Building a Winch?
Design considerations

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Introduction

This paper 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 it will provoke thought and discussion about winch construction.

The objective is not to set out a final winch design. Rather, it seeks to explore the possibilities and raise awareness of the options.

As a starting point, considerable effort was expended to gain an understanding of the current worldwide status of glider winches utilizing resources of Internet search engines such as Google with language translation capabilities.

Where appropriate, translation of the DAeC winch design guidelines are shown in italics. Special thanks to Ulrich Neumann for the translation of the German Aero Club's (DAeC) "*Technical Requirements for Winches*".

Searching the web with the German words *“Startwinde”, Windenstart”,* or *“Segelflug Winde”* will produce hundreds of web pages with information and pictures of winches. :

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 seek only to 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 rope 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 rope to the launch point for the next launch. Multiple drums provide little 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 the winch to loft the glider to the highest release height possible since the glider pilot must use the height above pattern entry to find thermal lift. High releases means long ropes and long rope retrieve intervals. This leads naturally to winches with multiple drums which can be retrieved together. Retrieve winches reduce the height achieved therefore are rarely used.

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, 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. I don't know of anyone who claims air tow is FUN.

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 aero tow. Compare one aero tow at $50 to six winch launches to see the point.

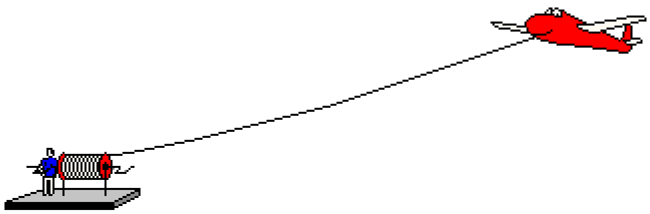
The price of 100LL AVGAS now averages $4/Gal and is $8 is some areas and the future availability is seriously in doubt. Aero tows will become more and more expensive as the price of oil continues upward. At some point only the rich can afford aero tows.

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 rope retrieval, the winch driver can perform that task. At the launch end, the wing runner can be equipped with a radio to signal the launch after the overhead airspace has been cleared. Larger operations with many ropes 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 far 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 hour for a cost of $30/tow which is uncomfortably close to the $30 - $35 price of those tows. A winch launch is likely to cost less than $2 while the charge to the pilot can be $10. The NET PROFIT/LAUNCH for the winch can substantially exceed the tug at 30 launches an hour**.** (30x$8/launch margin = $240/hr profit)
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 glamor of the latest racing sailplanes, technological improvements have lagged. This is changing 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 motor gliders 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: 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 designed from the start as steel cable winches. This explains many of the design features found on existing glider winches.

European winches tend to be very large, powerful, multi-drum machines mounted on trucks. This reflects the demands of large winch operations.

Jord Materiel Dieseline Electronic Winch

Winch launch is firmly embedded in European gliding for economic, environmental, and perhaps even enjoyment-based reasons. If the costs of operating airplane tugs continues to increase in the US as does the noise sensitivities of airport neighbors, 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.

Existing 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.

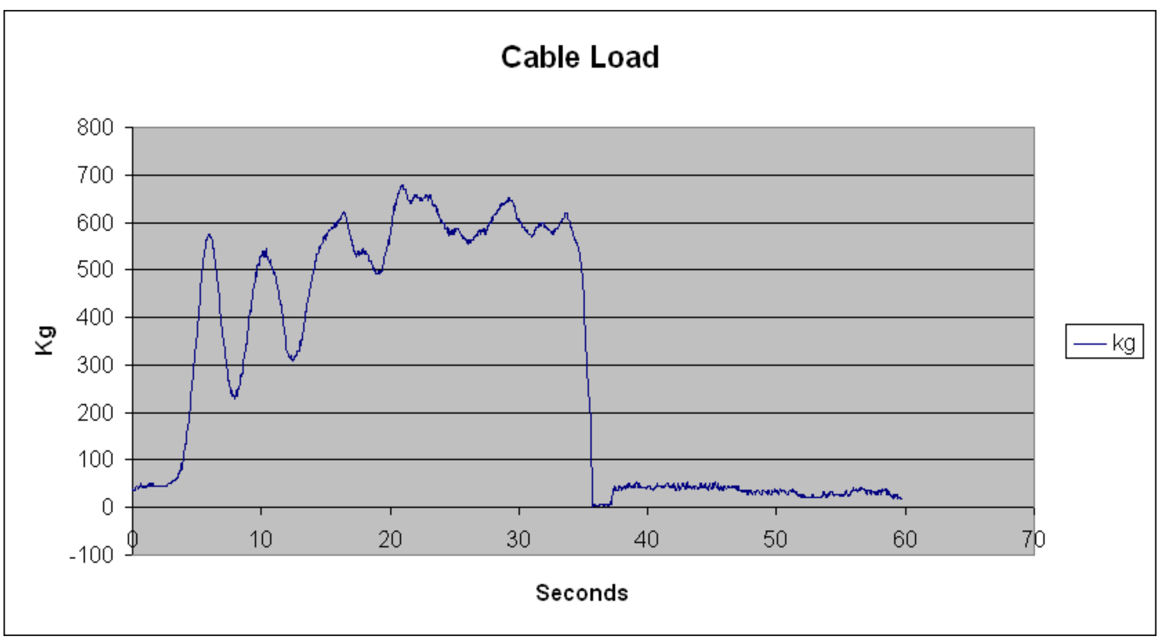
Typically, glider winches in the US are scratch built by volunteer members of glider clubs. They almost invariably use auto/truck V8 engines and automatic transmissions driving one drum through a locked differential in a solid axle. These parts are almost always obtained from wrecked cars in junkyards.

