WINCH PROJECT
A Proposal – Part One

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Introduction

The following proposal is based on a compendium ideas and concepts drawn together from years of investigation into the art, science and sport of winch launching gliders. It is hoped that this proposal will provoke thought and discussion about winch construction.

The Part One of this proposal does not set out a final winch design. Rather, it seeks to explore the possibilities and raise awareness of the options. The Part Two of the proposal will be based on input from the readers of Part One. If a decision is made to go ahead, the final configuration will be selected and presented along with a budget, timeline, detailed drawings and pricing.

As an initial part of this project, considerable effort was expended to gain an understanding of the current worldwide status of glider winches utilizing resources of the internet search engines such as Google with language translation capabilities.

Searching the web with the German words *"Startwinde", Windenstart",* or *"Segelflug Winde"* will produce hundreds of web pages with information and pictures of winches. For a gallery of European winches see: http://www.skylaunch.de/album/s.html

It was not appreciated at the outset that glider winches are often adapted to local conditions. Winch operators tend to assume that their local winch is designed to universal rules which is far from the case. Failure to understand and allow for these local variables can lead to confusion about winch design features.

For example, some winch sites ask only that their winch loft a glider a few hundred feet so that it can glide into steady, reliable ridge lift. Release heights are of no real interest and cable runs can be as short as 1200 feet. These winches provide leisurely acceleration and modest climb rates. It is not unusual to find these sites using a "retrieve winch" to return the cable to the launch point for the next launch. Multiple drums provide little in the way of productivity increase since the retrieve winch can get the main winch ready for the next launch almost as quickly as multiple drums could be sequenced. High launch rates, Low cost and high reliability are the main design points.

At the opposite end of the spectrum, flat land winch sites require that the winch loft the glider to the highest release height possible since the glider pilot must find thermal lift. Retrieve winches reduce the height achieved therefore are rarely used. The possibility of finding thermal lift increases dramatically as release height increases above the minimum deemed safe for pattern entry.

Of particular concern in this document are the design features required for launching at high density altitudes. Under these conditions, the glider must be accelerated to a higher true airspeed to reach the minimum safe indicated airspeed to start the climb. This increased acceleration demand has a strong impact on the minimum engine power required. The specified power of the engine must also allow for the deleterious effects of density altitude on the actual power output so that the power available always exceeds demand. Power requirements are discussed in detail later in this proposal.

This wide spectrum of designs found on winches around the world provides a rich source of ideas that can be adapted, picking the "best of breed" features, and incorporating them into a highly effective machine that meets the needs of American glider pilots. The intent is to "embrace and extend" the best of world winch designs.

In the last decade, new materials and technologies as well as an increased understanding of the dynamics of winch launch have made significant improvements possible. This proposal will discuss improvements that include, but are not limited to, significantly increased release heights, greater launch rates, safety and far greater accuracy in the control of the launch.

The desired situation, sought by all winch designers, is that the glider pilot will come to trust that the launch will always be exactly what is desired, without mechanical failure, regardless of how the launch is flown or the wind, turbulence or thermal conditions encountered.

Why winch at all?

We have aero tow, so why do we need winches? There are many good answers to this question, but all that is required to see the best one is to point to the age distribution of today's soaring pilots. We are getting older and young people are finding other outlets for their enthusiasm than soaring. According to some sources, the number of registered glider pilots in the world is actually declining. (Ref, April-May 2002 *Sailplane & Gliding*, 119,266 in 2001 as against 134,598 in 1990).

One of the reasons for this is that the costs related to learning to fly gliders is high relative to other pursuits that beckon young people. Learning to fly gliders using air tow is also frustrating and slow.

One of the most time consuming and expensive parts of learning to fly is landing practice. Winch launched trainers provide a lot of landing practice in a short period of time at a very low cost compared to airtow. Compare one airtow at $30 to six winch launches to see the point.

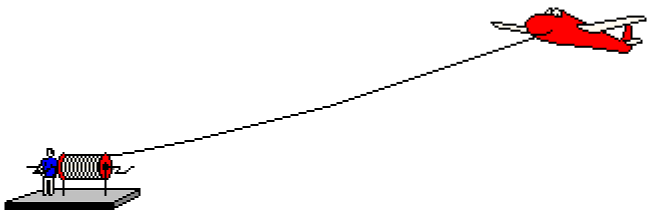
Note: I do not argue that airtow is unnecessary, just that it not the only launch method and certainly not the cheapest. Each launch method is required for a complete training environment. Some pilots will strongly prefer air tow and that preference should be respected.

Here are some objections to winch launch and my responses.

1. **Winching is not safe**. No launch method is any safer than it is made to be by the participants. Winching can be very safe as evidenced by the European experience. We need only to adopt the best practices of European clubs to achieve a level of safety that equals or even exceeds air tow.
2. **Winching requires a large crew**. Crew size is a function of the inherent safety and efficiency of the equipment used. In the minimum case, it can be the same as air tow. There is no need for anyone at the winch other than the winch driver. If the winch is designed for unattended cable retrieval, the winch driver can retrieve the cables. At the launch end, the wing runner can be equipped with a voice activated (VOX) headset and radio to signal the launch after the overhead airspace has been cleared. Larger operations with many cables and gliders to launch, may require glider pushers to clear gliders from the landing area but these are likely to be easily available under these conditions.
3. **Winch operations are a money loser compared to air tow**. This objection seems to be a result of confusing gross revenue with net revenue. A well run winch operation can produce a profit for the club or commercial operation that exceeds that possible from a tug while charging the glider pilots far less. For comparison, consider that a tug, with pilot, costs $120 an hour to operate and produces about four tows in that time for a cost of $30/tow which is uncomfortably close to the $25 - $30 price of those tows. On the other hand, a winch launch is likely to cost less than $2 while the charge to the pilot can be $5 to $10. The NET REVENUE for the winch can substantially exceed the tug. Costs will be addressed in more detail later.
4. **Winches will scare away new members**. Au contraire, winches ATTRACT new members with the excitement, action and low cost. Clubs that winch, grow quickly and much of that growth will be younger people.

Glider Winch State-of-the-Art

Glider winches are ubiquitous outside the USA. Lacking the glamour of the latest racing sailplanes, winches have not benefited as much from technological improvements. This is starting to change as the value of winch operations becomes more evident.



In Europe where regulations, fuel prices and noise issues are putting airplane tow under increasing regulatory pressure, winch use is expanding even as motorgliders are introduced.

Many *Akafliegs* in Germany and elsewhere have winch technology improvement programs underway. Some involve using embedded microprocessors to control the winch. Others are developing airspeed telemetry systems. See: http://www.akaflieg.uni-karlsruhe.de/

Mechanically, a glider winch is a moderately complex and powerful machine not unlike farm machinery. It draws on the same level of engineering sophistication and manufacturing capabilities. But, unlike other winches found in marine, off-road and industrial applications, it is a very high speed winch.

Most winches are predominately designed from the start as steel cable winches. This determines many of the design features found on existing glider winches.

