Chapter 4 **(..of *The Cambered Panel Junk Rig...*)**

Drawing a detailed sail

..the final job before cutting in canvas...

Introduction

Before we are ready to construct a sail (see chapter 5), we need to produce a detail drawing, which we can use when lofting it. Since I have focused on the *Johanna* type planform, I have made a set of ten 7-panel *Johanna*-style master sails with aspect ratios going from 1.80 to 2.25 in steps of 0.05.

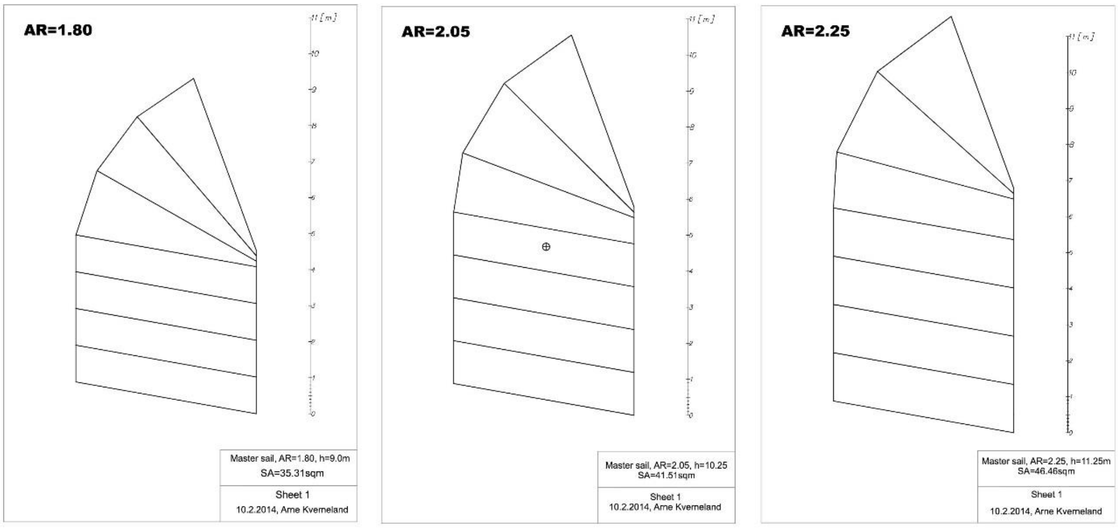


FIG 4.1 Three master sails...

Note 1: The whole range of master sails will be shown in full-page size in the final appendix to this chapter.
Note 2: There is a little word list in Appendix I, page 12: A few Norwegian, and some other confusing words have found their way into some of my diagrams and text...

All the master sails have only one length in common:

The chord=5.00metre **(..which locks the boom, battens and yard to B=5.077m...)**

The sail area of the lowest sail is just 35.3m^2 while the tallest is 46.5m^2 - 32% bigger than the lowest one.
The idea with these master sails is to speed up the drawing process, while retaining the high accuracy obtained with CAD, and, in addition, to save you the trouble of getting about equal sail area in each panel. Just pick one of these sails and scale it up or down to suit the needs.
The range of plans shows how “stretchy” this rig is with respect to aspect ratio. If I ever should need a taller sail than the one at AR=2.25, I would rather add a panel. Conversely, if I should need a shorter sail than the one at AR=1.80, I would go for a 6-panel sail.

About the master sail diagrams

Each of the ten master sails are presented on two sheets (..as said, in the final appendix ...).

- Sheet 1 shows the sail with just a couple of lengths plus the sail area of each panel.
- Sheet 2 shows the individual panels with all the dimensions needed to loft the sail.

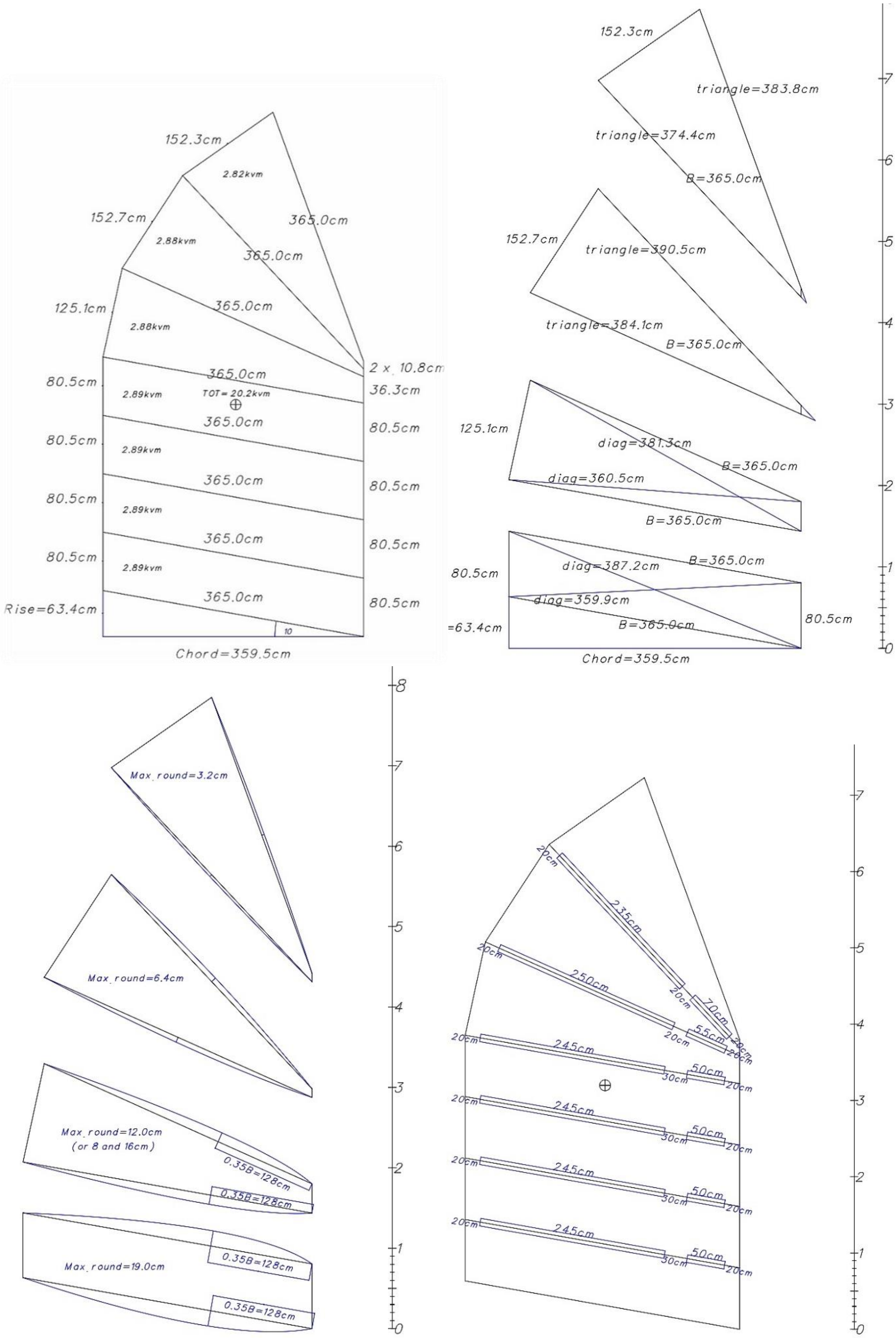


Fig 4.2, the 4-sheet sailplan of *Frøken Sørensen*,

I haven't bothered with drawing a third and fourth sheet to show the *round* in each panel (to create camber), or to show where the batten pockets should sit. Still, since I have a full 4-sheet sailplan of the sail of my own boat, *Frøken Sørensen*, I let you have a glimpse of it, to get an idea of how the round and batten pockets can be fitted (Fig 4.2, above, and more details on Fig 4.4).

Accuracy with CAD

One of the great assets with drawing in CAD is the high accuracy one gets. This is why my master sails are shown with millimetre resolution. In normal life we should be happy enough with an accuracy of one centimetre. Therefore, I suggest you scale up or down the sails in millimetre and then just round off to cm at the end.

Scaling up or down

There are two main methods to do this:

Method 1: If you have gone through the sketching process, described in Chapter 3, then all you have to do is to pick a master sail with the nearest aspect ratio to that on your sketch and scale it to the right chord (or batten) length. See the master sails in the 20-page appendix.

Example:
Let us try to scale a master sail to fit the biggest sail of the Marieholm IF, shown in Fig 3.1 in Chapter3. In that sketch the boom length, B=4.90m, the AR=2.02 and the roughly calculated sail area, SA=37.7m^2.

I first try the AR=2.00 master sail:

$$\textit{The } \boldsymbol{\textit{Linear Scale Factor}}, \ \boldsymbol{F_l} = \frac{\boldsymbol{Wanted\ boom\ lenght}}{\boldsymbol{Master\ sail's\ boom\ length}} = \frac{4.90m}{5.077m} = \mathbf{0.9651}$$

Since the ***Area Scale Factor***, $\boldsymbol{F_A = F_l{}^2}$, we find...

$$.. \ \boldsymbol{SA_{(AR=2.0)}} = \ Master\ sail's\ SA_{(AR=2.0)} \times F_A = 40.29m^2 \times 0.9651^2 = \mathbf{37.52}\boldsymbol{m^2}$$

That is pretty close to the SA= 37.7m^2 that we found in Chapter 3.

If we do the same exercise with master sails of AR= 2.05, the resulting sail area will come out at...

$$\boldsymbol{SA_{(AR=2.05)}} = 41.51m^2 \times 0.9651^2 = \mathbf{38.66}\boldsymbol{m^2}$$

And if we go down to AR=1.95, the result will be...

$$\boldsymbol{SA_{(AR=1.95)}} = \mathbf{36.35}\boldsymbol{m^2}$$

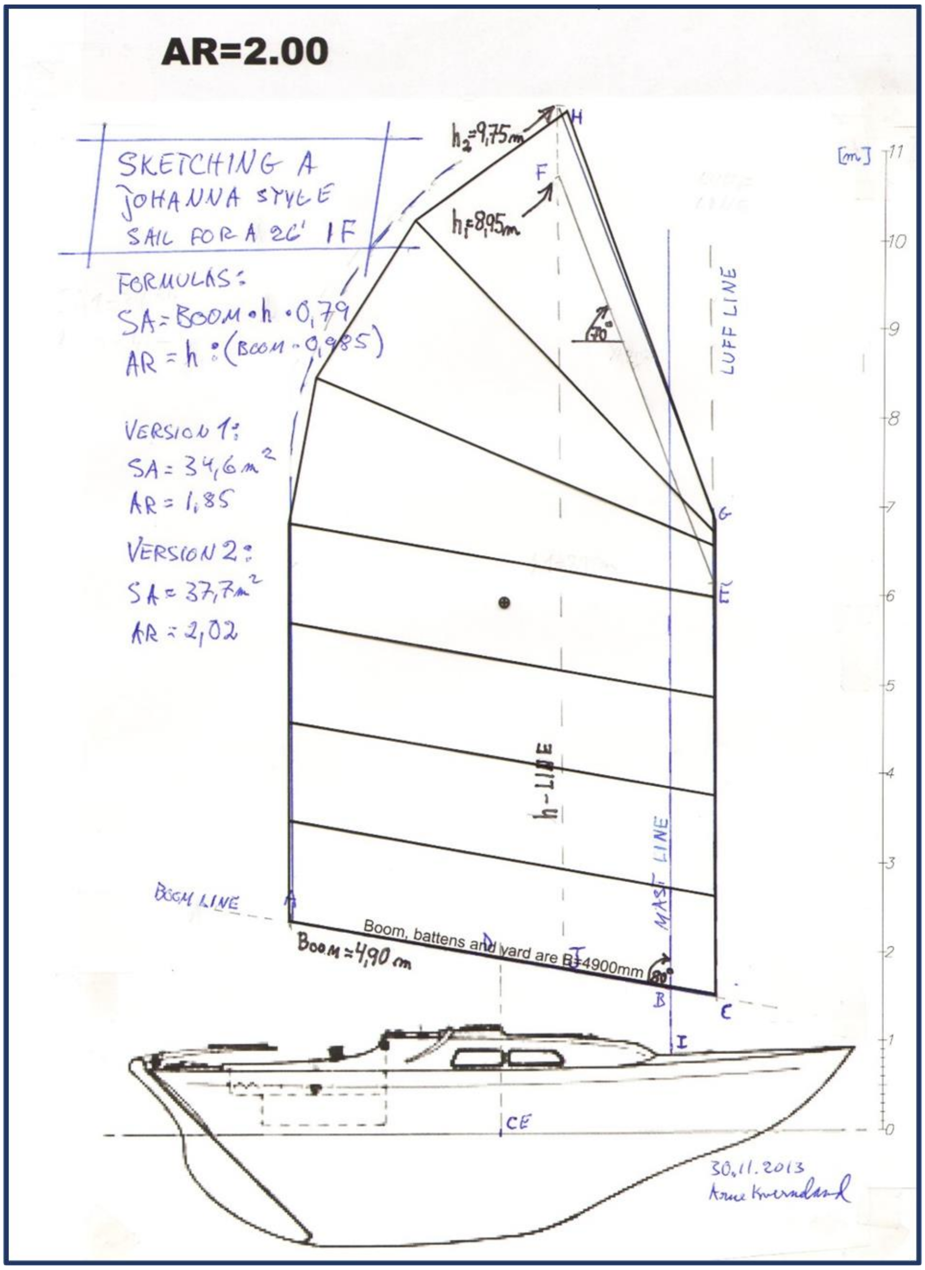


Fig 4.3 The Marieholm IF with the AR=2.0, CAD-generated junk sail attached

Fig 4.3, above, is the same diagram as Fig 3.1 in Chapter 3, but with the printed out (transparent) sail from the example above laid on top of it. As can be seen, the sketch and the CAD-generated drawing matches quite well. The only exception is the leech of the three upper panels, which were just hand-drawn on fig 3.1. **(..Since I had the original CAD drawings available in the PC, I could simply crimp the master sail with the linear scale factor $F_l = 0.9651$ and then print it to 1:50 scale...)**

I suggest you try it out yourself. When you have decided on which master sail to use, it is time for calculating the scale factor(s) and then calculate all the needed dimensions, found on sheet 2. That should be done in half an hour with a good calculator. I suggest you print out the actual master sail (both sheets) and then just write the calculated new dimensions and areas onto the sailplan.

(..I do recommend that you double- or even triple-check all your calculated dimensions...)

Method 2: In case you have not gone through the Chapter 3 procedure, but only want to grab a master sail that you like, and scale it to your needs, just follow the rules:

The ***Area Scale Factor*** $$\boldsymbol{F_A = \frac{Wanted\ SA}{Master\ sail's\ SA}}$$

When you want to check if the linear dimensions; chord, boom etc. will fit, the rule is:

The ***Linear Scale Factor*** $$\boldsymbol{F_l = \sqrt{F_A}}$$

It may take a few more attempts to get the sailplan you want with this method, but when you are there, you just calculate all the remaining dimensions, as in Method 1.

