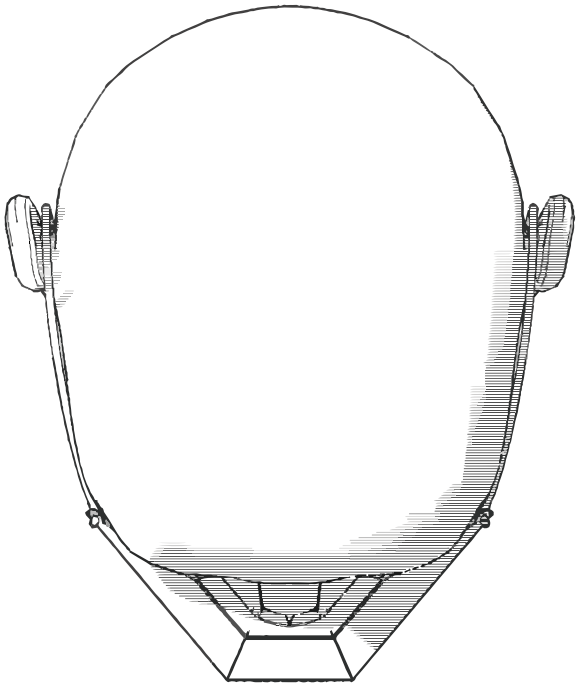

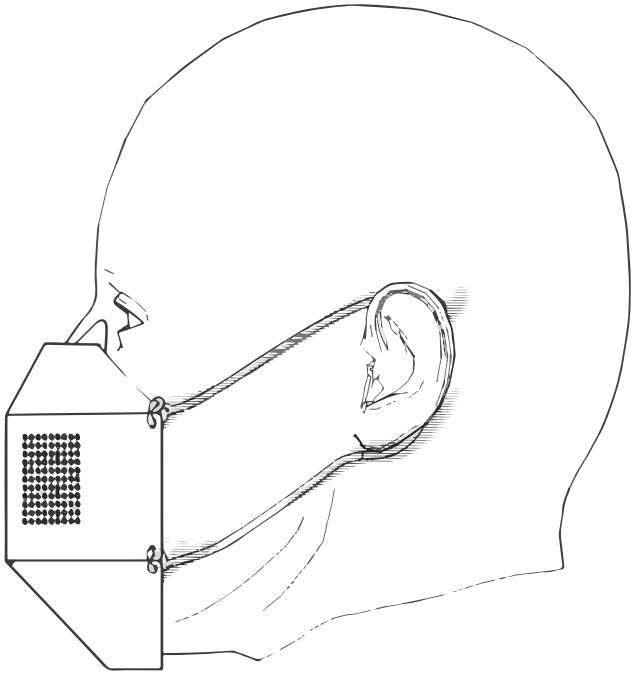

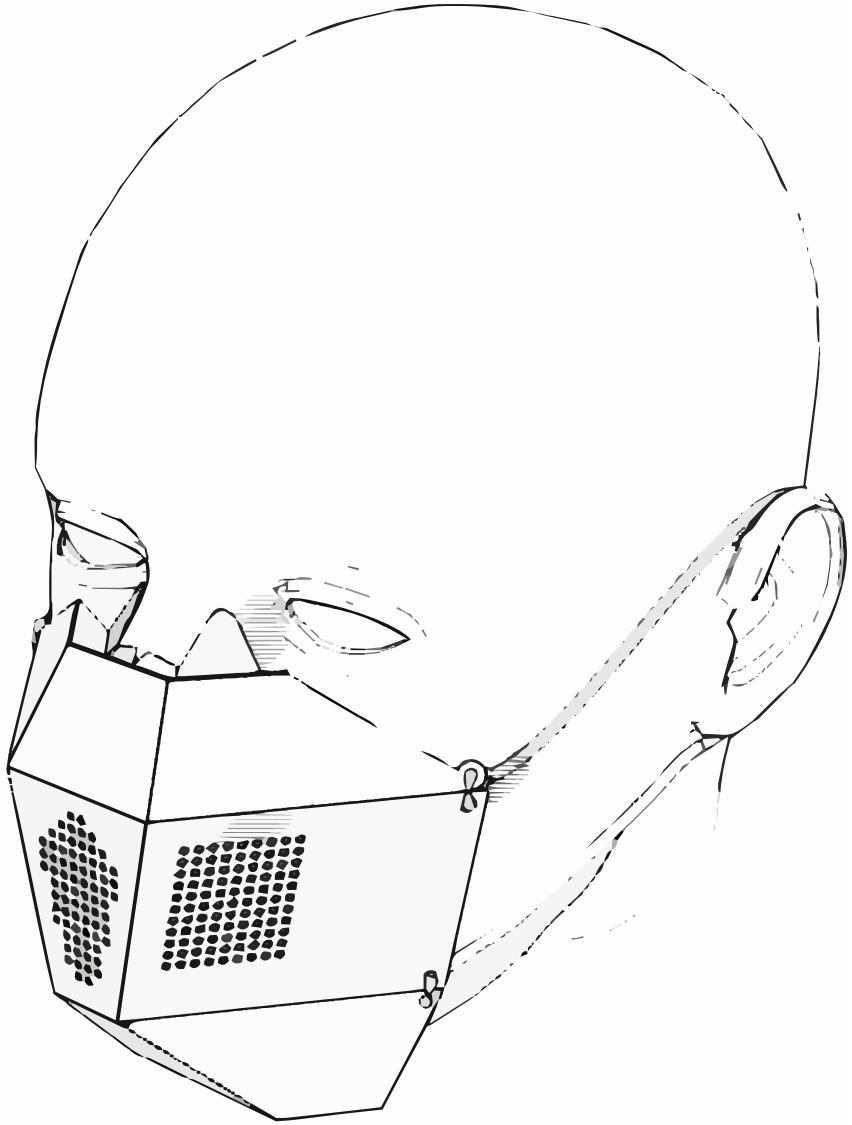

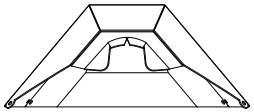

PaperMake: DIY Half-Face Mask

Version Number: v7.2
Date: 29th March 2020

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⚠ WARNING

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3. Wearing a validated mask, practice social distancing and proper hygiene like washing your hands with soap and not touching your faces are the preferred protection methods so far.

Design Motivation

On 25th March 2020, the Covid-19 pandemic had already struck the world hard. With severe shortages of surgical masks around the world, people turn to interesting innovations in a bid to minimize exposure to the virus particles which are naked to our eyes. The most promising designs were 100% layered cotton fabric which were sewn with/without slit as well as an optional nose bridge. With amazing people pooling together resources to sew and cut pieces of fabric together, that brings me to ponder about those who fall through the cracks and do not have access to such fabrics, sewing machines, 3D printers or lasercutters.

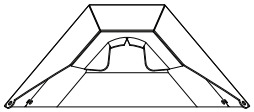
As a design engineer, maker and papercraft enthusiast, I decided to explore and challenge myself on the possibility to design a functional mask that could be printed in an A4 sheet of paper, cut and folded into a reasonably functioning mask which could potentially provide users with some sort of protection or containment from large droplets. This design would hopefully give accessibility to those in desperate need of some sort of temporary (but still unvalidated) protection.

Functional Requirements

