

# DIY laskuvarjo



Tuukka Mäkelä

Aloittanut: 2009

Hyppyjä: 900+

Kotikerho: TamLk

Ompelukoneen ajokortti ala-asteelta

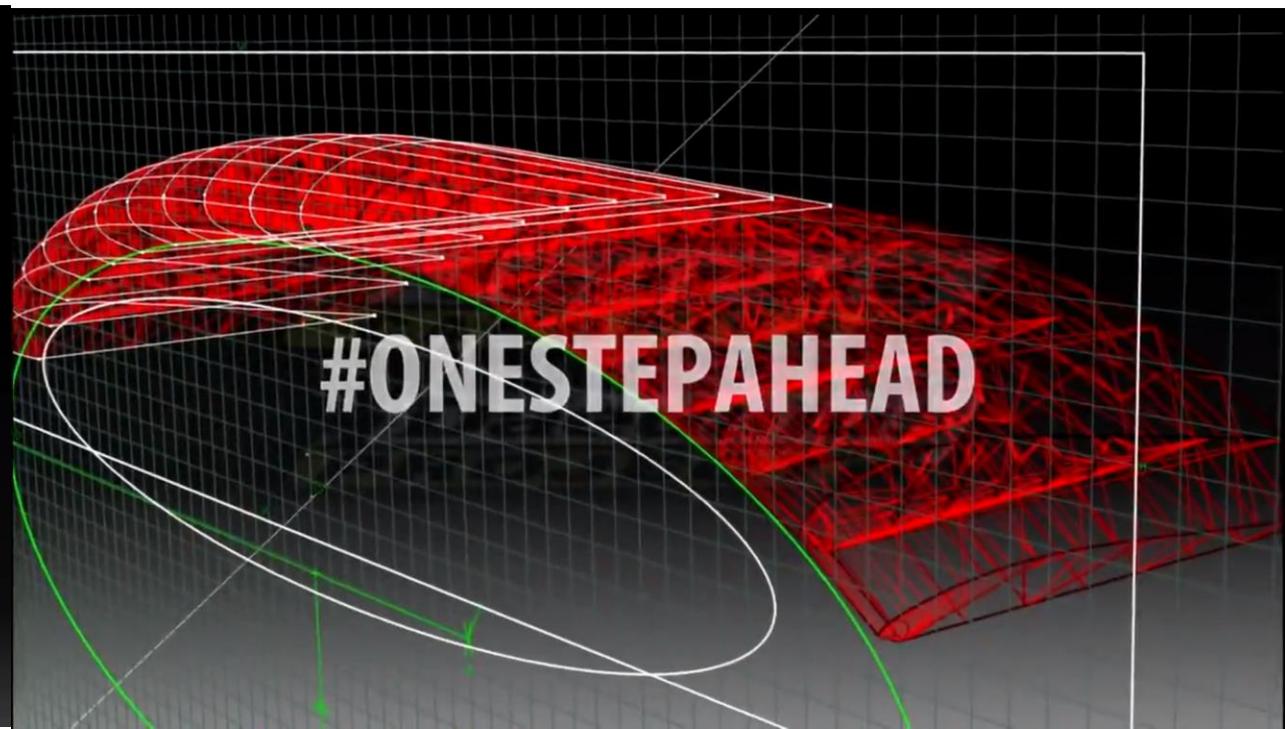
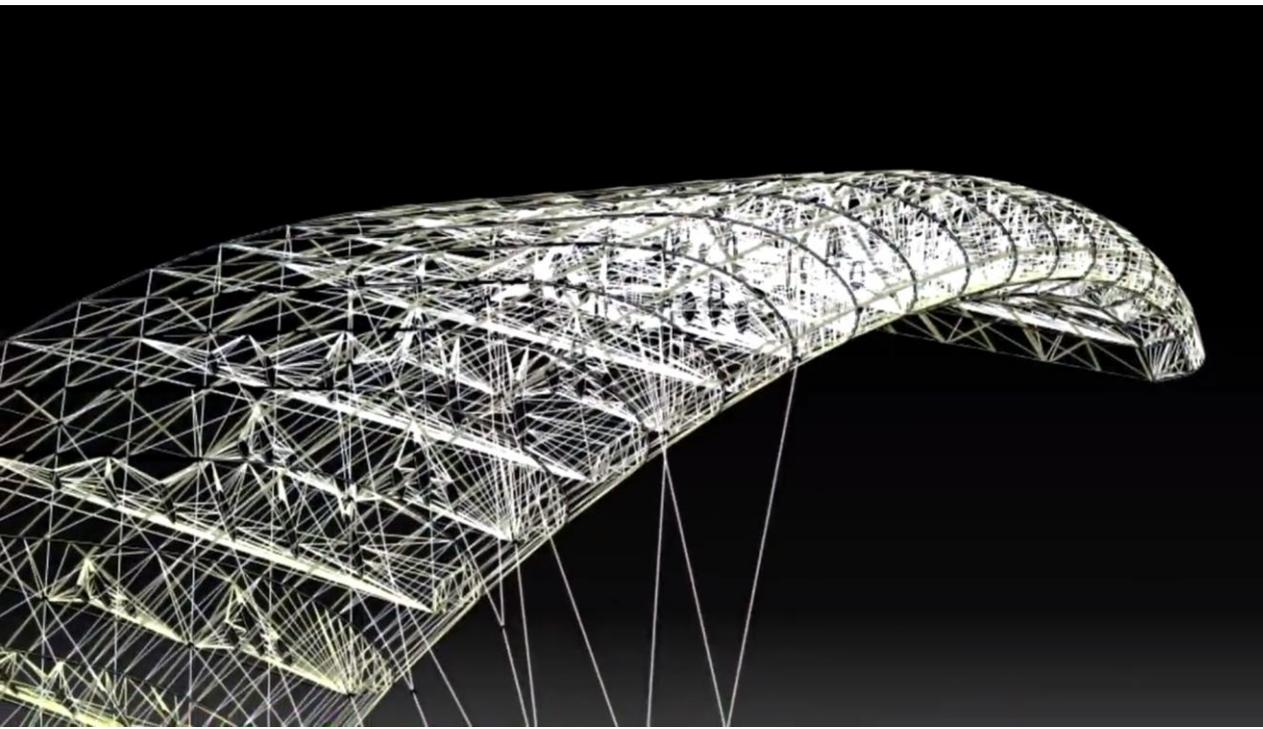
Pari suittia tehtynä



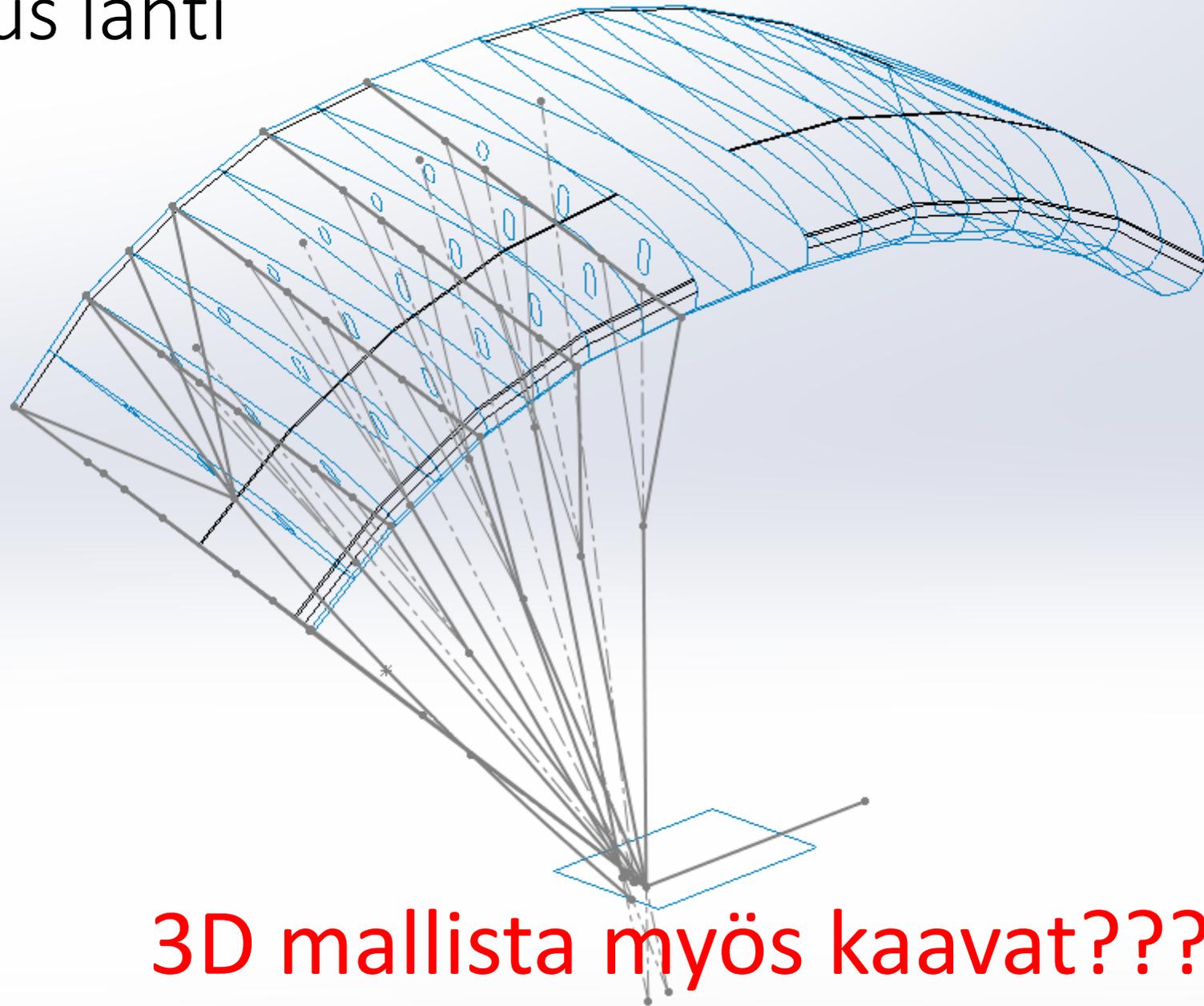
- Mistä ajatus lähti?
- Tiedonkeruu suunnittelun pohjaksi
- Liitovarjon mitoitusta
- Suunnitteluvaihe ja 10,4sqft protovarjo
- Oikean varjon valmistus
- Testihyppyjä ja tuloksia
- Riskienhallintaa
- Mitä määräykset tästä sanoo?