How to design camber in a junk sail

From an aerodynamic point of view, the junk sail is just another sail. As with Bermuda and gaff sails, it needs some sort of camber to generate enough drive when sailing on the wind. The ideal sail would be one that easily could have the camber adjusted between 3 and 15%: In weak winds, we want the sails to be baggy (15% +), while in a blow we want them fairly flat (3-5%). The method I use is to sew camber (fullness) into each batten panel. Since the camber of the resulting sails cannot be adjusted easily after completion, I play safe and cut the lower panels to only 8 – 10% camber, and with the top panels - the storm section - a good deal flatter.

Have a look at Fig 4.4 on next page. The lowest four panels have been designed so that the resulting sail panels have 8% camber (about 29cm max draught, or camber, when checking the hoisted sail on the photo below, right). It is the barrel-shaped *round*, cut along the battens, which induces draught or fullness in the sail, which again creates a wing-shaped camber from luff to leech, as shown on the photo below, left.

The cambered sail of *Frøken Sørensen*...

Measuring the max draught, here 29cm...

This characteristic barrel profile of the lower panels have given the method its name; the *Barrel Method*, or *Barrel Only Method,* as no broadseaming is used.

Calculating the round in the lower panels

It is a challenge to find which amount of round will give the desired depth of camber. To help me on this, I made my “Arne’s Chain Calculator”, back in the nineties.

(Continues on page 7)

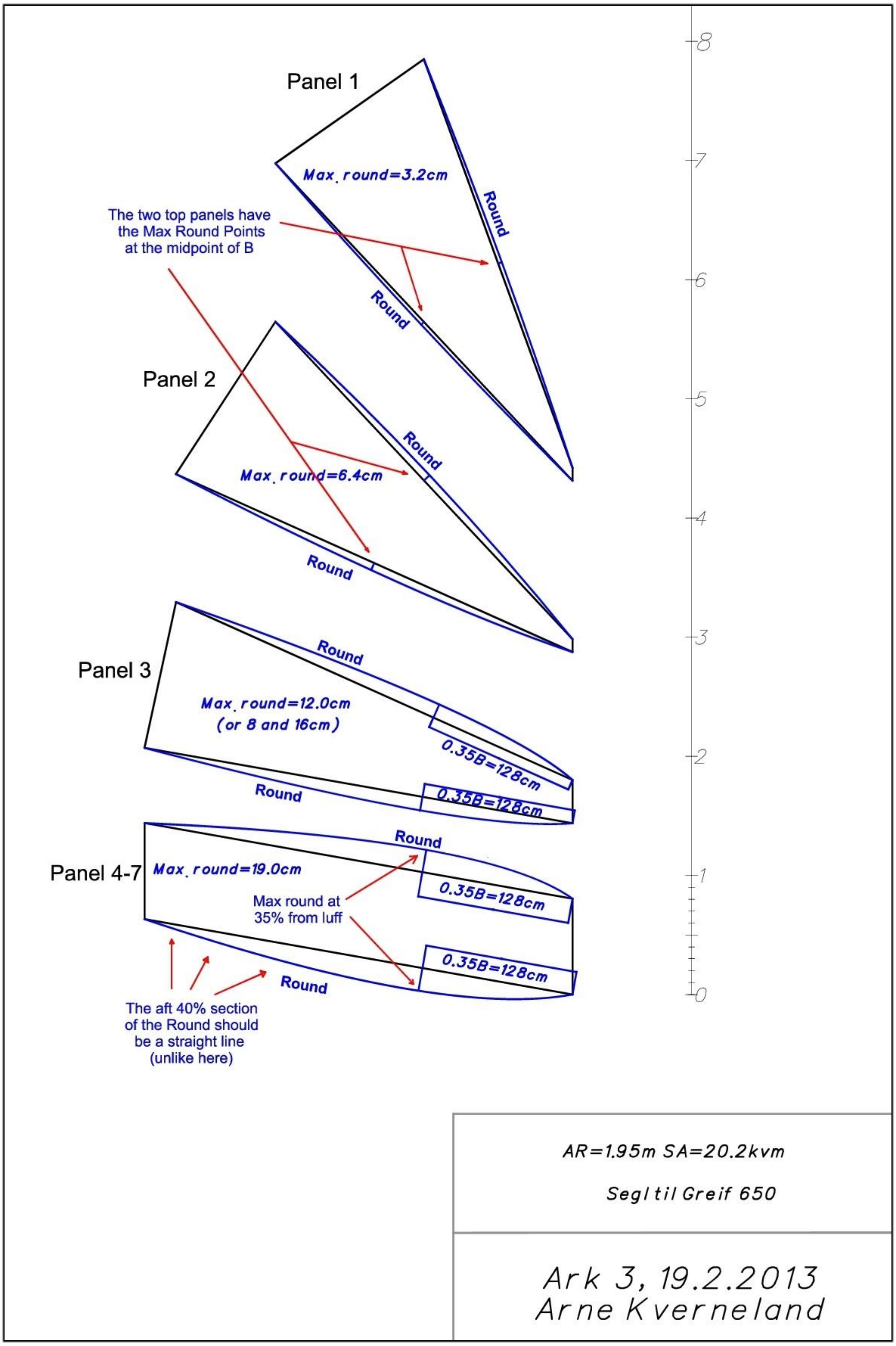


Fig 4.4 shows the round used in *Frøken Sørensen*'s 20sqm sail (sheet 3 of that sailplan).
The resulting, measured camber =8%.

[1] Master sails w/ rising ARs and 6, 8 and 10% camber	[2] PANEL HEIGHT, **P** [centimetre]	[3] Panel height over batten length, **P/B**	[4] SAIL CAMBER [centimetre]	[5] CHAIN CAMBER = 1.2 x sail camber[cm]	[6] ROUND, **R** [centimetre]
AR=1.80, 6%	102	0,201	30	36	14,4
AR=1.80, 8%	102	0,201	40	48	23,0
AR=1.80, 10%	102	0,201	50	60	32,5 *), see p.8
AR=1.85, 6%	106	0,209	30	36	14,2
AR=1.85, 8%	106	0,209	40	48	22,5
AR=1.85, 10%	106	0,209	50	60	32,0 *), see p.8
AR=1.90, 6%	109	0,215	30	36	14,0
AR=1.90, 8%	109	0,215	40	48	22,0
AR=1.90, 10%	109	0,215	50	60	31,5 *), see p.8
AR=1.95, 6%	112	0,221	30	36	13,7
AR=1.95, 8%	112	0,221	40	48	21,5
AR=1.95, 10%	112	0,221	50	60	31,0
AR=2.00, 6%	116	0,228	30	36	13,5
AR=2.00, 8%	116	0,228	40	48	21,4
AR=2.00, 10%	116	0,228	50	60	30,0
AR=2.05, 6%	119	0,234	30	36	12,7
AR=2.05, 8%	119	0,234	40	48	21,0
AR=2.05, 10%	119	0,234	50	60	29,7
AR=2.10, 6%	123	0,242	30	36	12,5
AR=2.10, 8%	123	0,242	40	48	20,2
AR=2.10, 10%	123	0,242	50	60	29,4
AR=2.15, 6%	126	0,248	30	36	12,1
AR=2.15, 8%	126	0,248	40	48	19,8
AR=2.15, 10%	126	0,248	50	60	28,7
AR=2.20, 6%	130	0,256	30	36	11,7
AR=2.20, 8%	130	0,256	40	48	19,2
AR=2.20, 10%	130	0,256	50	60	28,0
AR=2.25, 6%	134	0,264	30	36	11,5
AR=2.25, 8%	134	0,264	40	48	18,7
AR=2.25, 10%	134	0,264	50	60	27,5

Fig 4.5 Finding the round, R, in the lower panels as a function of panel height and wanted camber in all the ten master sails. For cells marked with *), see page 8, last paragraph.

This - not too accurate - method at least helps me estimate how much round I need: To save you the trouble on using the chain calculator, I have calculated a table for the whole range of master sails, see Fig 4.5, above. For practical use, you only need column 1 and 6 in that table. In the column 6, to the very right is the round, R. As you can see, for each master sail I have calculated three values of round, which gives either 6, 8 or 10% camber. When you scale a master sail up or down, you just scale the chosen round up or down as well.

Calculating the round in the top section

After I made the camber too deep in the top panel of my first sail (Malena 1994), I adapted this rule of thumb, which has worked well on the four sails I have made more recently:

When I have found what round I need to achieve 8% camber in the lower panels, I just divide it by 4 or 5 and use that on the top panel (**panel 1**). On panel 2 I use twice the round of panel 1. In panel 3 it depends. In the highest AR range it resembles a parallelogram, so I would treat it like that and use the chain calculator (or table in Fig 4.5) to find the round which gives about 6% camber. On the lowest AR sails, panel 3 is almost a true triangle, like panel 1 and 2. I guess I would give it about 0.6-0.7 of the round in the lower panels. Note that in Fig 4.4 I made the round different on both edges on panel 3, with 8 and 16cm instead of 12cm on both sides. This is to make the edges fit better with the adjacent sides on panel 2 and 4.

Accuracy with the Chain Calculator.
As said, the chain calculator is not that accurate. The chain calculator itself is within ±1cm, I guess. However, the *Chain Camber Constant* is rather uncertain. Its use is shown below:

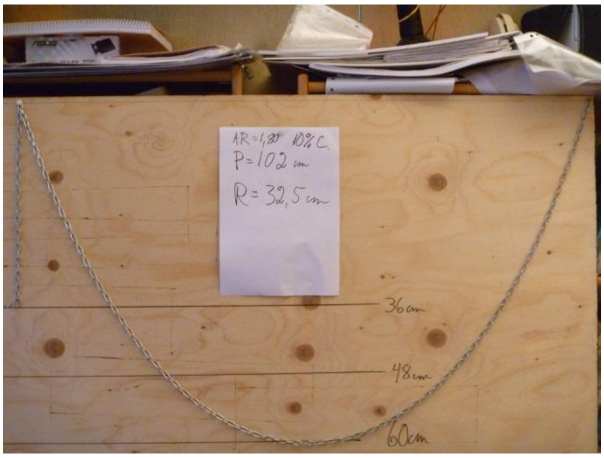
I set the $\boldsymbol{Chain\ Camber\ Constant} = \frac{\boldsymbol{Chain\ camber}}{\boldsymbol{Sail\ camber}}$ to **1.2** as a result of experience with a test panel.

This constant (“fudge factor”) varies a bit over the whole range of AR or P/B - so presenting the round with 3 digits hardly makes that much sense. Actually, when I designed the sail for *Frøken Sørensen*, last year, I aimed for 9% camber in the lower panels, but the resulting sail camber was just 8%. Still good enough for my use.

The good news is that the panels will not blow out of shape and get baggier over time, the way Bermuda or gaff sails do. This is because the load in the junk sail is only a fraction of that in the western sails.

Some examples showing the “Arne’s Chain Calculator” in use.

6% camber, AR= 2.25



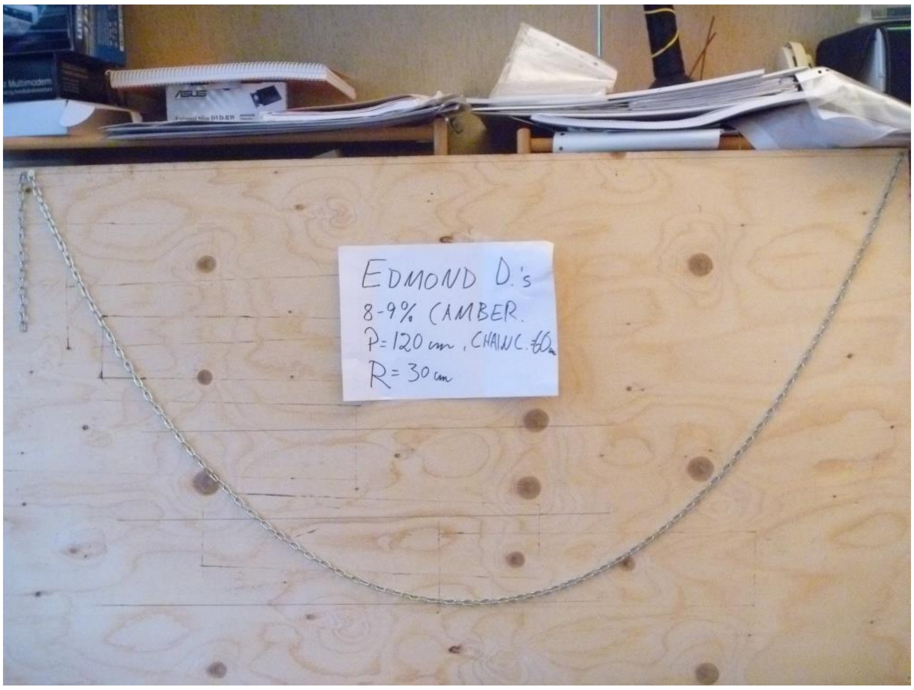
10% camber, AR=1.80

The two examples above have been taken from the extreme ends of the table in Fig. 4.5.

1. The photo to the left shows the slack chain curve and moderate round (R=11.5cm) needed to achieve a sail camber of 30cm, and thus a camber/chord ratio of 6%.

2. The photo to the right shows the very deep chain curve and lots of round (R=32.5cm) needed to get a sail camber of 50cm, and thus a camber/chord of 10%. I admit that I have my doubts if it will work with so much camber with so narrow panels. Three of the cells in Fig 4.5 have been marked with *). I would not make a whole sail with these panels without making a test panel first.

Nevertheless, I seem to get away with it, no matter how much camber I put in: When I came to make a copy of *Johanna*'s sail for the *Edmond Dantes* (48sqm, AR=1.87, 8% camber), I chose to increase the round in the lower panels from 26 to 30cm.



In the photo above I have hung the chain, using the numbers for ED's sail. In this sail P=120cm and R=30cm, the AR=1.87 and the P/B=0.207. The chain camber ends up on 60cm, which should give a sail camber of 50cm.
With a batten length B=5.80m, the resulting camber (camber/chord) should be 8.6%. I haven't checked the actual camber in that sail, but at least it looks OK and performs very well.

The 48m^2 sail of *Edmond Dantes*, made of white 6.5oz Odyssey III

Shortening the boom

In this chapter I have always shown the boom with the same length as the battens and yard. When it comes to cutting canvas, I actually shorten the sail about 4% along the boom, at the clew. I have found that the sail reefs better with this than if the boom is kept at full length. This has been described in Chapter 5, p. 6.

..the just finished white sail for Edmond Dantes, June 2012..

