Updating The Numbers: Pilot Technique 20 Years Later

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Introduction

It is about 20 years since the original "Pilot Technique" article was published. First in 1977 in the Speed and Racing Gazette which, although it had limited distribution, it reached a high percentage of F2C competitors in the West, then in Model Aviation (or whatever it was called then), in Model Flygvnet, and finally in The Aeromodeller Annual.

Some things like centrifugal force have not changed at all during this time but the numbers certainly have. The speeds are up by 20%. A smallish sounding number but in terms of the power required it is more than a 70% increase.

Because of the increased speeds there are quantitative changes in the numbers quoted in the original article. Some things like the normal load factor (this is what aeronautical engineers call the 'g' loading) while flying high have increased some but the weights have gone down so that the result is that this factor is probably less important than it was, but not by much.

The change in lap time due to flying position has changed, in percentage terms it is noticeably higher, and so has the speed advantage required to pass. This note just revises or presents new graphs to update those in the original article.

Handle Position and Lap Time

The model for the Y2K analysis is taken from Göran Olsson's spreadsheet.

Parameter	Value - SI units	Value - USCS units
Airspeed flown from a pylon	57 m/s	127.5 mi/hr
Weight‡	0.350 kg	12.346 oz
Line Length	15.92 m	52.23 ft
Line Thickness	0.300 mm	11.81 mils
Aircraft Drag Area	12.2 cm^2	1.89 in^2

‡Here I note that the name "weight", while idiomatic, is not correct. The kilogram is a unit of mass corresponding to the 'English' slug or pound mass. The weight should be a force so it is Newtons in SI and pounds (avoir.) in the 'English' or USCS (United States Customary System).

The drag area is the $C_d S$ product; The aircraft drag divided by the dynamic pressure.

There are two 'Lap Time *vs.* Handle Position' graphs: the first uses the baseline aircraft and shows the change in lap time when the handle is 0.2, $\cdots$ 0.5 meters in 0.1 meter increments from the center of rotation. The second uses the baseline aircraft but with varying weights of 300, 350, and 400 grams. The graphs assumes flying with the handle at 0.4 meters from the center. These graphs show why a heavy aircraft can be better if 'whipping' is allowed.

As a note, whipping was allowed in the first FAI team races. The 1959 Criterium of Europe (now the Eurochamps) had Nery Bernard's famous 'Startiger' piloted by Belgian stunt ace Henry Stouffs winning, the last several laps flown with a dead engine as it was felt this was faster than pitting.

The third graph is similar to the one in the original article except the changes are in lap time. There are lines for a change of +.2, +.1, 0, -.1, -.2 seconds change in lap time for the baseline aircraft as flown from a pylon. On the graph the baseline aircraft has $x = 0.3$ meters and $y = 0.2$ meters, which represents a 'standard' flying position.

Flying Height and Load Factor

The number of 'g's' an aircraft is 'pulling' is called the normal load factor. It has a value of 1 in level flight otherwise is is the acceleration in earth gravity units that is normal to the wing. When a control-line aircraft flies at a constant altitude above the earth that is higher than the altitude of the handle the normal load factor is more than 1. The next graph shows the normal load factor as a function of flying height for the baseline aircraft aircraft and a handle radius of 0.4 meters.

This graph assumes the aircraft is flying at the same speed for all altitudes. In fact a specific aircraft will most likely slow down due to the extra lift it has to produce.

Because speeds have increased so much the loads have grown to about 6.7 g's at the maximum legal height. Aircraft are lighter now, but the combination of weight and load factor mean that the aircraft have to about as much when flying at the maximum legal altitude today as in the past.

If the aircraft airspeed did not go down the lap time at the minimum legal altitude and the maximum legal passing altitude would go from 18.0 seconds for 10 laps to 17.3 seconds for 10. So it is possible that an aircraft set up in the best way could fly faster at passing altitude. A modern F2C aircraft would have to slow down by 3% to have no gain. Because this would mean something like a 9% increase in the power required it seems likely that some small improvement in lap time will result. This is speculation, of course, but it is a fact that can be determined by test flying. On the other hand the 3 meter maxim altitude in normal flight provides essentially no advantage over flying at the height of the handle.