# Mistä ajatus lähti

- dropzone.com "my little project"
- NZ Aerosportsin mainosvideo
- Liikaa vapaa aikaa → oman kuvun 3d mallinnukseen

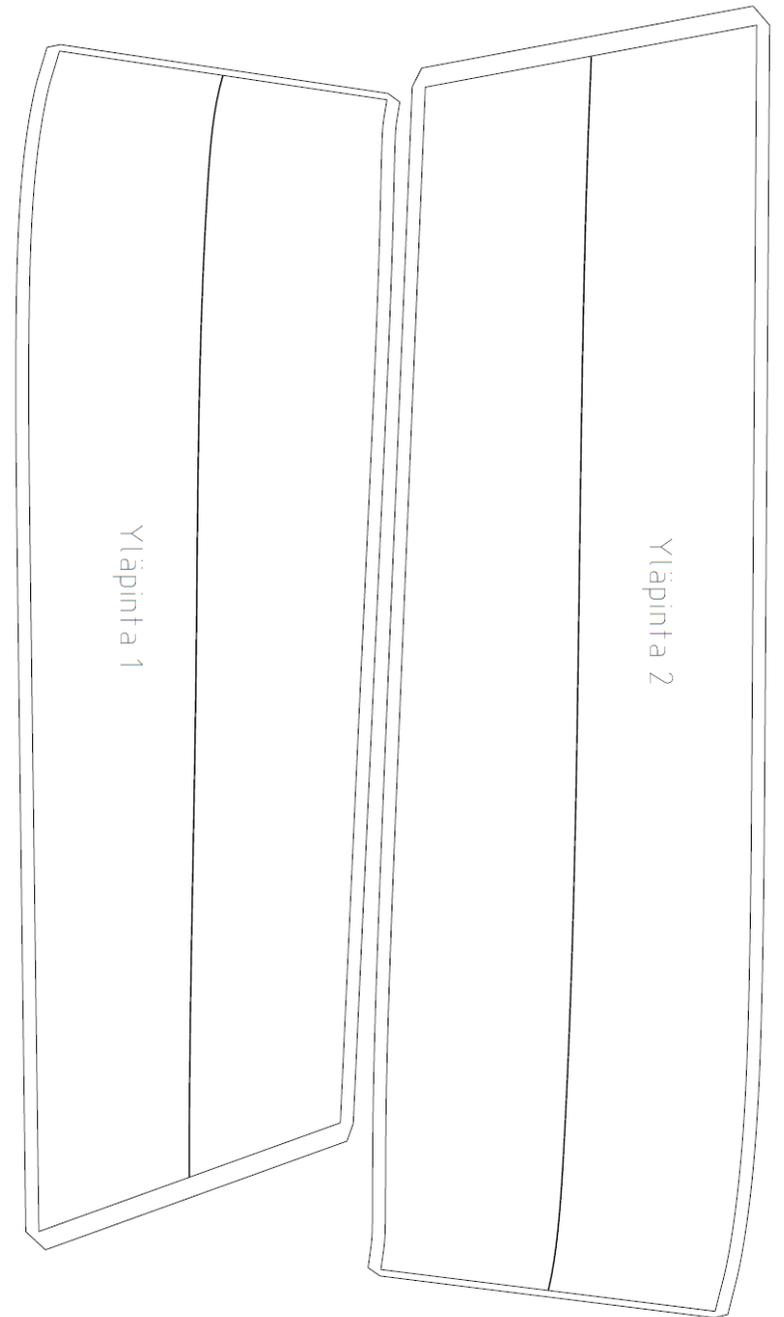
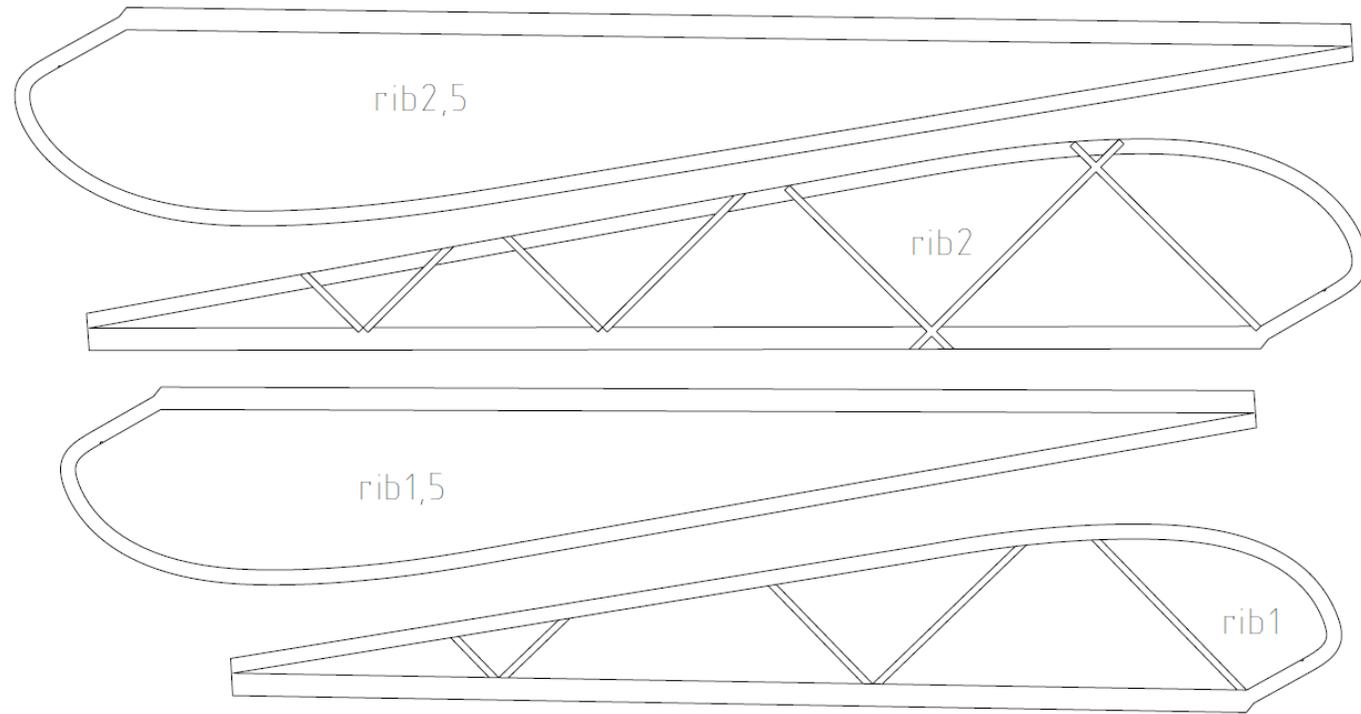


Mistä ajatus lähti



3D mallista myös kaavat???

# Mistä ajatus lähti



# Millainen varjo kannattaisi suunnitella?

- Tavoitteena ”seuraava itselle soveltuva varjo”
  - Sabre 2 150 → 120 → Stiletto 107 → ????
  - 9-putkinen
  - Elliptinen/semielliptinen
  - Vähän vauhdikkaampi kun Sabre
- Ei ääripäiden varjo
  - Riittävän haasteellinen elliptisyyden vuoksi
  - Hieman isompi kuin nykyinen Stiletto

# Tiedonkeruu suunnittelun pohjaksi

- Internet
- Valokuvat lentävistä kuvuista
- Siipiprofiilien tutkimusdataa
- Yksi silputtu tandemkupu
- Trimmikarttojen tutkimista
- Kommenttien kyselyä Brian Germainilta



© Twisted Hobbies

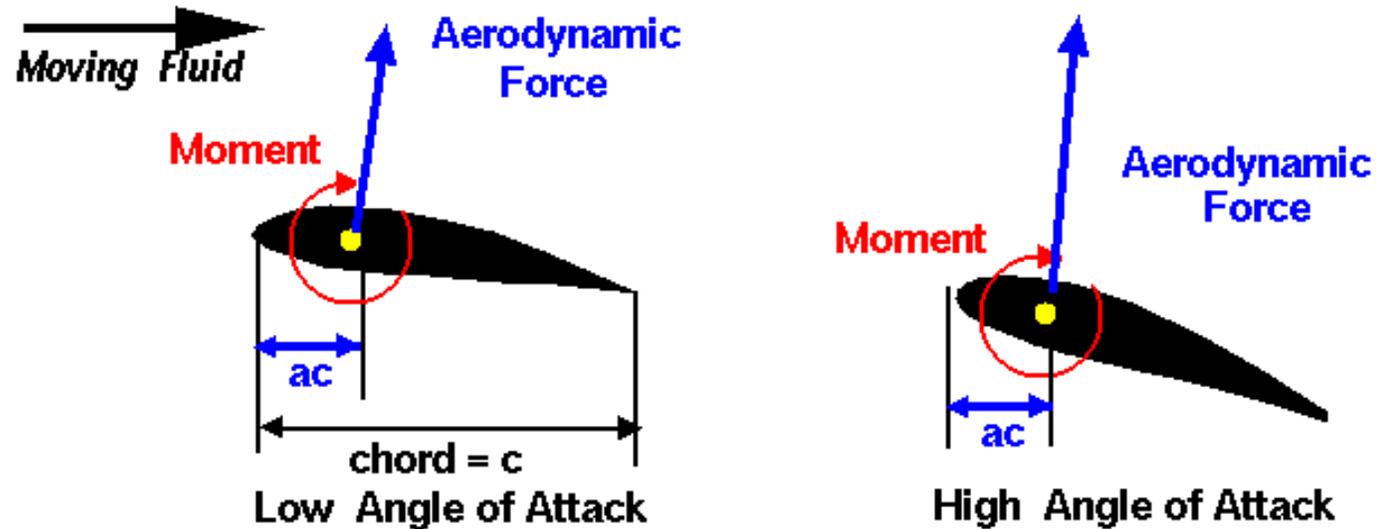


# Tiedonkeruu suunnittelun pohjaksi



## Aerodynamic Center – ac

Glenn  
Research  
Center



### Aerodynamic Center

For low speed, thin airfoils (flat plate):

$$ac = \frac{c}{4}$$

Moment about the aerodynamic center is constant with angle.