Conclusion

The designing of camber in the batten panels of junk sails is a forgiving business. Even if the calculations are a bit off, the resulting sails seem to perform well - so just go ahead - the master plans start after page 12!

Stavanger, 17.3.2014,
Arne Kverneland

PS: Again, thanks to Slieve McGalliard for looking over this chapter for me...

PPS:

Luckily...

...neither *Johanna*..

..*Frøken Sørensen*...

..nor *Edmond Dantes*...

..can read, so they don't worry whether my foggy theories are right or wrong...

Appendix I

List of words

I am afraid that the text in some of my old diagrams have some Norwegian in it. Here is a translation of some of them:

Norwegian	**English**
Ark (1, 2, etc.)	- Sheet (1, 2, etc.)
Frøken Sørensen	- Miss Sørensen
Kvm (kvadratmeter)	- Sqm, square metre
Rå	-Yard
Segl	- Sail
Skjøt	- Sheet
Spile	- Batten
Spilelomme	- Batten pocket

A few other words that need a comment:

Camber vs. **Camber/chord**. When camber is given in centimetres or inches, we mean its depth of draught. The *Sail Camber* and *Chain Camber* in Fig 4.5, column 4 and 5, are examples of that. If camber is given in percent, as in Fig 4.5, column 1, we actually mean camber/chord, but we still just write camber - in most cases.

Rounding vs. **Round**: I am afraid I have used the word “rounding” wrongly in my early write-up “Arne’s Chain Calculator”, and also elsewhere. The correct word is ***round*** and it describes here the convex curve along the battens in each batten panel, to produce draught, fullnes, and in the end, camber.

Triangle and **Triangle Side**. In this chapter, in Fig 3.2 and on sheet 2 of all the master sail diagrams, they describe helping lines to simplify the lofting of the almost triangular top panels. See more about it in paragraph 5.5 in Chapter 5.

Appendix 2, (2 pages)
6. January 2023

Increasing the mast balance flexibility of the Johanna sail.

In the beginning.

The junk sail I designed for my Johanna in 2001 was given a yard angle of 70°. This was to allow me to have minimum mast balance in the sail.
In 2014, after having learned to make use of the QCAD program, I made a whole range of 'master sails', based on Johanna's sail (AR=1.87), all with 5.00m chord. The AR of these sails ranges from 1.80 to 2.25 with steps of 0.05.

The need for more mast balance.

The mast balance of the Johanna 70 sail ('70' stands for 70° yard) has to be within a range of between about 12% and 17%. This does not give much flexibility with respect to positioning the mast. My original idea with this was to reduce the tendency of the mast to distort the camber of the sail, when sailing on port tack. However, other JRA members, like **Paul Thompson**, have shown that 22% mast balance works just fine.

Therefore, lately, I have liberated myself from the 70° yard angle. As the diagram below shows, four rig versions will now cover any need for balance between 12% and 30%. For instance, a Johanna 60 sail is now propelling JRA-member **Ketil Greve**'s Kelt 8.50 in Stavanger. This is being set with 21-22% balance.

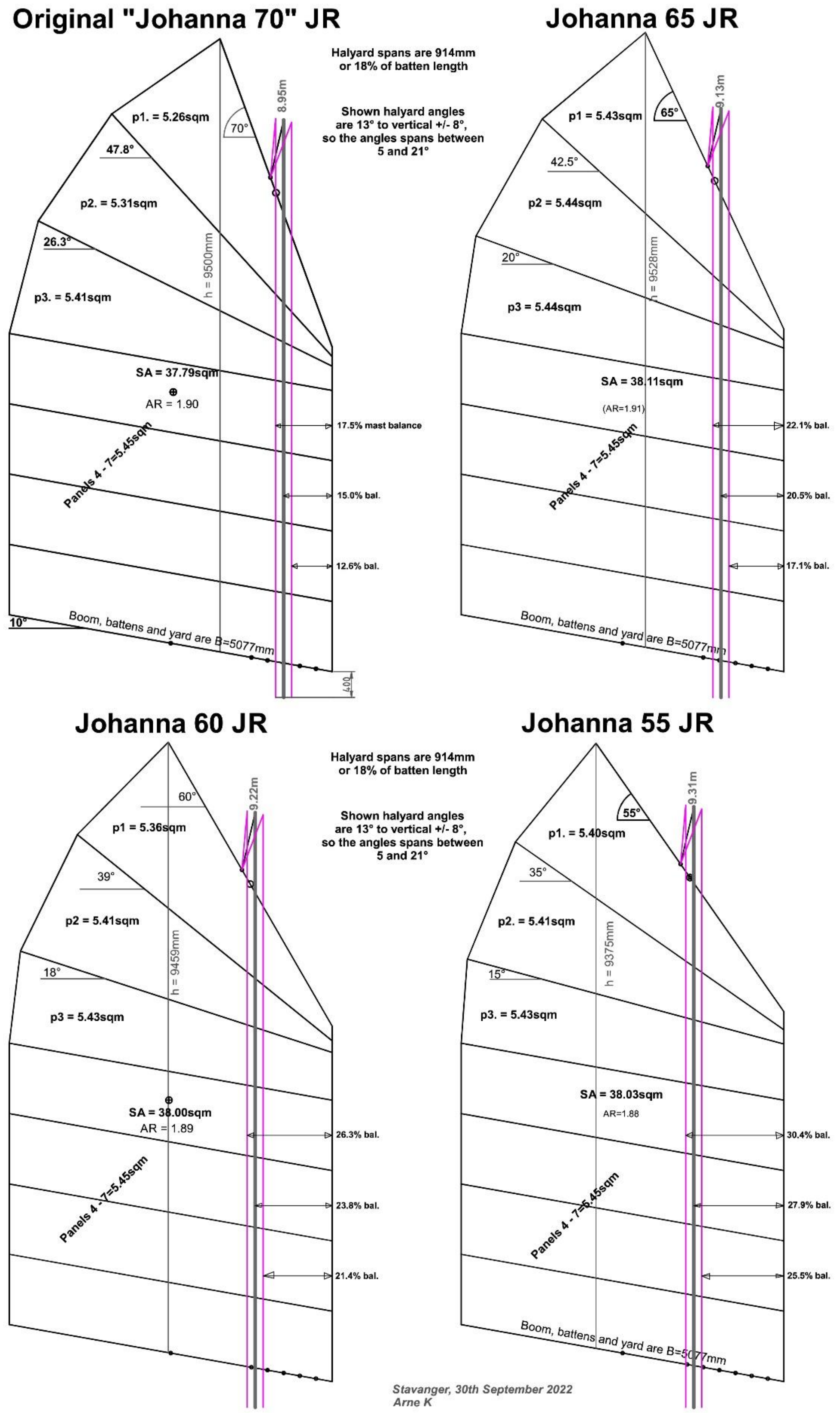
I haven't got around to making a full range of Johanna 65 and Johanna 60 master sails yet. My procedure these days when designing a rig for a boat, is to start with finding a place for the mast(s). Then I draw the boom. I know that the CE of the sail will sit directly above the mid-point of the boom (within 1% of its length), so I just use the mid point of the boom for CE.

Since the sail area, $SA = B^2 \times AR \times 0.78$, I can quickly calculate the length of boom I need to get a desired sail area. The resulting test boom on the plan will tell me the amount of mast balance the sail requires. If the number is 19%, for instance, I see that I need a Johanna 65 sail.

If I already have a master sail with the appropriate AR and yard angle, I just choose that one, and scale it up or down to the correct size.
If I don't have that particular master sail in my library, I make one. I do so by scalping the three top panel off the Johanna 70 master sail and building up three new panels (each about same area as the lower panels). This way, I am now free to vary the mast balance over a wider range.

Johanna 55?

I still have yet to try the shown Johanna 55 sails in practice. I hesitate to give a sail more than 25% mast balance until it has been tried on a small boat first. However, a Johanna 55 sail with, say, 28% balance would be very desirable (if it works) on really big sails. The increased balance would offload the battens a good deal, and the sheet loads would be much lighter as well. That would be fun - to be able to control a 100sqm sail...



(..the CAD-generated Johanna 70 Master Sails start on next page...)

Arne’s Johanna-style master sailplans

Comment to version 20170513 of master sailplans.

These plans are the same as the original from 2014. I have just added a bit more info on it, like the “5%-dots” on the boom and 50 plus 55% dots at the yard.

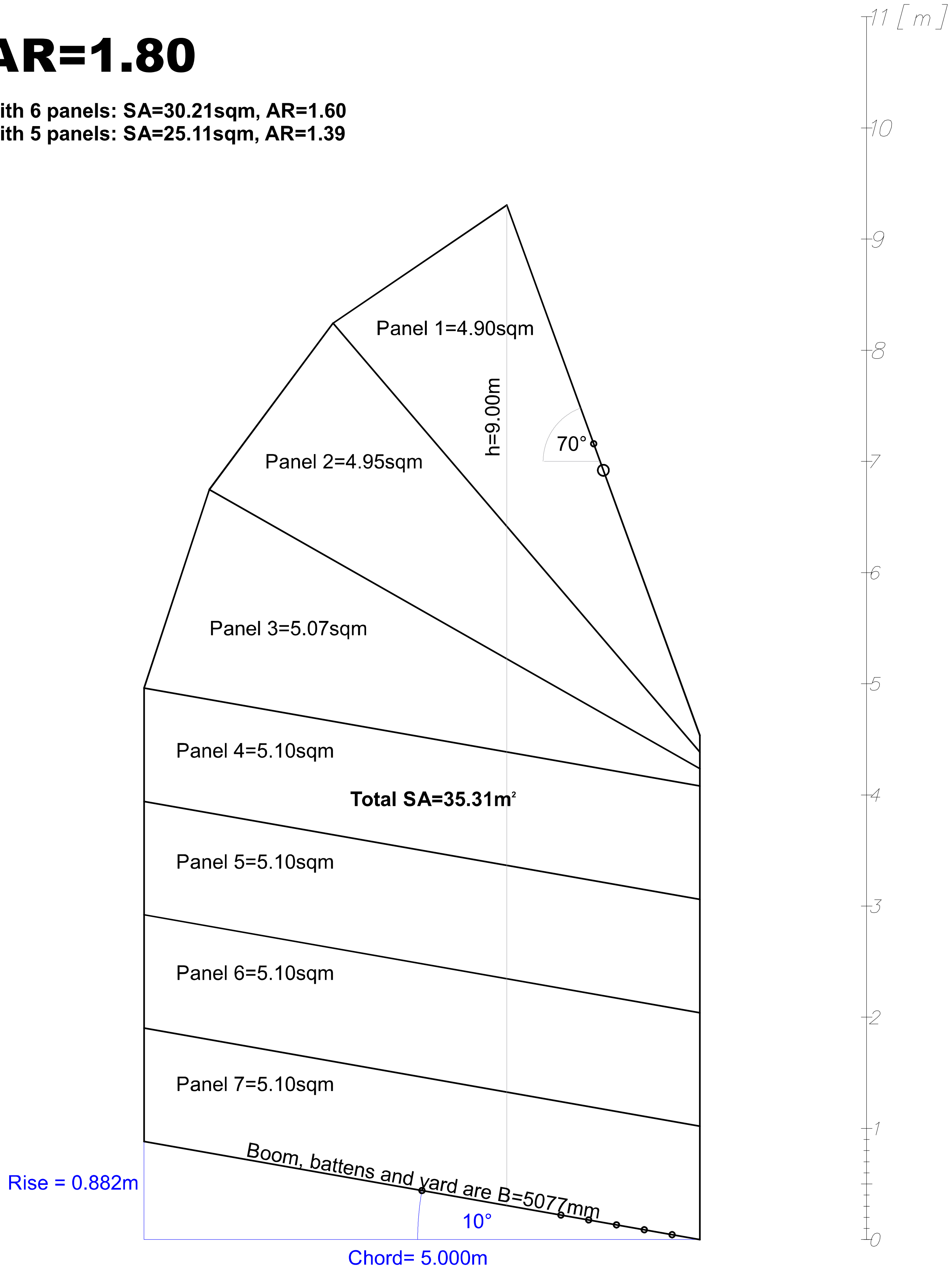
I addition I have shown, in the upper left corner of the *Sheet 1* how the sail would be if one add or subtract a panel or two.