Passing at heights well above the legal maximum, however, entail even higher loads and eventually will drive the aircraft into conditions well beyond the normal level flight set up. The consequences for passing when everyone else is flying high makes it extremely difficult.

The comments in the original paper still apply, but it seems likely that keeping aircraft low – that is within the altitude limits set by the rules – is really important if faster aircraft are ever to have a chance to pass.

Lap Time Change Required Foar Passing

This is the same table as appeared in the original article except the changes are change in lap time required. These changes are to pass in 2 or 3 laps of the opponent's aircraft and for a 'pass' meaning gainig 1/8 and 1/4 of a lap on the opponent.

	Pass in 2 Laps	Pass in 3 laps
gain 1/8 lap	.106 s	.072 s
gain 1/4 lap	.200 s	.138 s

A Postscript: The Flying Wing At High Lift

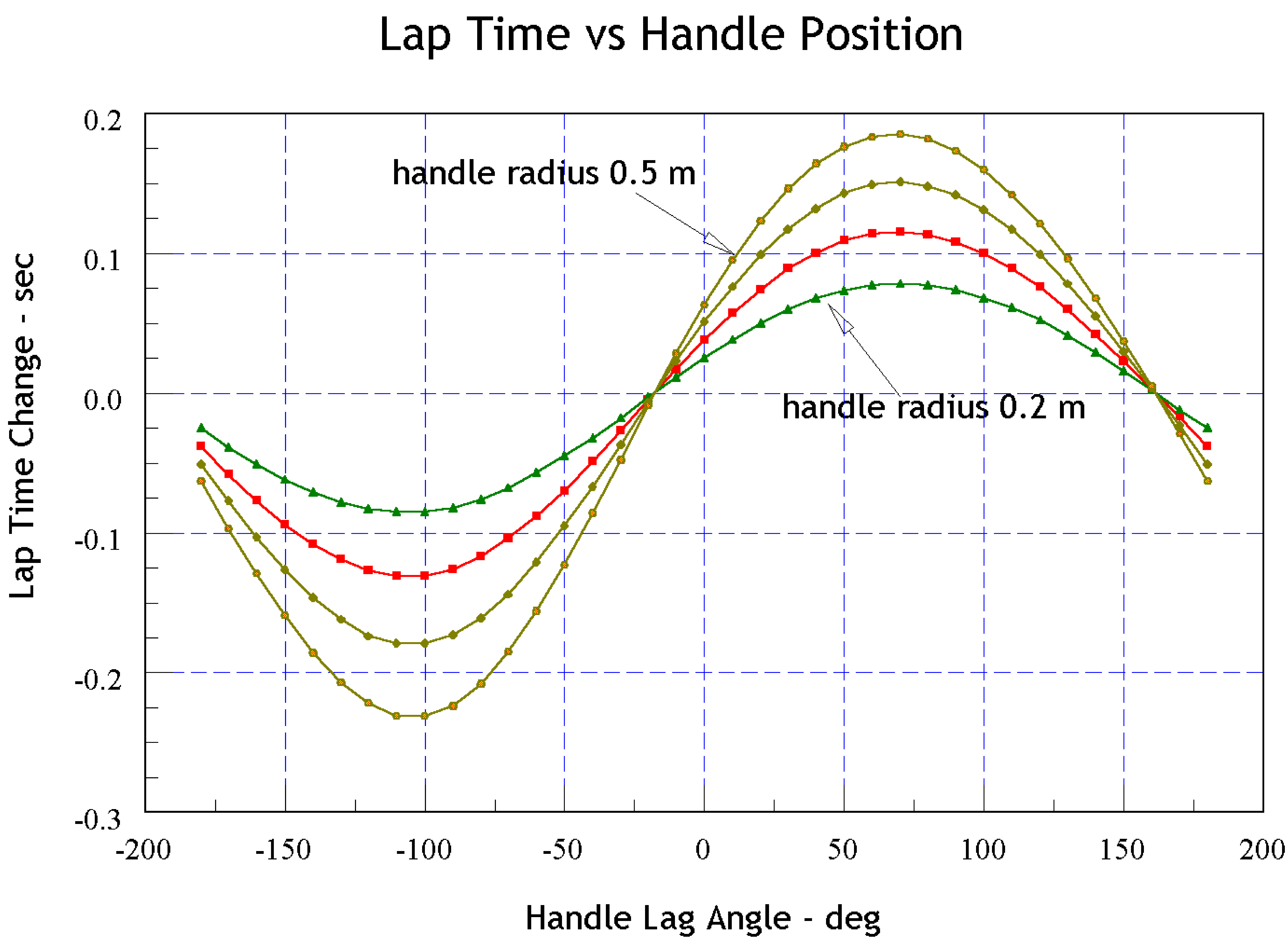
This is not about flying technique, but about the configuration of choice in F2C for more than a decade. The aerodynamics of this configuration at high lift are different from the conventional 'wing and tail' configurations of most aircraft, large and small.

