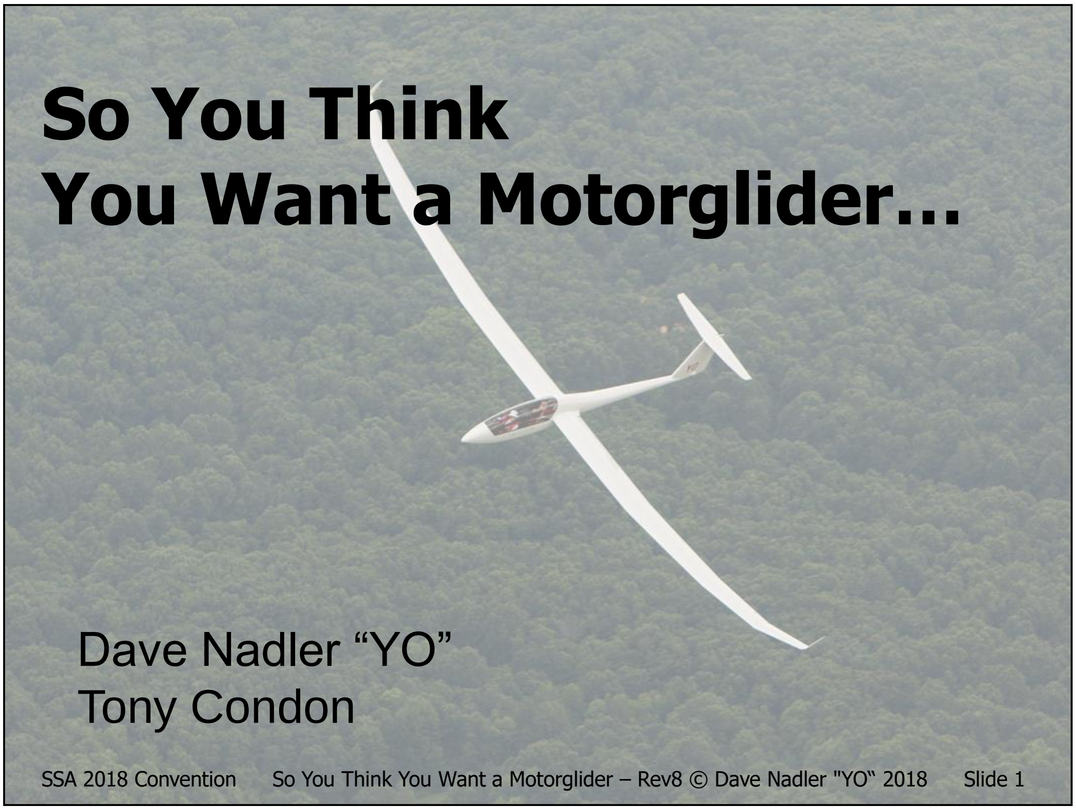


Audience check; how many:

- motor-glider pilots (sustainer, self-launch, touring, pylon, other)
- greater than 500 hours in gliders
- diamond badge or above

I’m a soaring addict, if I couldn’t fly a nice sailplane I’d fly hang gliders or even a PW-5.

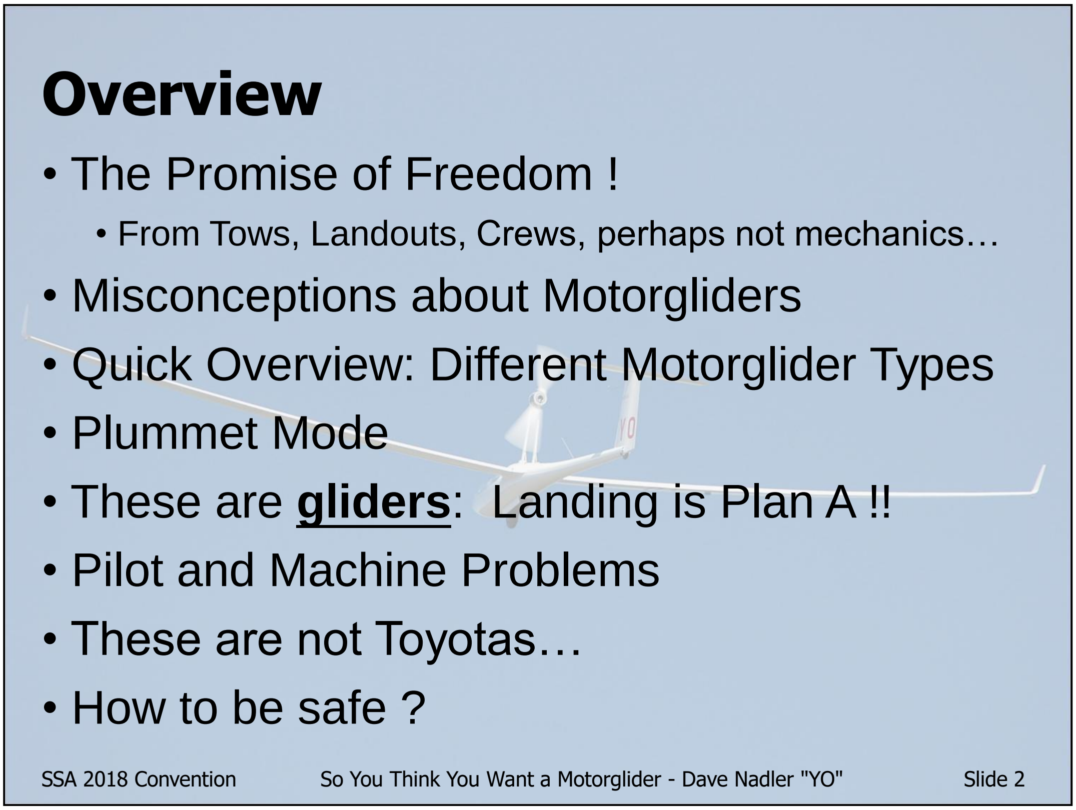
Experience: 4400 hours, including 2000 in motorgliders.

I’m now privileged to fly an ArcusM gas-powered and an Antares 20E electric motorglider.

SSA convention show floor: more motorgliders than unpowered.

Most gliders now built by major manufacturers have motors.

Clearly motorgliders are important in the future of gliding.



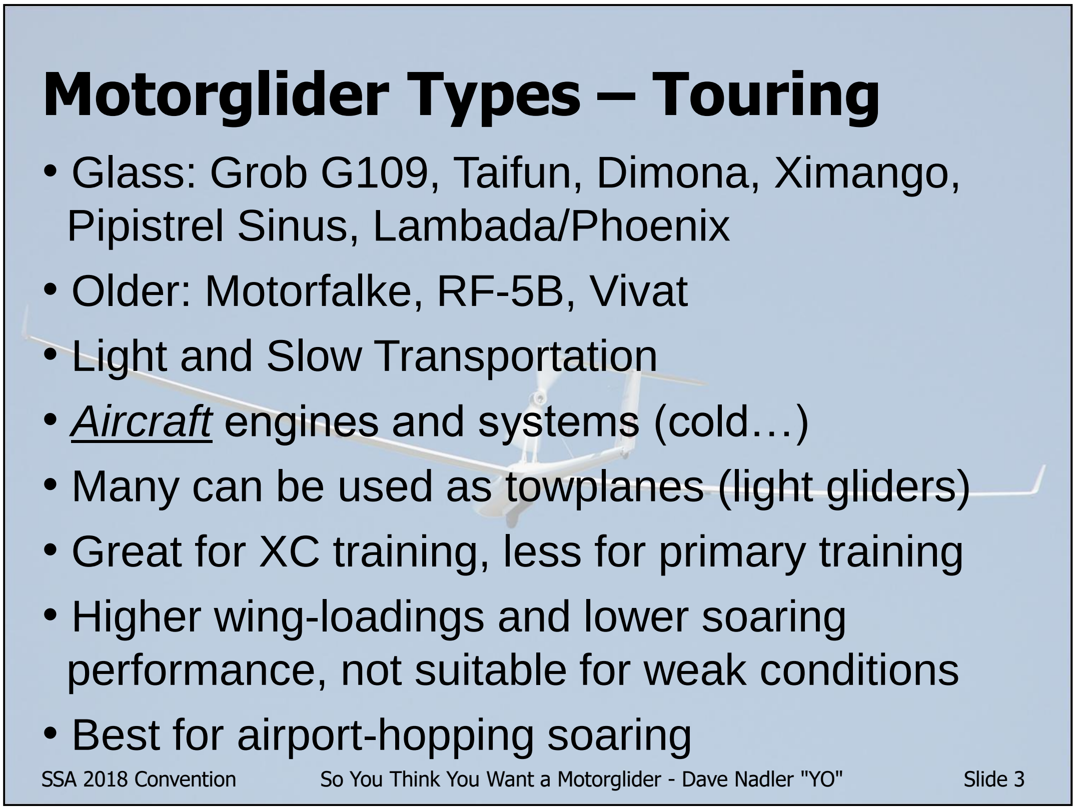
Misconceptions about motorgliders…

- Just turn the key and instantly be under power !