Stavanger, 13.5.2017

Arne Kverneland

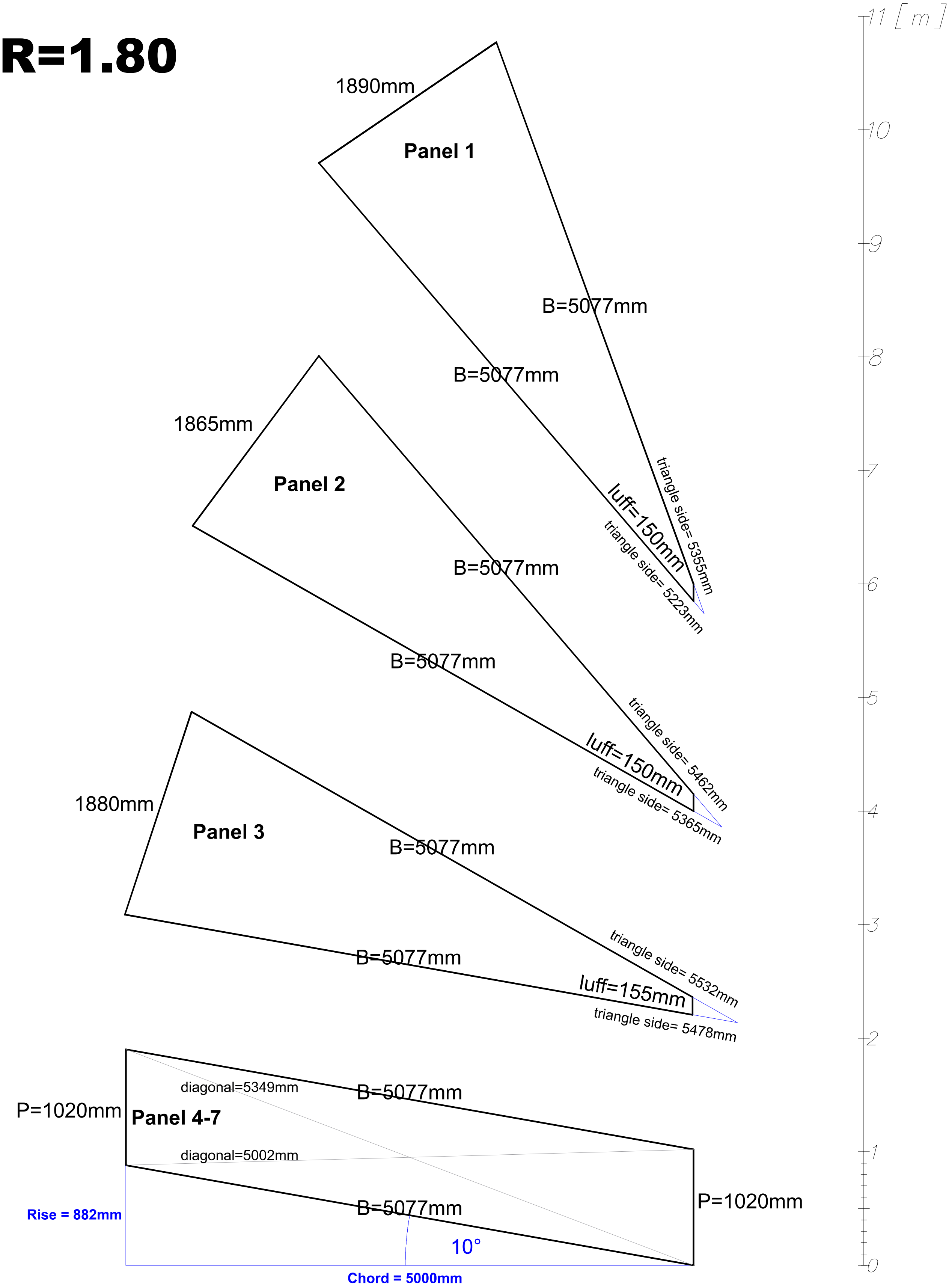
AR=1.80

With 6 panels: SA=30.21sqm, AR=1.60
With 5 panels: SA=25.11sqm, AR=1.39



Master sail, AR=1.80, h=9.0m SA=35.31sqm
Sheet 1 10.2.2014, Arne Kverneland

AR=1.80



Master sail, AR=1.80, h=9.0m

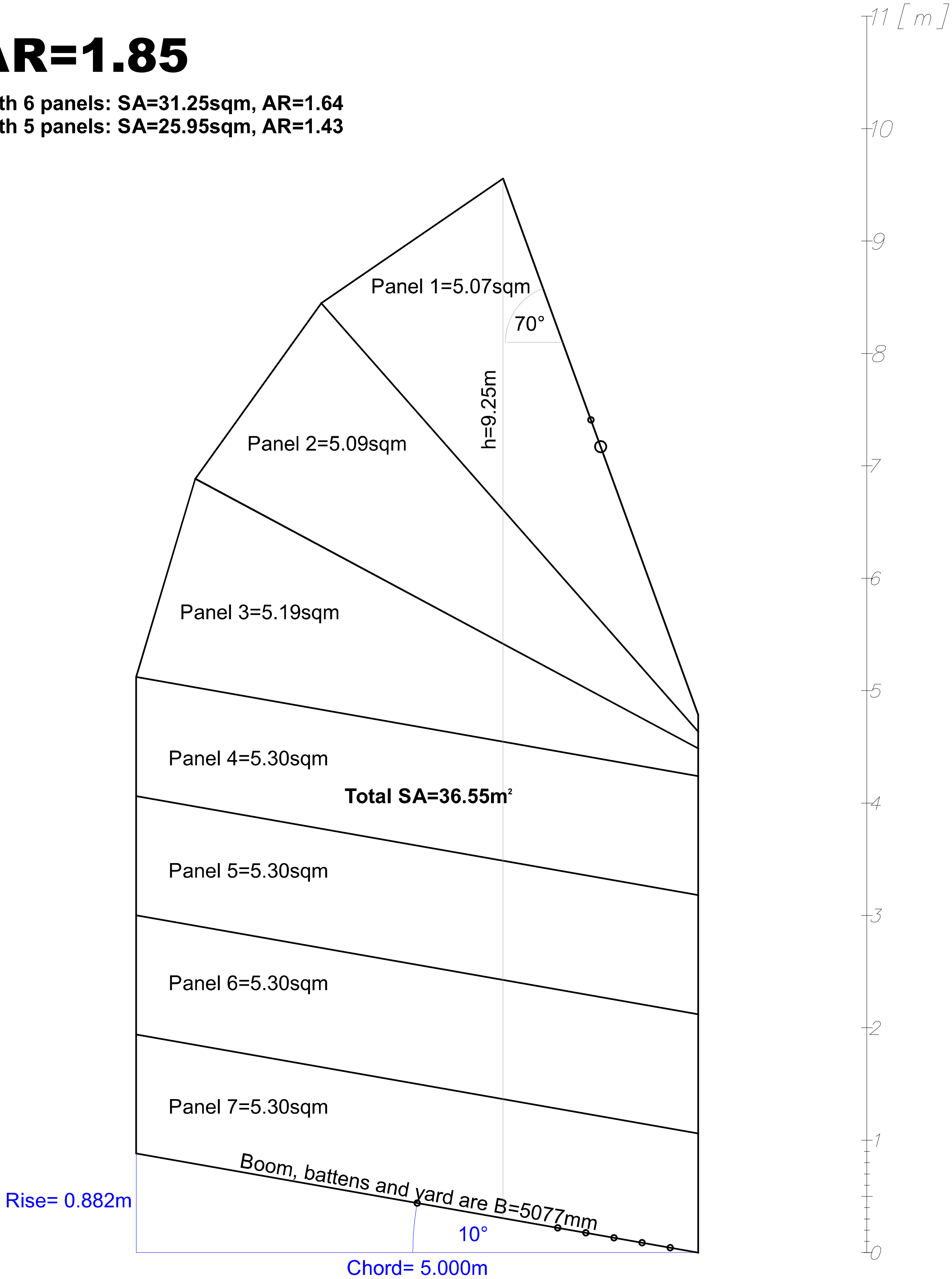
SA=35.31sqm

Sheet 2

10.2.2014, Arne Kverneland

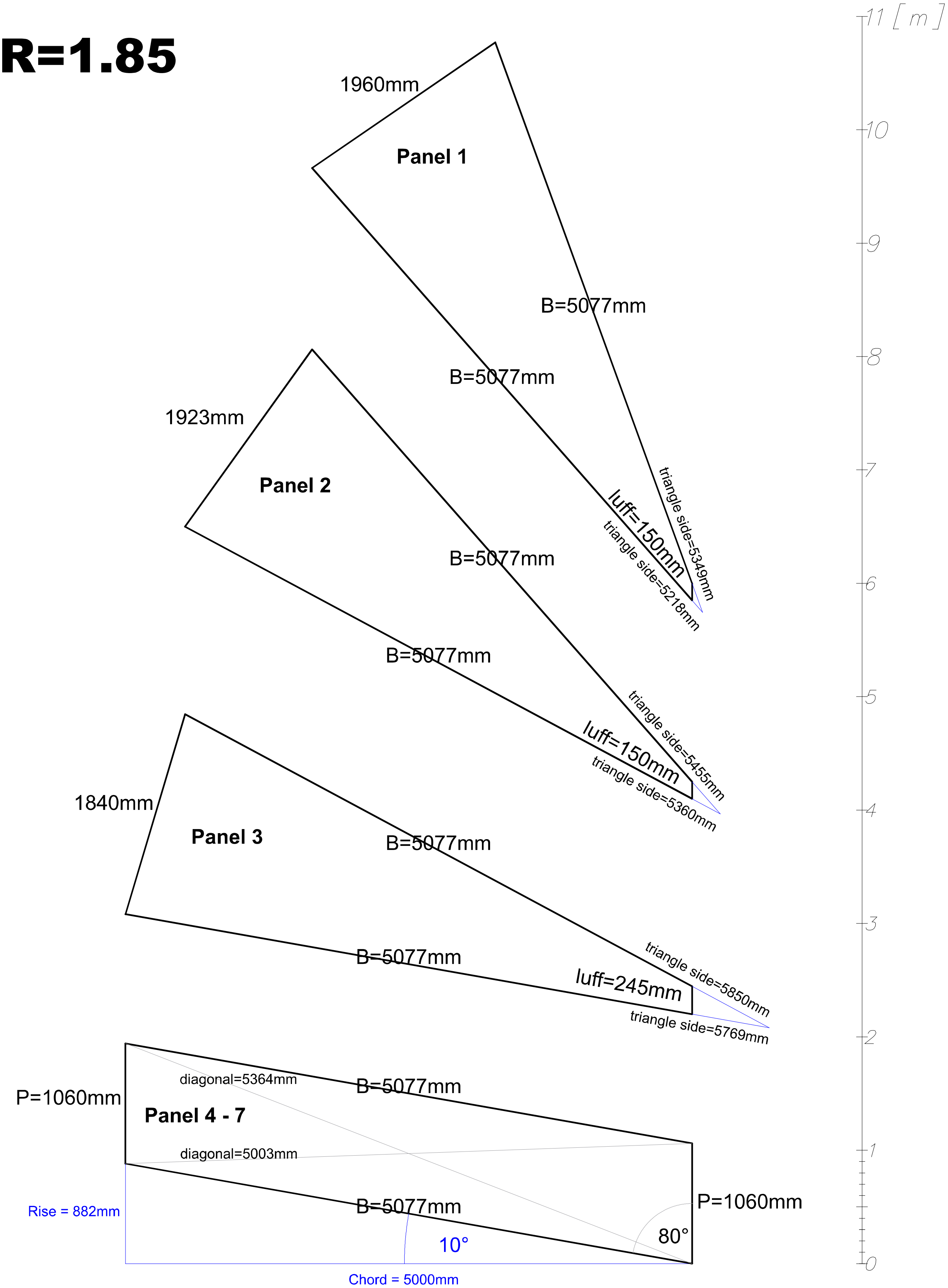
AR=1.85

With 6 panels: SA=31.25sqm, AR=1.64
With 5 panels: SA=25.95sqm, AR=1.43



Master sail, AR=1.85, h=9.25m SA=36.55sqm
Sheet 1 10.2.2014, Arne Kverneland

AR=1.85



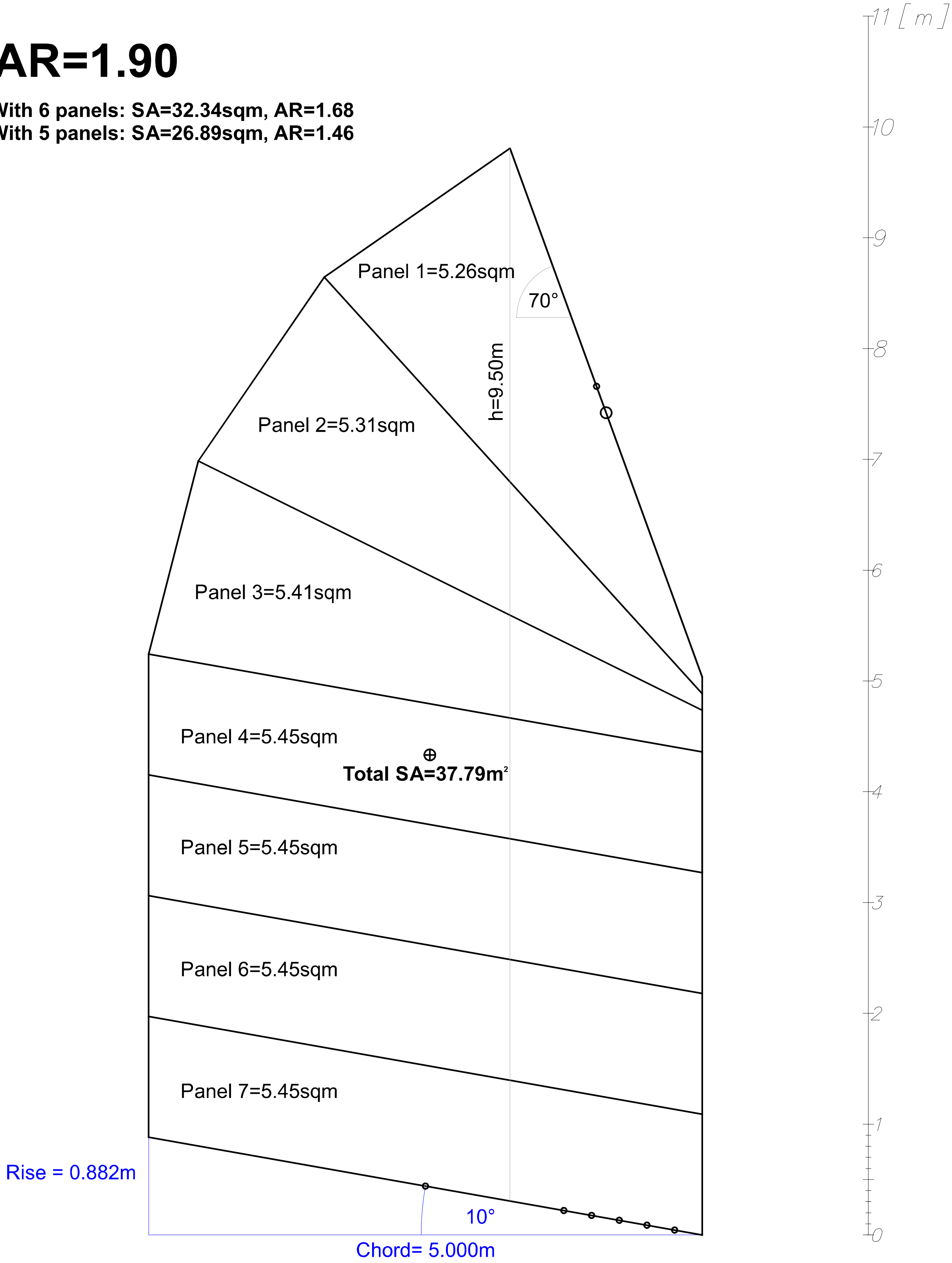
Master sail, AR=1.85, h=9.25m
SA=36.55sqm