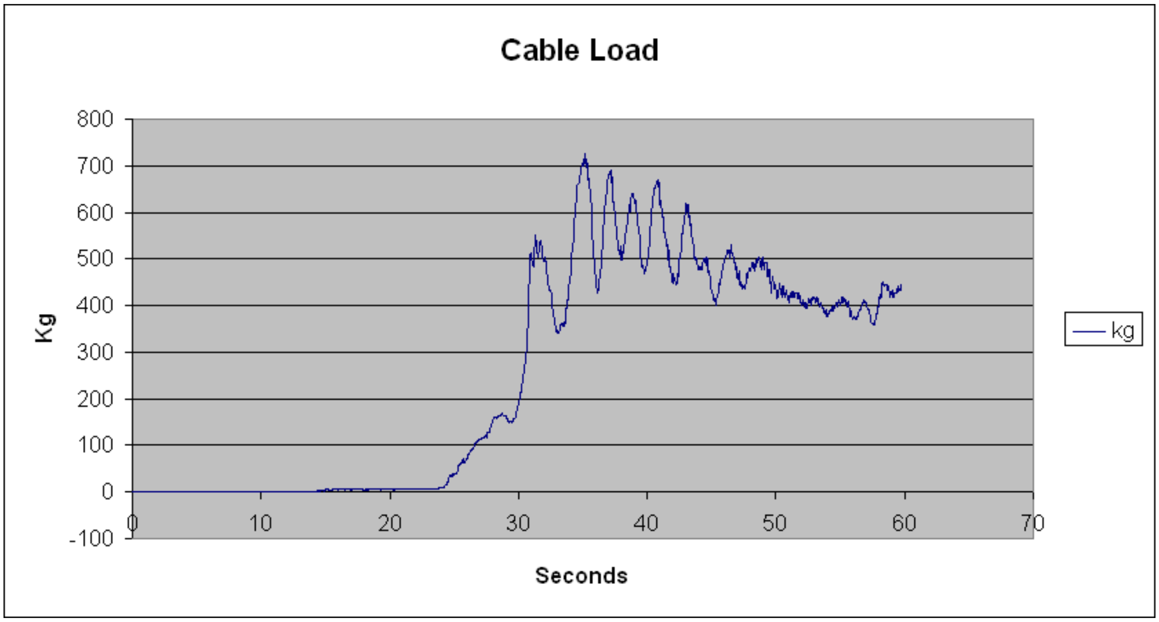
The overriding objective seems to be the lowest possible cost of construction to the exclusion of all else.

Aside from the limited efficiency of a single drum, the US winches, in general, suffer from a number of poor design features including the use of steel cable, heavy steel drums and automotive drive trains.

Simply adopting an automotive power train designed to propel a 6000 pound road vehicle to launch a 1000 pound glider introduces a number of problems. The most serious 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 unpredictable, multiplication of torque. (Typically > 2:1)

Automotive drive trains with a torque converter combined with a heavy drum and steel cable is vulnerable to oscillations in tension that can be more than 75% of the desired cable tension peak to peak. This leads to safety issues since the pilot can never be sure of the cable tension during the critical rotation into climb where stall margin is smallest.





The charts above are tension recordings from a commercial winch which uses a large GM V8 and TH400 transmission in unmodified form. This winch displays the high amplitude tension oscillations characteristic of automotive drive trains. Note that the largest oscillations are at the beginning of the launch as the glider is rotating from level flight into the climb phase. It is here where the gliders stall margin is a a minimum and where it is most critical to maintain smooth rope tension.

This wild behavior inherent in automotive drive trains installed in glider winches is no doubt the source of almost all "Scary Stories" commonly heard when one mentions winch launch in the US. This is understandable when one sees a tension graph from one. In fact, the surprise is that so few accidents have occurred.

Any engineer contemplating the use of an automotive drive train in a glider winch is referred to the First Principal of Ethics adopted by the ASME, "Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties." Choosing to use an automotive drive train is unconscionable.

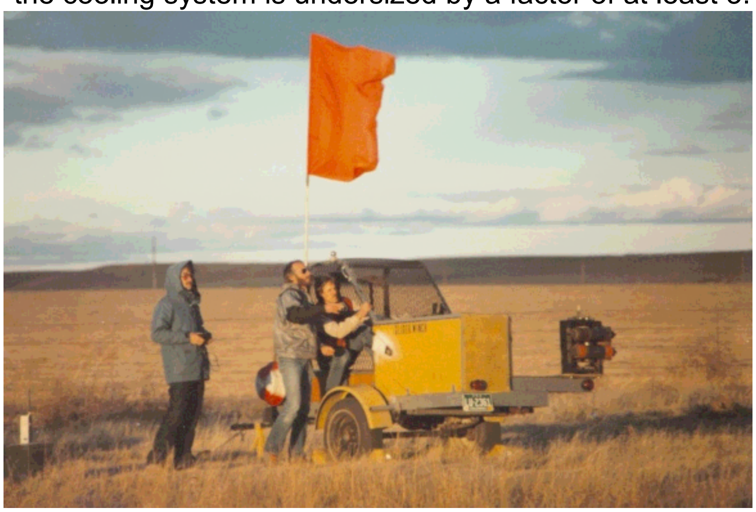
It is worth thinking about the response of a jury when presented with the above graphs by a lawyer representing an injured party. I think any engineering expert witness would conclude that the plaintiff was unreasonably placed at risk. The oscillatory behavior only becomes apparent when tension recordings are made so it's not reasonable to claim that a pilot knew or should have known about it nor is it useful trying to hide the data since any competent attorney would demand that they be produced. The solution is to build winches without oscillatory behaviors.

One has to recognize that there are many such winches in operation around the world. The most important action an ethical engineer can take is not to build any more of them.

If you already own one what can be done to improve it? The first step is to replace the steel cable with Spectra/Dyneema. This lightweight rope is highly damped and does not tend to support tension oscillations. The second step is to lighten the rope drum to reduce the rotational inertia while maintaining its crush resistance,. Together, these two steps can solve more than half the oscillation problem and you will get higher launches.

The remainder involves the automatic transmission. If the throttle position sensing cable is still in place, remove it to eliminate “kickdowns”. Automatic gear changing should be completely eliminated by installing a “Manual Valve Body” that converts a standard automatic into a “manumatic” which will start in the selected gear and remain there until the operator selects another gear. A single, overall gear ratio of about 14 kts rope speed/1000 RPM is about right. Finally, the torque converter action can be controlled by replacing the stock converter with one fitted with a lockup clutch. Set it to lock the torque converter any time the drum is above 100 RPM.