- Fly as low as a pure glider !

- Motor adds safety !

Wrong on all counts…



Not the main focus of this talk

Much more reliable systems

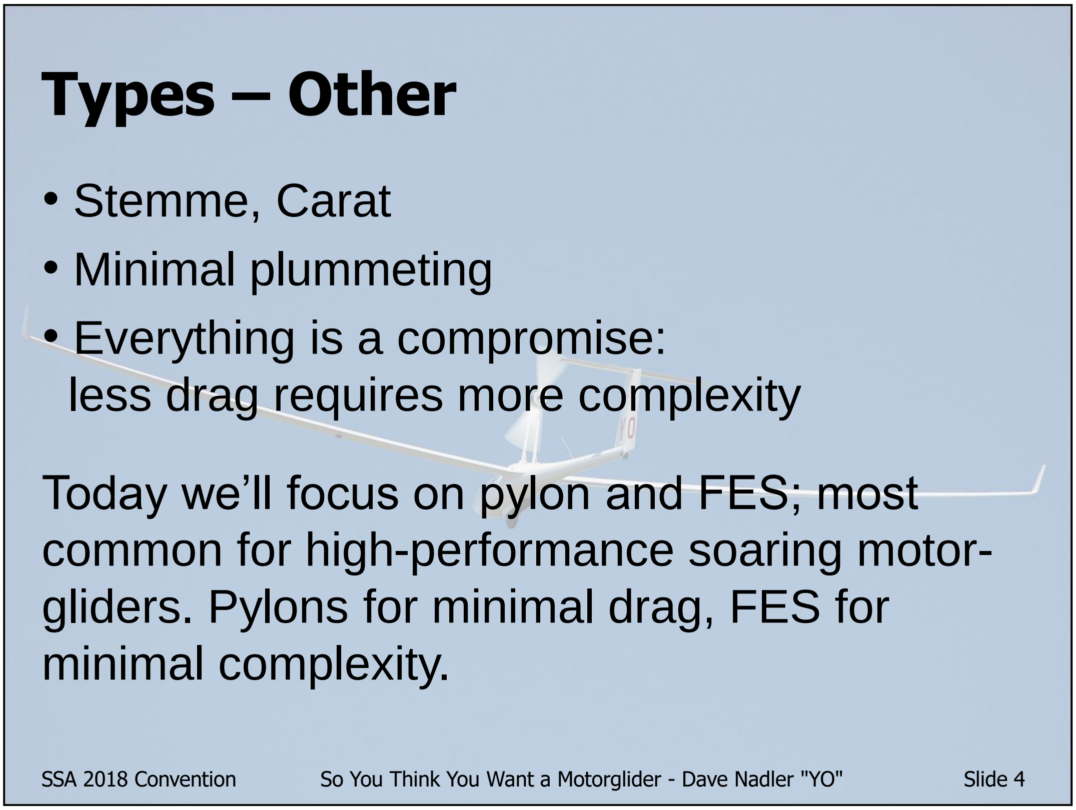
Cold-soaking motor during soaring can lead to restart difficulties

Take-off and landing more like tail-dragger airplanes than gliders, not great for training take-off and landing.

You don’t want to land these out – hop airports.

Because the LD isn’t so large, airport hopping can be challenging, but certainly XC soaring is possible.

Most for sale used have low engine-off time – not much soaring.


Types – Other
• Stemme, Carat
• Minimal plummeting
• Everything is a compromise:
less drag requires more complexity
Today we'll focus on pylon and FES; most common for high-performance soaring motor-gliders. Pylons for minimal drag, FES for minimal complexity.
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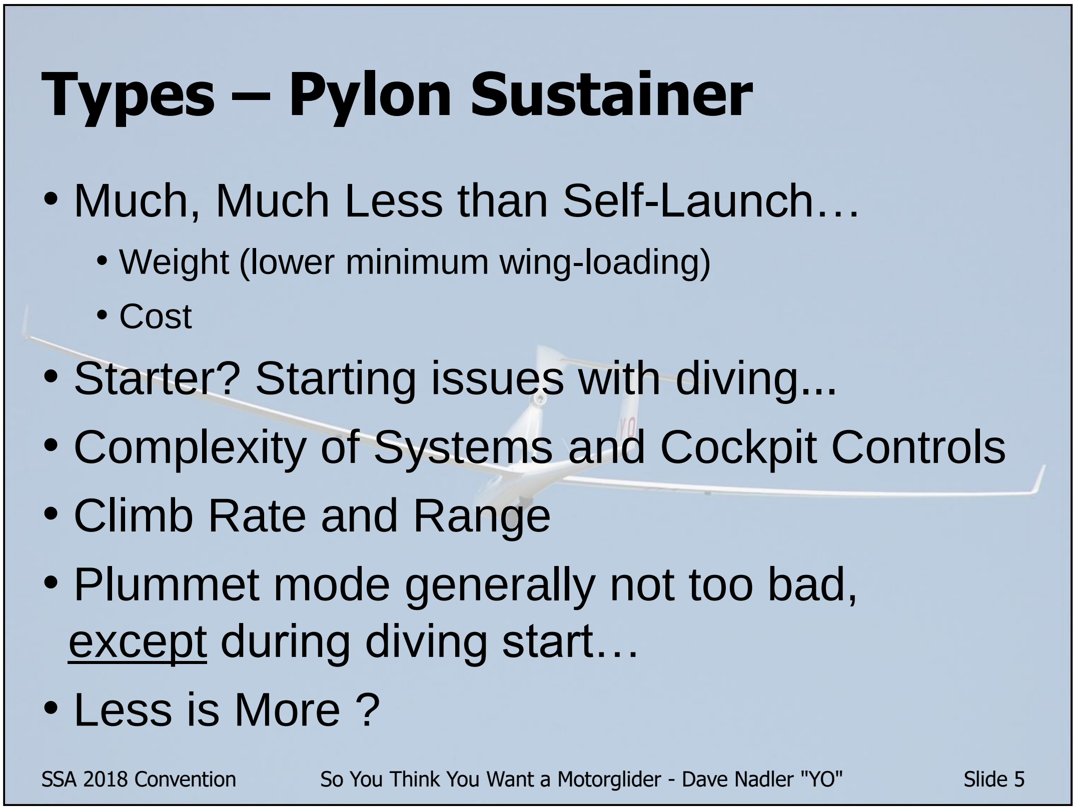
So You Think You Want a Motorglider - Dave Nadler "YO"
Slide 4



Cost example Arcus $35k sustainer over pure sailplane

Smaller gliders will have less expensive sustainer

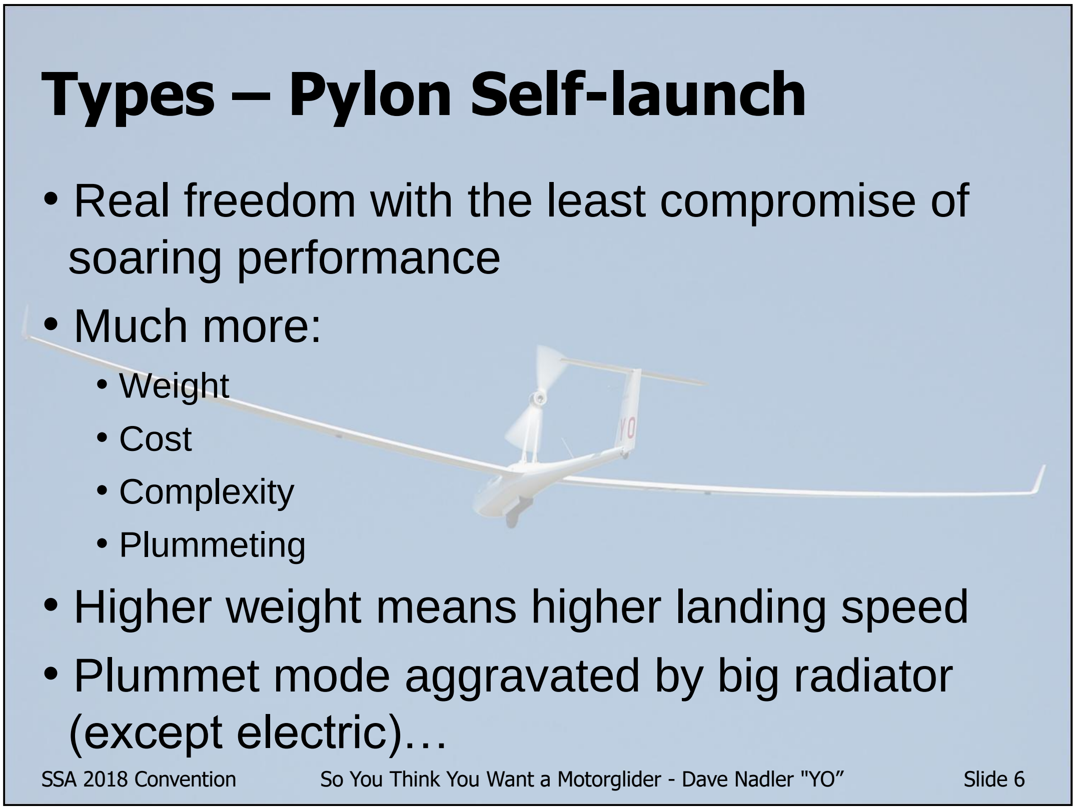
Starter Trade-off… No starter – may actually start in the cold
Can take a bunch of altitude to start (many are dive to bump-start)
Very careful airspeed management required for some bump-start.
One sustainer has a motor redline only a few knots higher than the speed required to start the motor, and when you exceed the motor redline the motor-controller shuts off the motor and your plummeting continues…