Sheet 2

10.2.2014, Arne Kverneland

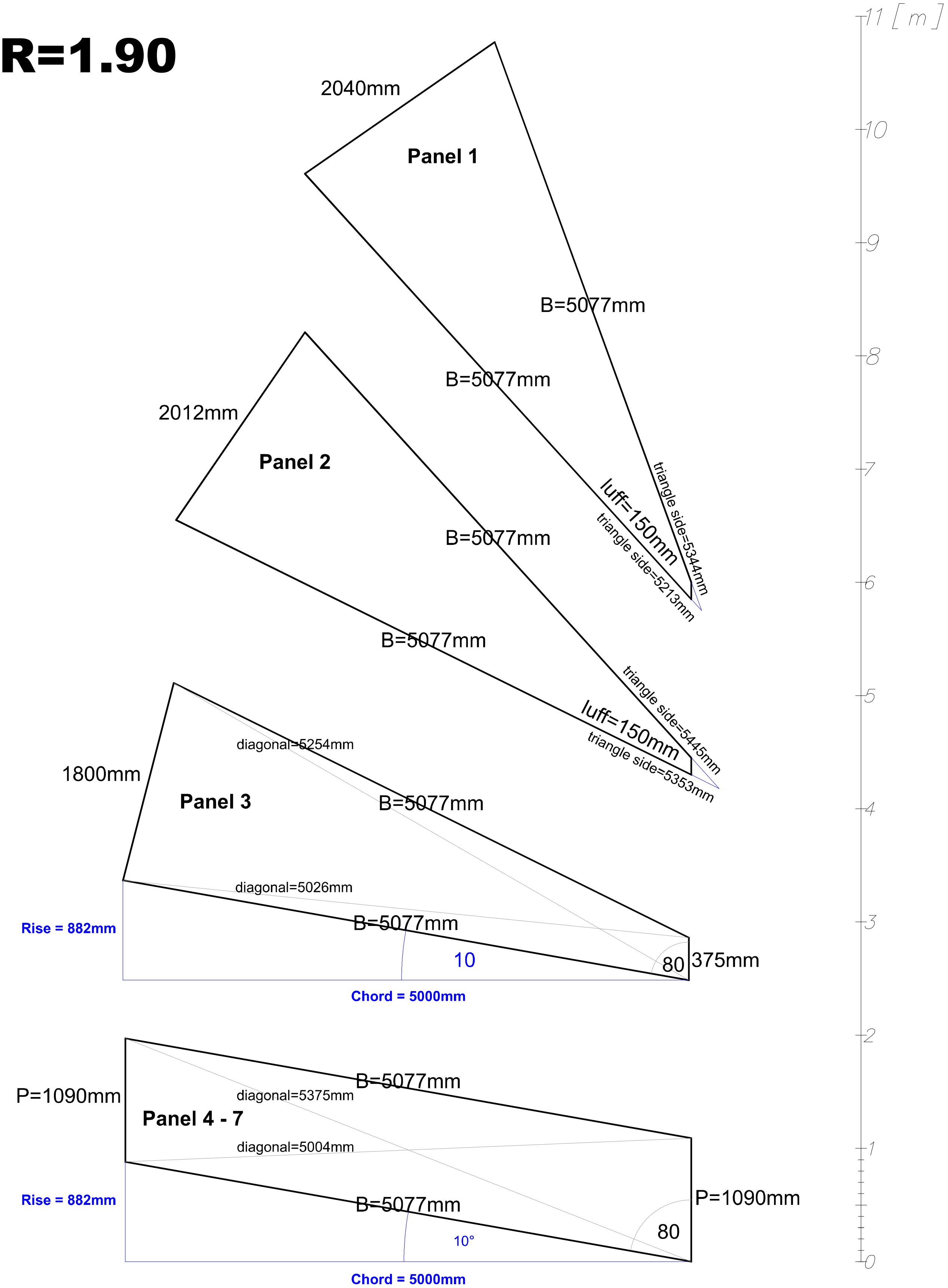
AR=1.90

With 6 panels: SA=32.34sqm, AR=1.68
With 5 panels: SA=26.89sqm, AR=1.46



Master sail, AR=1.90, h=9.50m SA=37.79sqm
Sheet 1 10.2.2014, Arne Kverneland

AR=1.90



Master sail, AR=1.90, h=9.50m

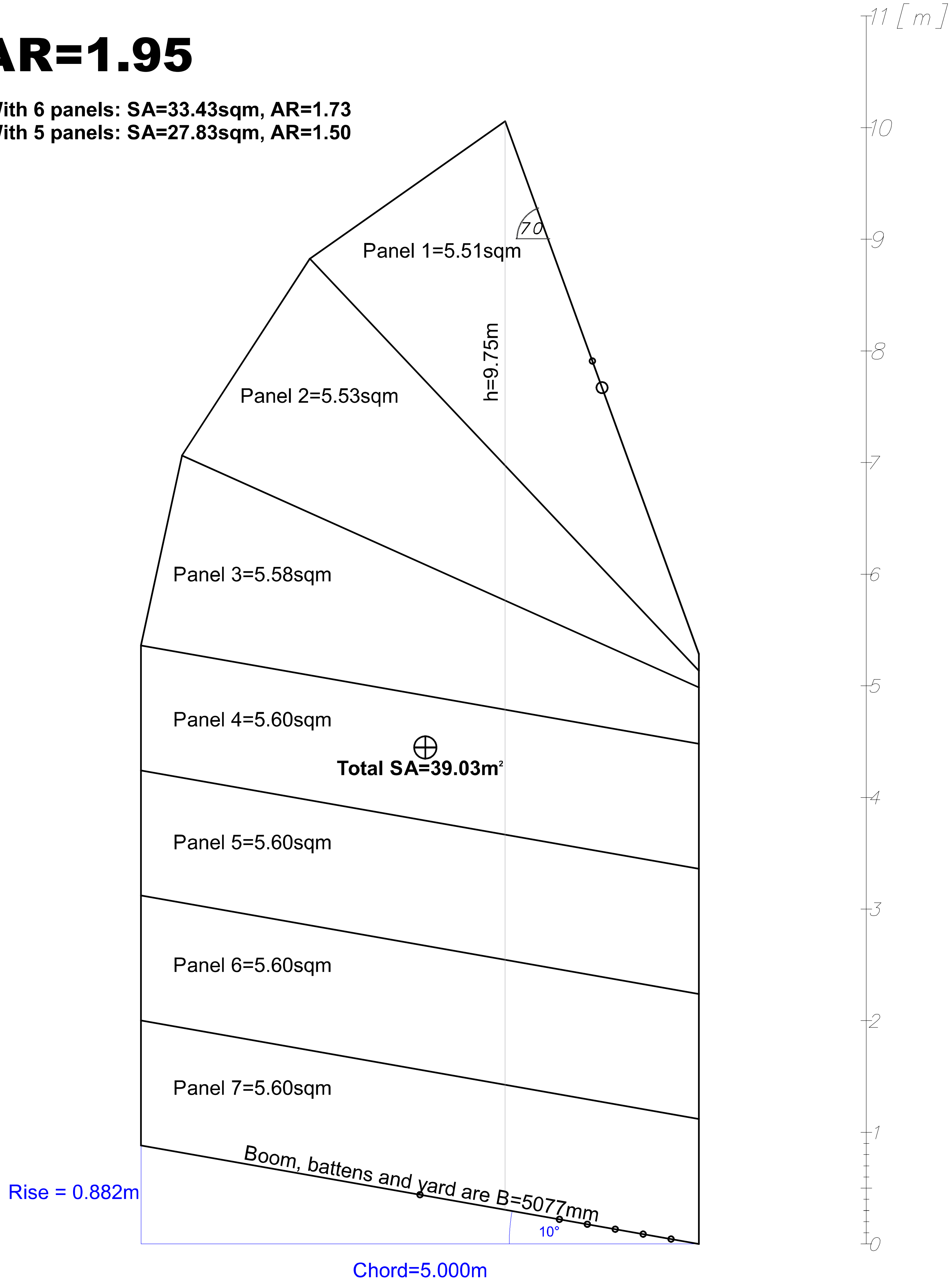
SA=37.79sqm

Sheet 2

10.2.2014, Arne Kverneland

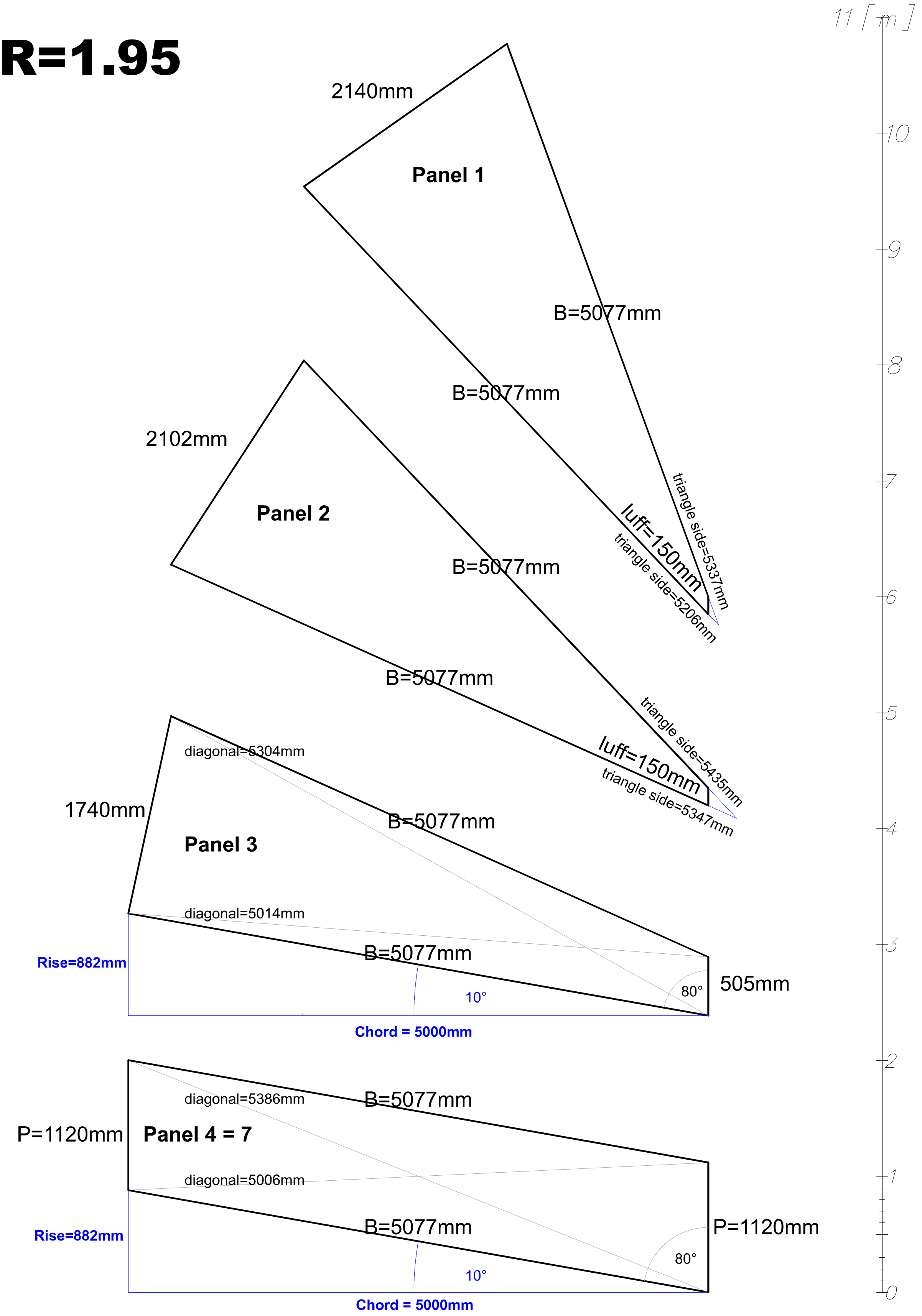
AR=1.95

With 6 panels: SA=33.43sqm, AR=1.73
With 5 panels: SA=27.83sqm, AR=1.50



Master sail, AR=1.95, h=9.75m SA=39.03sqm	
Sheet 1 10.2.2014, Arne Kverneland	

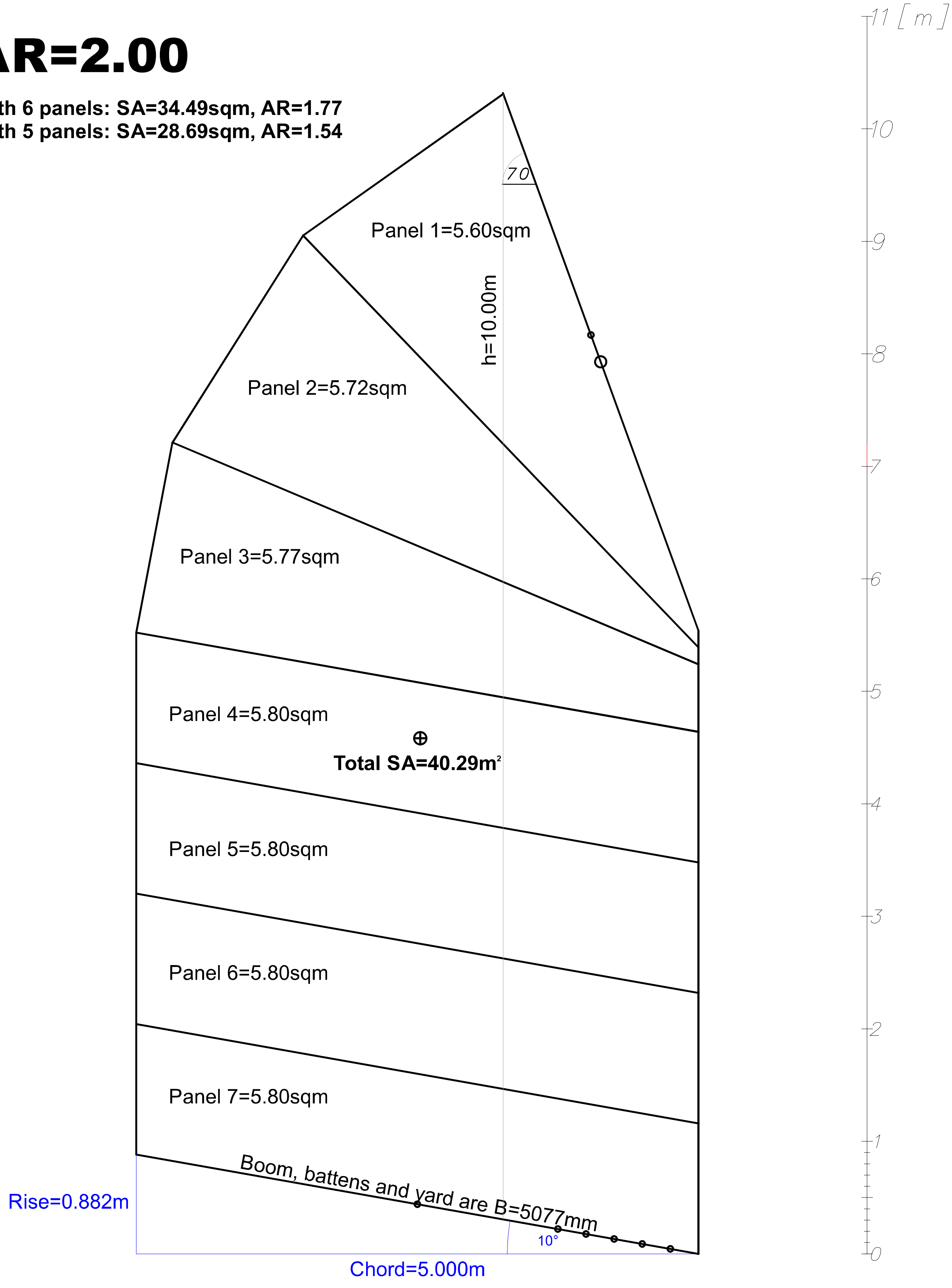