**Aerodynamic center does not move with angle.**

# Tiedonkeruu suunnittelun pohjaksi

13th AIAA Aerodynamic Decelerator Systems Technology Conference

Clearwater Beach, May 1995

## PRECISION AERIAL DELIVERY SEMINAR

### RAM-AIR PARACHUTE DESIGN

J. Stephen Lingard

Martin-Baker Aircraft Co. Ltd.

Higher Denham

Middlesex

England

#### 1 INTRODUCTION

Accurate delivery of a payload by parachute is a requirement in both the space and military fields.

The cost savings available from the recovery and re-use of expensive space vehicle elements provides an incentive to develop systems capable of allowing recovery to land sites<sup>1</sup>. Clearly, recovery to land engenders safety risks to population and property. Re-entry trajectories can only place recovered hardware at the position for initiation of the recovery system within certain tolerances. The recovery system must therefore have sufficient gliding capability and wind penetration to reach the designated landing site. It should also be able to achieve low vertical and horizontal velocity at landing to minimise the potential for damage to the payload. The only option for land recovery is a high reliability guided gliding parachute recovery system.

For accurate delivery of military payloads by conventional parachute system the aircraft must fly low and close to the target area. This exposes the aircraft to the risk of air defense weapons and small arms and may compromise the location of ground troops. If the aircraft flies at a safe altitude the drop accuracy is compromised due to imprecision of the drop point and the vagaries of the wind. A parachute with glide and a control system can compensate for inaccuracies in drop point and wind. The greater the glide angle the greater the offset that can be achieved for a given drop altitude.

## An Experimental Study of the Laminar Flow Separation on a Low-Reynolds-Number Airfoil

An experimental study was conducted to characterize the transient behavior of laminar flow separation on a NASA low-speed GA (W)-1 airfoil at the chord Reynolds number of 70,000. In addition to measuring the surface pressure distribution around the airfoil, a high-resolution particle image velocimetry (PIV) system was used to make detailed flow field measurements to quantify the evolution of unsteady flow structures around the airfoil at various angles of attack (AOAs). The surface pressure and PIV measurements clearly revealed that the laminar boundary layer would separate from the airfoil surface, as the adverse pressure gradient over the airfoil upper surface became severe at  $AOA \geq 8.0$  deg. The separated laminar boundary layer was found to rapidly transit to turbulence by generating unsteady Kelvin-Helmholtz vortex structures. After turbulence transition, the separated boundary layer was found to reattach to the airfoil surface as a turbulent boundary layer when the adverse pressure gradient was adequate at  $AOA < 12.0$  deg, resulting in the formation of a laminar separation bubble on the airfoil. The turbulence transition process of the separated laminar boundary layer was found to be accompanied by a significant increase of Reynolds stress in the flow field. The reattached turbulent boundary layer was much more energetic, thus more capable of advancing against an adverse pressure gradient without flow separation, compared to the laminar boundary layer upstream of the laminar separation bubble. The laminar separation bubble formed on the airfoil upper surface was found to move upstream, approaching the airfoil leading edge as the AOA increased. While the total length of the laminar separation bubble was found to be almost unchanged (~20% of the airfoil chord length), the laminar portion of the separation bubble was found to be slightly stretched, and the turbulent portion became slightly shorter with the increasing AOA. After the formation of the separation bubble on the airfoil, the increase rate of the airfoil lift coefficient was found to considerably degrade, and the airfoil drag coefficient increased much faster with increasing AOA. The separation bubble was found to burst suddenly, causing airfoil stall, when the adverse pressure gradient became too significant at  $AOA > 12.0$  deg.

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#### 1 Introduction

Low-Reynolds-number airfoil aerodynamics is important for both military and civilian applications. These applications include propellers, sailplanes, ultralight man-carrying/man-powered aircraft, high-altitude vehicles, wind turbines, unmanned aerial vehicles (UAVs), and microAir vehicles (MAVs). Nondimensional chord Reynolds number ( $Re_c$ ) is defined as the cruise speed multiplied by the mean wing chord and divided by the kinematic viscosity of air. For the applications listed above, the combination of small length scale and low flight velocities results in flight regimes with low wing-chord Reynolds number (i.e., chord Reynolds numbers,  $Re_c$ , ranging from 10,000 to 500,000). The aerodynamic design methods and principles developed over the past 40 years have produced efficient airfoils for conventional, large-scale, high-speed aircraft whose chord Reynolds numbers are usually in the range of  $10^6$ – $10^9$ . It is well known that the aerodynamic performance of airfoils that are optimal for conventional, large-scale and high-speed aircraft (therefore, high chord Reynolds number) significantly degrades when used for low-Reynolds-number applications where the chord Reynolds numbers are several orders smaller. While conventional airfoil design principles usually either neglect viscous effects or restrict its influence

to a very thin region near the airfoil surface at high Reynolds numbers, the predominance of viscous effects in low-Reynolds-number applications would result in boundary layers rapidly growing and easily separating from the surfaces of airfoils.

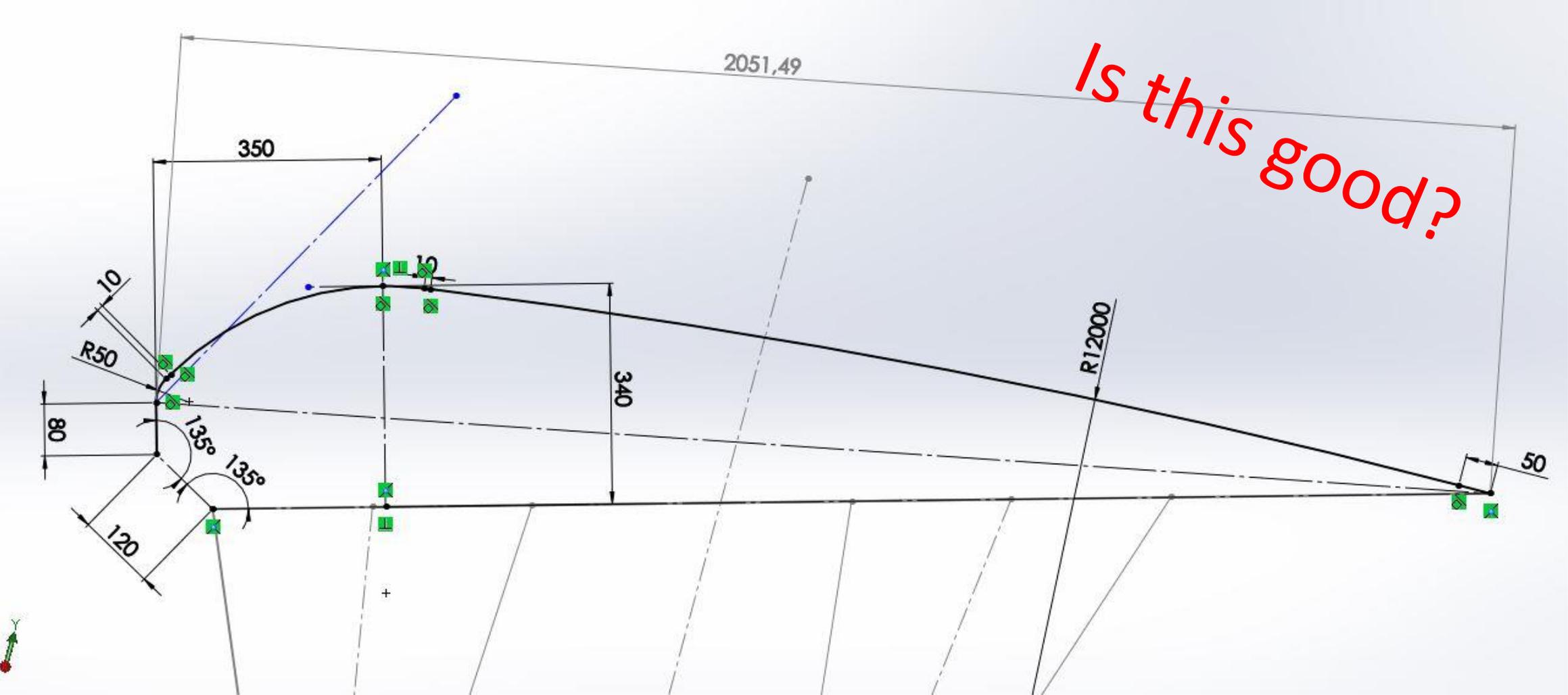
It is well known that the boundary layers on low-Reynolds-number airfoils remain laminar at the onset of the pressure recovery unless artificially tripped. The behavior of the laminar boundary layers on low-Reynolds-number airfoils significantly affects the aerodynamic performances of the airfoils. Since laminar boundary layers are unable to withstand any significant adverse pressure gradient, laminar flow separation is usually found on low-Reynolds-number airfoils. Postseparation behavior of laminar boundary layers accounts for the deterioration in the aerodynamic performances of low-Reynolds-number airfoils. The deterioration is exhibited by an increase in drag and decrease in lift. Extensive reviews about aerodynamics of low-Reynolds-number airfoils and the dependence of the laminar flow separation phenomena on the chord Reynolds numbers can be found at Tani [1], Carmichael [2], Lissaman [3], Mueller [4] and Gad-el-Hak [5]. It has been suggested that the separated laminar boundary layers would rapidly transit to turbulence, and then reattach to the airfoil surface as a turbulent boundary layer when the adverse pressure gradient over the airfoil surface is adequate [6]. This would result in the formation of a laminar separation bubble, as schematically shown in Fig. 1. As the adverse pressure gradient becomes more severe with the increasing angle of attack, the separation bubble would suddenly burst, which will subsequently result in airfoil stall.