Extremely slow climb rate (zero at high altitude).
Slow climb rate means, if terrain is unlandable,
you cannot just start and head home over the trees:
you will shortly be out of gliding range of a safe landing.

You may not have enough range to make it home.

You may not be able to climb over a mountain.
Some sustainers, especially two-seaters, cannot

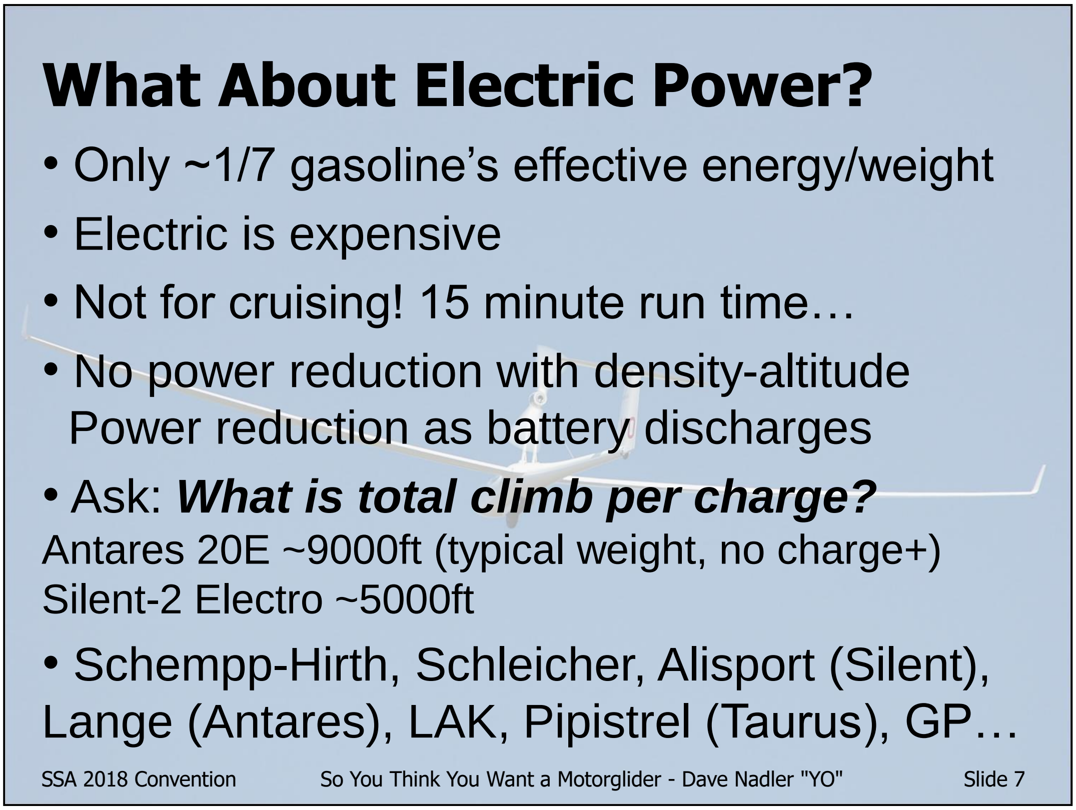
climb at higher density altitudes.
Someone I know ran the sustainer for a while,
couldn’t get high enough to clear a mountain range, and outlanded.



Really the dream

Example cost, Arcus: $63k over pure sailplane ($29k more than sustainer)

High cockpit complexity and plummet mode means it may be safer to land as a glider, then relaunch.



Effective energy includes relative losses for infernal combustion vs electric; 20% vs 95%.
Doesn't include massive cooling drag for internal combustion;
much of gas motor-glider power is used to overcome motor/cooling drag!

Antares uses very good and very expensive batteries.
Others use more economical (but lower capacity) batteries.

Partial charge means reduced max power, limiting take-off with partial charge.

Battery Technology Summary

Papers/Press		Watt-hours/kg	Available
	gasoline	13,000	
	kerosene	12,000	
	U-235 fission	25,000,000,000	
	SAFT VL41M (Antares complete pack weight)	136	2005
	Tesla Model S original	140	2010
November-2014	Sodium-Ion Brookhaven-Rutgers, short life, but promising cell-level	650	?
	Tesla 2017 (cell level; pack more like 200)	250	2016
October-2017	Toshiba EV battery SciB with titanium niobium oxide anode	200	2019
September-2015	Seeo solid-state (solid electrolyte, lab, cell level)	350	
January-2015	Bosch Seeo (demonstrated 130 wh/kg at pack level, Bosch acquired 2015, target 50 kWh battery pack weighing only 190 kg = 260 wh/kg at pack level, *production decision in 2018* as of Dec 2017)	260	?
	lithium iron phosphate	600	?
October-2017	Lithium Cobalt Phosphate (at sane cost)	800	?
October-2017	Asphalt with graphene nanoribbons and lithium	943	?
November-2017	Samsung Lithium-Air (only 20 cycles, low current)	580	2030
December-2017	University of Waterloo lithium metal anode (instead of graphite negative electrode, in-situ plating to prevent dendrites)	400-500	?
Safran Aircraft Engines president Jerome Bonini's estimate of situation:			
	system level	200	2017
	system level	500	2035

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Chaos in breathless publicity; the latest nano-magic-fragumfus battery!
Most publications you will read:

- Confuse material-level vs. cell-level vs. system-level performance (lots of weight for packaging, mechanicals, cabling, battery management)
- Lack plausible time-to-market, capacity, general performance, and cost information

Cell optimization axis include:

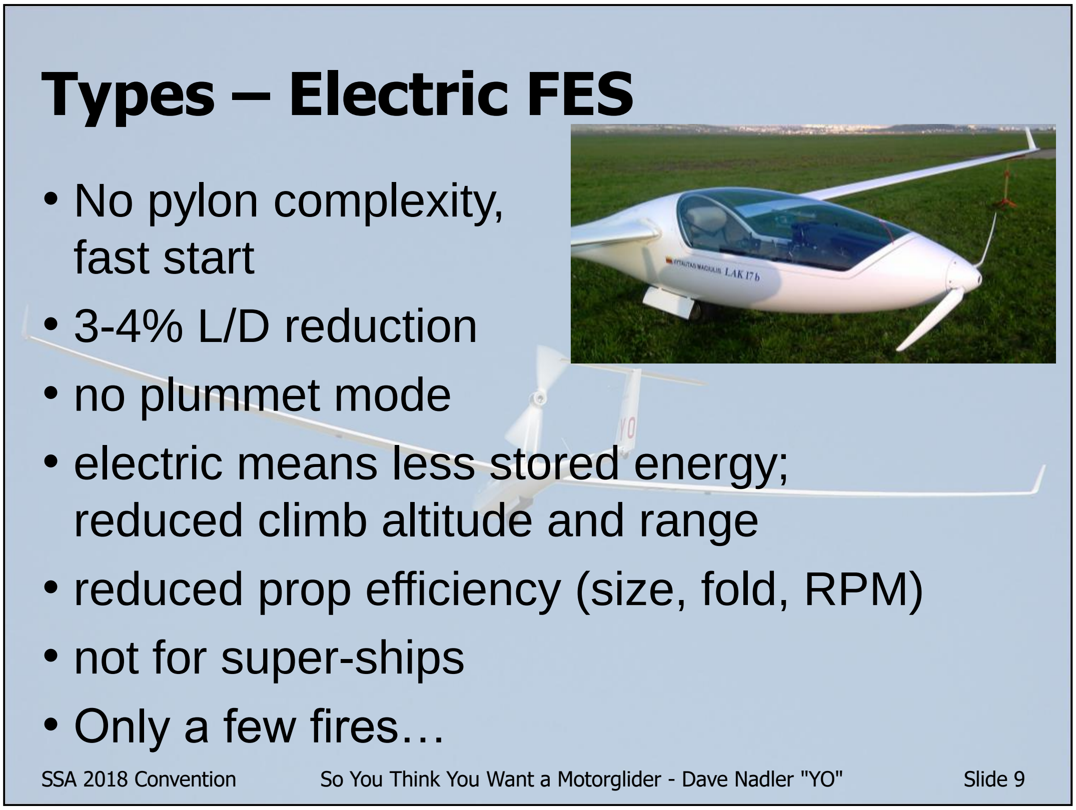
- Cost
- Energy/weight
- Safety (fires, material hazards, etc)
- Temperature range
- Discharge rate
- Power/volume
- Charge rate
- Number of cycles
- Allowable % discharge before cell is damaged
- Allowable % of charge before cell is damaged (self-discharge)
- Allowable overcharge (requires prompt discharge to avoid cell wear/damage, Tesla