AR=1.95



Master sail, AR=1.95, h=9.75m SA=39.03sqm
Sheet 2
10.2.2014, Arne Kverneland

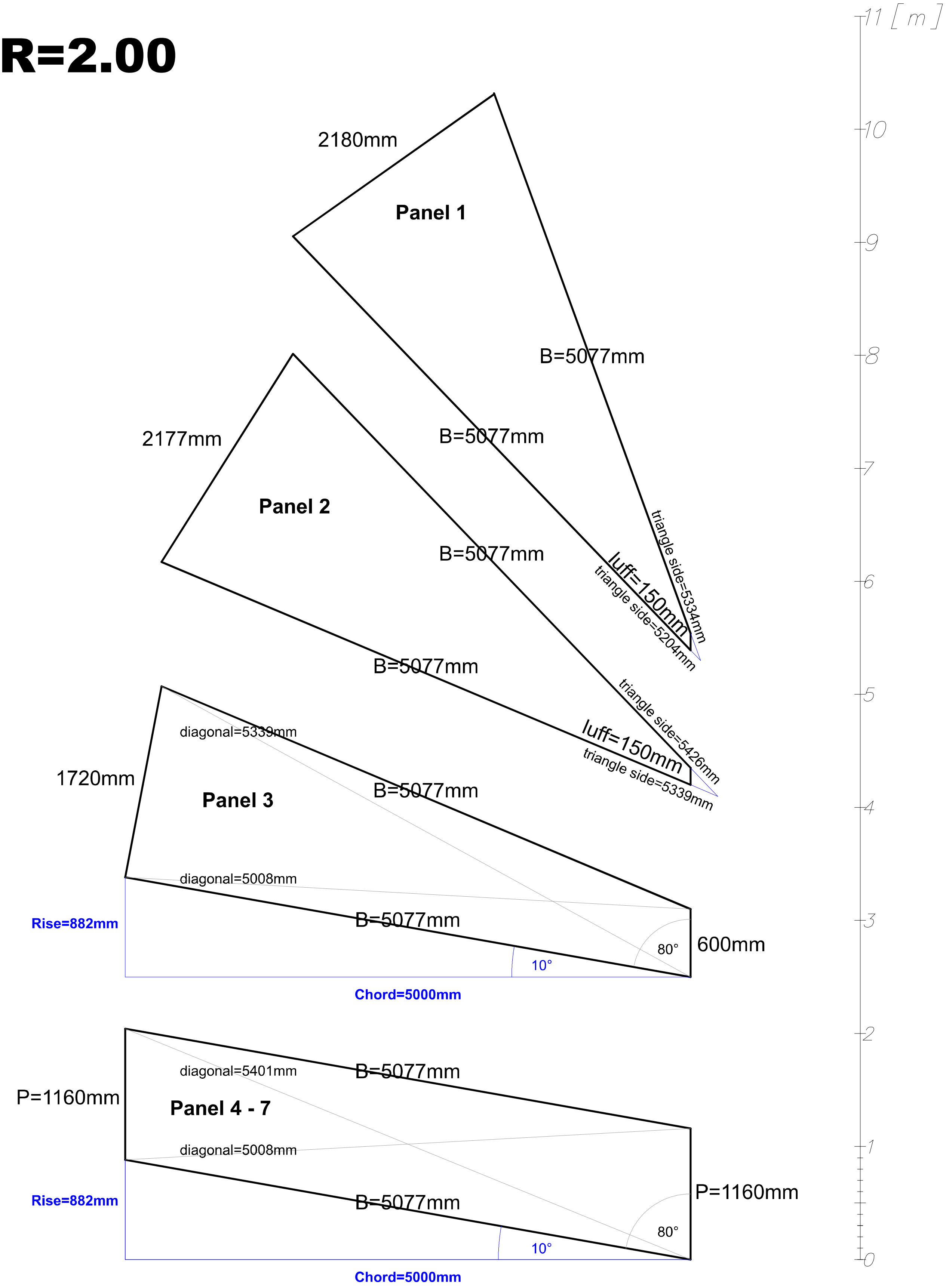
AR=2.00

With 6 panels: SA=34.49sqm, AR=1.77
With 5 panels: SA=28.69sqm, AR=1.54



Master sail, AR=2.00, h= 10.00m SA=40.29sqm
Sheet 1 10.2.2014, Arne Kverneland

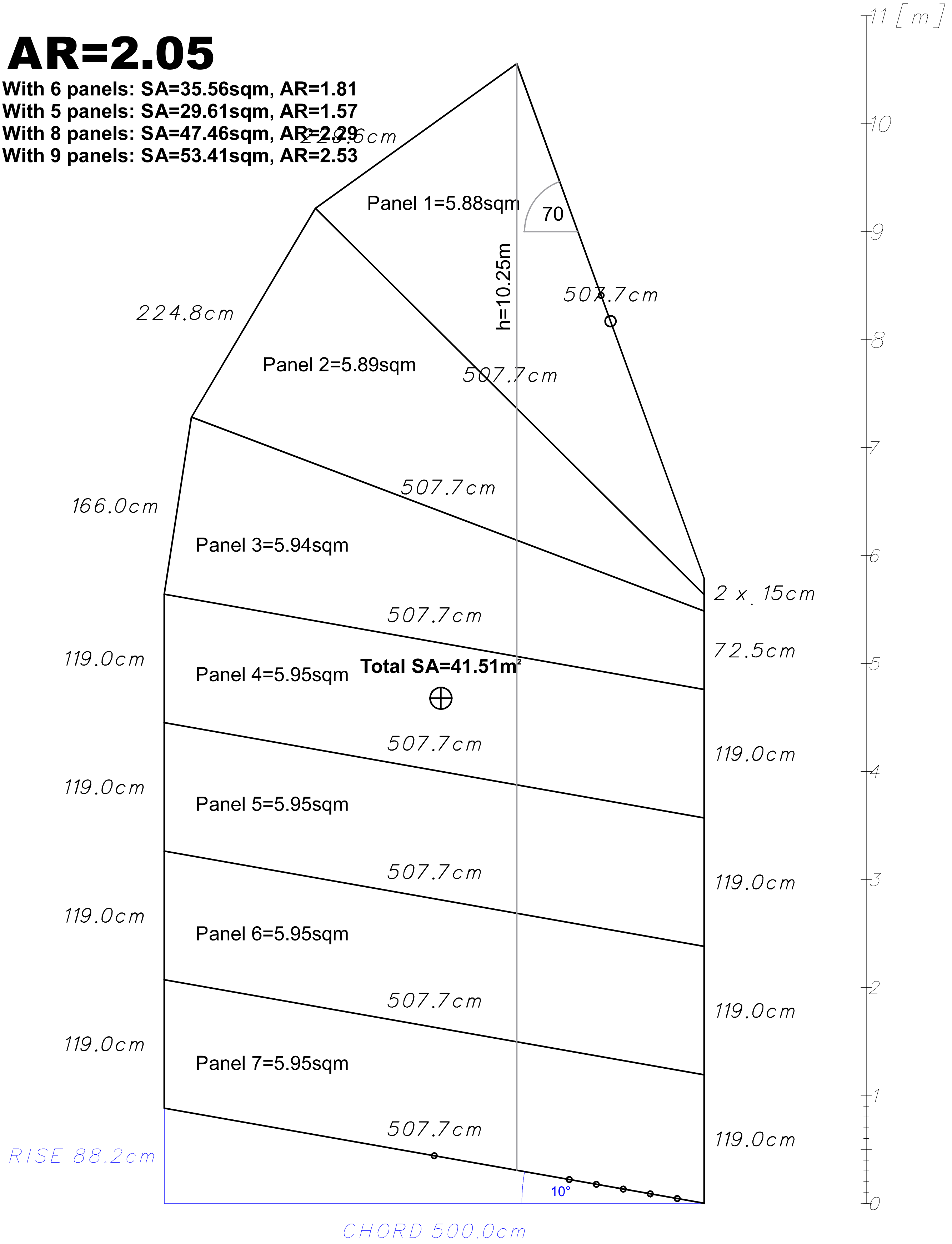
AR=2.00



Master sail, AR=2.00, h= 10.00m SA=40.29sqm
Sheet 2 10.2.2014, Arne Kverneland

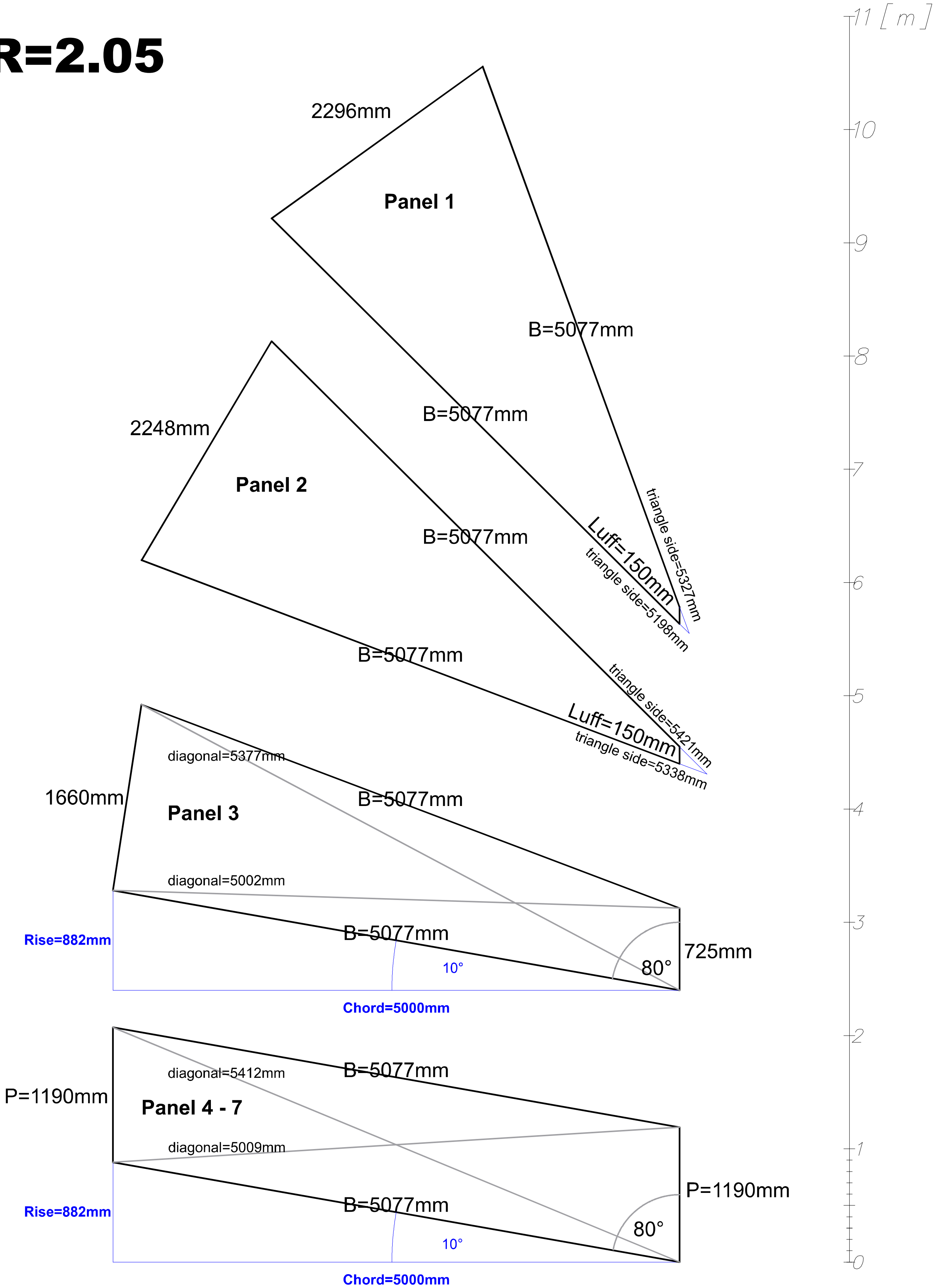
AR=2.05

With 6 panels: SA=35.56sqm, AR=1.81
With 5 panels: SA=29.61sqm, AR=1.57
With 8 panels: SA=47.46sqm, AR=2.29
With 9 panels: SA=53.41sqm, AR=2.53