Beyond the very serious safety issues, 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.



US glider winches typically use pairs of crude, small diameter, crossed rollers to guide the rope onto the drum - a feature borrowed from low speed winches. When operated at high speed, this results in rapid wear of both the rope and the rollers – especially when the rope gets caught in the corner of the roller box.

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 winch cable is 3/16” 7X7 galvanized aircraft control cable which weighs about 8 pound per hundred feet. This material has many drawback beyond its weight. It combines with the automotive drive trains to produce an oscillating system as discussed above.

US winches typically lack logical controls and adequate instrumentation forcing he winch operator to rely on 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 judgment are trusted.

The overall result is that many glider pilots 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.

20.63 meter Caproni Vizzola Calif A21S Launches in France

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.

The trend in Europe is to use large diesel engines in the 300 - 500 HP range. These high-torque, low RPM diesel engines are ideal for the purpose.

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

Hydrostart, NL http://www.hydrostart.nl
Hydrowinch USA http//www.hydrowinch.com
Elektrostart, Ger. http://www.startwinde.de
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 Hydrostart, employ two drums.

In Germany and Holland, 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.

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

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 often a huge surprise to those not familiar.

While low prices welcome, release heights and launch frequency are also important. Release heights above 2000' AGL 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 aero tow.

Most pilots would see a $15 fee as very 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.

Dividing costs into operational and capital categories helps understand the cost breakdown. Operational costs should include fuel, set asides for rope replacement, engine overhaul or replacement and other maintenance. If the rope retrieve 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.)	$0.50
rope replacement ($1000 @1000 Starts)	$1.50
Maintenance ($3000 @ 10,000 Starts)	$0.30
Retrieve vehicle	$0.50
Total Operational Cost Per Launch	$2.80

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 $100,000 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 $150,000, 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 $15 launch fee would produce a large operating surplus for a club. If the acquisition were to be financed, this surplus would initially go to debt service.

Assuming a $12 surplus on each launch, a $100,000 winch would be paid off with 8334 launches. That's less than 167 operating days with 50 launches each day. The "fly to buy" idea is attractive but can that many launches be made? Ask the Europeans – they commonly do more than 100 a day.

The key point is that the profit margins are so high that the initial cost of the winch is almost immaterial.

Calculates effects of multi-drum winch on daily operations

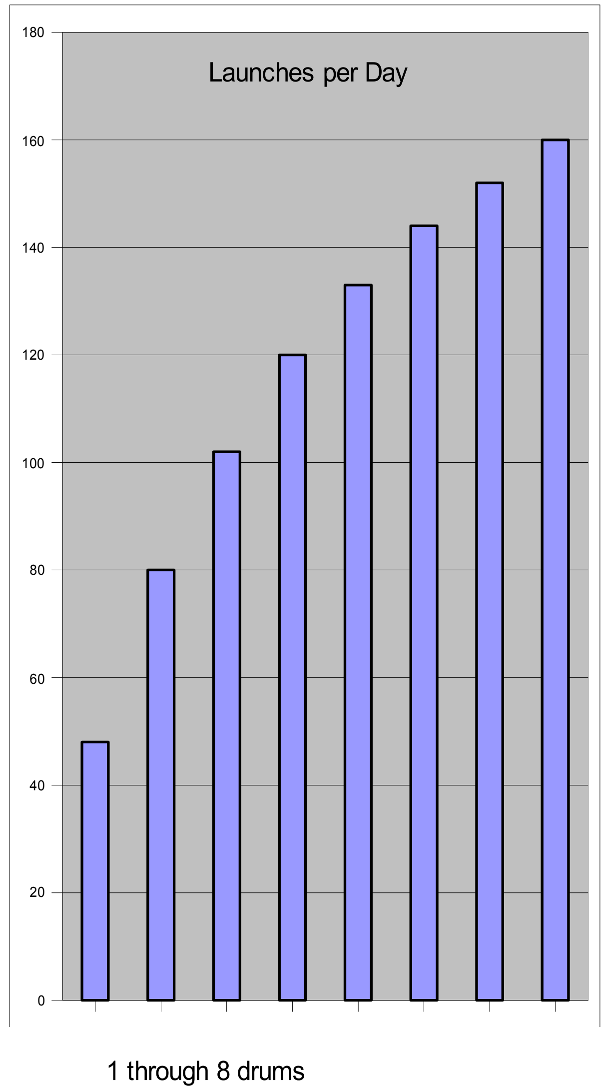
Enter starting data in box below:

Hours in flying day	8.00
Price of launch $US	15
Launch Interval. (min)	2.00
Payout Time (min)	8
Average Height	2500

Daily Vertical Capacity

Drums	Launches	Feet	Revenue
1	48	120000	$720.00
2	80	200000	$1,200.00
3	102	255000	$1,530.00
4	120	300000	$1,800.00
5	133	332500	$1,995.00
6	144	360000	$2,160.00
7	152	380000	$2,280.00
8	160	400000	$2,400.00

Key assumptions: Glider queue always full
Note: Under no-lift conditions and 4 gliders,
one glider will always be waiting.
Launch "Set" quickly at Launch Interval
Then, retrieve all wires (Payout)



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*.

Multi-drum winches are most suitable for use with long runways where the rope retrieve times are a significant fraction of the launch cycle time. The are less effective on short runways where a retrieve winch is more suitable and where the retrieve winch rope has less impact on height gained.

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.

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 winch at more than $100,000 US will strike many as impossibly expensive. If it is likely that it would only be used on weekends, this is even more so. However, it's not difficult to pay for a $100k winch if you can make 150 – 200 launches a month – or roughly 160 launches on each of 12 days a year. Scheduling 12 “pay for the winch” days each year can insure making the loan payment.

A review of state of the art Active Tension Control winches can be found at:
WWW.Hydrowinch.com
http://www.romansdesign.com/winch.htm
www.hydrostart.nl
http://www.startwinde.de/

A group of serious enthusiasts can build a world class winch if they have the right skill set which includes engineering design, machining and welding skills. Unfortunately in this computerized world, these skills are less common than they were 40 years ago when most club member built winches were constructed. This is not to say that these skills can not be learned as the project proceeds.