Jord Materiel Dieseline Electronic Winch

European winches tend to be very large, powerful, multi-drum machines mounted on trucks. The trend toward multi-drum winches seems to be accelerating in Europe.

I seems unlikely that airplane tow will displace winch launch in Europe for economic, environmental, and perhaps even enjoyment-based reasons. If the costs of operating airplane tugs continues to increase in the US, we may be looking at a similar situation in the not too distant future.

It is often said that the major disadvantage of winches is that the glider release is always over the winch which is often not ideal for finding the first thermal. This objection is becoming less important as the release heights and glider performance increases. As the average glider performance increases above 35:1 L/D, releases at more than 2000' AGL in thermic conditions will allow the pilot to contact thermal lift as often as with an air tow. When the probability of soaring flight from a winch launch reaches parity with airplane tow, the overwhelming cost savings of winch launch becomes irresistible.

US Winches

In the US, winch launch is regarded as a novelty to be undertaken on rare occasions, so winches are not expected to be capable of full-time operations.

Typically, glider winches in the US are scratch built by volunteer members of glider clubs. They almost invariably use auto/truck V8 engines and automatic transmissions driving one drum through a locked differential in a solid axle. These parts are almost always obtained from wrecked cars in junkyards.

The overriding objective seems to be the lowest possible cost of construction to the exclusion of all else.

Aside from the limited efficiency of a single drum, the US winches, in general, suffer from a number of poor design features.

Simply adopting an automotive power train designed to propel a 4000 pound road vehicle to launch a 800 pound glider introduces a number of problems. The most serious problems relate to the torque converter in the automatic transmission. The torque converter, while necessary to provide adequate vehicle acceleration, imposes difficulties in controlling the initial acceleration of a glider due to the large, and sometimes unpredictable, multiplication of torque. (Typically > 2:1)

The three widely spaced ratios found in automatic transmissions make it difficult to find the exact final drive ratio to produce the desired launch performance. The 1-2 up-shift is sometimes harsh enough to break weak links. The "coasting" function can make it difficult to accurately cut the power at the top of the launch without braking the drum.

Automotive engines are high RPM engines with "peaky" torque curves. Usually, the narrow torque band is unsuited for the heavy pulling required of a glider winch.

US winches are generally under powered for low wind, high density altitude conditions. For example, a 1300 pound gross weight glider in the middle of a 1G launch, in zero wind, may require 250 HP delivered to the glider hook for a safe launch - implying an engine with "data plate HP" of over 400. Unfortunately, the typical automotive engine used in a winch produces only around 200HP. *See section on power requirements.*

Under-powered winches are problematic since the behavior of glider airspeed with varying pilot technique is the reverse of what pilots are trained to expect. This means that the airspeed will decay with increased back pressure on the stick as the glider "bogs down" the winch engine. The airspeed should increase with increasing back pressure if the winch is delivering adequate power.

The typical launch starts with ferocious acceleration followed by a sag in wire tension as the transmission shifts to second gear causing the torque at the drum to drop below demand. This shifts the responsibility for airspeed control from the winch operator to the pilot who must control airspeed with pitch attitude. Then, as the wire angle reaches about 45 degrees, airspeed control shifts back to the winch operator as the power demand drops below engine output. A winch with a substantial power reserve avoids confusion by keeping speed control with the winch operator.

Many US winches also suffer from overheating. The radiator is usually placed in the winch facing downwind. This is a problem since the original radiator installation in the source vehicle depended on forward motion for most of the airflow through the radiator. Installing this radiator in a glider winch facing away from the wind, usually without the benefit of a fan shroud, results in an situation where the cooling system is undersized by a factor of at least 3. Multi-drum operations will need even more cooling capacity since the "cool-down" period between launches will be shorter.

US glider winches typically use pairs of crude, small diameter, crossed rollers to guide the cable onto the drum - a feature borrowed from low speed winches. When operated at high speed, this results in rapid wear of both the cable and the rollers.

Often the operator's cab is neither weather tight nor comfortable enough to entice winch drivers to volunteer their time. The light weight expanded metal cages are too weak to provide adequate protection for the operator from lashing cables and attached hardware.

The most common wire used in the US is military surplus armored target towing cable. This material is very heavy for it's strength. It is also becoming less available since the military is no longer buying it. Some operators have replaced target cable with 3/16" 7X7 galvanized aircraft control cable which is stronger and lighter. But even 7X7 3/16" steel is still too heavy and suffers from a tendency to tangle and kink. In general, US pilots are far more tolerant of wire breaks than their European cousins who treat them with the same seriousness as engine failures in airplanes. *See section on cable.*

US winches typically lack logical controls and adequate instrumentation forcing he winch operator to rely experience and "gut feel" as they try to deliver consistent launches under highly demanding conditions. This means that the operation of a glider winch is assigned to only a few people whose skill and judgement are trusted.

The overall result is that launches are often wildly inconsistent despite the winch drivers' best efforts. Wire breaks are far too common. This leads many glider pilots to distrust winch launches and avoid them despite their obvious economic advantages.

European winches

European glider pilots rely on winches for most of their launches, subsequently, they place far more importance on winch design and construction.

These machines are expected to provide many decades of service and millions of launches. Their cost can exceed $100,000, however, amortized over their long life, this is seen as reasonable.

20.63 meter Caproni Vizzola Calif A21S Launches in France

The trend in Europe is to use large diesel engines in the 300 - 500 HP range with torque limiting electronic controls. *Luftsportgruppe Rastatt* uses a 600HP Mercedes V12 railway diesel. These high-torque, low RPM diesel engines are ideal for the purpose. John Gibson has popularized powerful winches with his 412HP Skylaunch.

European winches are most often scratch built (*Eigenbau*) by glider club members. Occasionally, they are purchased from one of the following manufacturers.

Skylaunch, UK http://www.skylaunchuk.com/index.htm
SupaCat, UK http://www.supacat.com/
Van Gelder, NL http://www.proximedia.com/local/netherlands/m/machine-el/various.htm
Hercules H4, Czech Republic.
Egger, Germany http://www.eggerwinde.de
TOST, Germany, http://www.tost-startwinden.de/indexengl.htm

Almost all European winches, except the Van Gelder and Busio, employ two drums. The Van Gelder is available in 4, 6, and 8 drum versions.

In Germany, there is a trend toward full automation where the winch operator selects the glider/pilot combo to be launched from a computer which sets the winch for a near perfect automatic launch. The intent is to remove any variables due to winch driver abilities.

From South Africa to Finland, Universities and Academic flying groups are working on technical improvements to the winch and the instrumentation they employ. *Akaflieg Karlsruhe* as well as others are working on the telemetry of glider airspeed to the winch operator. This is seen as the last technical issue to be addressed in winch launching.

Frequent wire breaks are simply not tolerated. Cables are replaced on a schedule that, to the largest degree possible, precludes wire breaks.