Master sail, AR=2.05, h=10.25 SA=41.51sqm
Sheet 1 10.2.2014, Arne Kverneland

AR=2.05

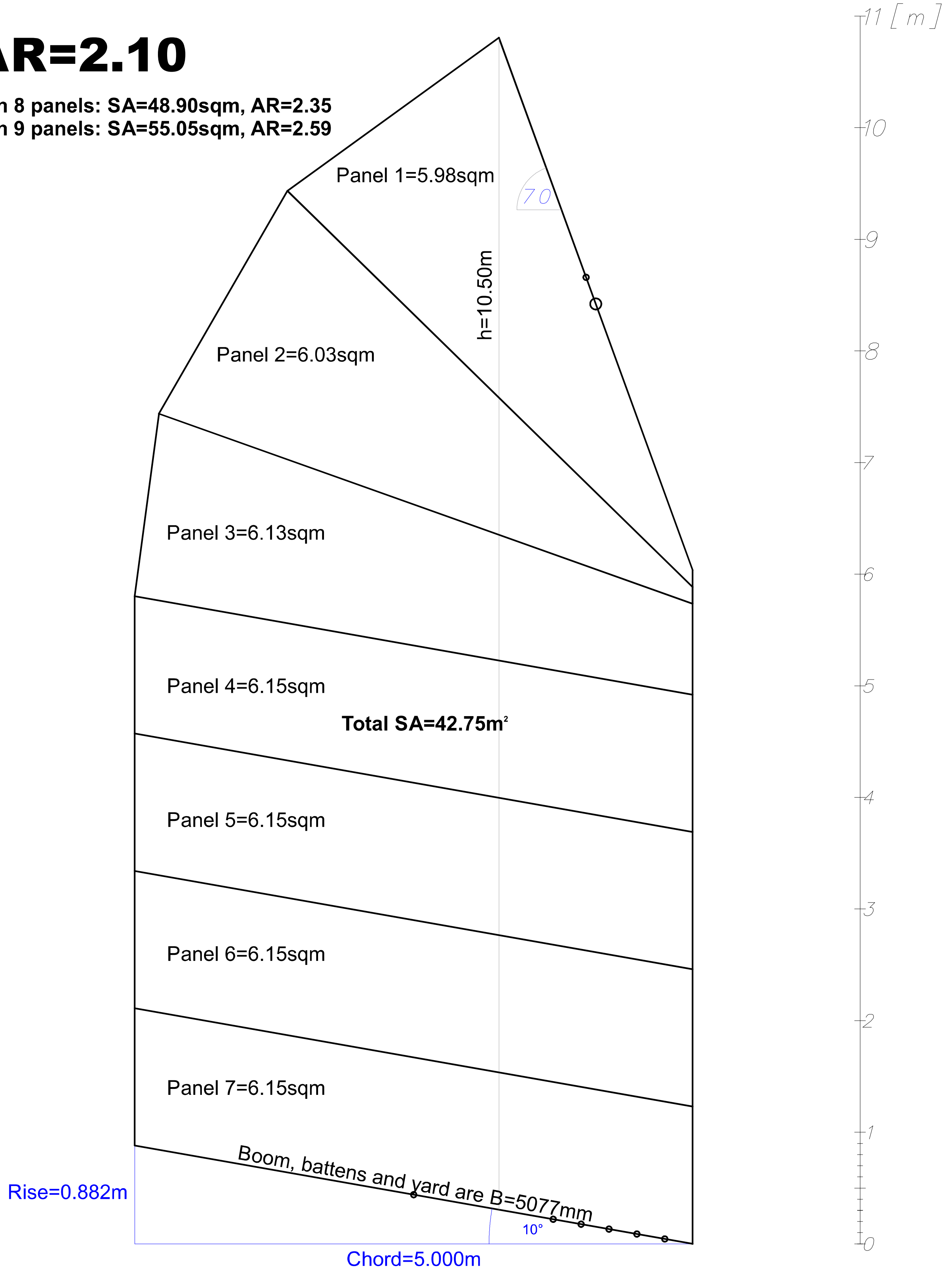


Master sail, AR=2.05, h=10.25
SA=41.51sqm

Sheet 2
10.2.2014, Arne Kverneland

AR=2.10

With 8 panels: SA=48.90sqm, AR=2.35
With 9 panels: SA=55.05sqm, AR=2.59

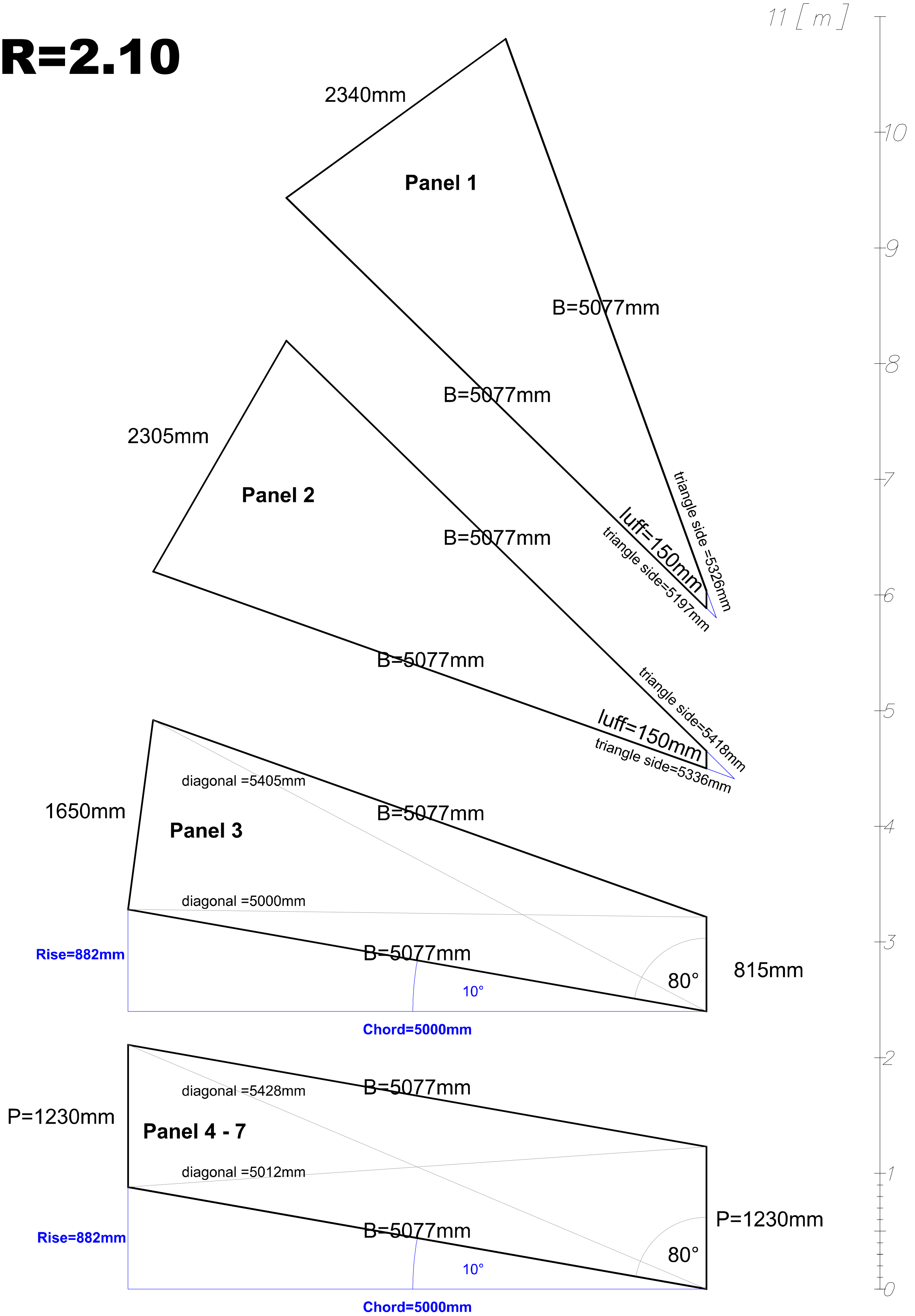


Master sail, AR=2.10, h=10.5m
SA=42.75sqm

Sheet 1

27.02.2014, Arne Kverneland

AR=2.10



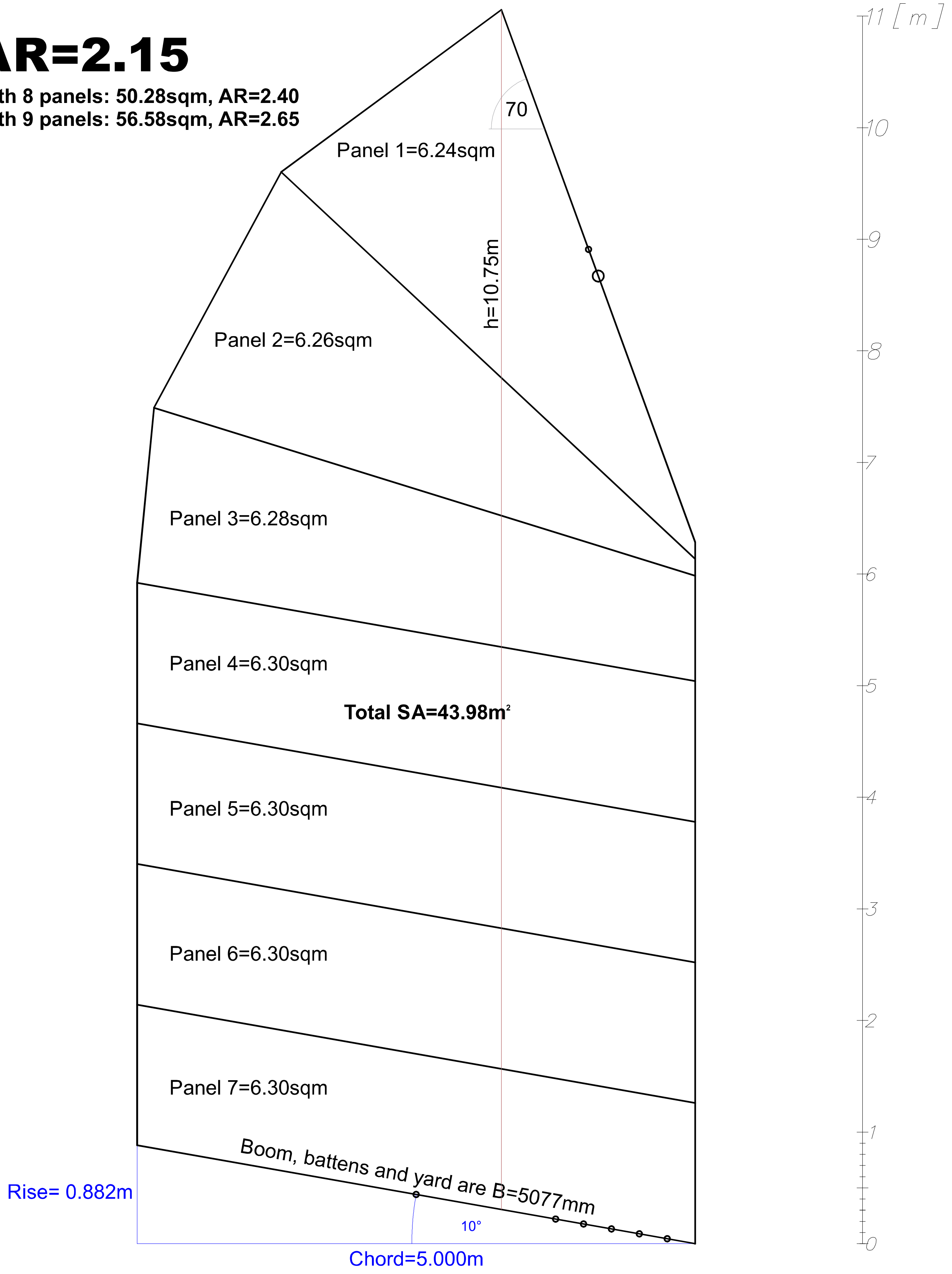
Master sail, AR=2.10, h=10.5m
SA=42.75sqm