Winch Design Elements

Rope

"The ultimate tensile strength of a new launch rope, including all its harness components but excluding the weak link, has to be able to support at least 1.5 times the MTOW of the glider to be launched." – German Aero club

The key starting point for a winch design is rope selection since many design feature follow from that.

Steel cable is both heavier and weaker than desired. Widely used 7x7 3/16" galvanized aircraft control cable weighs 6.2 pounds per hundred feet and has a safe working load of only about 900 pounds. It fails at about 3700 pounds but is notably susceptible to shock loads. A lighter, stronger and more durable alternative is needed.

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

Some will point out that rope 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 rope to the longitudinal axis of the glider reaches 70 – 75 Degrees.

The winch operator must reduce the rope 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 rope increases. At some point, depending on the weight and drag of the rope, the CG hook will release automatically as the rope angle reaches 70 degrees, effectively limiting the release height. The heavier the rope, or the greater the drag, the more sag and the earlier the automatic release occurs.

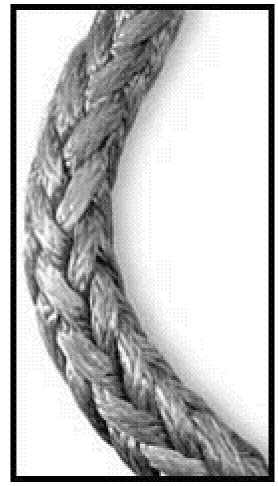
The lighter the rope, the smaller the sag and the smaller the angle at the CG hook for a given rope tension. In mid-launch, the pull vector is more nearly aligned with the flight path of the glider. The result is a higher launch.

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

The weight of steel cable also significantly increases the rotational inertia of a winch drum.

Heavy steel cable also acts as a spring that supports tension oscillations. The ideal rope material is light, strong, thin and exhibits a high damping coefficient in tension.

Spectra/Dyneema (UHMWPE)



Looking at all candidate rope materials, one stands out as superior - Ultra 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, Some rope makers claim a ~25% increase in release heights compared to steel cable. The extra strength is likely to significantly reduce the incidence of rope breaks.

3/16" **Spectra** coated with abrasion resistant polyurethane is available in strengths of 3800 – 5500 pounds weighing 1 pound per 100'. 3/16" steel weighs 7 – 8 pounds/100 feet.

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

The performance gain expected, based on claims by Lippmann of Germany, is around 25%. A winch that delivers 2000' AGL with 5000' of steel cable, or 40% of the runway, should deliver 2500' AGL on a no-wind day with **Spectra**.

Spectra is strong and light with 10x the strength-to-weight of steel and 15x the abrasion resistance. (Ref. Wikipedia) It is largely immune from degradation by UV and common chemicals. It has been tested under extremely harsh conditions in the marine, logging and mining industries and found far superior to steel cable.

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. It offers less chance of damaging aircraft or cars if dropped on them. 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 can be quickly spliced the same way as water ski rope and the resulting splice is nearly invisible.

Spectra cord suffers compared to steel in three areas where design allowances must be made. The manufacturer guarantees the specified strength up to 150F but It begins to lose strength above that until it melts at 285F. It is easier to cut on sharp edges than steel. It is more expensive.

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 rope while pulling the winch across the airfield instead of pulling it out with a vehicle.

Some Spectra vendors web sites:
http://www.samsonrope.com/products/mi_12strand.cfm
http://www.lippmann.de/english/index.html
http://www.psrope.com/psrope/catalogpdf/NewPlasmaRev9.pdf
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. If the glider demands more power than the winch engine can supply, the glider airspeed will decay. The peak power demand is just at the beginning of the rotation into climb where the wire speed is greatest. A power deficit at this point has a large effect on the height achieved – and on the safety of the launch.

There are two formulas for instantaneous power calculations.
(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 main part of the launch. The wire tension at the winch at peak power is 1300 + 300 + 100 = 1700 pounds.

This computes as 1700 * 100/550 = 309 HP at peak demand. 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 ‘25 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, as a rough estimate, the wire speed has dropped by 66%, the drum circumference has grown by 33% thus the drum RPM has dropped to 238. 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, which means the engine RPM must drop to 522. The fluid coupling will allow significant slippage below 1100 engine RPM which will help maintain torque levels somewhat. At this point the drum torque must be 1.33 times 1300 (from the first example), less the wire weight hanging below the glider – assume 140 Lbs. - to maintain tension equal to the glider weight. This means that the drum torque is 1.33 x1300 – 140, or 1589 Ft.-Lbs. This demands 1589/2.2 or 722 Ft.-Lbs. of engine torque at about 1000 RPM.

Large, low RPM, high torque diesels with torque limiters can easily deliver the power and torque demanded. Spark ignition engines will have more difficulty, especially with low-end torque. The HP calculated above is actual horsepower. The power output advertised by the engine manufacturer is likely to be optimistic so the "data plate" HP should be ~50% larger than the peak HP demand especially where operation at high density altitude is planned.

"*The power of the winch , the pull force and the rope speed have to be matched in a way that all possible launch operations with aircraft supposed to be launched can be carried out in a safe way*."

1. "*In dead calm air, the aircraft has to be fully controllable around it's longitudinal axis (Aileron control) after less than 15m acceleration distance and must reach it's take-off speed after a minimum of further 45m. (The total distance from standing to take-off rotation must not exceed 50m.)"*
2. *"The drum speed (RPM) has to be chosen such that, using the core diameter and the required power to accelerate the aircraft according to 1.), a rope speed of no less than 1.2x the liftoff speed."*
3. *"The power of the winch has to be such that an aircraft at Max GW in dead calm air can be launched at the placarded maximum permissible airspeed for winch launching (Vw) and achieve a release altitude of 25% of the initial rope length. The minimum release altitude has to assure a safe execution of a normal pattern."*
4. *"Either by means of calculation or by trial, the capability of the winch to provide sufficient rope pull force to launch aircraft at Max GW in dead calm or up to the strongest wind condition in which the winch is intended to be used, has to be proven."*

--- German Aero Club

Note that these regulations set minimum power and speed requirements. The best solution requires substantially more power.