In Scotland, there has been a successful implementation of radio telemetry of glider airspeed giving the winch operator access to the one parameter that can produce the perfect launch. Read: “High-Tech Winching”, Jun-Jul ’99 *Sailplane and Gliding*.

TOST kits, completed winches.

The operators of this Busio 6-drum winch report that it will launch 45 sailplanes to 1800-2600’ AGL in 90 minutes consuming 6 gallons of diesel fuel.

Hercules H4, 185HP engine $34,150

The Skylaunch winches $77,752

The SupaCat winch uses a level-wind, paying-on mechanism and large swiveling pulleys.

Launch Pricing and the Economics of Winch Operations

It will surprise no one that winch launches are much cheaper than air tow. Just how much cheaper is open to discussion. Most operations price winch launches at about 20% the amount charged for air tows of the same height or about $5US. This seems to be based on a guess as to what the "customers" would judge to be reasonable.

The enthusiasm among glider pilots for winch launching is determined less by low prices than by release heights and launch frequency. Release heights of 1500' AGL do not interest serious soaring pilots. More interest in evident at 2000' AGL and 2500' generates genuine enthusiasm. The low price of launches is icing on the cake.

The short wait in the launch queue is a strong additional advantage for multi-drum winches. For example, 6 launches in 12 minutes vs. 6 launches in 1:30 for airtow.

Most pilots would see a $10 fee as reasonable if the launch heights achieved were on the order of 2500 feet AGL since this would almost assure that a thermal could be found if any were available. Most likely, it will be found that the "reasonable" price for a launch will be closer to $5, even with a technically elegant, modern winch.

Dividing costs into operational and capital categories helps understand the cost breakdown. Operational costs should include fuel, set asides for cable replacement, engine overhaul or replacement and other maintenance. If the shag vehicle is owned and operated by the club, that should be included as well.

The following are estimates of the operational costs per launch.

Fuel (0.5 Liter Diesel or 1Kw/Hr.)	$0.20
Cable replacement ($1000 @1000 Starts)	$1.00
Maintenance ($3000 @ 10,000 Starts)	$0.30
Shag vehicle	$0.20

Total Cost Per Launch $1.70

This compares with the 2.0€ /launch costs reported for the European winches.

The capital costs are the acquisition costs amortized over the expected life of the winch. It assumes that at the end of the useful life, salvage value would be zero.

If the winch originally costs $20,000 and is expected to last at least 30 years and 120,000 launches or more, the amortization gives $0.16 per launch. Even if the acquisition costs were $40,000, the impact on the per launch costs would be trivial.

One may quibble with these estimates but, even if the costs per launch were to be put at $5.00 a $10 launch fee would produce a large "profit margin" for a club. If the acquisition were to be financed, this "profit" would initially go to debt service.

Assuming a $3 "profit" on each launch, a $20,000 winch would be paid off in less than 130 operating days with 50 launches per day. This revenue stream compares very favorably to towplanes where profits are elusive even with the best operations.

Calculates effects of multi-reel winch on daily operations

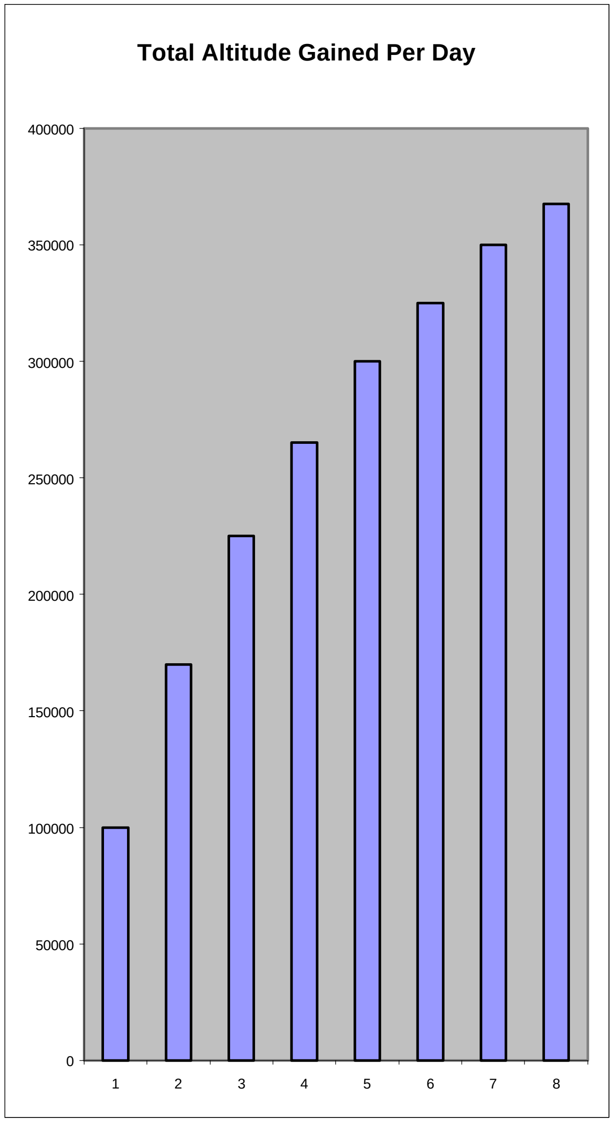
Enter starting data in box below:

Hours in flying day	8.00
Price of launch $US	8
Launch Interval. (min)	2.00
Payout Time (min)	10
Average Height	2500

Daily Vertical Capacity

Drums	Launches	Feet	Revenue
1	40	100000	$320.00
2	68	170000	$544.00
3	90	225000	$720.00
4	106	265000	$848.00
5	120	300000	$960.00
6	130	325000	$1,040.00
7	140	350000	$1,120.00
8	147	367500	$1,176.00

Key assumption: Glider queue always full
Note: Under no-lift conditions and 4 gliders, one glider will always be waiting.



The graphic above calculates the productivity, (defined as total height gained, launches and revenue per day), resulting for the use of a multi-drum winch with 1 – 8 drums. The starting assumptions are in the box in the upper left. The two minute launch interval has been confirmed by the *Amsterdam Soaring Club*.

More Important to some pilots is that 8 gliders can be launched in a 16 minute window. This compares very favorably to the 1.5 hours an airplane will take to launch the same number of gliders. The theoretical advantage of airplane tow to deliver a glider to distant lift loses considerable significance if you are #8 in the launch queue.

There are numerous ways to assess winch operation. Both the numerical approach above and the personal utility suggest that a winch can be a formidable launch method.

Winch Design Objectives

A truly modern winch should meet the following criteria.

Low cost per launch
High launch rates
Highest release heights possible
Perfectly consistent launches under all conditions
Easy, safe, reliable operation
Comfortable working conditions for the operator
Space for operator trainees in the cab
Simple to operate controls
Minimum crewing requirements
Low maintenance costs

At present, few winches in existence meets all these criteria. Should they all be met, winch launch would be a formidable competitor to airplane tow wherever space allows their use.

Buy or Build Decision

Buying a new European winch at more than $100,000 US would impose a heavy financial burden on any but the largest and most well financed organization. If it is likely that it would only be used on weekends, this is even less attractive.