a. Prevent large particles expelled by wearer when you are ill, from reaching the environment[1]
b. Used as physical barrier to protect user from large droplets[1]
c. Modular in nature (i.e. user chooses the material for the mask and filter as per material that is available or to alter the parts' protection capabilities, robustness and durability)
d. Usage of household objectives which are easily available and cheap
e. Flat-packed and able to be mass produced via stamping/lasercutting/cutting

Side Notes

- No one should be gaining montetary benefits from selling this design for commercial gains.
- Designs were tested mainly on a 0.3mm cardstock (refer to page 3)
- The olson mask design is probably much easier to be made and assembled out of sheets as the cutting is directly at the center
- As date of publication, I have found 2-3 independent designers who have the similar intentions. Paul De Graaf, a full-time paper engineer made an olson mask which has most potential so far (from my perspective). This article layout was inspired by his presentation format.
- Further improvements (e.g. collapsable design, different sizes, diffferent geometries etc.) assembly instructions and updates will be available at www.planarworks.com and Instructables.



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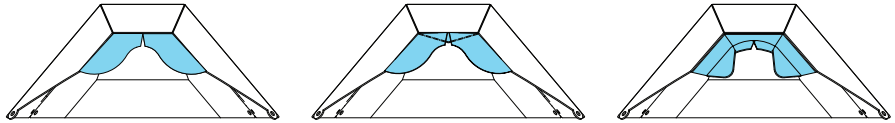
Design Challenge: Creating a Good Seal



One of the key challenges in the design of the mask is to achieve good air seal around the face. Also a design that is able to conform to various facial features. Some key areas that gave a good challenge were areas around the nose bridge as well as a the sides. A total of more than 17 prototypes were made. Designs were experimented using negative/positive pressure test by inhalation and exhalation.