The requirements that the glider reach aileron control speed, and subsequently takeoff speed in a minimum distance directly addresses a major safety concern. Should a wing tip drop to the ground during the takeoff roll, there is a chance that a ground loop will occur because the rope is attached at the gliders center of gravity and thus the glider derives no directional stability from the ropes pull.

Because the glider is accelerating under considerable force, the ground loop is likely to progress quickly into a flick roll causing the glider to impact the ground inverted with fatal consequences for the pilot.

For this reason, all pilots are trained to release the rope at the first indication that a wingtip will or has contacted the ground. However, a ground loop happens very quickly after a wing tip touches the ground and the pilot may not release quickly enough.

By quickly accelerating the glider to takeoff speed, the chance of a wing drop is all but eliminated. Reaching takeoff speed quickly places the glider pilot in a better position to deal with a rope break since this results in more altitude early in the launch while more airfield is available straight ahead.

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, a fluid coupling will require a heat exchanger to cool the working fluid. Fluid couplings and hydrostatic transmissions produce substantial heat.

"*The cooling system of the winch has to be designed such that while using the shortest possible launch sequence in hot summer weather, the maximum permissible operational temperatures of the engine and transmission are not exceeded*" – German Aero club

Engines - Spark Ignition

Automotive engines can be made to work especially with hydrostatic drive, but they won't have the standard flywheel housing bolt pattern of industrial diesels to which hydraulic pumps or fluid couplings must be mounted requiring a custom adapter.

The best spark ignition power plants are large displacement "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" engine blocks cost around $6,000 - $15000 new. They must then be fitted with fuel injection, ignition and exhaust systems which may raise the cost to $20,000. Adding a custom adapter for a pump or fluid coupling may increase the cost to more than $25,000. This will likely be more than the cost of a large used diesel engine.

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

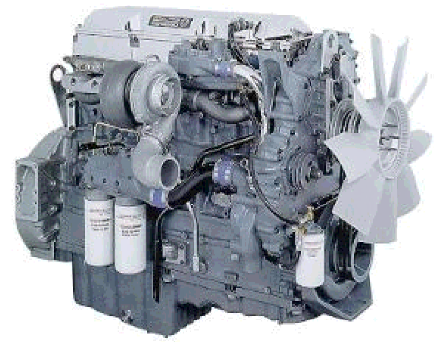
Transmissions - Automotive

Using automatic transmissions in glider winches is strongly discouraged but if you already have one, several modifications are needed for safe operation. Specifically, replace the stock valve body with a "manual valve body" and a locking 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.

Locking torque converters are available for most automatic transmissions. The electrically operated ones can be controlled so as to lock the converter whenever the drum is rotating above 100 RPM.

Engines - Diesel



Cummins 14.7L 6Cyl

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

Many 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.

Alternatively, used diesel generators are sometimes on the market at reasonable prices. These are perfectly outfitted for extended stationary operation with large radiators and water pumps. The electric components can be sold to recover much of the prices of these units.

Cat 3406E 15.2L 6Cyl

Used 350 HP diesels 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 red-line. 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.

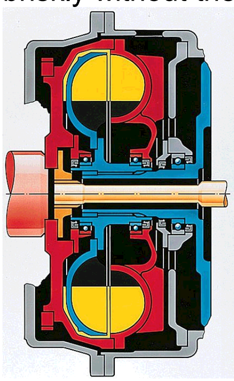
Engine power is a function of the transmission type chosen. A fluid coupling is inefficient wasting much of the input power as heat. To overcome this inefficiency, a much larger engine is needed. Hydrostatic drive is much more efficient allowing a smaller engine to be used.

Unlike automobile engines, these diesels are complete, self-contained "drop in" power units. They may 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.

Transmissions - Fluid coupling

Many European winches, use 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 overcome the inefficiencies of a fluid coupling and still accelerate a glider briskly without the need for a starting gear or torque multiplication.



A fluid coupling is like a torque converter except the torque transfer 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. The engagement time can be adjusted for smooth, precise start-ups.

Fluid couplings for diesel engines bolt to the standard SAE flywheel housings found on large industrial diesels.

A winch fitted with a fluid coupling works like one equipped with an automatic transmission but without the “PRND2L” gear selector. It also eliminates the overdrive coasting function found in automatic transmissions. See: http://www.voithturbo.com/applications/documents/document_files/379_e_ca_cr273_en.pdf

Transmissions - Hydrostatic

An even better solution is a “Hydrostatic” transmission which uses a variable displacement hydraulic pump on the engine and hydraulic motor(s) to drive the drums.

A hydrostatic transmission is a Continuously Variable Transmission (CVT) that can provide any gear ratio. Rope speed is controlled by changing the displacement of the pump and not engine RPM. The engine is brought up to its most efficient RPM before the launch and the hydrostatic transmission does the rest.

These drive systems lend themselves to computer control since the winch computer controls both the engine and transmission.

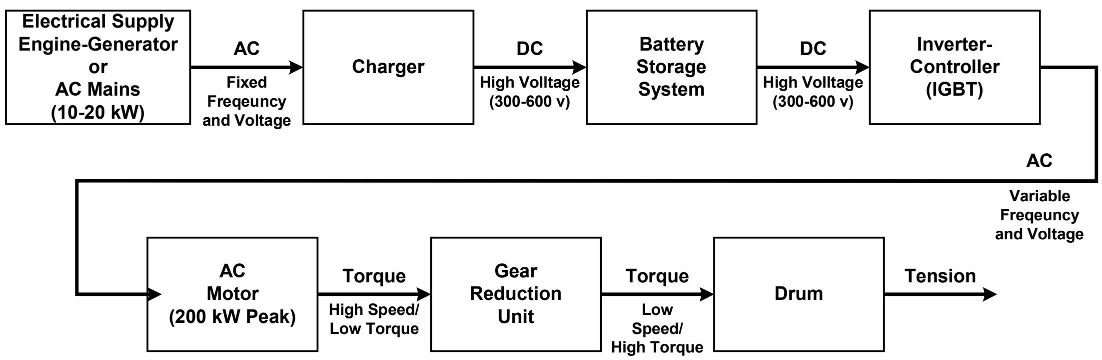
A hydrostatic transmission can be used instead of a retrieve brake. A small reverse torque is applied to the drum to maintain rope tension.