As I will attempt to show in this proposal, if even a quarter of the $100,000 were spent on welding and machine shops services, an equal or better winch could be built in the US by a group of serious enthusiasts.

Design Elements

Cable

It should be intuitive that heavy cable places a limit on the launch height achievable. However, discussions with glider pilots indicate this is not always understood to be the case. Hopefully, the following discussion will help clarify the issue.

See Larry Bogen's mathematical treatment in Appendix A.

Cable weight acts to limit the height gained in several ways. The power required to merely lift the weight of the cable is a minor factor requiring only about 10% of the power budget. The most important factor is the sag of the cable and the angle at which the cable pulls on the glider release hook. This sag, or catenary arc, is the product of both the weight of the cable and aerodynamic drag acting on the cable.

Some will point out that cable weight is indistinguishable from the pull of the winch. While true, this does not address the sag of a heavy cable.

Most CG hooks are designed to automatically release when the angle of the cable to the longitudinal axis of the glider reaches 70 – 75 Degrees.

The winch operator must reduce the cable tension as the glider approaches the top of the launch to prevent the airspeed from increasing above a safe limit. As the power is reduced, the sag of the cable increases. At some point, depending on the weight and drag of the cable, the CG hook will release automatically as the cable angle reaches 70 degrees, effectively limiting the release height. The heavier the cable, the greater the sag and the earlier the automatic release occurs.

The lighter the cable, the smaller the sag and the smaller the angle at the CG hook for a given cable tension. In mid-launch, the pull vector is more nearly aligned with the longitudinal axis of the glider. The result is a higher launch.

The release height limit, imposed by cable weight, usually is not significant with relatively short cable lengths. But, at around 4500', steel cable becomes the major limiting factor. The weight of steel cable places a practical upper limit at about 5000'.

Spectra (HMWPE)

Looking at all candidate cable materials, one stands out as superior to all others - High Molecular Weight Polyethylene fiber cord. This material is sold in the US under the brand **Spectra** and in Europe as **Dyneema**. At a tenth the weight of steel of the same tensile strength, **Spectra** offers the possibility of a 25% increase in release heights compared to steel cable. The extra strength is likely to significantly reduce the incidence of cable breaks.

3/16" **Spectra** coated with abraision resistant polyurethane is available in strengths of 3800 – 5500 pounds weighing 1 pound per 100'. By comparison, steel 7X7 3/16" offers only 2800 to 3500 pound breaking strength and weighs 8 pounds per 100'.

Unlike steel, the light weight of **Spectra** does not impose a practical upper limit to the length of cable that can be used.

Spectra is strong, light, abraision resistant and largely immune from degradation by UV and common chemicals. It has been tested under extremely harsh conditions in the marine, telecommunications and mining industries and found superior to steel cable.

The marine and mining industries use larger diameter **Spectra** rope than would be the case with a glider winch. The largest market for the 3/16" (4.5mm) **Spectra** is the telecommunications industry. The telecoms use **Spectra** to pull fiber optic cable through the plastic conduit we all see being buried alongside roadways. **Spectra** is very light and can be blown through miles of conduit with compressed air. It is strong enough for a powerful winch to pull the fiber optic cable through the conduit while **Spectra's** low coefficient of friction eases the process.

In an effort to determine the bulk prices paid by telecom companies, the author contacted purchasing agents in the industry. In 10,000' quantities, they pay $0.13/Ft. It should be possible to entice a purchasing agent to "piggyback" an order to get a larger volume discount for both parties.

Since it is a hollow 12 strand braid with no "torque" or tendency to twist, it is far less likely to tangle than twisted steel. This allows the drum spacing to be much closer than with a multi-drum winch using steel cable.

Spectra is far safer than steel in the event of breakage. It simply falls to the ground with little tendency to snap back. There is no chance of injury from "meat hooks" that result from breakage of single strands of steel cable. This feature alone has driven its adoption as a replacement for wire rope by industrial users.   The hollow braid is spliced the same way as water ski rope and the resulting splice is nearly invisible.

Spectra cord suffers from a few drawbacks and winch engineering design allowances must be made for these. It begins to lose strength above 150 degrees F, melts at 285F and it is easier to cut on sharp edges than steel.

To address these issues, the winch must be designed such that the life of the cord is maximized. This means a minimum of friction induced wear imposed by the drum and guide mechanism. It must be protected from temperatures above 150F and any sharp edges must be kept away from the cord. Cord life can also be extended by changes in operational procedures such as paying out cable while pulling the winch across the airfield instead of pulling it out with a shag vehicle.

The performance gain expected, based on calculations done by in Canada by Larry Bogen, suggests a 25% release height gain over 5mm steel. A winch that delivers 2000' AGL with 5000' of steel cable, or 40% of the starting cable, should deliver 2500' AGL on a no-wind day with **Spectra**.

It should be noted that while light weight **Spectra** reduces the power required at takeoff, it increases the power required at release since the winch engine must make up in torque for the reduction in the hanging cable weight.

Web sites:
http://www.samsonrope.com/products/mi_12strand.cfm
http://www.psrope.com/psrope/catalogpdf/NewPlasmaRev9.pdf
http://www.go.ednet.ns.ca/~larry/bsc/winch/winch.htm
http://www.samsonrope.com/pdf/AMSTEEL_END_FOR_END_SPLICE.pdf

Engines (Power Requirements)

Winch engines must be selected to satisfy the peak power demand. There are two formulas for instantaneous power calculations that have proven useful.

(1) HP = force (Lbs.) X speed (FPS) divided by the constant 550. (HP = Lbs*FPS/550)
(2) HP = RPM X Torque (Ft-Lbs.) divided by the constant 5252. (RPM*Torque/5252)

The following power calculation examples use these assumptions:

Wire friction with the ground = 100 pounds
Mass of the wire and drum = 300 pounds.
Glider weighs 1300 pounds and will be accelerated to 100 FPS (59 Kts).
Drum radius = one foot (Therefore wire tension in pounds = drum torque in Ft.-Lbs.)

A "One G" launch assumes that the wire tension, at the glider, is equal to the glider's flying weight and remains constant throughout the launch. The peak power demand is just at the beginning of the rotation into climb where the wire speed is greatest. The wire tension at the winch at peak power is 1300 + 300 + 100 = 1700 pounds.

This computes as 1700 * 100/550 = 309 HP. Alternatively, the winch drum will be delivering a torque of 1700 Ft.-Lbs. and be turning at 955 RPM, then 1700*955/5252 = 309 HP.

If the glider to be launched is a ASH 25 at 1654 Lbs., the peak power demand increases to 374 HP. If the density altitude rises to 10,000 feet, the glider must be accelerated to 120 FPS then the peak HP demand increases to 448 HP.

The torque requirements place yet another constraint on engine selection. (It is useful to think of engines producing torque, not HP which is a mathematical abstraction.)