A few key parameters that affects good seal were the stiffness of the bands, the direction at which the bands are pulling relative to the mask, datum points of the mask on the cheek and the nose bridge. One of the novelties of this design lies in the geometry at the nose bridge to provide compressive seal.

Another consideration in the design was the sealing of air from a person's cough. Based on a study[2], there was still significant sideway leakage even with wearing N95 mask. Handling of pressure from a person's cough is a tough-one. Based on the prototypes, being smart in directing how the air flow will help to minimize particle dispersion from the forward, lateral or upwards position. Ideally, the volumetric flow rate from the lungs during cough should be expelled through the filter as fast as possible to minimze pressure built up in the mask that may lead to mask deformation and subsequent leakage. Altering the material quality and tightness of the mask may help but may result in discomfort.

Review of Existing Design

✓ Able to be printed in an A4 sized sheet (Tesed on HP Deskjet 3070 Home Printer: 0.3mm Paper)
✓ There is reasonable amount of seal using this deisgn on the sides and the nose bridge (normal operation)
✓ A large surface area to potentially allow higher air flow out of the mask (via filter)
✓ Allows users to use any available sheet resource to create a more robust design (e.g. using plastic sheet will enable the mask to be water resistant)
✓ Allows users to use best available filter pieces to enhance filtration capability (e.g. layered 100% cotton, HEPA filter etc.). Note that filters that uses glass fibre are found to be harmful to lungs, not all filters are waterproof and Covid-19 virus particles are approximately 0.125microns[3]
✓ Potential to be mass produced quickly via stamping and distributed as well as ability to print and mark logo or designs to leverage on marketing for free distribution to those who cannot afford

✗ Definitely note medically approved or officially proven to be a functional replacement for surgical masks
✗ Requires 4 locking points which means more resource spent on sticky tapes (e.g. double sided tapes)
✗ Multiple hole design improves water-resistance capabilities when using non-waterproof filters but are still tedious for users to create manually. An variant of this design is available in page 4.
✗ Still some small leakage during coughs at the nose bridge that were observed during tests but works well in creating an air tight seal during normal operation (i.e. regular inhalation/exhalation).

References:
[1] https://www.hsa.gov.sg/consumer-safety/articles/guide-to-masks-and-respirators
[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3516468/
[3] https://www.hsa.gov.sg/consumer-safety/articles/guide-to-masks-and-respirators

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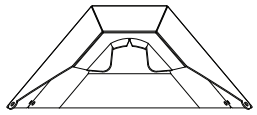
Tools Required

1 X A4 Sized ~0.3mm Cardstock (Template Printed)
4 X Rubber Bands
1 X Scissors/Penknife
1 X Masking Tape/Double-Sided Tape (or non-porous tape)
1 X Sharp Tip Tool (e.g. Math Compass/Needle etc.)
1 X 10cm by 8cm Filter Sheet (size depends on your air inlet/outlet)

Assembly Instructions

Step 1: Cut out the borders of the design with a pair of scissors
Step 2: Make sure to cut through solid lines which are red
Step 3: Fold inwards for lines -.- to create mountain folds
Step 4: Fold outwards for lines - - to create valley folds
Step 5: Using a penknife, cut slits for lines -.-
Step 6: To create holes, place the sheet on a sponge and using a sharp tip tool, pierce the paper. Widen them if necessary. To increase airflow, make more holes.
Step 7: Assemble the pieces by slotting the flaps through the slits. Secure the flaps in place by bending them in the opposite direction. Your mask will hold its shape.
Step 8: Cut strips of masking tape and seal the joining edges.
Step 9: Snip a rubber band to a strip, 2 bands per side.
Step 10: Loop the rubber band in and out the labels with the following order: 1-2-3-4. To complete the band, connect the ends with another using a sqaure knot.
Step 11: Apply double sided tape to the longer side of the filter, remove the backing and paste onto the mask to position.
Step 12: To seal the mask, apply masking tape to cover up the remaining edges and press down firmly to create a good seal.
Step 13: Adjust the nose bridge and tightness of the bands to give a good seal. Cover the inlets and outlets and breathe in/out for seal check. Repeat Step 14 if air leak is observed..