Sheet 2

27.02.2014, Arne Kverneland

AR=2.15

With 8 panels: 50.28sqm, AR=2.40
With 9 panels: 56.58sqm, AR=2.65

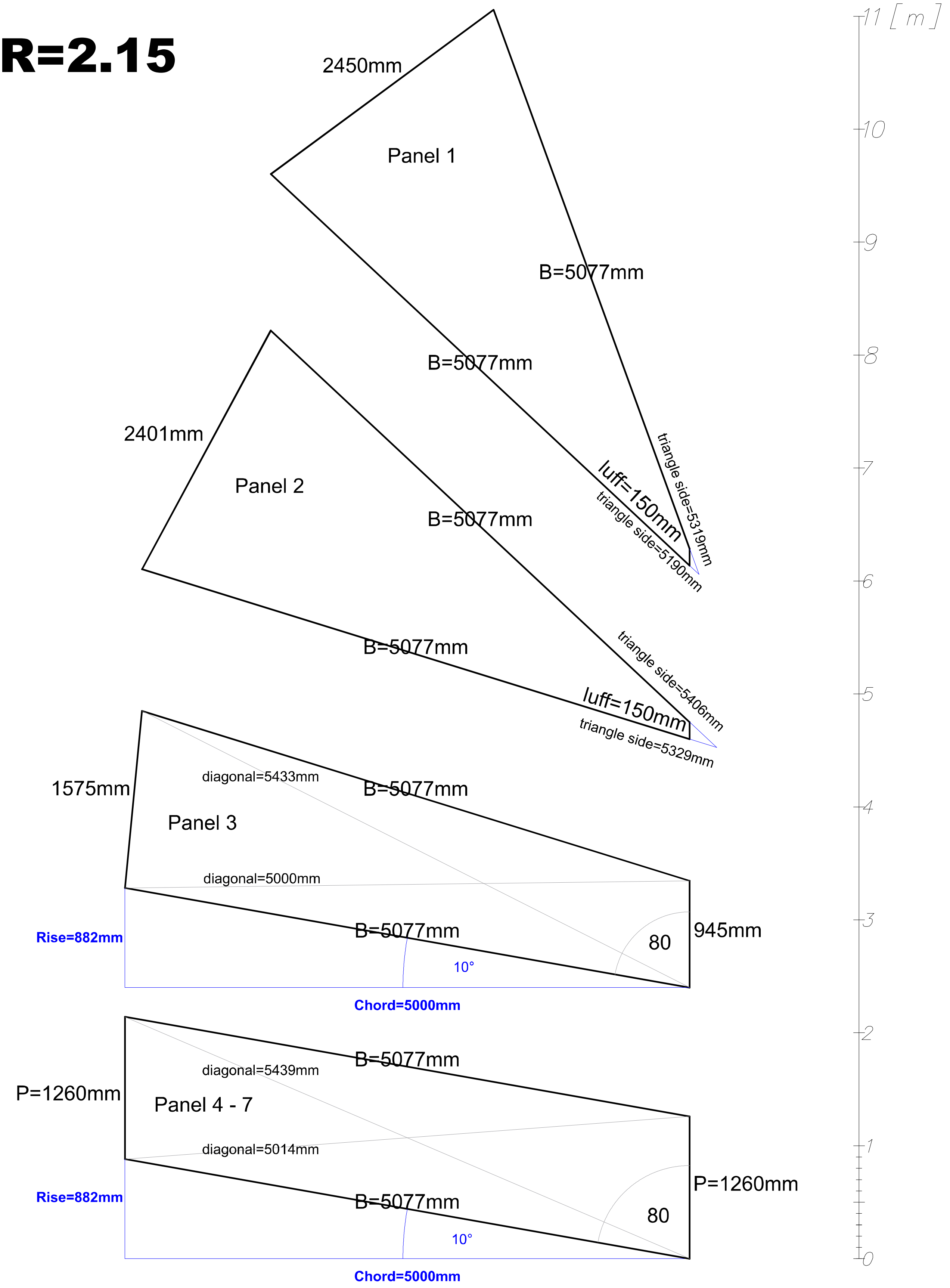


Master sail, AR=2.15, h =9.75m
SA=43.98sqm

Sheet 1

10.2.2014, Arne Kverneland

AR=2.15



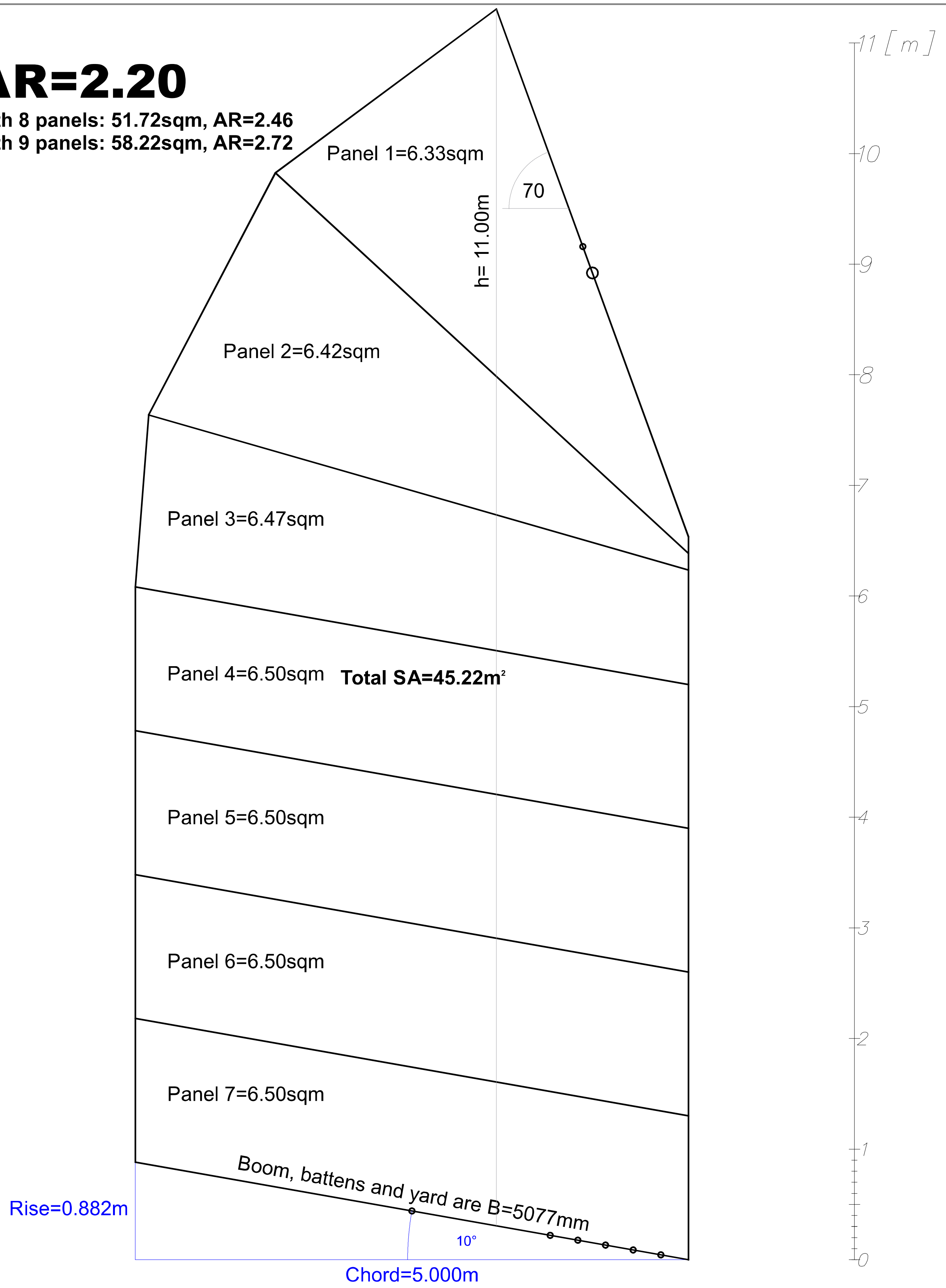
Master sail, AR=2.15, h =9.75m
SA=43.98sqm

Sheet 2

10.2.2014, Arne Kverneland

AR=2.20

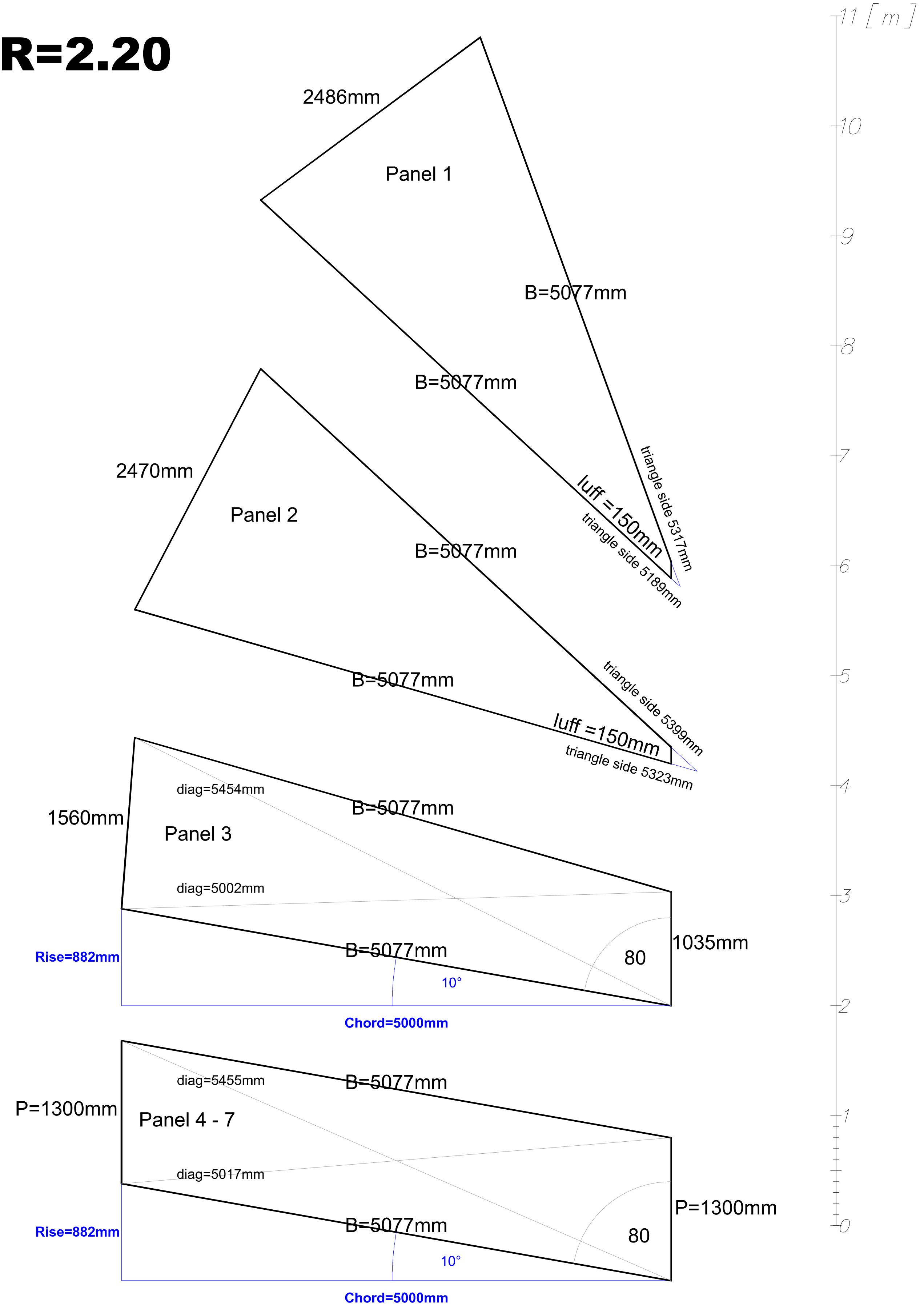
With 8 panels: 51.72sqm, AR=2.46
With 9 panels: 58.22sqm, AR=2.72



Master sail, AR=2.20, h=11.00m
SA=45.22sqm

Sheet 1
10.2.2014, Arne Kverneland

AR=2.20

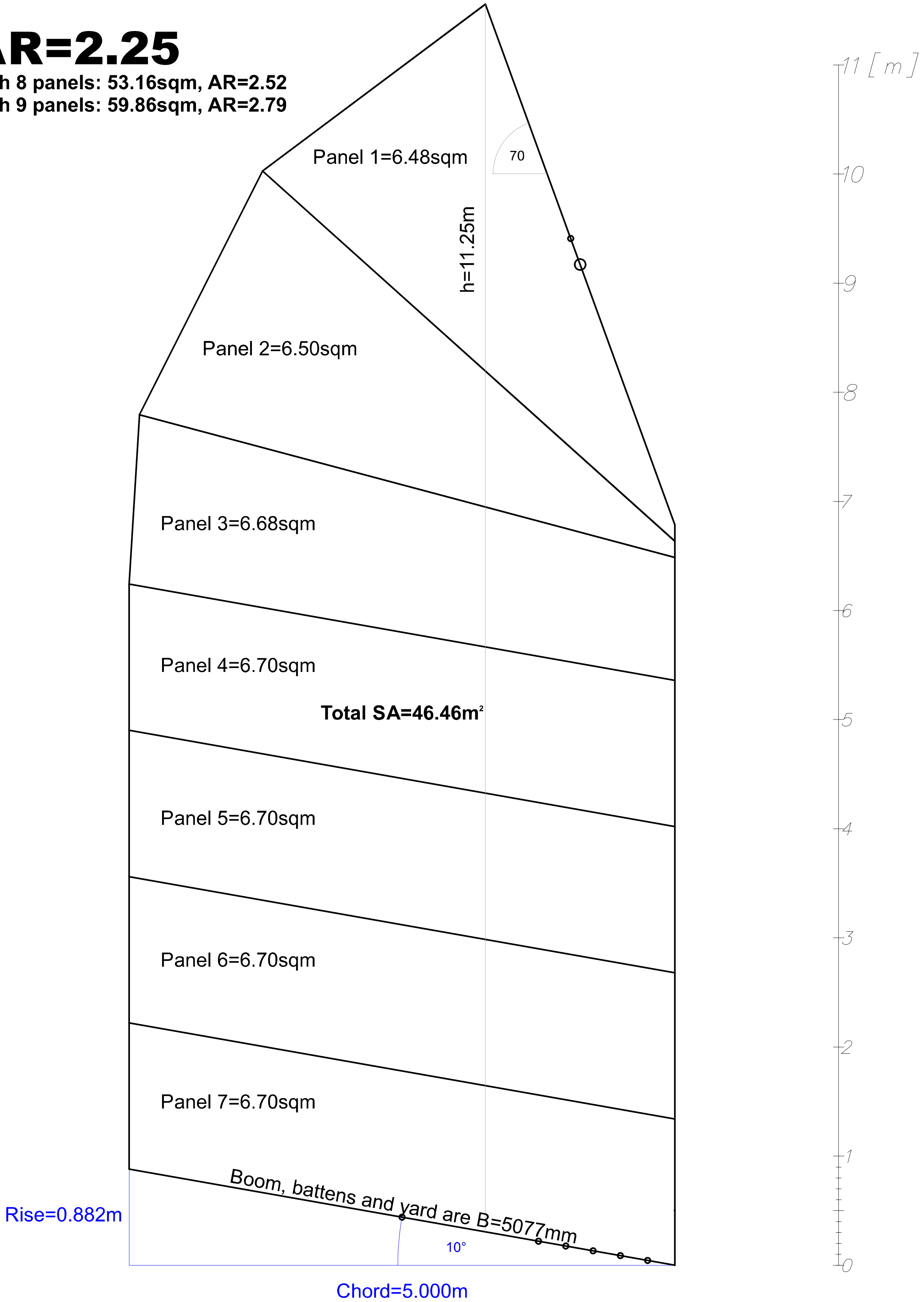


Master sail, AR=2.20, h=11.00m
SA=45.22sqm

Sheet 2
10.2.2014, Arne Kverneland

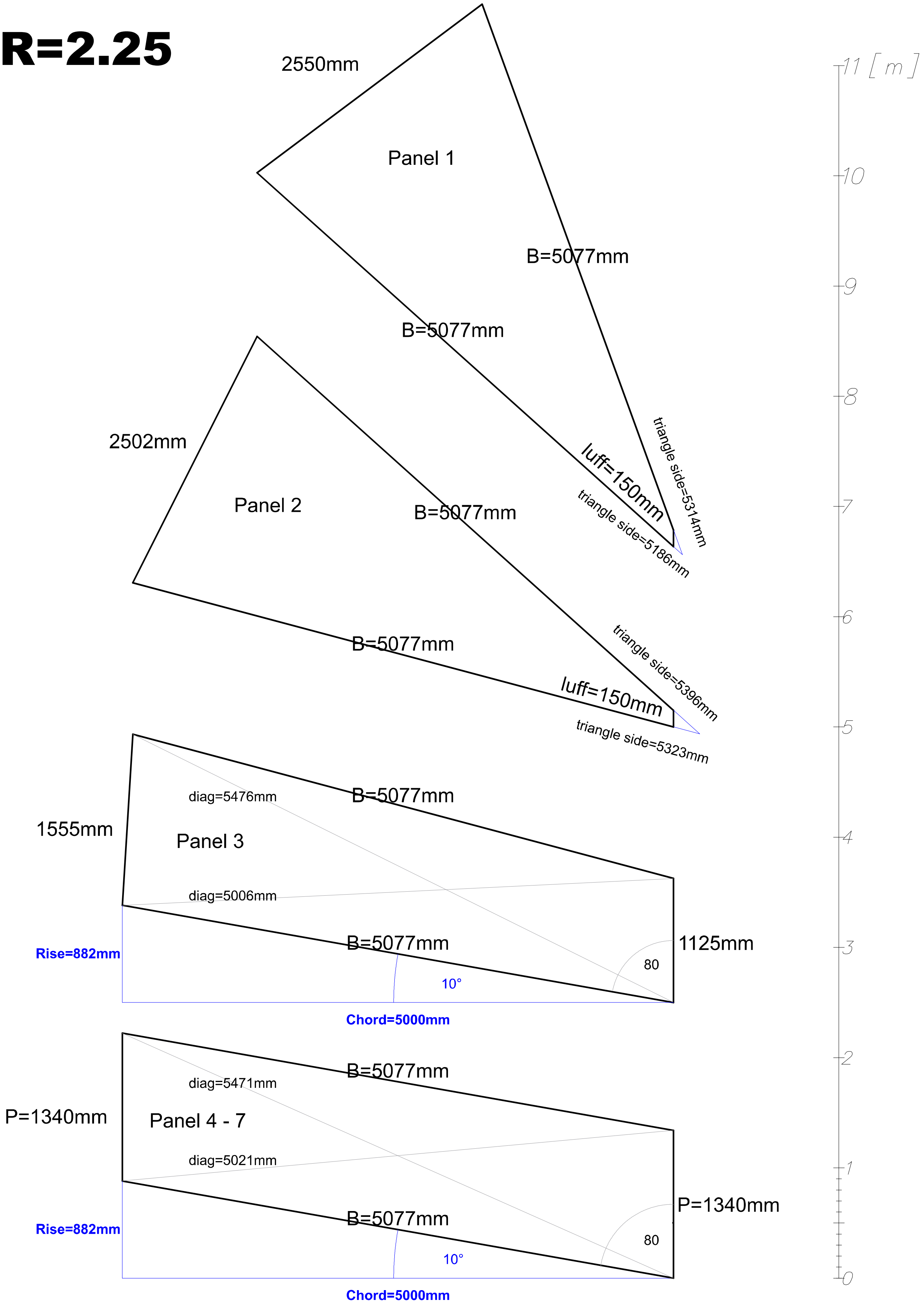
AR=2.25

With 8 panels: 53.16sqm, AR=2.52
With 9 panels: 59.86sqm, AR=2.79



Master sail, AR=2.25, h=11.25m SA=46.46sqm
Sheet 1 10.2.2014, Arne Kverneland

AR=2.25



Master sail, AR=2.25, h=11.25m
SA=46.46sqm

Sheet 2

10.2.2014, Arne Kverneland