Finally, hydrostatic transmissions greatly simplify winch design by allowing almost unlimited engine and drum placement.

Electric Power – by George Moore

Electric power is both feasible and elegant allowing for easy computer control. The technologies associated with electrically driven winches are in a state of rapid evolution with new development occurring monthly. The information that follows represents the current state of these technologies as of May, 2008.

Electric drive components suitable for winch applications have just become readily available in the last 10 years delaying development of such winches. The German ESW-2b winch, introduced around 2003, uses an electrical drive configured very similar to what is termed a series hybrid design for Electric Vehicles (EVs). A block diagram for this configuration is shown below.



Series Hybrid Electric Winch Configuration

Batteries provide the energy for the launch and much lower power AC mains or an integrated engine-generator replenish the batteries as required. The electric motor may be required to provide around 200 kW peak output during a launch. Electric drives have Constant Variable Transmission (CVT) attributes similar to hydrostatic drives where the conversion efficiency is high and the amount of wasted energy is small.

A characteristic of most electric motors allows them to provide peak powers considerably above (150-200%) their continuous rating for periods on the order of a minute – a period very well matched to winching applications. This allows smaller and lower cost motors to be employed than would be suggested by the peak power requirement. The advent of cost effective, high power solid-state inverters has made AC motors preferable over DC motors. Both synchronous and asynchronous AC motors have their merits but the asynchronous are generally less expensive and more rugged. The ESW-2b winch employs an industrial asynchronous AC motor.

The DC battery power is converted to AC by a high efficiency three phase switch-mode industrial inverter in the ESW-2b winch. This inverter employs Insulated Gate Bipolar Transistors (IGBTs) as the switching elements. A microcontroller commands the inverter to produce a variable frequency, variable voltage output to control the motor speed and torque. These controllers can provide torque control to zero speed and even in reverse when vector controllers are employed in conjunction with an incremental shaft encoder. This eliminates the need for fluid couplings and mechanical brakes greatly simplifying the winch mechanical configuration. The combination of low motor inertia and a simplified mechanical system allows the winch inertia to be considerably lower than with IC designs. Torque response times of these motors can be very fast, on the order of milliseconds, allowing excellent closed-loop feedback control.

The ESW-2b winch employs 50 88 Ah lead-acid maintenance-free starter batteries. The energy required per launch averages about 1 kWh. The battery size is generally determined not by the energy capability but by the peak power requirements and the allowable recharge rates. The large number of batteries allows peak currents well below rated capability and the very small Depth of Discharge (DoD) operation yields an expected battery lifetime of 5 to 7 years – far more than the typical 3 to 4 years such batteries yield in automotive applications.

The battery replenishing source, either AC mains or an engine-generator, can be sized to support the desired launch rate. A 10 kW source can sustain about 10 launches per hour and some peaking above this rate can be obtained if excess battery energy capacity is exploited. With some peaking capability, there is generally little value in sources larger than 20 kW providing a sustainable 20 launches per hour.

The intense interest in Electric Vehicles (EVs) due to rapidly rising energy costs is driving rapid advancements in the associated technologies. There are major initiatives to improve motors, controllers, inverters, and battery components. The components that are emerging in support of this market will be better matched to winching applications and the associated economies of scale should make them much less costly than the industrial components used in the ESW-2b winch. Electric drive components sized for buses or over-the-road trucks are appropriately sized for winch applications. The motors and controllers are generally liquid cooled and much smaller, lower weight and purpose designed for the harsh vehicle environment. The demands for winching are generally far below those for transportation applications.

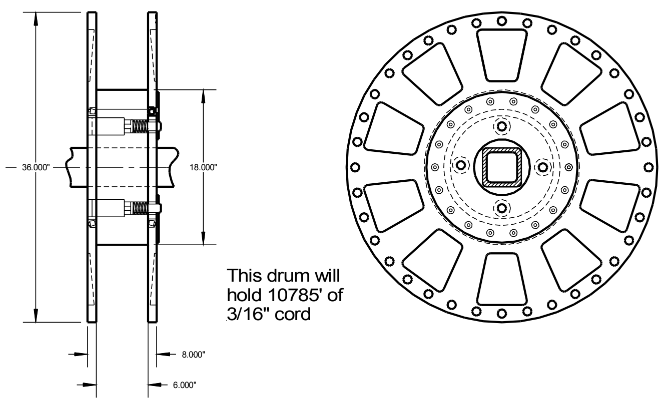
There is a revolution in battery technology that is just now emerging offering huge increases in power density. The battery chemistry involved is Lithium Iron Phosphate. A winch battery system employing these cells could be constructed weighing less than 100 kg – more than a factor of 10 less than the ESW-2b lead-acid system. This chemistry has calendar and cycle lives of over 10 years and 10,000 launch cycles.

The adaptation of components developed for EV applications holds great promise for higher performance, enhanced safety, and lower cost, size, and weight winches within a few years. The advantages of this drive configuration are becoming ever more compelling. Further information on this electric winch configuration and components may be found in the Yahoo Group “WinchEngineer” Files section.

Drum(s), Dog Clutches and Retrieve Brakes

There is considerable empirical evidence to suggest that long runway 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 Hydrostart and Van Gelder 6-drum winches.

One rope 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 clutches inside each drum serve the purpose well. Power can be routed from slip rings through wires in the hollow drum shaft to the solenoids.

Some hydrostatic winches have incorporated a hydraulic motor for each drum greatly simplifying the design while providing some system redundancy. The drums are selected by valving hydraulic fluid to the selected drum.

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 to improve rope speed control. To reduce inertia, drum should be made of the lightest material that provides adequate strength.

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

Smooth control of the rope 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. Reverse torque from a hydrostatic drive can also be used.