example)

- Calendar lifetime
- Damage tolerance
- Glider pilot tolerance? Especially if batteries are removable or pilot accessible…

There is no magic battery!
It is going to take a long time to get really big increases in performance, but…

While its early days for electric power usable for gliders, real products exist.



Propeller in front - No laminar flow aft of the canopy like you see in Loek Boerman's slides

(maybe on Stemme, certainly not on Carat)

Very limited prop clearance to ground – prop strikes are common attempting self-launch

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Electro Panel showing FES FCU lower left

Power remaining indication

RPM & power usage (KwH)

Batteries, controller, motor temp

Time remaining at current power setting

Voltage & Amps

Warning Messages

Knob for "Throttle"

Master power key is below Radio

READ THE MANUAL

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Hi, Long time Airplane & Glider Pilot, relatively new motorglider pilot

13.5m team selection late 2014

Endorsement in Super Ximango

Silent 2 Electro intro early 2015 - Leo

Several fair soaring flights around the Pan American Championships

Self Launching and self retrieve experience, in flight restarts

Shipped glider to Slovenia

World Championship 2015 flying

Took aero tows during competition

- Save electric power for retrieve
- Rough field, witnessed one prop strike
- Several other Electros self launched
- One ~60km cruise. I believe 100km claim. FES seems most efficient in level flight.
- Two other shorter retrieves, one soared home after short motor run

Leah charges me Ice Cream for retrieves

In Lithuania, when I used FES to get home, Leah bought Luka Ice Cream!

My next encounter with Electro was Summer of 2016

Several Self Launched soaring flights in Kansas

Self Launched

- Watch motor temps in hot climates
- Limit time at full throttle. More efficient power use that way anyway
- Retrieve Range limited after self launch

Picture from Norwich, KS. 32 miles from home.

Aerotow retrieve the rest of the way

Uvalde Sports Class Naitonals 2016

Self Launched for competition

90% of winners score

Qualified for 2017 13.5m WGC

The Flight Home

Drove 200 miles from Uvalde to Winters to get out of the rain

Flew 400 miles from Winters to Ulysses, KS

7.5 hrs

The freedom of self launching!!

Talihina

Lucky me, Leo didn’t want the glider back

Wave forecast in Talihina

Drove down night before, slept in car

Airport manager helped rig at sunrise

8:30 AM launch, Diamond Altitude and State Altitude Record and landed by Noon

Ran Randy Teel’s wing behind Dooley Ruckers towplane and he got higher!

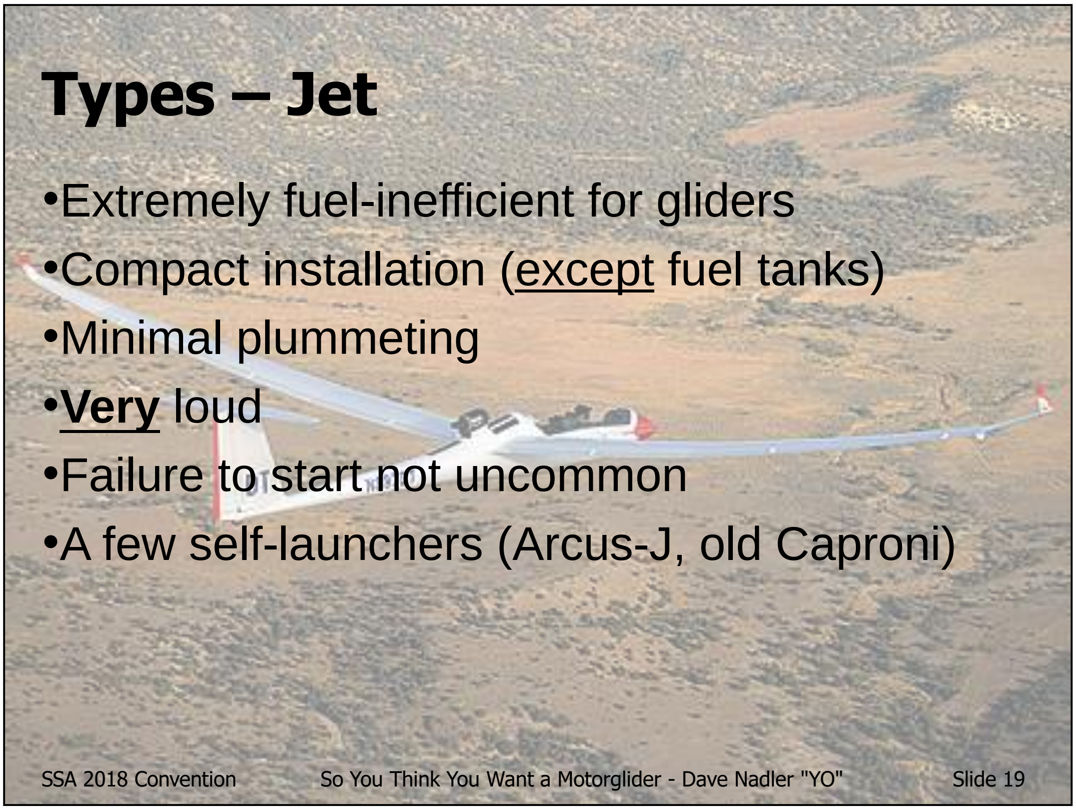
2017 13.5m WGC

Borrowed Electro from Factory – Thanks!

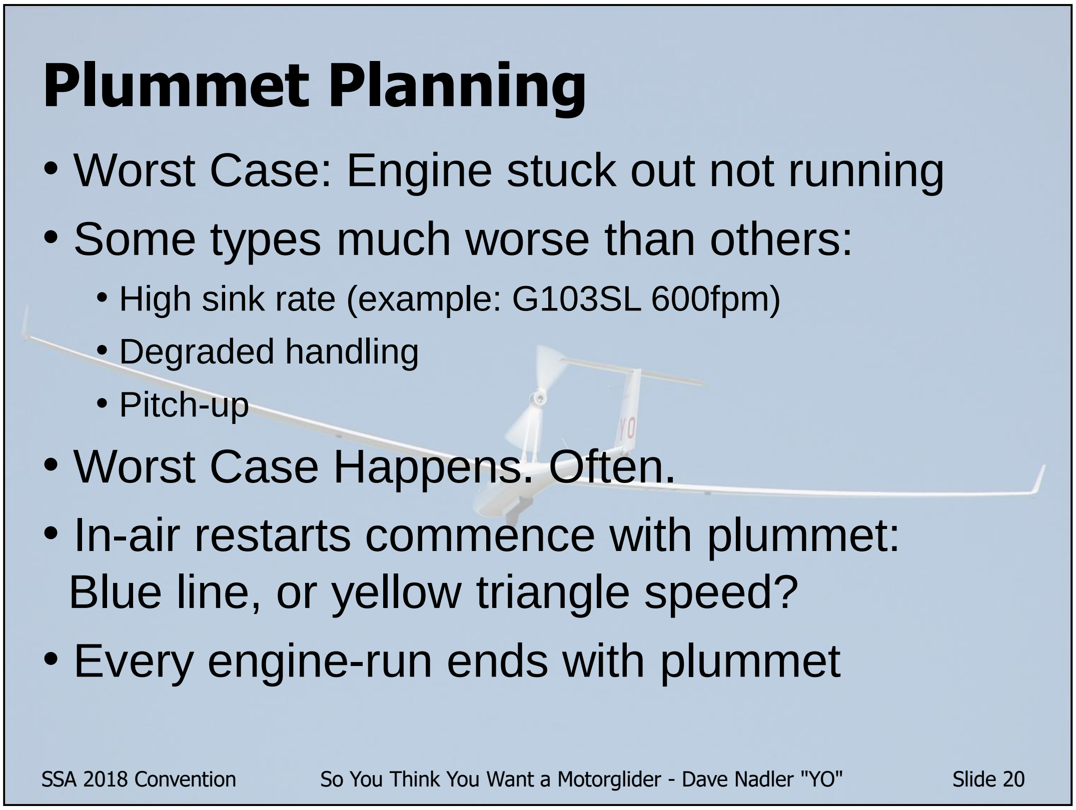
Similar experience to 2015

Picture of landout at **Hódmezővásárhely**, about 25km east of Szatymaz. Aerotowed home.