A good physical understanding is essential in order to control

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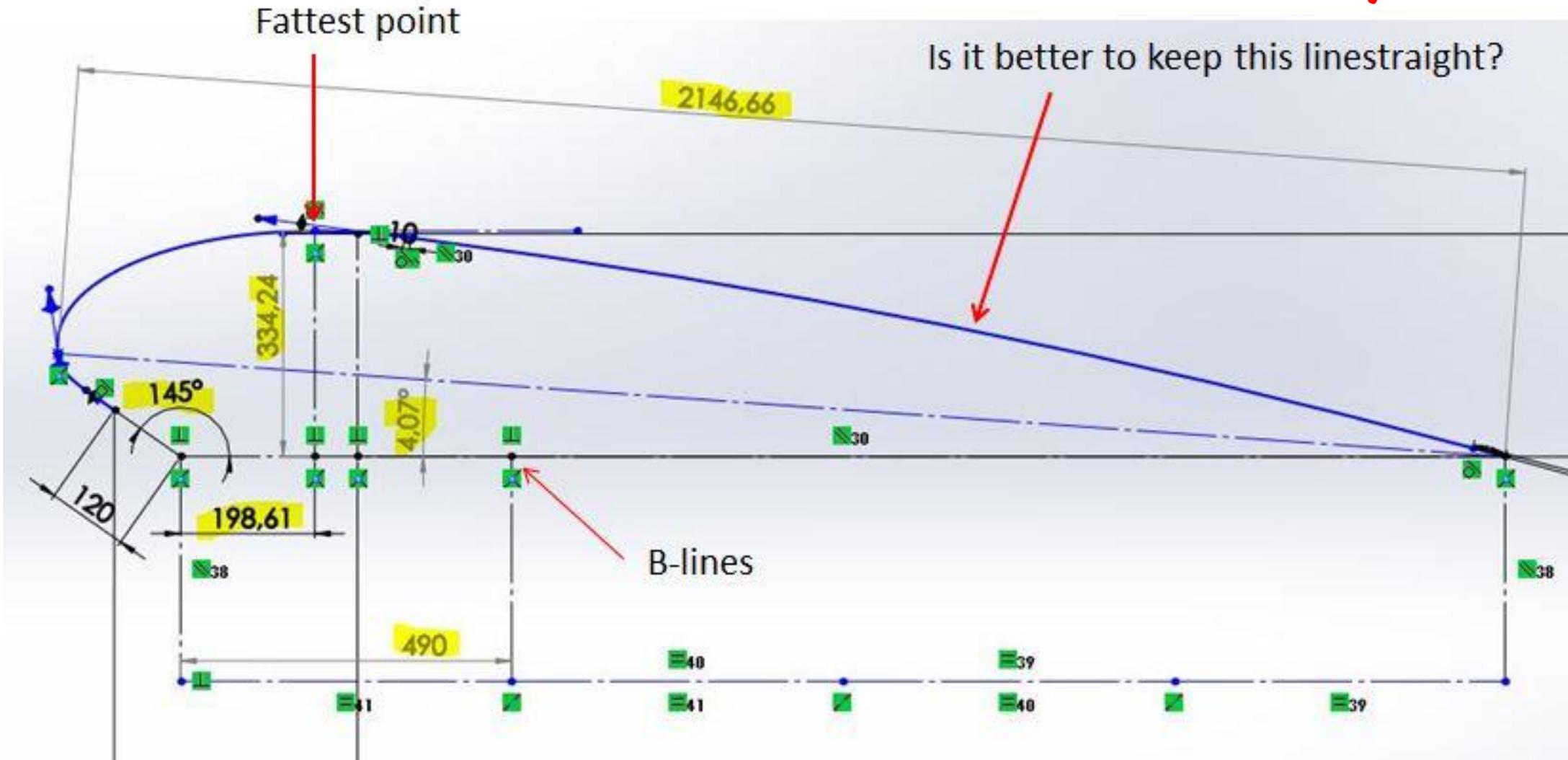