A wing alone in a wind tunnel is tested at various angles of attack. Maximum lift, for example, is measured. An airplane with this wing will have a lower maximum lift. This is because the tail has to produce a down force to hold the aircraft at a high angle of attack. The result is called the 'trimmed maximum lift'.

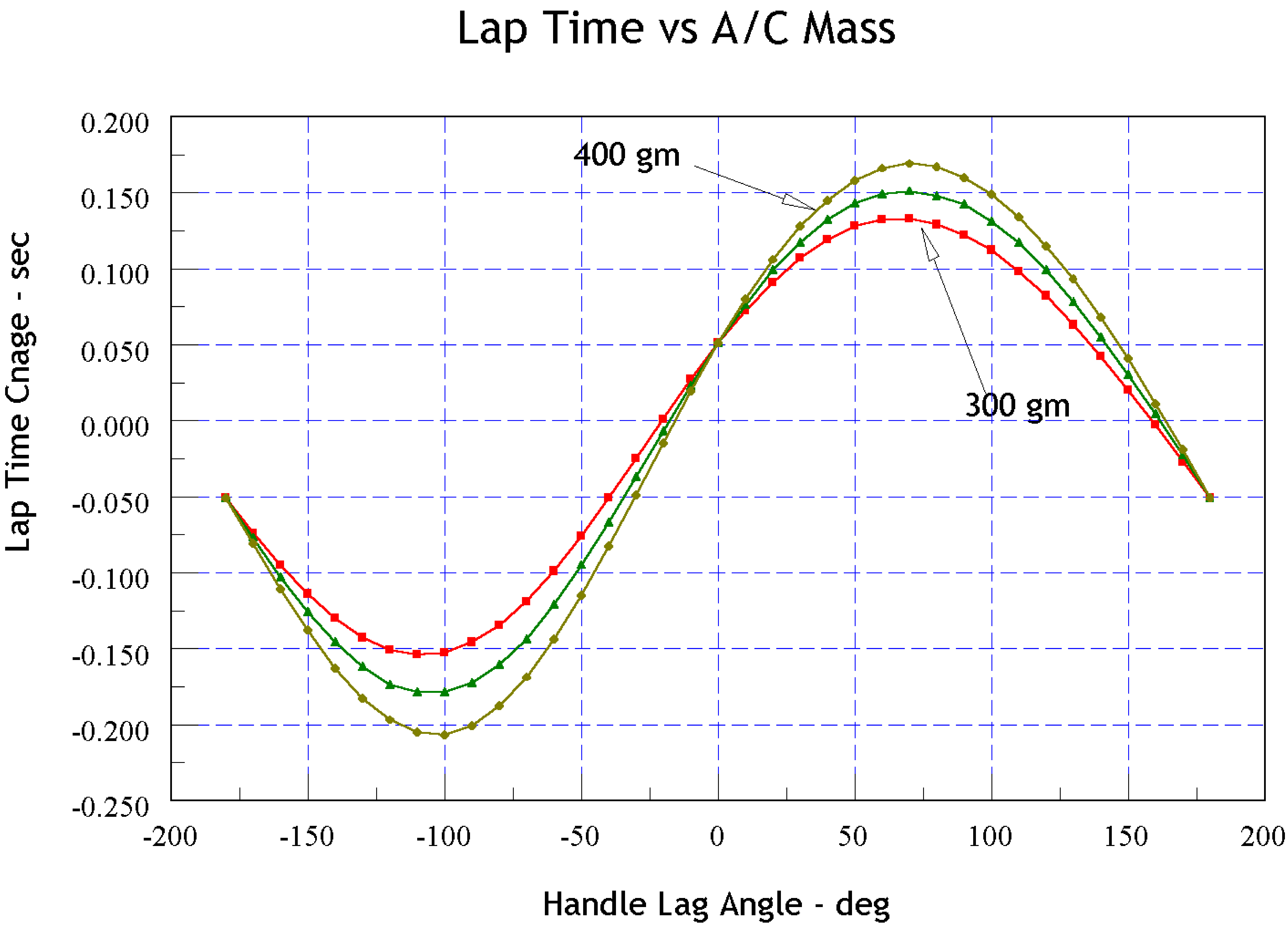
This is true for a flying wing or delta wing as well. In order to hold the nose up at the high angle of attack the flap at the trailing edge has to be deflected up. Here the moment arm for the trim flap is less so more down force has to be generated to hold the wing at the angle of attack required for high lift. In addition this flap increases the pressure on the upper surface of the wing and decreases its lift. In most airplanes the wing has a flap deflected int the opposite direction to help increase the lift, here just the opposite is required.