Won day by 100 meters!



In-air starts seem to be sensitive to side-slip, rain, and???



Example sink rate from Steven Dee:

G103SL 600fpm

Some are much, much worse
Jets not so much, FES no plummetting

For in-air start:

- Handbook value of engine-out min sink may at min sink speed (typically blue line), but…
- The yellow triangle speed is much faster!
- Next add your wind-speed margin!

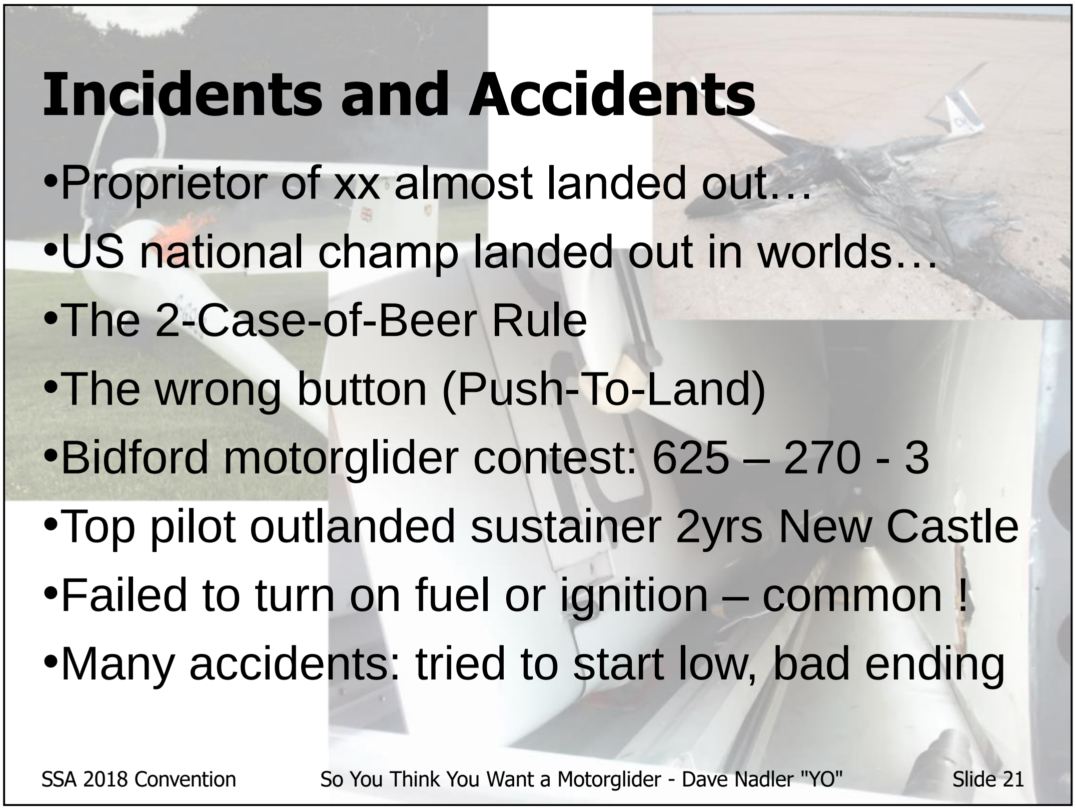
What speed are you going to try an in-air restart in the pattern?

Now what is your sink rate?
ArcusM Example:

- book is 455fpm sink at yellow triangle 57kt
- plan on 500fpm with a little wind
- Max engine extension is 65kt

Plummet during shutdown may take a long time:

- cool-down required prior stowage (hopefully at power-setting for level flight)
- difficulties with prop centering (time, workload)



Images:

- FES battery fire
- Duo Discus T crashed in January after turbo didn't start
- Nimbus 4DM burned after fire on take-off

Reason for talking about incidents – they are common and often with experienced pilots

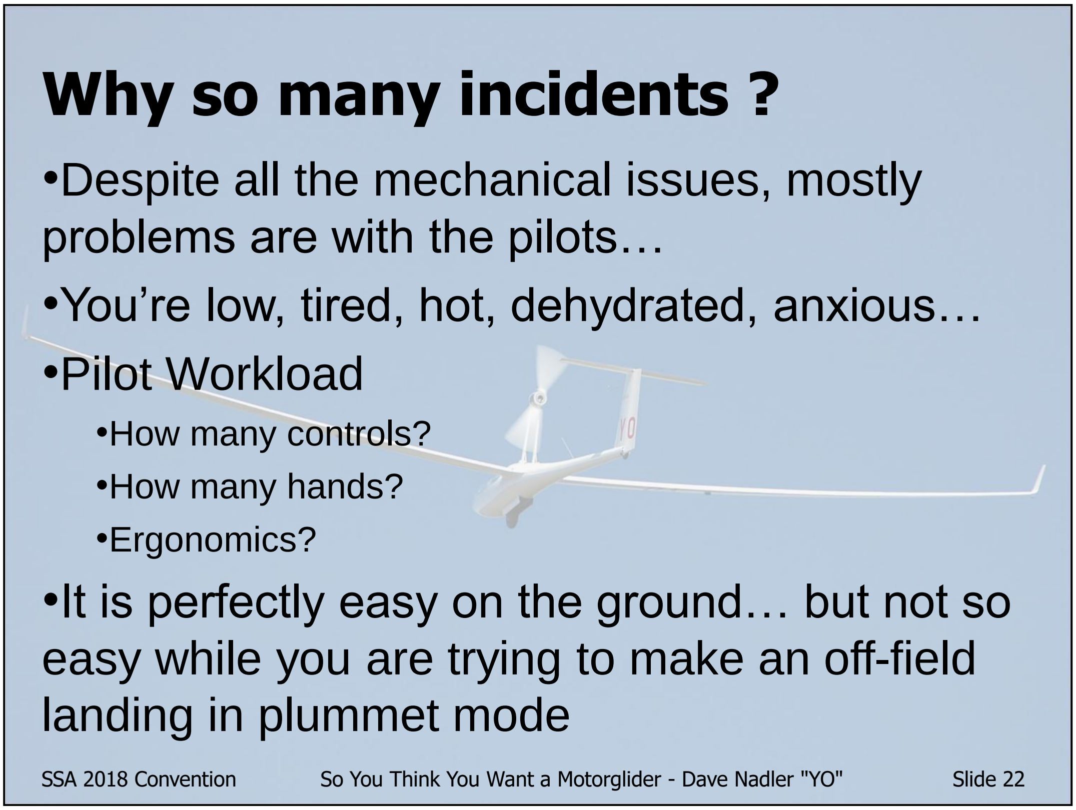
Understanding how these happen can help us avoid repeats…

How come proprietor of major sailplane company almost landed out,
and one of our top pilots did during world championship ?

Bidford stats over 6 years: 625 total launches, 270 technical landouts (in-air restarts), 3 field landings.
ALL field landings resulted in damage – why ?

OK – why does this keep happening ? How can top pilots forget to turn on the ignition ?