# Tiedonkeruu suunnittelun pohjaksi



# Tiedonkeruu suunnittelun pohjaksi

*Better?*

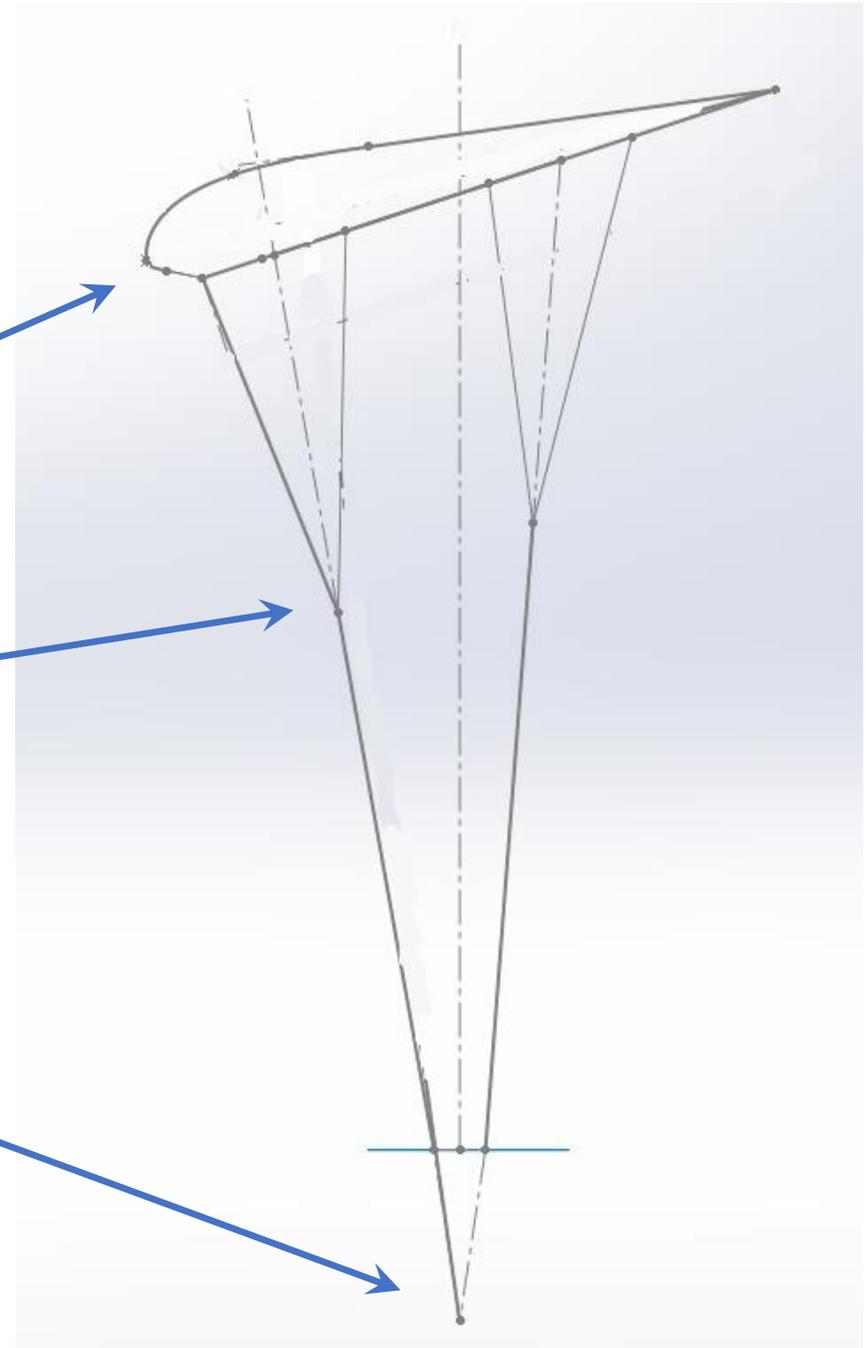


# Liitovarjon mitoitusta (lyhyesti)

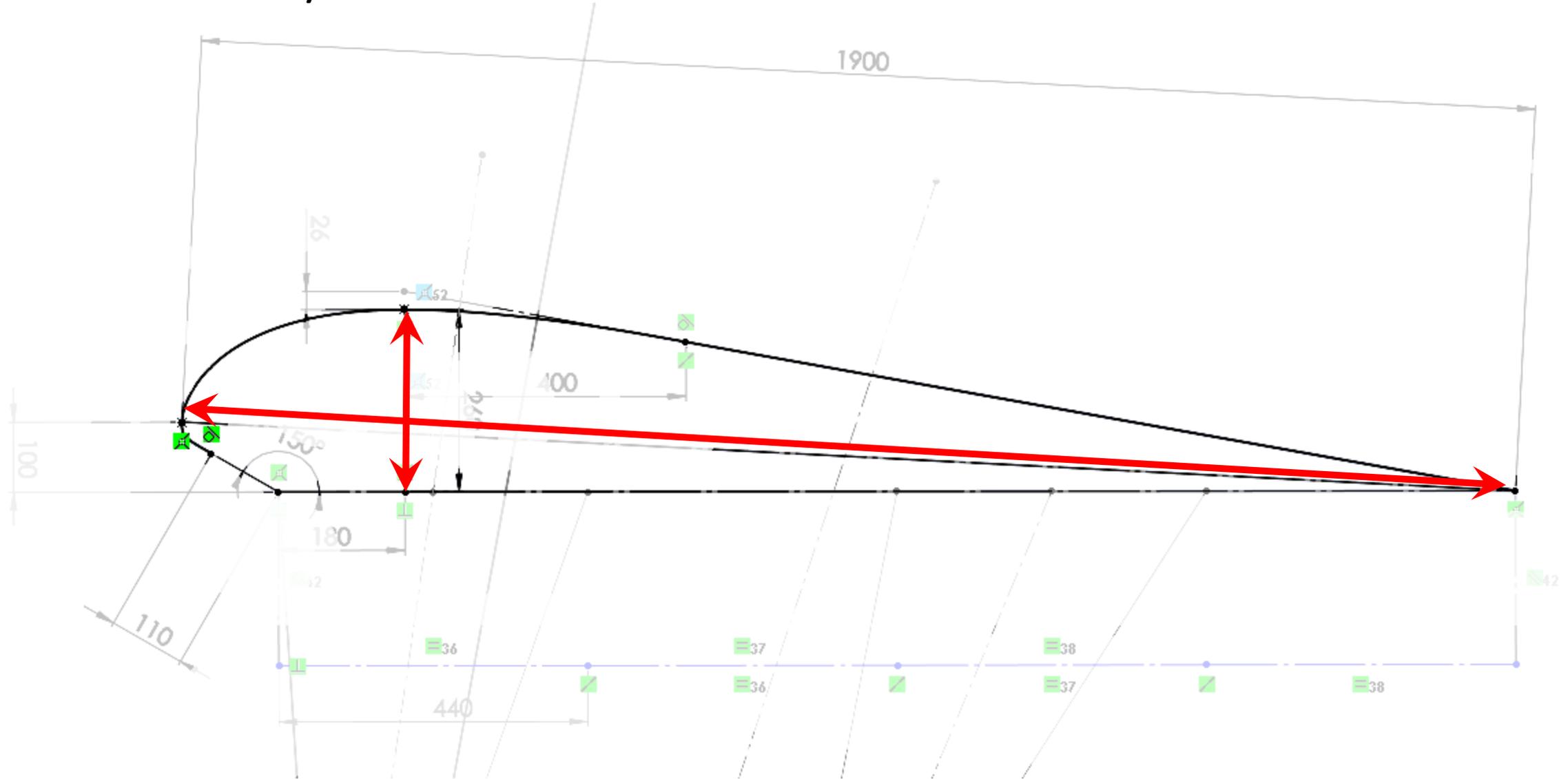
Kuvun siipiprofiili

Punosten haarakohta ja trimmi

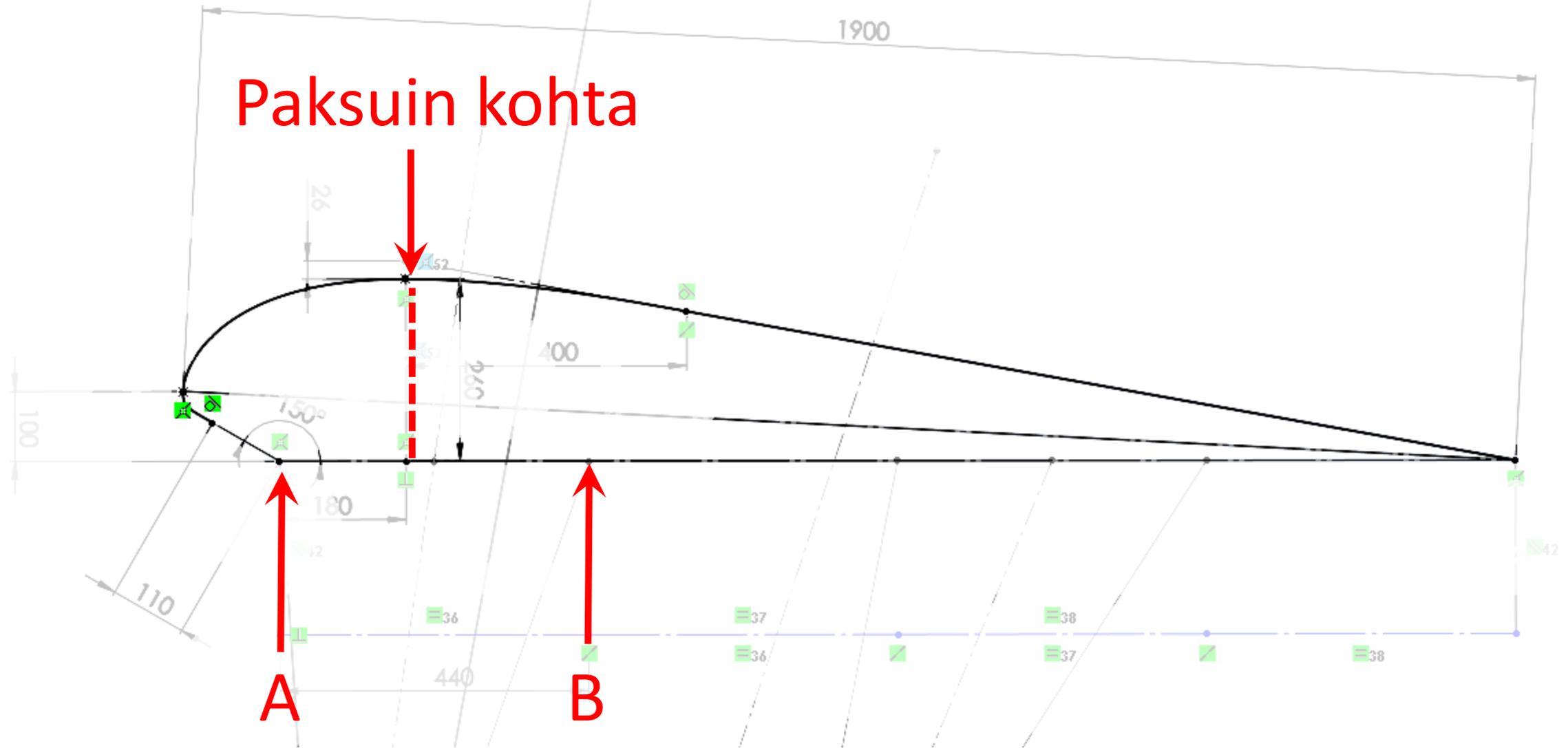
Viilekkeiden alapää



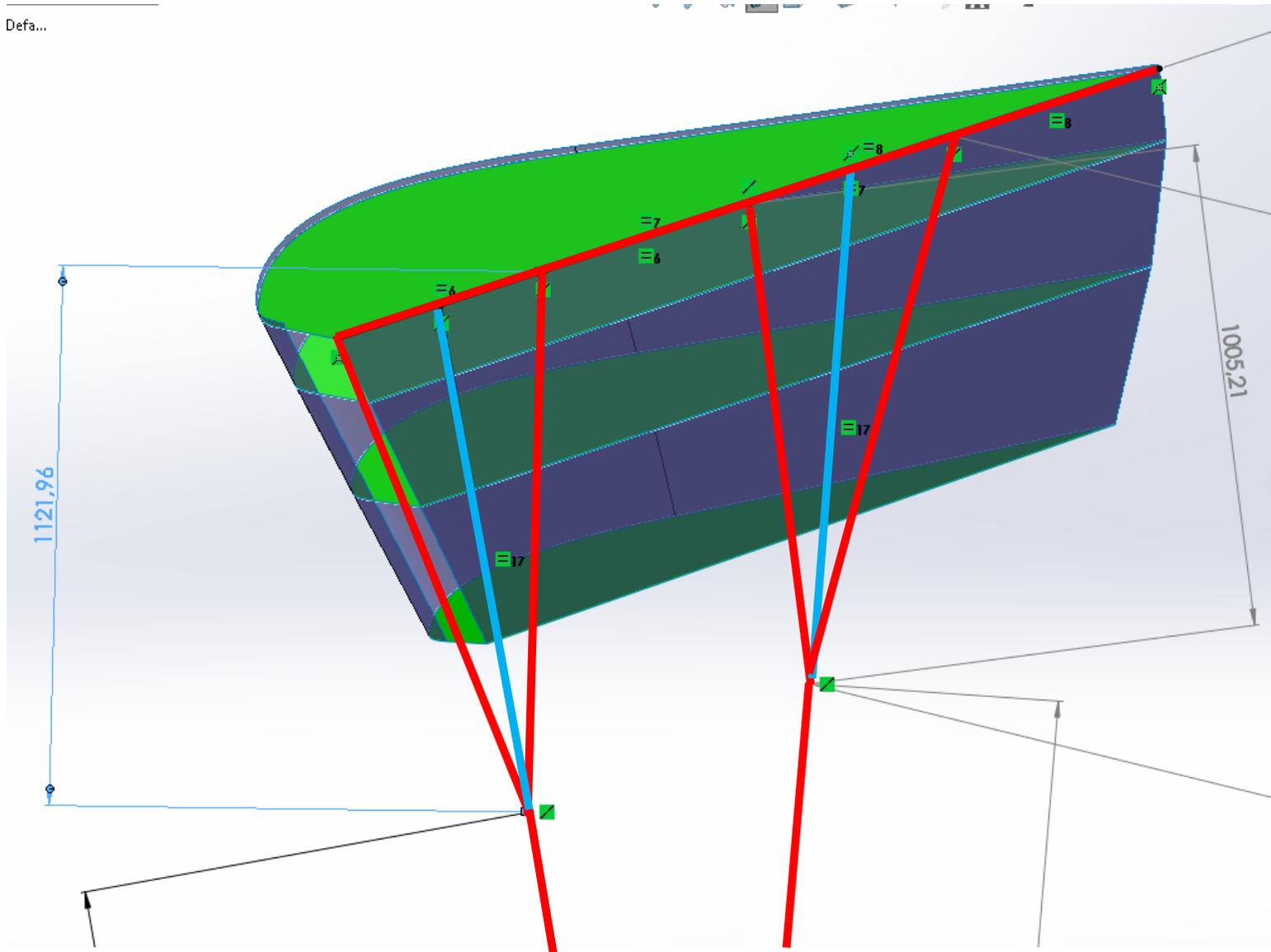
# Thickness/chord suhde



# Paksuimman kohdan sijainti



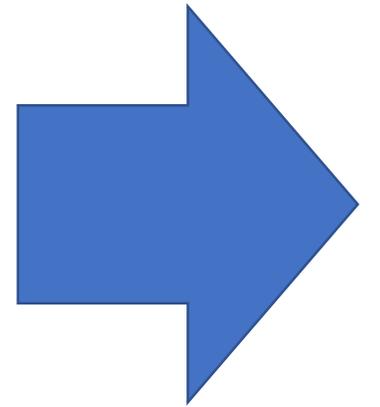
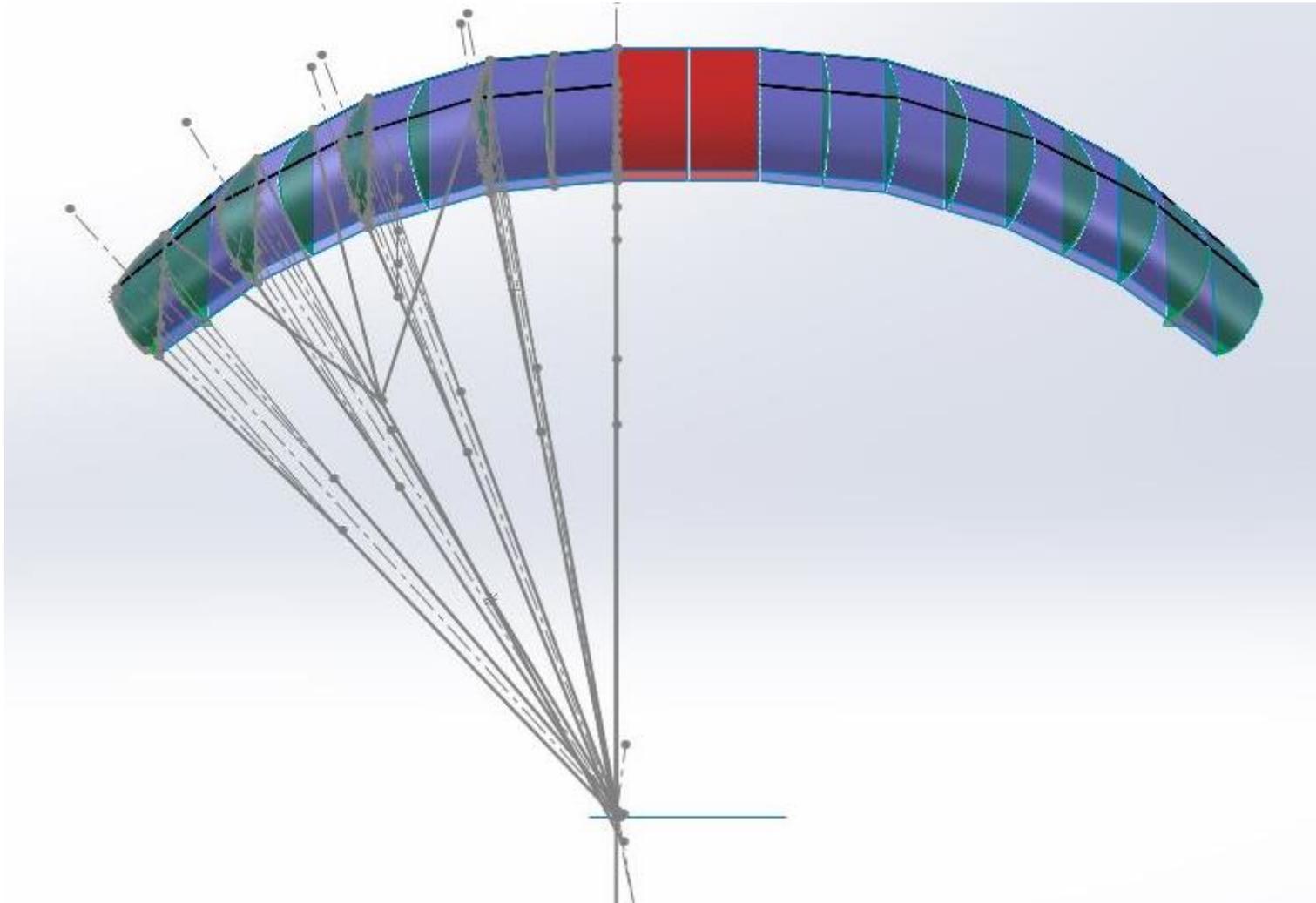
# Trimmi + punosten pituus



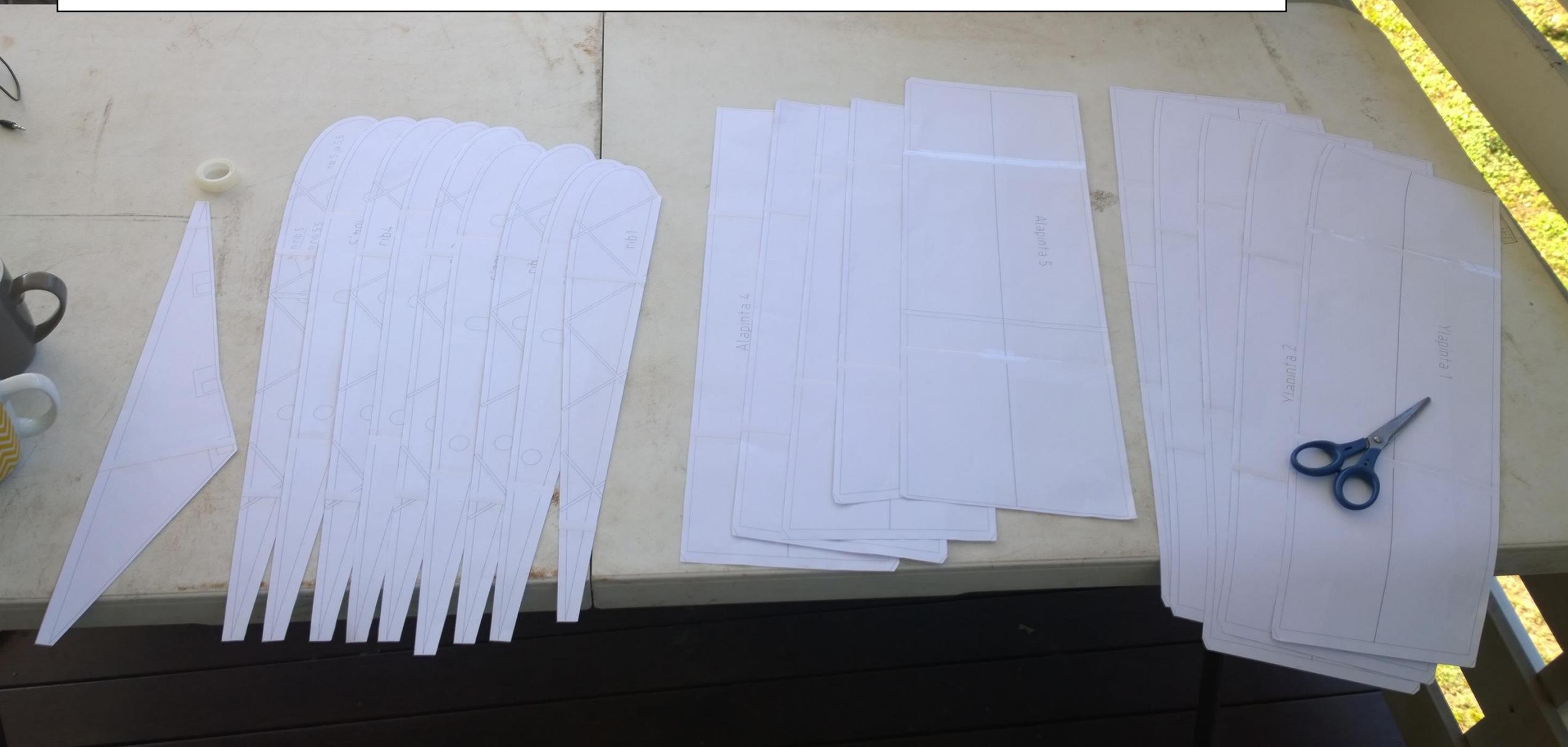