There are two schools of thought about how to lay the rope on to the drum. One says that the rope should be laid neatly on the drum in parallel wraps with a level-wind or paying-on mechanism. (SupaCat, Hercules H4) This extends the life of the rope whether it is Spectra or Steel. The other says that if the pulley and drum are separated by a sufficient distance, just let the rope fall randomly on the drum.
Spectra rope may require the use of a level-wind system since the material is so "well behaved" that it tends to pile up in the center of the drum.

Finally, drums intended for use with **Spectra** must withstand huge crushing forces generated when the rope is wound on under high tension. Experience has shown that this rope slides easily on itself creating a situation not unlike a liquid under pressure. The resulting force is applied both inward and to the side so the drum flanges must withstand large sideways forces as well as inward ones.

The requirement for extreme strength and lightness to reduce rotational inertia means that the winch drum is one of the most critical parts of the winch. To meet this requirement, high performance materials like aircraft aluminum alloys or even carbon fiber composite are appropriate choices. Some designers use finite element analysis programs to insure strength and lightness. On the other hand, heavy welded steel drums are likely to introduce control problems like oscillating tension while still not achieving the required strength.

"If the rope tends to pile up in the middle of the drum, an automatic level-wind mechanism has to be used. The design of the level-wind mechanism has to minimize the wear on the mechanism and the rope as well as assure that the rope is distributed evenly on the drum."

"Note: A level-wind mechanism is required if the ratio between the drum width and the distance from the drum to the fairlead is smaller than 1:18."

"Drums have to be balanced statically and, if necessary, dynamically."

"On double drum winches, a safeguard has to be installed which assures that only one drum can be engaged with the drive train at a time."

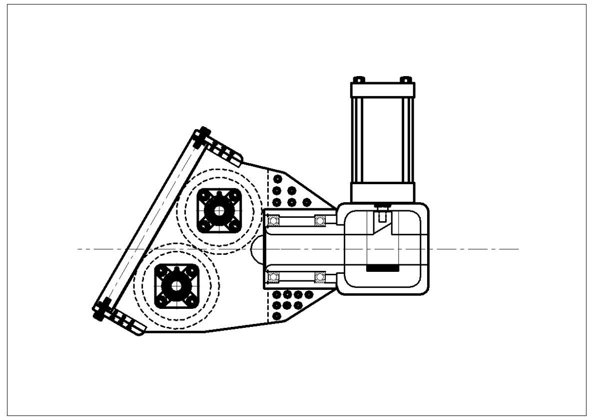
"The drum must be capable of adjusting to uneven speeds during pay-out automatically without the attention of the winch driver. (i.e. an automatic pay-out brake)"

"Note: The core diameter and width of the drum(s) must be sized in consideration of the rope diameter and the maximum length permissible rope length as well as the available engine speed range, so that the requirements for power, rope force and rope speed are met at all times." (Example: a narrow drum fills up with rope during the launch thus increasing its effective diameter. To maintain a constant rope speed, less engine speed is required but, at the same time, more torque must be supplied from the engine to maintain a constant rope force."

--- German Aero Club

Rope Guiding Mechanism

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

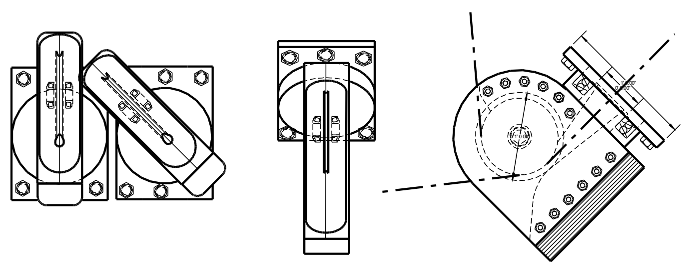


Azimuth Pulleys with air Guillotine

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 rope. The pulley housing block is designed so that the rope cannot jump off the pulley.

The inclined swivel pulley is attractive design because it drops the rope away from a spinning pulley at the end of the launch protecting it from friction as the pulley spins down.

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



Inclined Swivel Pulley

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

The German Aero Club has quite a bit to say about guide pulleys.

"The fairlead (guide pulley) has to be designed so that the launch rope is guided safely under all possible forces, rope speeds and rope angles. The following limits are defined for the rope angles:"

"Upward: 90 Degrees – (rope vertical) at a lateral angle of zero."
"Downwards: 20 degrees with the lateral angle of zero."
"Lateral: + or – 30 degrees through a vertical angle of –20 through +90."

“No winch components may be placed in front of the fairleads that can obstruct the free movement of the rope or in which the rope could become entangled after the guillotines were activated.”

“Rollers and sheaves meant to guide or re-direct the rope have to be designed in such a way that the rope can not slip off even in the most unfavorable angles.”

“All bearings have to be sealed against dirt ingress.”

“Rollers and sheaves may not have any sharp corners which could damage the rope.”

“The diameter of the rollers and sheaves and their materials have to be selected in consideration of the rope’s diameter and the minimum wrap radius.”

“Proven design principals should be copied.”

“The weight and inertia of the guide rollers and sheaves should be kept as low as possible.”

“The surfaces of the guide rollers and sheaves coming into contact with the rope should be harder than the material of the rope.”

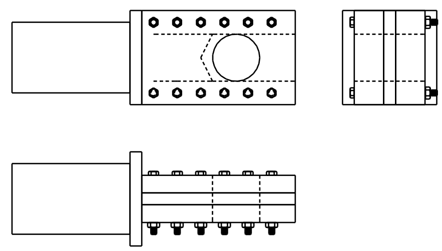
--- German Aero Club

Guillotine

Since guillotines are a key safety devices, they need to be extremely reliable. In addition, they should not pose any danger whatever to the winch driver.

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

An excellent design is a “cigar cutter” guillotine actuated by a pneumatic piston. The rope passes through a hole in the box so that it cannot escape 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. Simple spring return air solenoids or cylinders are available for $30-40 on eBay. A 2” bore pneumatic cylinder can produce more than enough force with 100 PSI air pressure.