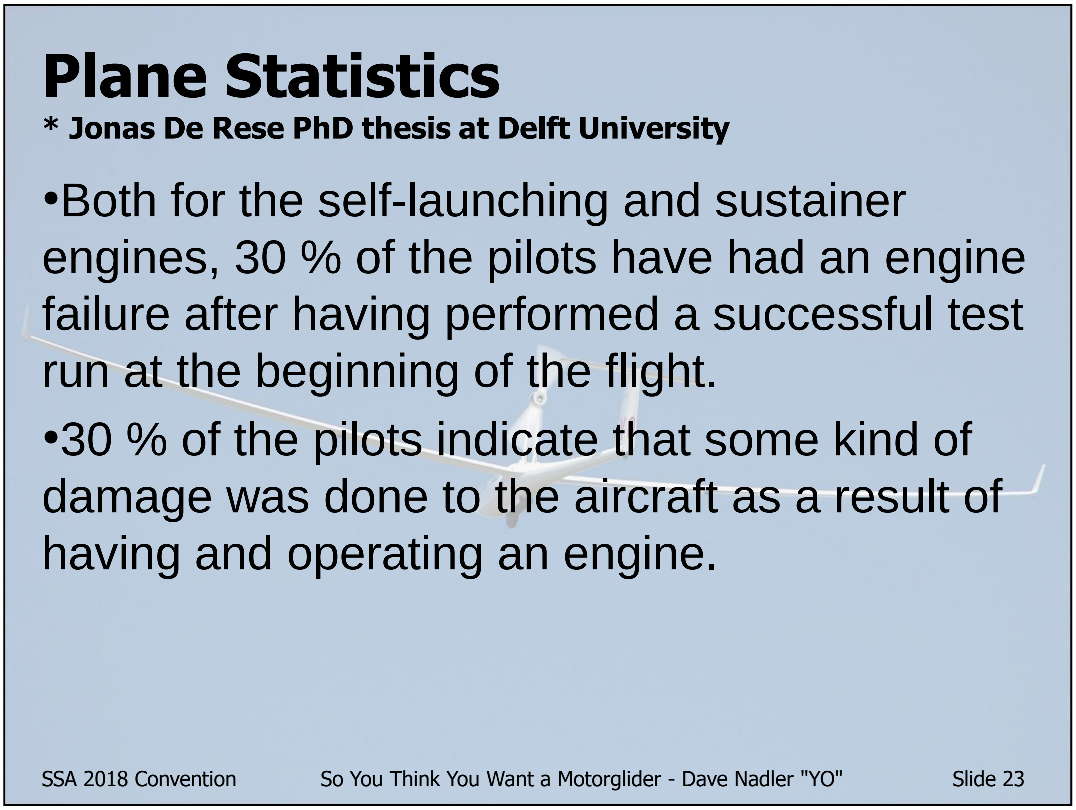
Seems unlikely – but it sure is not !



You will be trying to do an air-start under difficult circumstances.
You’ve been struggling trying to stay up, pick a field just in case…
Its been a long day, you’re hot, tired, dehydrated, etc.
You will not be performing at your best.

Many controls scattered around cockpit make it
extremely difficult to get it all right under stress.
Example I used to fly had separate controls for:
- Master switch (breaker) for engine system
- fuel shut-off
- prop brake
- engine pylon up-down
- ignition
- static source for ASI and vario
- primer (under left knee)
- throttle
- starter button (next to and easily confused with radio PTT)
These nine controls needed to be operated precisely,
then fiddled when the engine didn’t start.

Newer models have better automation.
Antares 20E has one power-lever and is completely automated.



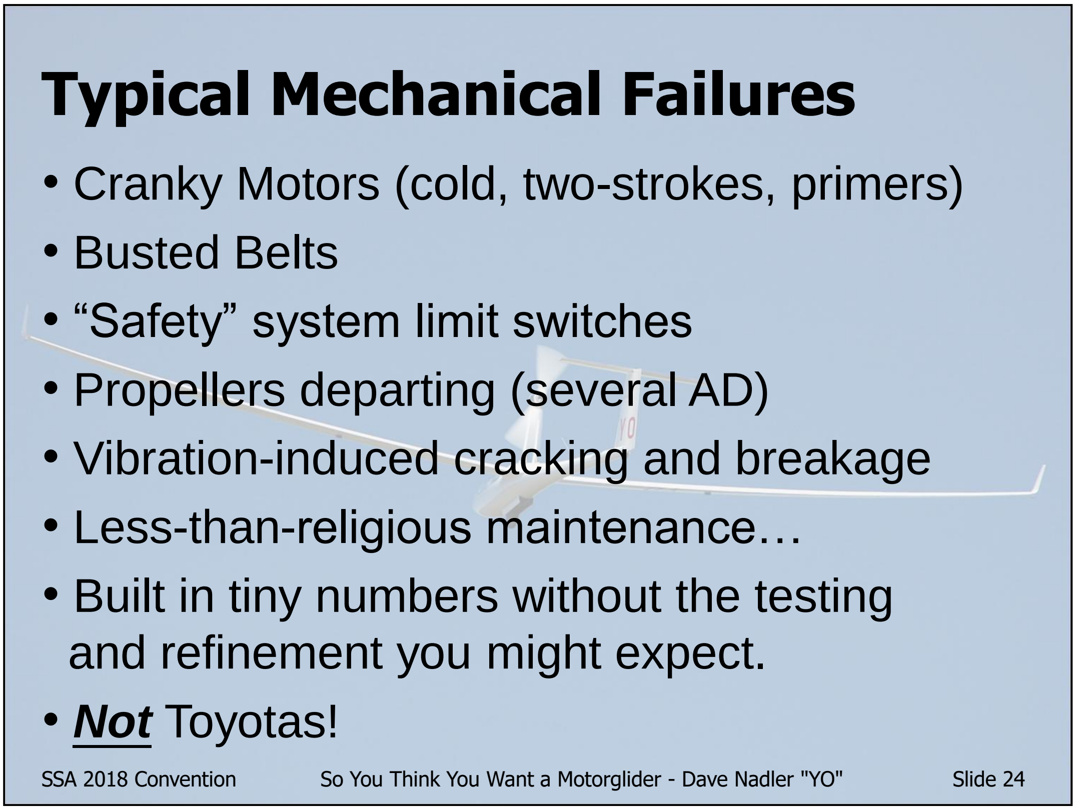
Jonas De Rese Phd thesis at Delft University

Read that first statistic again.

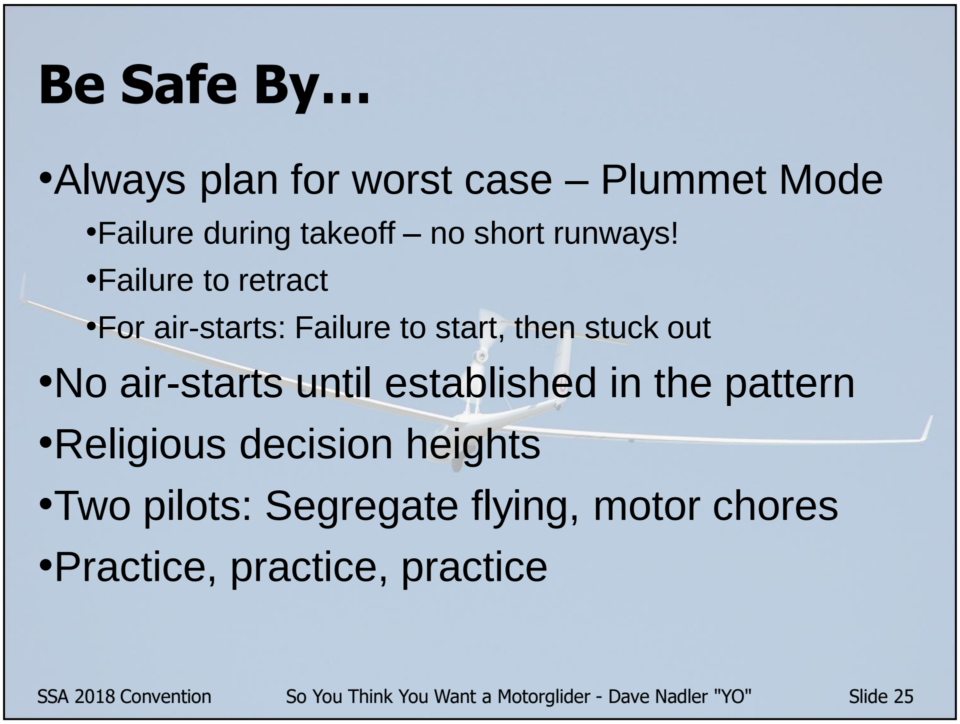
These are not hypothetical.

This **<u>will</u>** happen to you.

Plan for and practice engine failures.



It is economically impossible in this tiny market for a manufacturer to invest in the amount of testing and refinement required to achieve the level of reliability we take for granted in our cars and appliances. Consequently, these machines are not as reliable !



NEVER start the engine in the air until you've finished your landing checklist and are in the pattern.
Your PRIMARY job is a safe landing; **Landing is Plan A!**
IF the engine starts, great, but landing is more important.

You need lots of altitude and time to try and start The motor, and fiddle a while when it doesn't.
LOTS OF ALTITUDE.