# Muita havaintoja

- Elliptisyys ei ehkä niin merkittävä tekijä kuin yleisesti luullaan
- Aspect ratio periaatteessa isompi->parempi tiettyyn rajaan asti
- Punosten pituudella ja jyrkkyydellä iso vaikutus recovery arc:iin
- Isoin nostava voima tulee kuvun keskialueelta
- Ilmanvastuksen pienentäminen lisää aina kuvun ilmanopeutta ja jarrutehoa → pienempi angle of attack  
→siipi toimii kaikinpuolin tehokkaammin

# 3D cad mallista protoksi



10,4 sqft 0,32 skaalattu proto!



10,4 sqft 0,32 skaalattu proto!



10,4 sqft 0,32 skaalattu proto!



10,4 sqft 0,32 skaalattu proto!



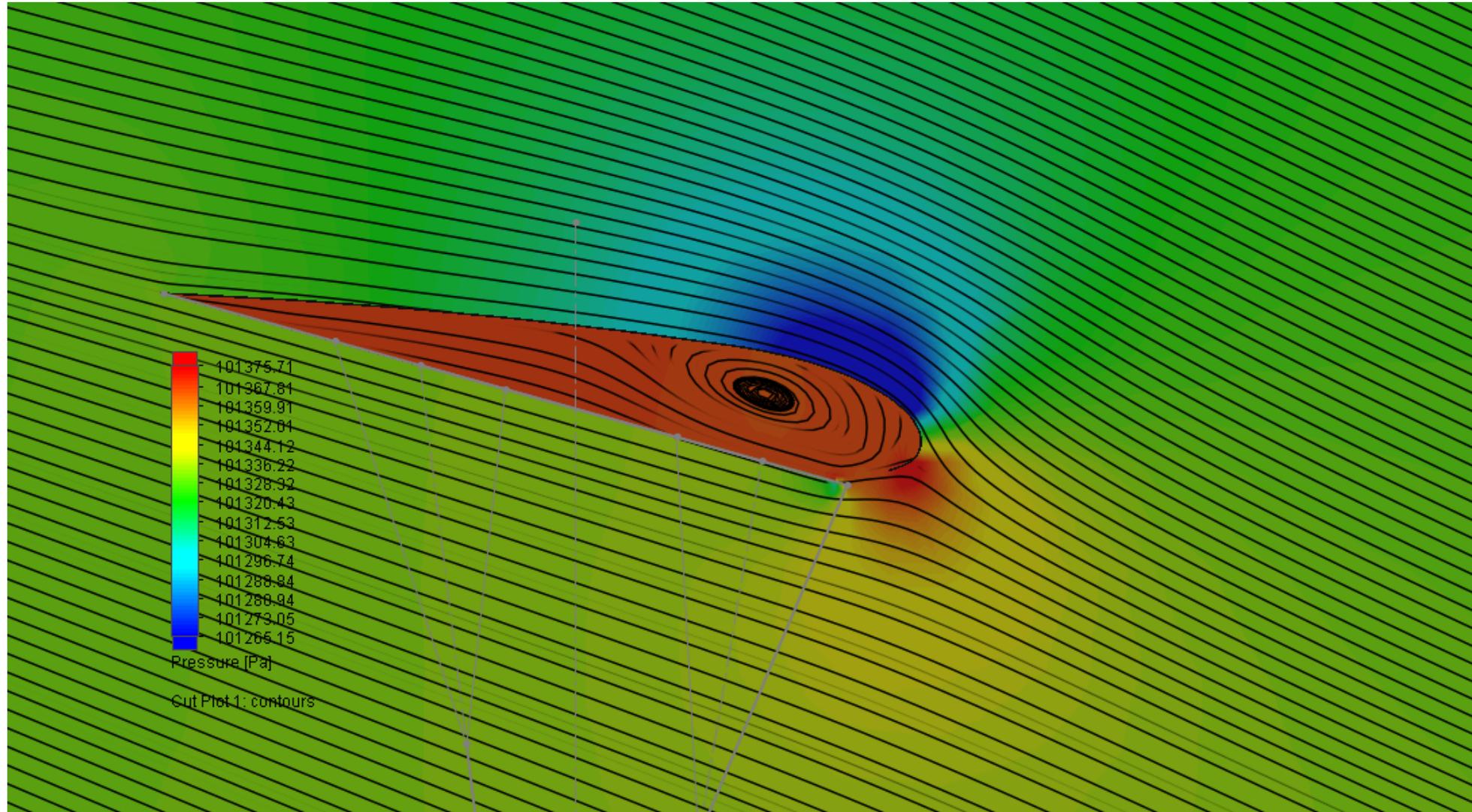
10,4 sqft 0,32 skaalattu proto!