At the top of the launch, the wire speed is far less but the tension at the glider is the same as at peak HP demand. If the peak drum RPM is 955 and is powered by an engine with a peak HP at 2100 RPM, this requires a gear reduction of 2.2:1. If the wire speed is reduced to 33 FPS at the top of the launch, the drum RPM will have dropped to 315 and the engine RPM to 693.

At this point the drum torque will be 1300 (from the first example), less the wire weight hanging below the glider – assume 140 Lbs. This means that the drum torque is 1300 – 140, or 1160 Ft.-Lbs. Again assuming 2.2:1 gearing, this means that the engine must produce 527 Ft.-Lbs. of torque at 693 RPM. It seems unlikely that auto engines can meet this torque demand.

Some winch designers have noted that peak power is required for only a few seconds and that thereafter, power demand drops quickly. They have devised strategies to store power in advance of peak demand using batteries, flywheels or hydraulic accumulators. This allows a smaller engine to do the work of a larger one. Unless fuel costs are far greater than at present, the complications of this approach far outweigh the benefits.

Large, low RPM, high torque diesels still seem the better approach.

Engine Power (Cooling Requirements)

The cooling system must be sized for an engine that will be producing substantial power while stationary. The extra large radiator must face into the wind and be provided with a large and dependable source of air movement. The huge radiators on Diesel Generator sets are a good example.

In addition to engine cooling, the automatic transmission or fluid coupling will require a heat exchanger to cool the working fluid. Fluid couplings and torque converters produce substantial heat as they slip.

Engines (Gasoline)

Adapting automotive power plants and transmissions can be made to work, but the required modifications to produce the required power and torque can be expensive and tend to reduce reliability. Low RPM torque is still likely to be less than desired.

The best spark ignition powerplants are “crate” engines sold by major car manufacturers for racing, marine and industrial uses. These large V8 engines are available in displacements exceeding 600 cubic inches. They can reliably produce more than 450 HP and 500 Ft.-Lbs. of torque.

“Crate” engines cost around $6,000 new. They must then be fitted with fuel injection, ignition and exhaust systems which may raise the cost to $10,000. Adding a transmission with the required modifications may increase the cost to more than $15,000. This will likely be more than the cost of a large diesel engine with a fluid coupling Power Take Off (PTO).

A point in favor of gasoline engines is that the fuel will not gel at low temperatures.

Transmissions (Automotive)

High-revving automobile engines need modified transmissions if they are to work well in a winch. Specifically, they will need an automatic transmission modified with “manual valve body” and a racing torque converter.

A “manual valve body” converts an automatic transmission to one that can be shifted manually somewhat like a clutchless stick shift. If placed in 2nd, the transmission will start in 2nd and remain there regardless of load or RPM. If a 3-speed transmission with overdrive is used, the transmission can be controlled with a shifter mechanism that provides the equivalent of a close-ratio, 6-speed manual transmission. This would allow the winch driver to select a ratio that works best with the prevailing conditions of wind and glider weight.

Racing torque converters change the RPM at which the converter reaches “stall” from a typical 1800 RPM in stock vehicles to 2500 – 3500 RPM. This allows the engine to rev to peak torque before the glider starts to move. This would provide fast acceleration without the need to start in 1st gear. It also means that the engine cannot be “lugged” down below its torque peak.

Engines (Diesel)

Taking guidance from the rest of the world, large 12 – 18 liter heavy diesel engines would seem to be the most desirable for glider winches.

Cummins 14.7L 6Cyl

These engines produce massive torque at very low RPMS - typically, 1850 Ft. Lbs. of torque at 1200 RPM with a redline of 1800 - 2100 RPM.

Many over-the-road heavy truck operators replace engines at about half their million mile useful life. This results in a supply of used engines with far more than enough life left for glider winches. Manufacturers include Cummins, Detroit, Caterpillar, Mack and Volvo and others.

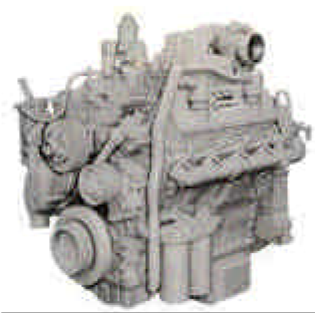
Cat 3406E 15.2L 6Cyl

Used 550 HP diesels such as the CAT 3408 DITA are available in the $5000 - $10000 range. See: http://www.trucks.com/parts_truck_engines.asp

Diesel engines manufactured in the last 15 years have electronically controlled “common rail” fuel injection with a torque limiting function. (This limiter is intended to be set by the owner/operator to control fuel consumption and engine abuse by hired drivers.) The setting device is a simple hand-held unit. Limiting the torque makes the full-throttle torque curve a straight, horizontal line from just above idle to redline. Making the torque limiting function a winch cab control allows limiting the winch power to match the glider to be launched. This is a major aid to consistent launches.

Unlike automobile engines, these diesels are complete, self-contained “drop in” power units. They even include air compressors to power guillotines.

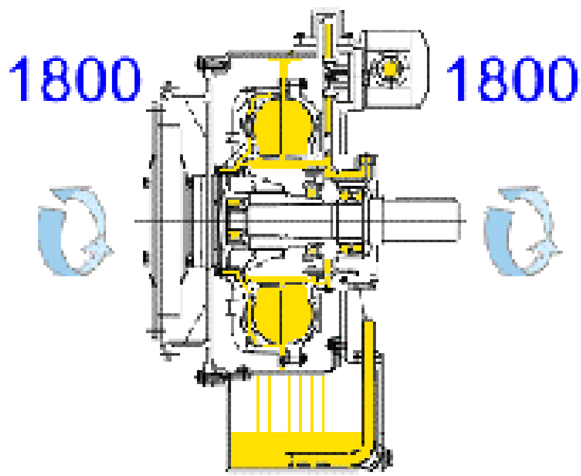
These massive engines are expensive to buy but cheap to operate and dead reliable. It is clear why diesel power is the overwhelming choice of winch builders everywhere.



Cat 3408 18L V8

Transmissions (Diesel)

While automatic transmissions are available for big diesel engines, they are not even needed. A far more attractive choice, used in most European winches, is a fluid coupling and a fixed final drive ratio, thereby eliminating all shifting during the launch. (The torque available from big diesels is more than enough to accelerate the glider without the need for a starting gear or torque multiplication.)



Fluid coupling PTO

A fluid coupling is like a torque converter except the torque multiplication ratio is fixed at 1:1. Like a torque converter, it permits the engine to idle while the winch is in gear and the drum is held stationary with the brake.

Fluid couplings for diesel engines are called PTO's and bolt up to the standard SAE flywheel housings found on all large diesels.

A winch fitted with a fluid coupling works like one equipped with an automatic transmission but without the "PRND2L" selector. It also eliminates the overdrive coasting function found in automatic transmissions.

Some can be controlled from a remote control panel allowing the fluid coupling to be disengaged from the engine. The engagement time can be adjusted to smooth start-ups. In effect, this is the equivalent of the "N" and "D" on a automobile transmission.