Assembly Guide:



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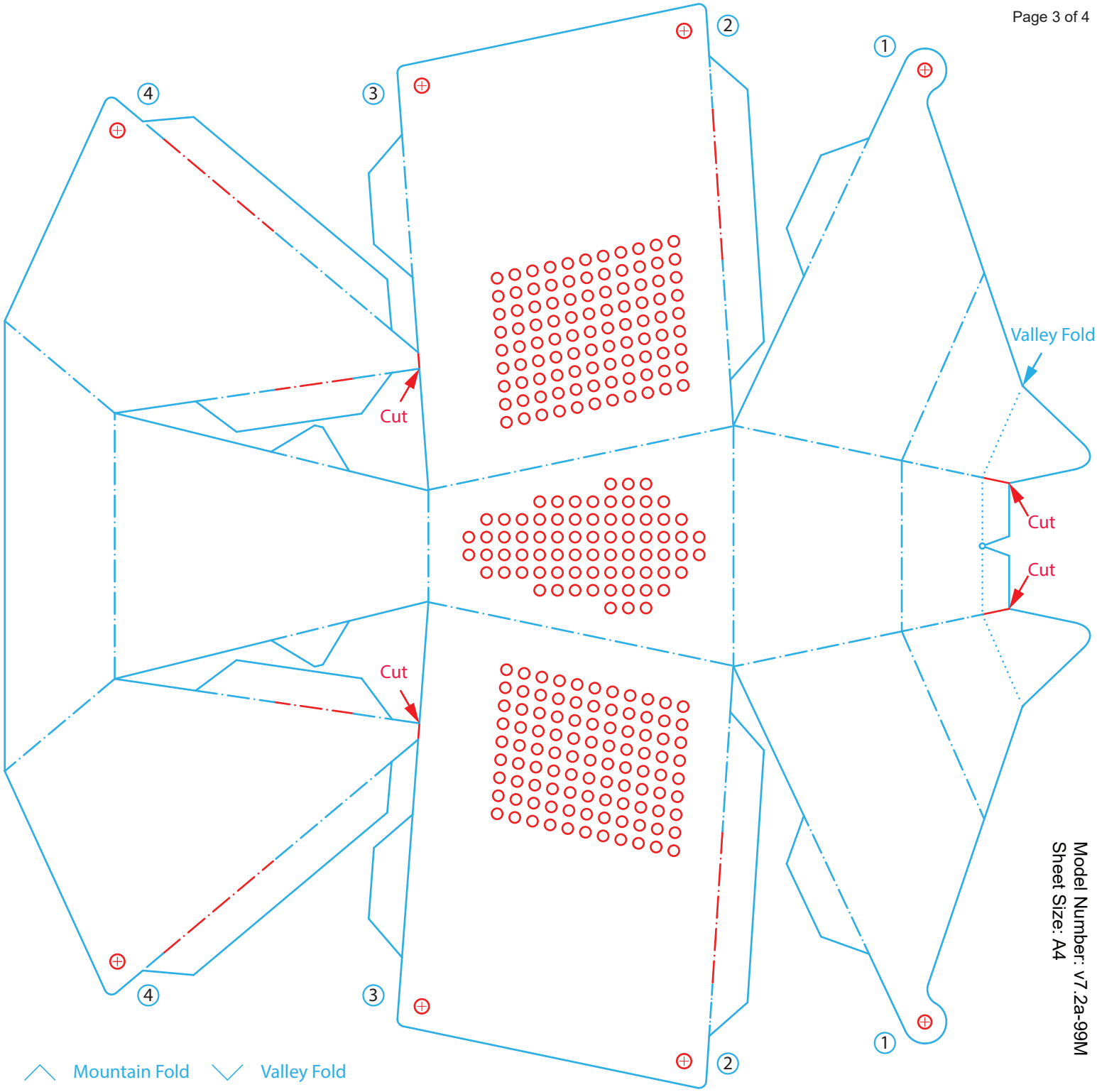

Model Number: v7.2a-99M
Sheet Size: A4

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Tools Required

1 X A4 Sized ~0.3mm Cardstock (Template Printed)
4 X Rubber Bands
1 X Scissors/Penknife
1 X Masking Tape/Double-Sided Tape (or non-porous tape)
1 X Sharp Tip Tool (e.g. Math Compass/Needle etc.)
1 X 10cm by 8cm Filter Sheet (size depends on your air inlet/outlet)

Assembly Instructions

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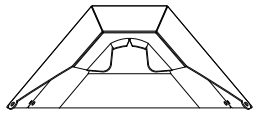
Step 9: Snip a rubber band to a strip, 2 bands per side.
Step 10: Loop the rubber band in and out the labels with the following order: 1-2-3-4. To complete the band, connect the ends with another using a sqaure knot.
Step 11: Apply double sided tape to one side of the filter and paste onto the mask to position.
Step 12: To seal the mask, apply masking tape to cover up the remaining edges and press down firmly to create a good seal.
Step 13: Adjust the nose bridge and tightness of the bands accordingly. Cover the inlets and outlets and breathe in/out for seal check. Repeat Step 13 if air leak is observed.