This combined effect has resulted in poor trimmed maximum lift for delta wings. The price was paid because for supersonic speeds and the low thickness/chord ratios required the structural weight was less. The minute automatic controls became good enough all the delta wing aircraft and a few others began to sprout leading plane surfaces that provided nose up moment as well as lift and let the flap at the trailing edge of the wing stay neutral or deflected down. On the French Mystére fighters these leading plane are called 'moustaches'

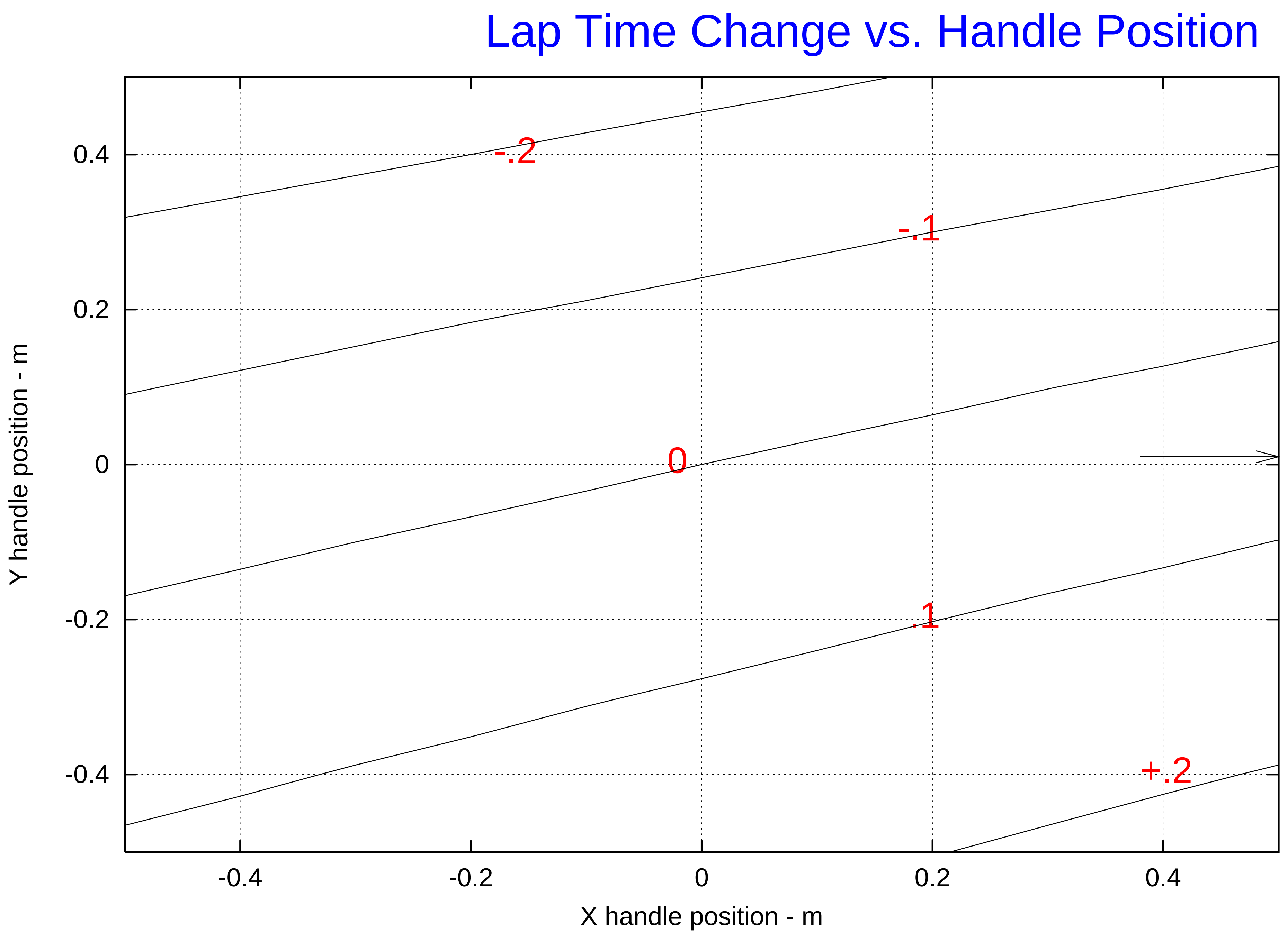
For F2C the rotation of the propeller and counter–clockwise flight produced a nose–up gyroscopic torque that helps significantly in balance in level flight. Flying high the tail flap deflection to produce the additional nose-up moment eating away at the lift will also cause flow separation at the underside of the tail. This is common in all low Reynolds number applications. As a consequence flight testing, in my opinion, should be used to measure the net effect of all these things on lap time. If a slow–down is noticed at legal passing altitudes some changes in set up and/or aerodynamics at the trailing edge are in order, In addition some built in reflex in the trailing edge should be beneficial, certainly better than no reflex and having to fly at normal altitudes with the tail flap deflected.