All guillotines will require ergonomic cab controls. In multi-drum winches, cab controls must insure that the correct rope is cut. If the correct guillotine is not selected by the drum switching system, one might consider firing all guillotines cutting all ropes. Guillotines are rarely used “in anger” so the inconvenience of splicing multiple ropes is minimal.

It is also possible to use the guillotine as a way to protect the fairlead pulleys from damage if the winch driver tries to pull the parachute assembly through them. This scheme requires a way for the winch to automatically sense when the parachute is approaching too fast to be stopped and fire the guillotine. A magnetic reed switch that detects a magnet embedded in the rope or a Veeder-Root drum revolution counter might be used to trigger the guillotine before the parachute assembly reaches the fairlead.

Splicing the rope is far easier and cheaper than repairing the fairlead pulleys and parachute assembly.

“The guillotines, their operation and release mechanisms have to be designed in such a way that the operator can activate them from the operator’s seat during any phase of the launch to sever the rope between the winch and the glider being launched”

“The guillotine has to be able to function as intended even while the rope is moving through it. Its capacity has to be sized such that a minimum of two (2) strands of the rope can be sheared off smoothly in one activation.” – German Aero Club

Winch Control Instrumentation and Automation

Powerful winches need precise control systems to consistently deliver just the right power for different gliders launched under a wide range of conditions. Correctly implemented, Instrumentation/automation will make the winch operator's and the pilot's tasks safer and less demanding.

Rigid control of the initial acceleration is mandatory when a particular glider is subject to uncontrollable pitch-up due to a combination of low CG hook, high CG and limited down elevator authority when the initial acceleration exceeds a critical value.

Automation can make launches perfectly consistent, without a requirement for highly experienced winch operators. There is a significant payback that results from the reduction in training required for new winch drivers. The dynamics of winch launch are so fast that a human winch driver cannot control the throttle accurately.

Any winch control system seeks to control the two critical parameters – glider airspeed and rope tension. It is obvious that the winch cannot hold both variables since as one changes it affects the other. The only way to succeed is to assign one to the winch and the other to the pilot.

The simplest and most desirable is for the winch computer to control rope tension (Known as "Active Tension Control" or ATC.) and for the pilot to control airspeed with pitch as he does in free flight. For this to work well, the tension controller must be very fast and accurate so the pilot instantly sees a linear response to his efforts to control airspeed. The tension is adjusted for each glider to be launched at between 70% and 150%of the glider flying weight depending on glider characteristics and pilot preferences.

Active Tension Control has been championed by George Moore who has written extensively on winch dynamics and control laws. Any winch builder is strongly advised to obtain copy's of Georges excellent work and study it carefully.

The tension control system should be backed up by an engine torque limiter set as a fail-safe to prevent too much power.

There are currently four "Active Tension Control" winches available from commercial builders. The Hydrowinch and Roman's Design winches are US made.

Hydrowinch USA www.hydrowinch.com

Hydrostart, Netherlands www.hydrostart.nl

Roman's Design www.romansdesign.com/

Elektrowinde http://www.startwinde.de

Winch cab and chassis

Hydrowinch Trailer

Most European winches are fairly large machines for stability and ease of maintenance. It should also be easy to set up or reposition if wind conditions change. But any size is suitable if it can achieve these objectives. Lightweight winches will need strong anchors to prevent 2000 pounds of rope tension from overturning them.

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 for the the winch cab to be the most comfortable place on the glider port.

Egger Winch Cab

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

The cab windows should be made of materials that protect the occupants from the rope and attached hardware. 0.188" Lexan (Polycarbonate) is quite adequate. 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. Noise canceling headsets are very useful in the winch. Either wire line telephones or radio can be used for winch to start line communications but they must be dead reliable. Wireless video cameras are available from any electronics store that can provide the winch operator with useful view of start line activities.

There are points to be made for mounting the winch on a truck chassis as 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.

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.

“The seat for the operator has to be firmly attached to the winch and should be comfortable enough to prevent fatigue. The visibility of the glider during tow may not be obstructed unnecessarily. The seat has to be reachable without the risk of injury. Ladders and footholds have to comply with occupational safety standards.”

“All operating levers and handles have to be placed within easy reach of the winch operator. They have to be functioning with a minimum of effort and must be clearly labeled. The lever or handle activating the guillotines must be marked in red and may only be activated by hand. All levers and handles have to be designed so that an uncommanded or unintentional actuation is impossible during all phases of operation. If required, special safeguards must be installed to prevent shifting the transmission to positions not intended for the launch. (i.e. the R position on an automatic transmission.”

“Noise, both within the cab and outside it, should be kept to a minimum in light of the required communication during the launch between the winch operator, the launch director at the takeoff point and maybe the pilot, if so equipped.”

---- German Aero Club

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.

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 time-line 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 since costs are heavily dependent on the skill set of the team and their ability to scrounge or buy components and materials at deep discounts.

One method is to estimate the cost with all parts and sub assemblies professionally built or purchased at list prices with the final assembly done by volunteers. Then, if one or more team members has valuable skills, the estimate can be reduced by an appropriate amount with generous recognition given to the member who realized the savings.

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 metal working shops and instruction on how to use them.

To make reasonable progress on the winch during the winter months, a heated workshop easily accessible to team members is needed. Setting a work schedule of two weekday evenings and one day on weekends seems to work out well.

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 freeze the design after a consensus is achieved.

Summary

The ideal winch design 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 300 – 400 HP torque-limited diesel engine driving up to 8 drums through a fluid coupling or hydrostatic transmission. It will use high strength, lightweight synthetic fiber rope so that the highest possible launches are achieved.

It will employ engine torque limitation computer controls such that every launch is perfect regardless of pilot technique or environmental conditions.

The major advantages of a homebuilt 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 downside of club winch construction is that many if not most glider clubs will lack the skills needed and the members will not be inclined to learn them. If this is the case, the only option remaining is to buy a commercial winch.

Buying a new winch may make sense if the club members are better at making money than making things. There's nothing at all wrong with buying a winch but the buyer should be familiar with the principals laid out in this paper.

If the choice is to buy a winch, at the very least, demand that tension logs be made to assure that the winch can deliver smooth launches.