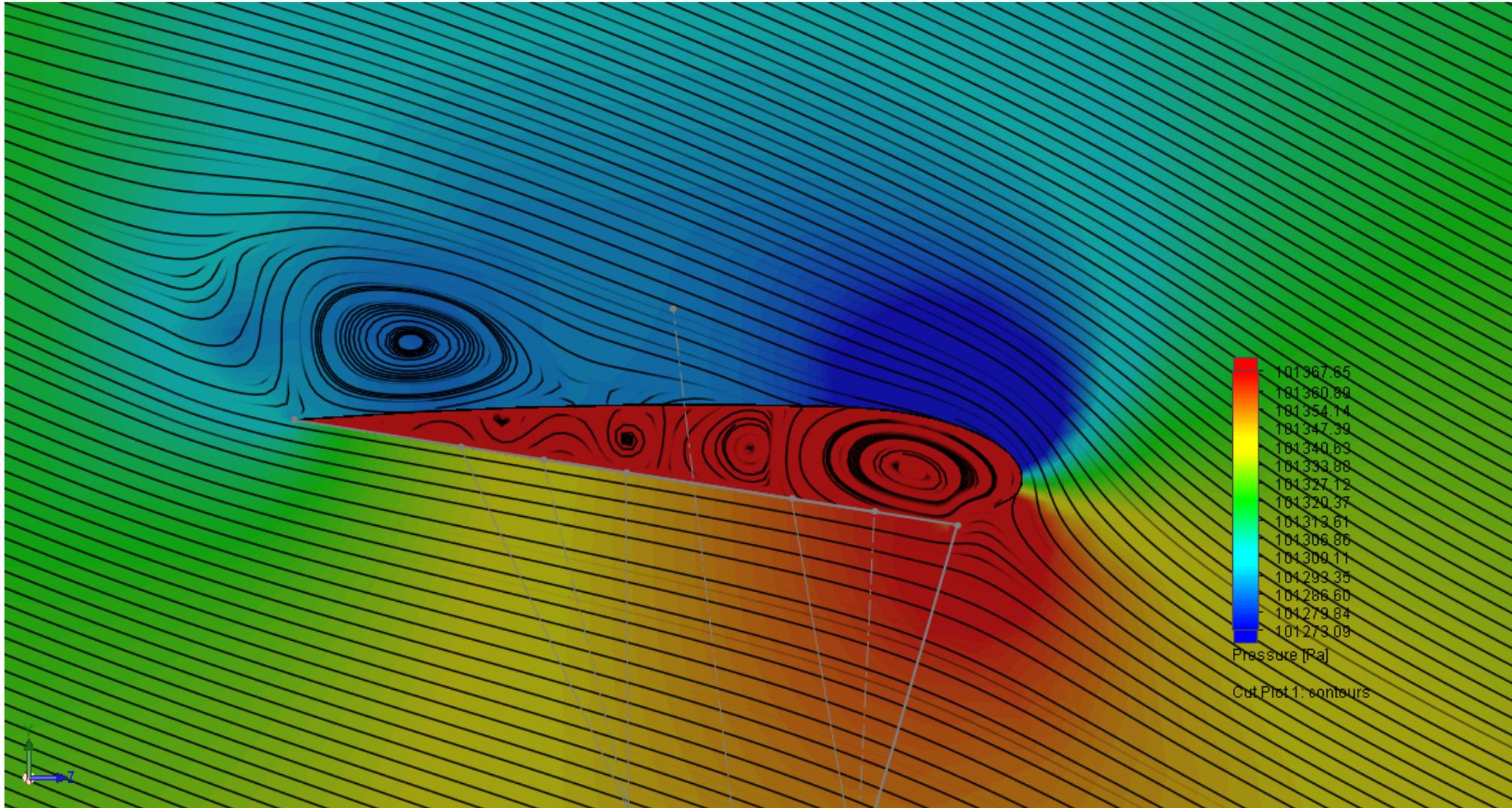
10,4 sqft 0,32 skaalattu proto!



# Virtauslaskennalla varmuuttaa siipiprofiiliin



# Virtauslaskennalla varmuuttaa siipiprofiiliin



# Oikean kuvun valmistusvaiheet:

- Kaavojen teko
- Palojen leikkaus
- Saumojen merkkäus
- Tukinauhojen ompelu + stabilisaattorien prikkataskut
- Paineentasausaukot
- Väli ribsit kii ylä- ja alapintoihin
- Kantavat ribsit yläpintoihin
- Kantavat ribsit alapintoihin + stabilisaattorit
- Takahelma
- Punosten kiinnityslenkit
- Punosten teko
- Punosten kiinnitys