My personal rule with the prior (gas-powered) motorglider I owned:
No in-air restart unless >1500 feet AGL on downwind, with landing checks complete (gear/flaps etc).
This means deciding to stop soaring ~2000 ft AGL in order to get to downwind, do landing checks, etc.
A lot higher than a pure sailplane ! Restricts your working altitude band…

ArcusM is much better, as are Schleicher motor-gliders (lower sink-rate gives lower decision height)

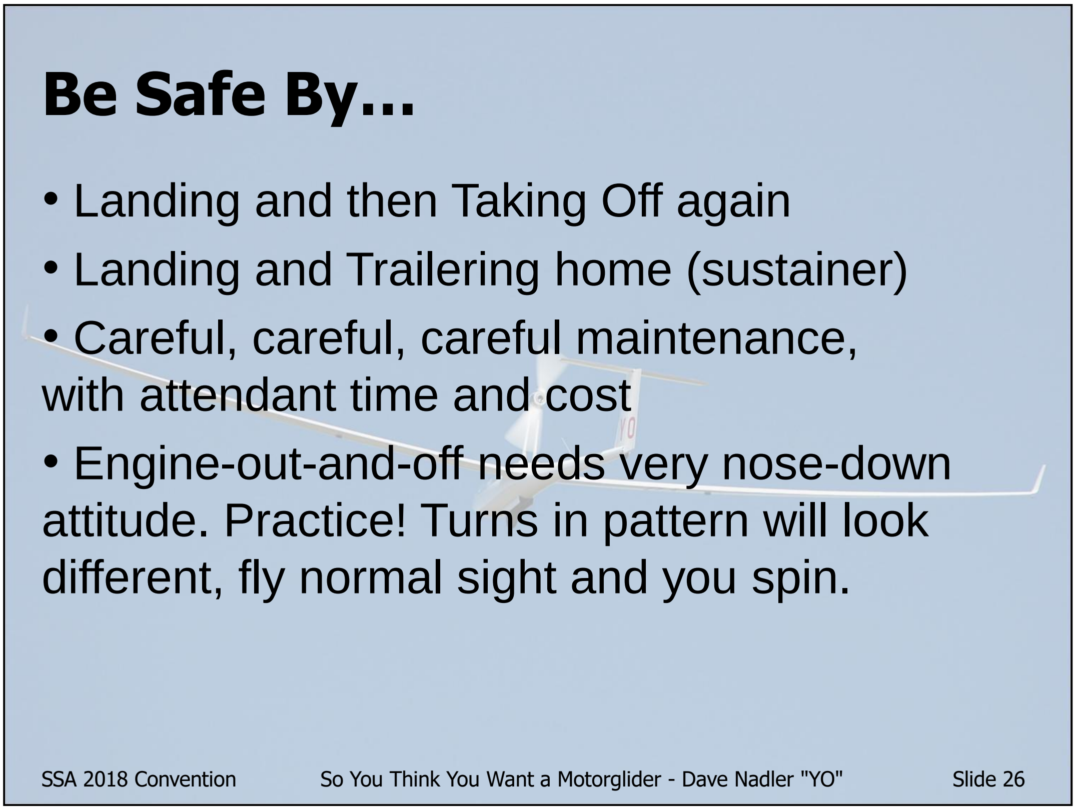
Think through the plan prior each launch
Say out load the decision points during the launch
(at start of launch: straight-ahead, later: turn-around OK, etc)

Decide in advance your limiting decision heights
For your aircraft, risk tolerance, and proficiency…

Practice start sequence sitting in cockpit with eyes closed (best on the ground ;-).
At altitude: Practice turns and simulated pattern in plummet mode.

Beware of fixation on engine start! Tunnel vision under stress is common!
Careful you keep track of position: don't keep flying downwind beyond reach of field whilst trying to start motor.
Most important is fly a good pattern first; **Landing is Plan A!**

You need to have enough bandwidth to fly outlanding pattern comfortably with enough bandwidth remaining to handle engine issues.
Running out of bandwidth is especially a trap for lower-time pilots, though fixation/tunnel-vision can happen to very experienced pilots.



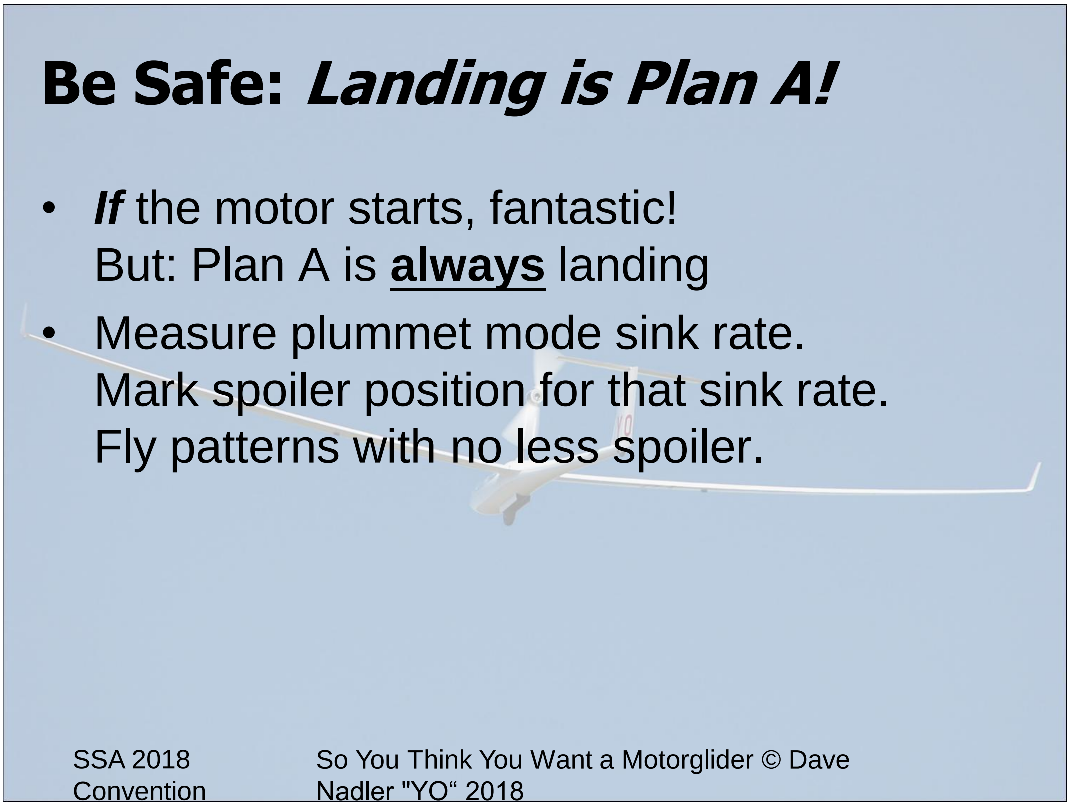
Get low near a big airport.

Fly as low as you would in a pure glider.

If you have to, land, then take off and fly home.

Avoids in-air restart and its required altitude.

A good example is earlier-mentioned competition pilot who landed out his sustainer two years in a row at New Castle: For competitions he flies like a pure glider with corresponding lower decision height for landing.


