoor skydiver enjoying their first taste of body flight

In addition to increasing public exposure, wind tunnels have had a very real effect on the sport of skydiving, particularly within the freeflying discipline. Wind tunnels give skydivers time

to practice advanced freefall techniques that would be impossible to learn through traditional skydiving alone. A typical skydive has about a minute of freefall (45 seconds if freeflying) and the parachutist can expect to jump approximately five times per day, weather permitting. This means that a freeflier has at most about 5 minutes per day to practice their technique.

Figure 18: Training in indoor wind tunnels allows free fliers to become far more skilled than possible through traditional skydiving alone.

In contrast, tunnel flying allows unlimited freefall time. This addional practice time allows tunnel fliers to control their bodies with a natural precision that is astonishing to skydivers and non-skydivers alike.

7 ADVERTISING WITH SKYDIVING

Sport skydiving has become an important part of media and advertising. Luke Aikins is an extreme sports athlete and a member of the Red Bull Air Force; Red Bull is a brand so committed to sponsoring human body flight that its name has become inseparable from the sport of skydiving. Aikins believes skydiving is a draw for advertising because “it gets everyone’s attention. Even people who don’t like skydiving are fascinated by it [18].”

Historically, Jose Cuervo was the first to use skydiving in advertisement [18]. In the late 1970s traditional parachute accuracy was one of the highest regarded skydiving disciplines. Jose Cuervo hosted an interesting biathlon event in which parachutists did traditional accuracy jumps but the target was located on the side of a mountain. Once they landed, the parachutists began a ski race [18]. Budweiser made skydiving history in the late 70s by being the first company to sponsor a team of skydivers. The Budweiser Skydiving Demo team did mainly demonstration jumps into crowded events such as sporting events. In 2003, when Red Bull began a team of their own, dubbed the “Red Bull Air Force”, extreme sports advertising increased the visibility of skydiving and lead to improvements in the technology of the sport as well.

7.1 *Red Bull's Effect on Skydiving*

With their appropriate slogan "Red Bull gives you wings", Red Bull began sponsoring extreme athletes, including skydivers and, for the first time ever, BASE jumpers. BASE jumping is an extreme form of skydiving that involves jumping off fixed objects with only one parachute designed to open rapidly (Figure 19). Red Bull has had great success using a variety of extreme sports to advertise their product. Red Bull's sponsorship strategy has advanced human body flight by providing financial stability to professional skydivers and giving sponsored athletes room for creativity [18].

Figure 19: BASE jumping at the Perrine Bridge in Idaho

Red Bull accelerated the progression of human body flight when they began sponsoring skydivers, BASE jumpers, paragliders, etc. to do what they loved and be creative. Prior to Red Bull, a professional skydiver had to work 7 days a week as an instructor to make a living wage. As Luke Aikins puts it, "skydivers don't have the money to make full time work out of skydiving. With sponsors, they can dedicate their whole lives to [their area of interest] wingsuiting, tunnel flying, BASE jumping, etc." Red Bull gives people like Aikins an outlet to show the world what skydivers do and push boundaries. They also promote safety in traditionally high-risk activities such as BASE jumping because they, in his words, "don't want to do the super crazy stuff" [18].

7.2 *Red Bull Stratos Project*

If there is one single event that clearly demonstrates Red Bull's dedication to the technology of human body flight it would be the Red Bull Stratos Project. Red Bull Stratos was an ambitious advertising stunt which saw man jump from a high altitude weather balloon 24 miles (128,000 ft.) above Earth's surface. No jump like this had been done successfully since 1960, when Joe Kittinger jumped from a balloon at 102,800 ft. for the U.S. military. Red Bull pushed the envelope of scientific knowledge and broke four world records by making Felix Baumgartner the first human to break the sound barrier with his body at 690 mph, conducting the highest parachute jump ever recorded, conducting the longest freefall of 5 minutes 35 seconds,

Figure 20: Felix Baumgartner prepares for the highest skydive ever made during the Red Bull Stratos stunt.

and making the highest manned balloon flight. For the mission, Red Bull created a pressurized capsule weighing 2,900 lbs. which lifted Baumgartner at a rate of 1000ft. per minute. Baumgartner also wore a specialized space suit designed for increased mobility during freefall. Fully geared, Baumgartner weighed 260 lbs. Additionally, a sophisticated monitoring, tracking, and communications system attached to Baumgartner's chest allowed critical data acquired

during the jump to be transmitted to mission control (and the world) in real time [19].

This project was a major advertising success. Companies sponsoring stunts is nothing new, but sponsoring a stunt and scientific endeavor of this size was something revolutionary, and is “something other companies are now trying to replicate” [18]. There was a three year buildup by the Red Bull media, with 2-3 hour commercials which seemed far more like a documentary on a scientific or historic project than an advertisement [18]. Millions of people tuned into these long commercials and were following the project as it was being worked on. When the event was live streamed to the internet, it had more than 8 million concurrent viewers, 52 million views of the video the first day alone, and used 7% of the internet that day [18]. Over 150 news stations around the world covered the event. Clearly this was a massive advertising success, and the fact that it was a skydiving stunt made it one of the greatest moments of global exposure for sports involving human body flight. Jumping from the edge of space was “a cool project that people have wanted to do for years, but Red Bull was the first to make it possible by financing it” [18]. The Stratos event opened up this kind of stunt for other companies and skydiving enthusiasts; several similar high altitude jumps have been made since Stratos, and more companies are attempting large scale stunts which push scientific, as well as athletic, boundaries.

8 CONCLUSION

This thesis has contributed to a more complete history and summarized the current state of human body flight. This has been based largely on interviews with prominent individuals who have made significant contributions to the sport of skydiving, including Jerry Baumchen, Jay Gile, Rodney Holberton, and Luke Aikins. The origin of human body flight began with sport parachuting made possible by a few adventurous veterans of WWII and the Korean Wars who had access to surplus military parachuting gear. Advancements in parachuting hardware made the sport safer, and allowed a diverse group of individuals to begin skydiving. The advent of tandem skydiving brought much needed revenue to the skydiving industry and allowed people to make a living skydiving, which in turn led to the creation of many sub disciplines within the sport. One of these sub disciplines, wingsuiting, has undergone a transformation over the last 15 years due to design improvements, viral videos, and the recent advent of competitions. In that time, wingsuiting has diverged from traditional skydiving and become an entirely new form of human body flight. The recent popularity of vertical wind tunnels and indoor skydiving has led to even greater public exposure and understanding of the fundamentals of human body flight and allowed a group of experienced tunnel fliers to become proficient at body flight to a degree previously thought impossible. The use of skydiving in advertising permitted sponsored skydivers to push the boundaries of human body flight, the most significant event being the Red Bull Stratos jump. Overall, human body flight has progressed quickly from its origins in the military to a sport that is enjoyed by a diverse population. In the future, additional improvements in safety can be expected along with additional increases in public exposure brought on by vertical wind tunnels.

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