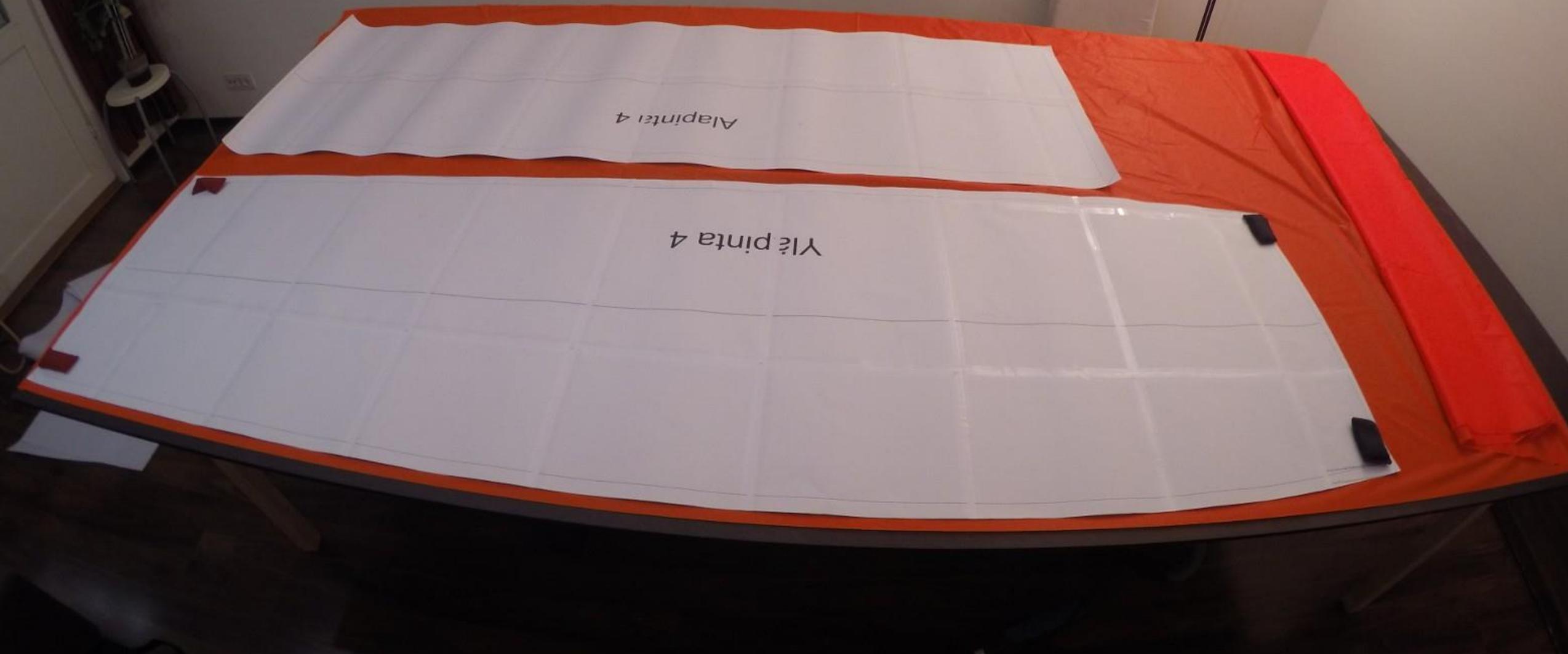
# Kaavojen valmistus



# Puuhapaketti ParaGearista



# Palaset kankaasta



# Palaset kankaasta



# Ompelukoneen upgrede Länsi-Saksalaiseen Pfaffiin



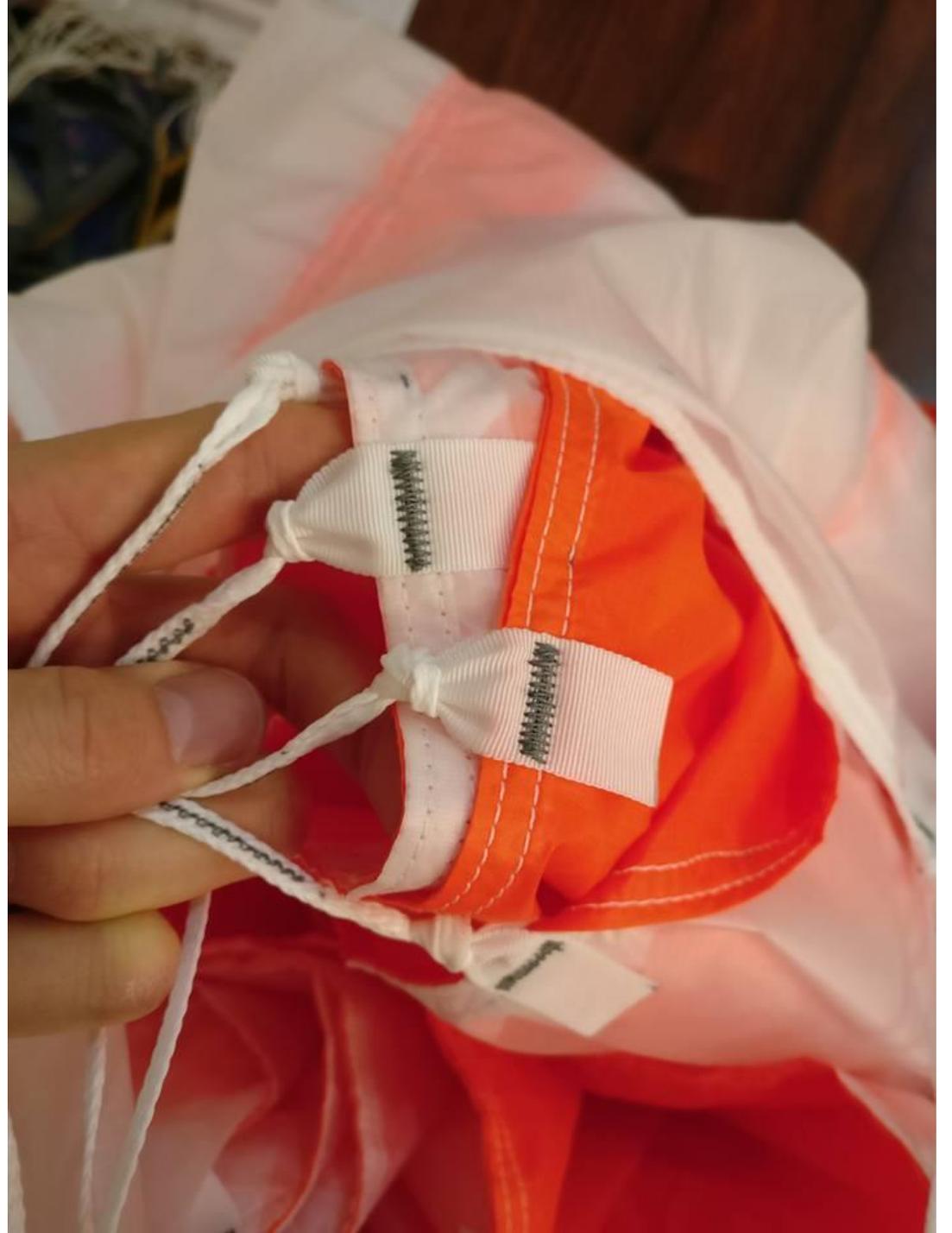
Vahvikenauhat paikoilleen



Palat yhteen









**ELINA**

SIZE: 120 SQFT

SN: 001

DOM:

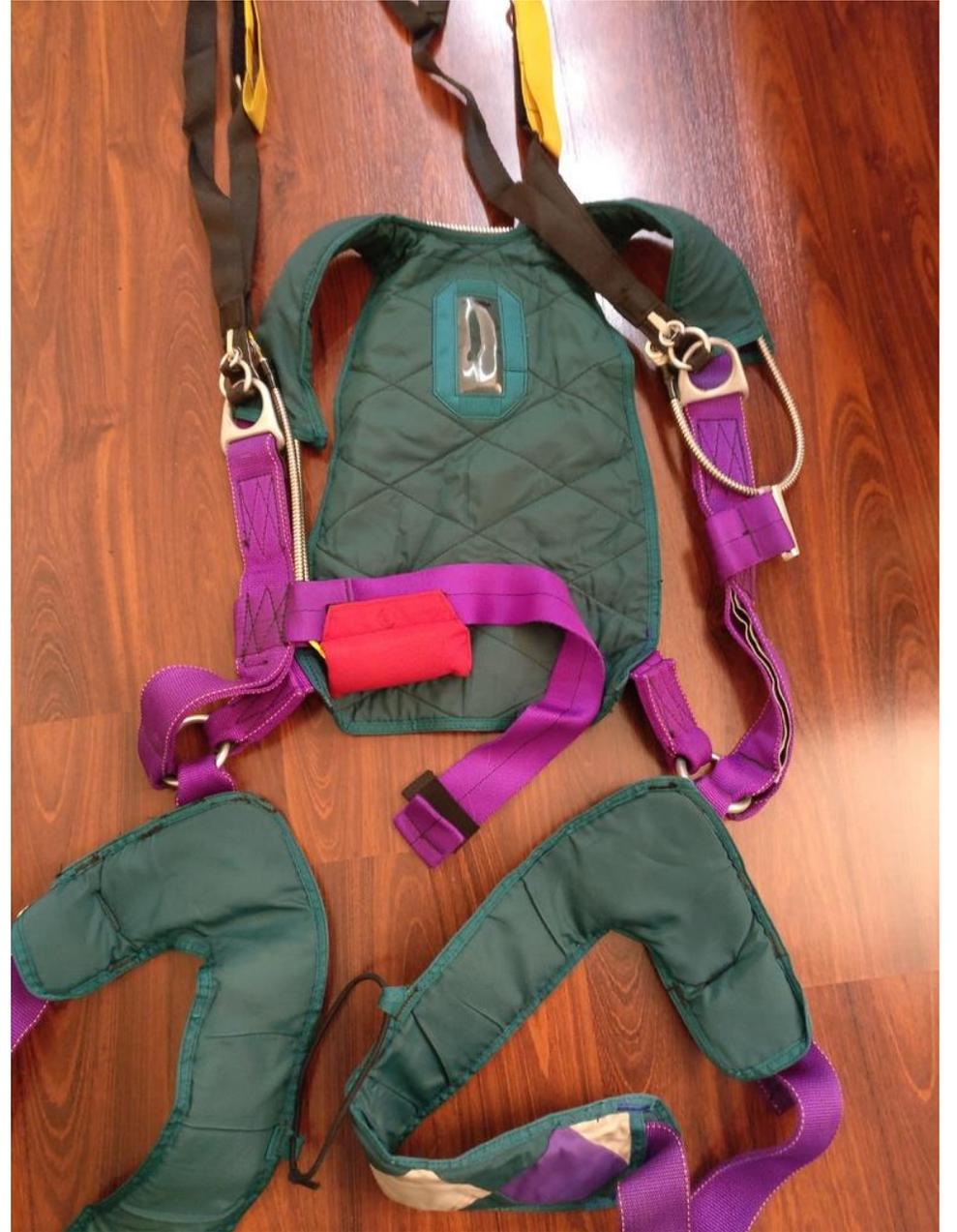
THIS CANOPY IS DESIGNED AND MADE BY:

HOME-RIGGING

**PROTOTYPE**

# Testihypyn suunnittelu

- Ainakin ensimmäiselle hypylle irtipäästövaljas
- Lyhyt vapaa, 2400m hyvä korkeus
- Kuvun reagoinnin kokeilua jarruihin, etummaisiiin ja takimmaisiiin eri lentotiloissa
- Sakkauskokeilut





1. Hyppy



# Valjaskäännöksiä



# Laskeutuminen 0-tuuleen



FlySight data liitettynä videoon

# Testihyppyjen tuloksia

- Siipikuorma testihypyillä ~1,45
- Hyppyjä 15
- Avaukset ok, hieman kovia täydestä vauhdista
- Ilmanopeus täysliito ~16m/s, täysjarrut 11m/s
- Jarrut, range erittäin hyvä
- Etummaisiet / takimmaisiet
- Muuta ihmeellistä: etukulmien värinää pienillä jarruilla

# Tulevaisuuden suunnitelmat

- Sliderien testausta
- Trimmin hienosäätöä A1-2 punoksissa

# Riskien hallinta

- Irtipäästövaljas
  - Hyvä kahva irtipäästölle
  - Pinni suojattu ja tatti taskussa
- Ensimmäiset hypyt
  - Ole valmis irtipäästöön
  - Vain hyvään keliin
  - Älä tee mitään matalalla mitä et ole kokeillut ylempänä
  - Jos fiilis ei ole hyvä, älä hyppää
  - Ulkopuolinen kuvaaja

Mitä määräykset tästä sanoo?

Antopäivä: 19.5.2017	Voimaantulopäivä: 22.5.2017	Voimassa: toistaiseksi
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Säädösperusta:

Ilmailulaki (864/2014) 9 § 5 mom. ja 33 § 2 mom.

## 2.5 Korjaaminen ja valmistus

2.5.1 Laskuvarjon huoltaja saa tehdä saamansa koulutuksen ja kokemuksensa mukaisesti laskuvarjon osia tai osakokonaisuuksia korvaavia osia, jos valmistaja ei ole yksilöinyt korvattavaa osaa tai osakokonaisuutta sarja- tai osanumerolla, sekä edellä mainittujen osien tai osakokonaisuuksien korjauksia, joihin ei ole valmistajan ohjeita. Näissä toimenpiteissä on noudatettava yleisesti hyväksytyjä ohjeita, kuten ”Poynter Parachute Manual”.

2.5.2 Suomessa saa valmistaa laskuvarjohyppyihin tarkoitettuja päävarjoja, varavarjoja, valjaita ja automaattilaukaisimia tai niiden yksilöityjä osia Euroopan unionin jäsenvaltioissa yleisesti käytössä olevien teknisten normien mukaisesti.

2.5.3 Kaupallisesti valmistettuun laskuvarjoon tai sen osakokonaisuuteen on merkittävä valmistenumero, valmistajan tunniste ja valmistusvuosi. Valmistuksesta on pidettävä kirjanpitoa, josta ilmenevät käytetyt piirustukset, valmistuspäivämäärä ja valmistaja.

Ei muuta kun ompeluhommiin!