A fluid coupling generates considerable heat so the working fluid will need a heat exchanger (transmission cooler) to keep the fluid temperatures reasonable.

The usable RPM range of large diesel engines is roughly 900 – 2100 RPM. The maximum wire speed required is 65 Kts. in no-wind conditions - less under windy conditions. Using the drum diameter suggested in a later section, this implies a 2:1 speed reduction with the drum partially filled as in mid-launch.

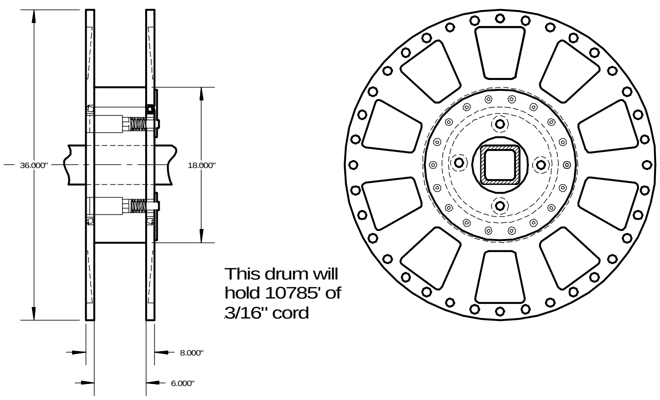
The Busio and other winch designs use industrial roller-chain and sprockets to achieve this speed reduction. This allows sprocket changing to either fine-tune the winch gearing or to allow seasonal changes to accommodate the prevailing density altitude.

If widely varying launch conditions are expected, a close ratio, manual truck transmission might be fitted so a drive ratio could be selected to keep the engine RPM within the desired range while delivering the wire speed desired. The intent is to select a ratio for the prevailing conditions and not to attempt a shift during the launch.

Drum(s), Dog Clutches and Retrieve Brakes

There is considerable empirical evidence to suggest that long-wire winch operations strongly benefit from multiple drum winches. As a rule of thumb, the number of drums should equal the number of gliders cycling through the launch queue in no-lift conditions. The efficiency of multiple drum operation is confirmed by Dutch clubs using the Busio and Van Gelder 6-drum winches.

Multiple drum winches reduce the crewing requirement by one since the shag driver can act as launch captain. One cable retrieve every 6 – 8 launches is a much more relaxed operation while reducing the wear on airfield grass.



Multiple drum winches require a means to select the drum to use. This means a “dog clutch” that engages the selected drum.

Simple electromechanical “dogs” inside each drum serve the purpose well. The power for these “dogs” can be routed from slip rings, through wires in the hollow drum shaft to the solenoids that drive the “dogs”.

Alternatively, an external dog clutch using a mechanism resembling a standard friction clutch with the friction plates replaced with disks using pins and holes instead of friction material could be used.

The drum(s) rotational inertia should be minimized to help avoid over-runs and tangles. To reduce inertia, drum should be made of the lightest material that provides adequate strength. Constructing the drums of aluminum or even high strength plastic such as UHMWPE is very desirable.

The cable capacity should be at least 10,000’ of 3/16” Spectra. This allows for those occasions where large spaces are available for high launches. The table to the right is an example of a capacity calculation.

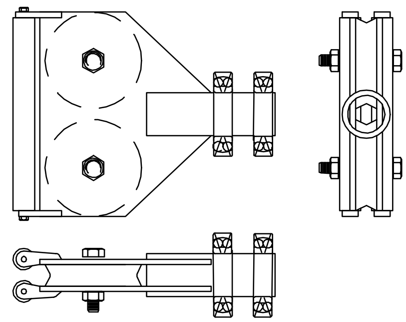
Drum Capacity		
Drum Diameter (In.)		18
Traverse (width) (in.)		6
Flange dia. (in.)		36
Rope DIA (in.)		0.188
Rope Capacity (feet)		10785

Drum Capacity Calculations

Smooth control of the cable during retrieval or pay out requires a special retrieve brake . This should be incorporated into each drum. The characteristics of a retrieve brake are different from the main brake in that smooth but steady braking is needed without heat buildup in the drum that could damage Spectra. An electromagnetic EMF brake should be perfect.

Cable Guiding Mechanism

The successor to crossed rollers employed by Skylaunch and American winches is a swiveled pulley block with one or two large pulleys. The TOST design uses a horizontal swivel axis and two pulleys. (Right)

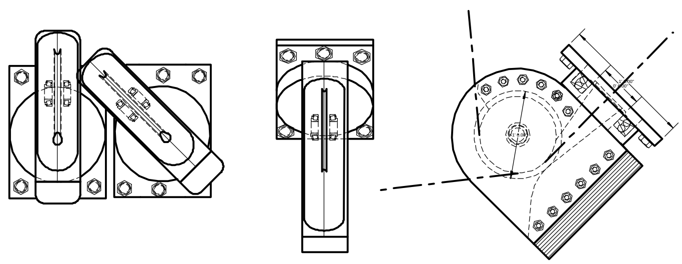


Tost Style Azimuth Rollers

SupaCat uses one very large pulley with the swivel axis inclined downward at 45 degrees. The SupaCat-style pulley is weighted so that it always assumes a vertical when there is no tension on the cable. The pulley housing block is designed so that the cable cannot jump off the pulley.

The SupaCat pulley is the best design because it drops the cable away from a spinning pulley at the end of the launch protecting it from friction as the pulley spins down.

The cable path passes under the pulley, up through the hollow swivel axis and on to the top of the drum. The swiveling action insures that the pulley is always aligned with the cable no matter the angle of the cable to the winch. The large diameter of the pulley avoids flexing the cable any more than necessary.



Inclined Swivel Pulley

There are two schools of thought about how to lay the cable on to the drum. One says that the cable should be laid neatly on the drum in parallel wraps with a level-wind or paying-on mechanism. (SupaCat, Hercules H4) This significantly extends the life of the cable whether it is Spectra or Steel.

The downside is that level winding introduces a level of complexity and cost. There is anecdotal evidence that this increases the possibility of snarls and the resetting required after a snarl is laborious. This problem may be related to the use of steel wire.

The other option is to place the guide pulley at a distance from the drum equal to approximately 5 times the width of the drum. This allows the cable to wrap onto the drum randomly, but surprisingly smoothly.

In all cases, the cables' path from the glider, under the swivel pulley, into the winch and onto the drum should not allow the cable to deviate from the desired path. This means that the drum should be in a box or chamber that controls the cable so that it must always go onto the drum.

Guillotine

Since guillotines are a key safety device, they need to be extremely reliable. In addition, they should not pose any danger whatever to the winch driver. Cutting a winch cable is somewhat difficult since the cable has undergone extensive engineering to defeat just this sort of attack.