Be Safe: *Landing is Plan A!*
• ***If*** the motor starts, fantastic!
But: Plan A is **always** landing
• Measure plummet mode sink rate.
Mark spoiler position for that sink rate.
Fly patterns with no less spoiler.
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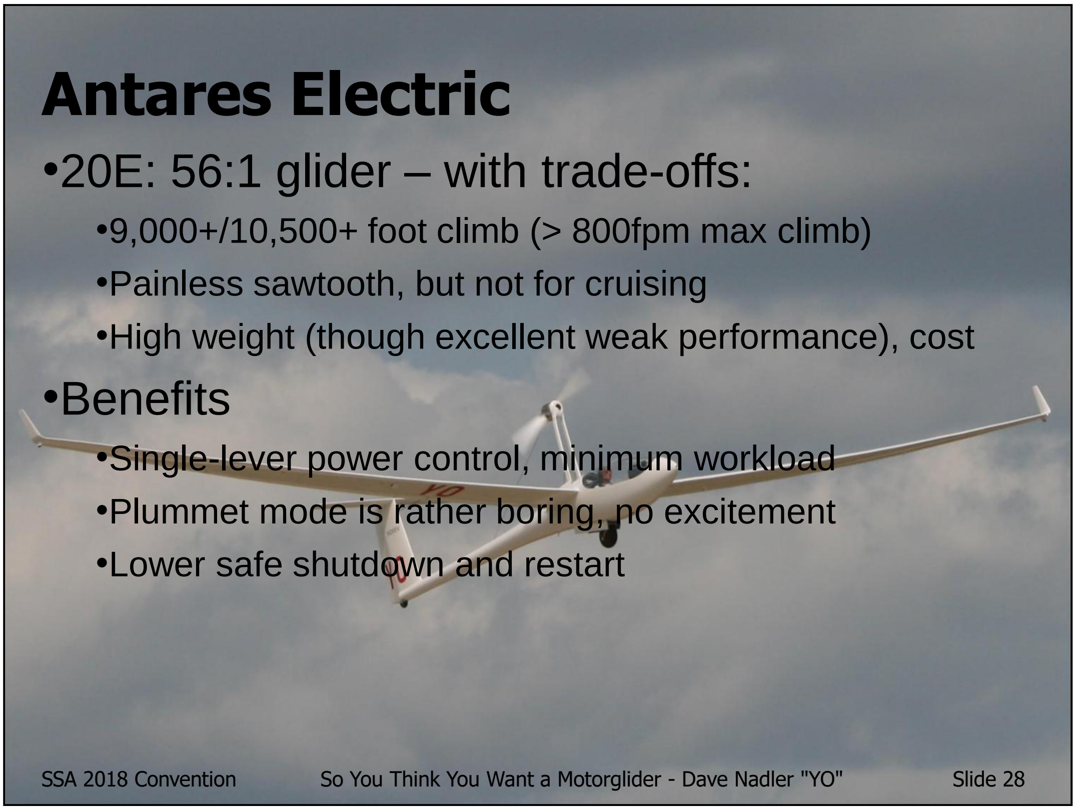


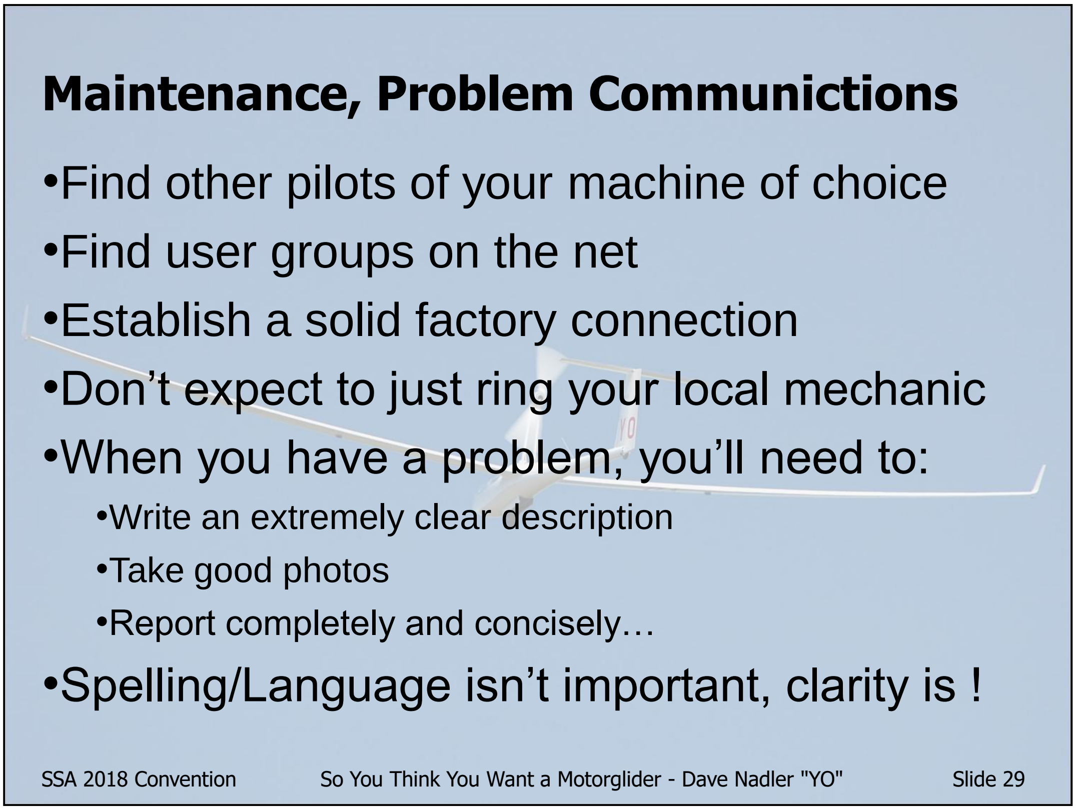
When you push the handle forward, it either works or not. You concentrate solely on flying the glider.

Lower drag with pylon out (no radiator), more like spoilers cracked than plummeting.

Lower decision height, more like a pure glider.

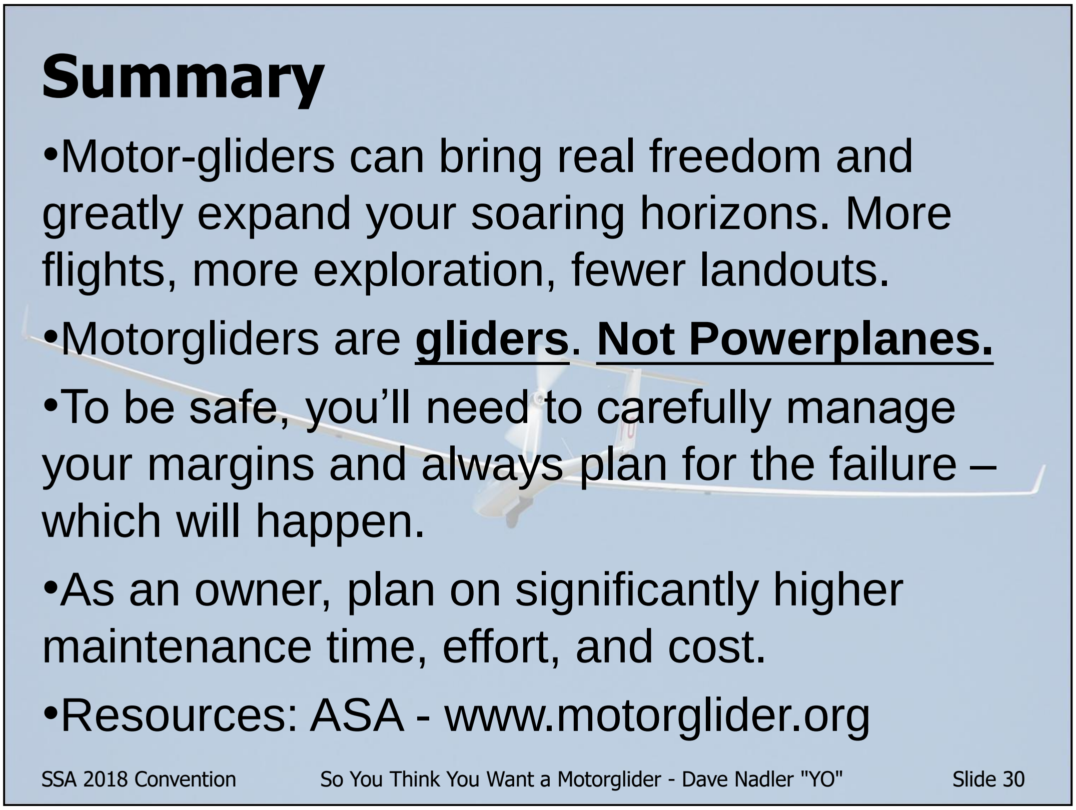
Still takes bigger margins than a pure glider – explain field length vs. height trade-off.

Cost of total package delivered around 10% - 15% more than gas-powered 18m self-launchers.



You will need to make a big time investment in finding out how to safely maintain your machine,
and to manage repair of the problems you will encounter.

Make sure you know where the closest factory-trained mechanic is located.
You may need to trailer your plane a couple of days to have it worked on.



Re-emphasize the positives !

Dave's motor-gliders have brought real freedom:

- Antares over 10 seasons:
  - 58,000 miles XC in 1260 hours
  - only two land-outs (once took off and flew home after thunderstorms cleared)
  - Average flight 300km 4 hours
  - Typical shutdown altitude 1k
  - Typically use motor to avoid land-out a couple times per year.
  - No inflight failures, ~dozen ground failures; one per 25 flights
- ArcusM over two seasons:
  - 5-10x more mechanical failures per hour (vibration induced, starter, ignition)
  - Similar stats for times/distances flown
- No crew !

I wouldn't trade it – its worth it !

But, motorgliders have big demands as compared to a pure sailplane

A great resource for finding where to get training, learning about motorgliders, and contacting motorglider pilots is the **Auxiliary-powered Sailplane Association** (ASA).
See: **www.motorglider.org**