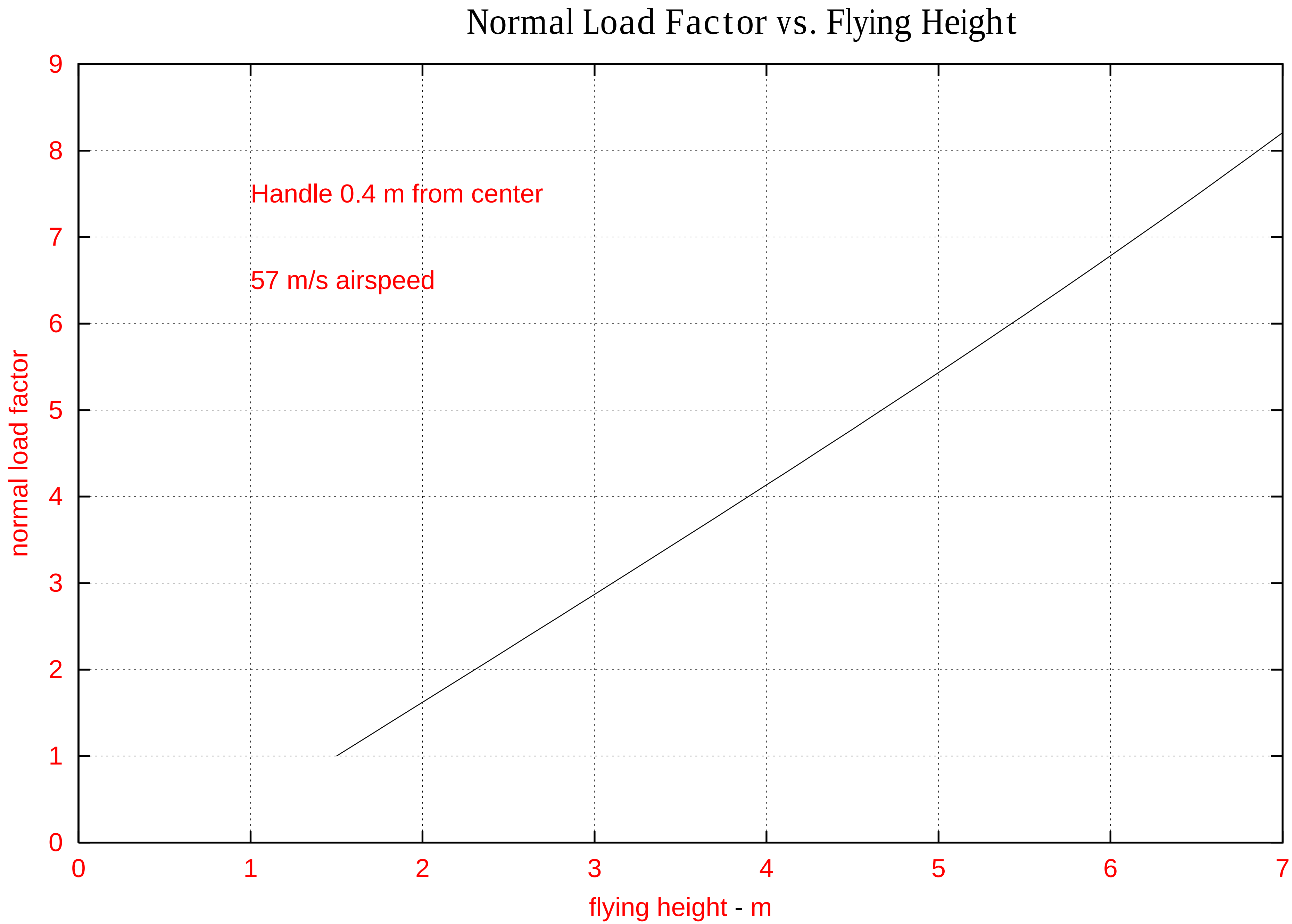
Lap Time vs Handle Position
handle radius 0.5 m
handle radius 0.2 m
Lap Time Change - sec
Handle Lag Angle - deg
0.2
0.1
0.0
-0.1
-0.2
-0.3
-200
-150
-100
-50
0
50
100
150
200



Lap Time vs A/C Mass
400 gm
300 gm
Lap Time Cnage - sec
0.200
0.150
0.100
0.050
0.000
-0.050
-0.100
-0.150
-0.200
-0.250
-200
-150
-100
-50
0
50
100
150
200
Handle Lag Angle - deg



Lap Time Change vs. Handle Position
-.2
-.1
0
.1
+.2
0.4
0.2
0
-0.2
-0.4
-0.4
-0.2
0
0.2
0.4
X handle position - m
Y handle position - m



Normal Load Factor vs. Flying Height
Handle 0.4 m from center
57 m/s airspeed
normal load factor
flying height - m
0
1
2
3
4
5
6
7
8
9
0
1
2
3
4
5
6
7