"Pick-Axe" Guillotine

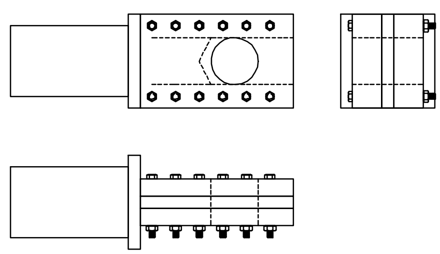
The American winches tend to use a heavy, medieval-looking “pick-axe” device that swings down through several feet onto the cable and cuts it against an anvil. Although this is claimed to work, better ideas are available.

Rarely, explosive devices have been used to cut the cable. One such device used a modified shotgun shell to drive a chisel-like blade through the cable. These devices are recalled with fear and respect by all who used them.

Many older European winches seem to use a simple side-swinging weighted arm that cuts the cable with a scissor-like blade. This device is triggered by pulling a restraining pin and the weight supplies the energy. Given enough mechanical advantage, this is a possible solution. German search word: “*KAPPVORRICHTUNG*”.

The explosive and weight-driven guillotines appear to deserve their reputation of posing significant danger to winch operators trying to untangle a snarl – particularly the “Pick-Axe”. They also suffer from being “one-shot” devices. Re-setting one under duress seems unlikely.

The latest designs use a “cigar cutter” guillotine actuated by a pneumatic piston. The cable passes through a hole in the box so that it cannot escape the attention of the blade. This “blade-in-a-box” design appears to be extremely reliable while posing little danger to the winch operator.



"Cigar Cutter" Guillotine

The diesel truck engines described in a previous section are equipped with air compressors that can supply the compressed air to operate a pneumatic cylinder. Given a sufficient compressed air supply, the pneumatic guillotine can be fired repeatedly, if needed, until the cable is cut.

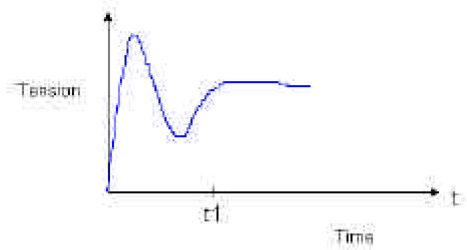
The adoption of **Spectra** offers another choice for guillotine design. Since it melts at 285 degrees F, a blade heated by current from the starting battery would easily melt through the cord. German testing shows steel cable guillotines do not cut **Spectra.**

Either the “cigar cutter” or hot blade guillotines will require ergonomic cab controls.

Winch Control Instrumentation and Automation

Correctly implemented Instrumentation/automation will make both the winch operator's and the pilot's tasks easier and less demanding. There is a significant payback that results from the reduction in training required for new winch drivers. Automation can make launches perfectly consistent, increasing pilots trust in the launch process.

Many winches try to determine the quality of a launch by monitoring line tension at the winch. This requires interpretation by the winch operator since, even in a normal launch, cable tension varies unpredictably as the cable leaves the ground at T1. (Right)



Wire Tension at Winch vs. Time

Tension should be monitored at the glider with the information presented to the pilot since the pilot is in the best position to control tension with back pressure. Tension load cells equipped with short distance "*Bluetooth*" wireless links are inexpensive and small enough to be inserted into the winch cable at the parachute. The safe tension values would be color marked on the glider panel instrument.

The pilot would set the desired airspeed and initial acceleration on a panel instrument which, in turn, would send these data to the winch by a radio telemetry link. Once the launch is underway, this link would send real-time acceleration, airspeed and altitude data to the winch.

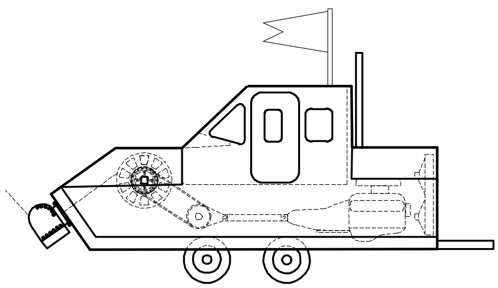
Once the glider airspeed data is available at the winch, the driver would "ride the throttle" to keep the glider airspeed at the requested value, alternatively an auto-throttle could be employed.

Mounting a telemetry instrument in a glider is not a significant problem - of course, one would have to do the required FAA paperwork. Date transmission would start with initial acceleration and stop after one minute, eliminating the need for an ON-OFF switch.

Almost full automation of the launch is possible. Under this scenario, the driver would press and hold a button that would initiate the launch. The winch Process Logic Controller would advance the throttle to produce the acceleration set by the pilot until the selected airspeed was reached. That airspeed would then be automatically maintained until the winch driver released the button to assume manual control of the winch.

The complete package would be an engine torque limiter set as a fail-safe to prevent too much power, a fluid coupling to smooth the acceleration, wire tension measured at the glider and displayed to the pilot during the launch. (Airspeed and acceleration would be sent to the winch by a radio telemetry link.) The winch driver (or a PLC computer) would use these data to produce perfectly smooth, consistent and highly optimized launches, independent of changes in wind, lift or pilot technique.

Winch cab and chassis



Possible 6-drum Trailer winch

There is no obvious advantage in making a glider winch small. In fact, size and weight make the winch more stable and less likely to overturn. A large chassis makes it easier to install components and gain access to them in the event that maintenance is required.

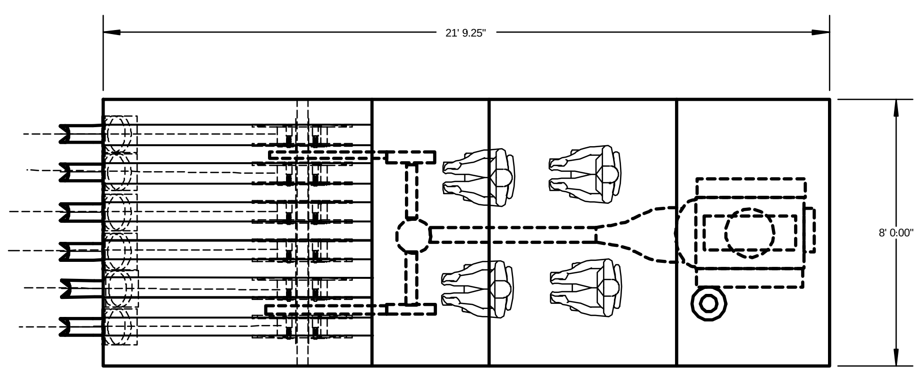
Any winch operation depends heavily on the services of the winch operator. It therefore behooves the winch designer to go to considerable lengths to provide a safe and comfortable working environment. It would be desirable to make the winch cab the most comfortable place on the glider port.

The cab should be weather tight, sound proofed and climate controlled. It should provide superb visibility down field and overhead. To facilitate the training of new winch operators, the cab should accommodate the operator and several observers in comfortable seats.

Egger Winch Cab

The cab windows should be made of materials that protect the occupants from the cable and attached hardware. 0.75" Lexan (Polycarbonate) is used in bullet proof windshields of armored limousines. (It will stop a 9mm pistol round at point blank range) The rest of the cab should be at least 0.125" steel sheet.