Assembly Guide:



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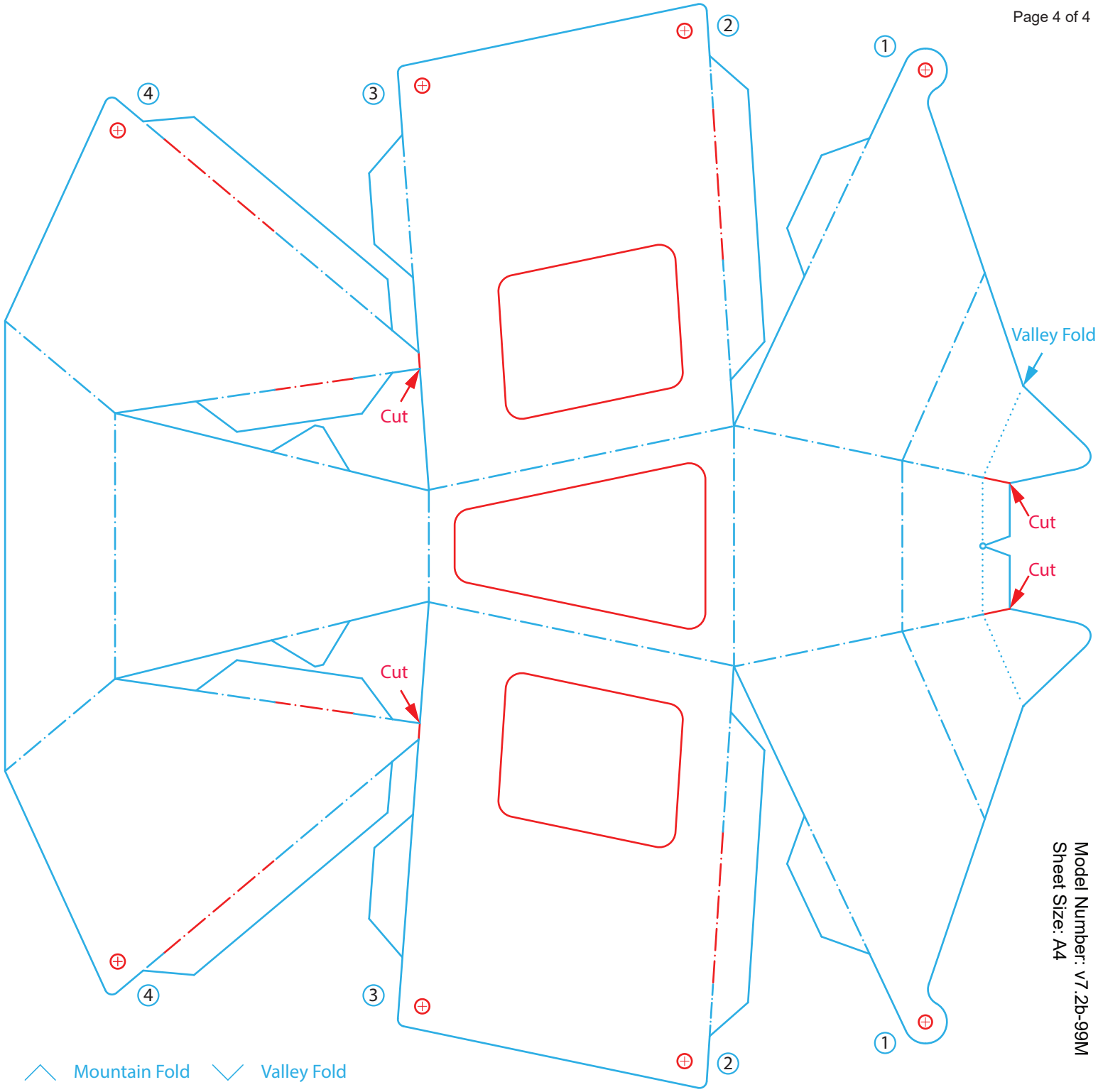

Model Number: v7.2b-99M
Sheet Size: A4