High quality communications should be available to ground personnel and airborne gliders.

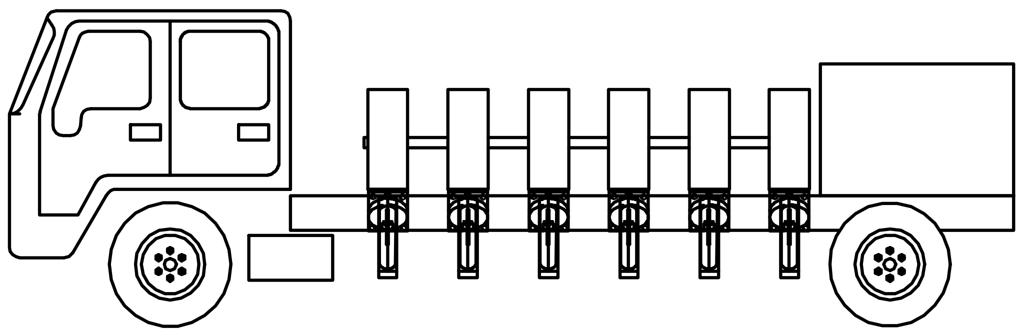


Possible 6-Drum Trailer Winch With Large Cab for Trainee/Observers

There are points to be made for mounting the winch on a truck chassis. This is common practice with European winches. It eliminates the need to anchor the winch while making it extremely mobile on the airfield.

If a truck winch were to be driven on public roads, licensing and insurance issues would have to be addressed. Mounting the winch on a trailer makes it easy to license and places the insurance burden on the pulling vehicle.

At the moment, used commercial trucks are cheap. For example, "cab-over & chassis" trucks (Volvo, Ford, GMC, International, Isuzu) in reasonable condition are advertised as low as $5000. These are more than large enough for a big winch.



Possible 6-Drum "Sidewinder" Truck Mounted Winch with Separate Winch Engine

Summary

The winch design proposed is a large machine, at least compared to the typical US winch. It will be a "gentle giant" that will deliver many decades of quiet, trouble-free service. It will provide millions of launches at trivial costs while building the trust of the pilots with perfectly consistent launches.

The entire winch will be weather proof and lockable so that it can be left outdoors without concern. It will seat up to 4 people in an armored, insulated and climate controlled cab. It will use a large 400 – 500 HP torque-limited diesel engine driving up to 8 drums through a fluid coupling. This large engine will provide enough torque that an automatic transmission is not needed. It will use high strength, lightweight synthetic fiber cable so that the highest possible launches are achieved.

It will employ engine torque limitation and airspeed telemetry to insure that each and every launch is perfect regardless of pilot technique or environmental conditions.

The major advantages of a winch are:

1. They require less out-of-pocket investment than a tow plane.

2. They appear likely to contribute significantly to the growth of soaring by attracting new people to the sport with their excitement and low cost.

3. Winch launching is almost silent compared to air tow so airport neighbor relations is less of a problem.

4. Multi-drum winches provide more “uphill capacity” than tow planes due to their fast cycle time. (>200,000 vertical feet per day vs. < 50,000 for a tow plane.) (Ref, Amsterdam Soaring Club, CSA tow log.)

5. Winch operators are much easier to train than tow pilots and require no FAA certificates.

6. Winch economics are better for everyone concerned than tug economics.

The disadvantages are:

1. Winch launching requires more space than air tow.

2. Winches may require a larger (usually one more) crew than air tow.

3. Releases are directly above the winch.

4. This winch does not exist nor do build-worthy plans.

5. Investment in a winch is in addition to that required for a tow plane but adds significantly to a clubs assets.

These disadvantages can be offset with careful operational guidelines and winch design. For example, the crew requirements can be as little as a winch operator and wing runner. The winch operator can retrieve the cables if the winch is designed to permit it. The wing runner can also be the signalman if radio is used.

If release heights are on the order of 2500’ AGL, most gliders will be able to find lift if any is available.

On balance, winch launch compares very favorably with air tow, particularly in training operations.

Project Organization and Initiation

How does a project like this get done? In Europe, 80% of the winches were funded by glider clubs with the major part of the winch construction is done by member volunteers. (reference: http://www.skylaunch.de/album/a.html Eigenbau means "Self Built")

If club funding is unavailable, a smaller group may decide to undertake the project.

The project is likely to take at least a year or more. Even with volunteer workers, a significant part of the work may need to be contracted to machine shops.

The usual steps are:

1. Form a core team of like-minded volunteers
2. Inventory team members' skills
3. Finalize concept through consensus
4. Independently validate concept
5. Secure funding commitment
6. Produce final working drawings
7. Locate workshop space
8. Develop schedule with timeline and funding charts
9. Purchase key components such as engine
10. Start machine shops working on drums and pulleys
11. Weld trailer frame and make it road worthy
12. Install components
13. Completion work (instruments, paint etc…)
14. Systems Integration and Test (De-Bug)
15. Write documentation and operations manual

Estimating the total cost of a winch project is a difficult proposition. The reason is the costs are heavily dependent on the skill set of the team and their ability to scrounge or buy components and materials at deep discounts.

The best method is to estimate the cost with all parts and subassemblies professionally built or purchased at list prices with the final assembly done by volunteers. Then, if one or more team members have valuable skills, the estimate can be reduced by an appropriate amount.

For example, if a team member has access to a machine shop and the skills to use it, the costs can come down dramatically. Sometimes enrolling in adult education classes will give access to shops and instruction on how to use them.

To control costs, "design drift" must be tightly controlled. The best way to do this is to invest considerable time in the concept phase and then to get commitment from all involved to a final design.

Project Cost Breakdown (Rough Estimates)

The following estimates are based on the best information available. Where possible, costs have been confirmed by discussions with vendors. Otherwise, estimates, based on used or salvage prices have been used.

Obviously, if team members have access to parts sources, machine shops, welding equipment and the skills to use them, the costs can be far less.

When finalized working drawings are made, exact quotations will be provided and the cost estimates will be far more accurate than the following "guesstimates".

		Trailer winch	Truck winch
Engine		$5000*	$5,000*
Fluid coupling		$1,000 **	$1,000 **
Truck rear axle		$500*	
Machine work – drum & pulley (ea.)		$3,000 *	$3,000*
Spectra for one drum		$1,100 *	$1,100*
Frame and welding		$2,000**	$1,500**
Trailer axle (dual)		$1,000	$5000* (truck)
The Rest		$6,400**	$6,400**
Approximate cost	(worst case)	$20,000	$23,000
	(best case)	$10,000	$15,000

(Note that the incremental cost for each additional drum is ~ $4100, including the cable.)
(* cost confirmed by direct quotation or average advertised prices)
(** cost estimated)

It may be desirable to buy certain tools with the plan to re-sell them when they are no longer needed. For example, a MIG welder for the shop would be needed throughout the project. These can be bought used in the $500 - $800 range. Most other tools are available from the team members.

The costs will accumulate as the project advances. There is no need to allocate all funding up front.