A basic workflow about designing cardmodels with digital applications

A verbal workflow like this cannot be complete at all as it also does not reflect the different personal style of a certain designer or every aspect which may pop up during the design process.
What's also not reasonable within this workflow, is to explain all the little tricks, helpful procedures and work-arounds I've made myself familiar with over a long period.
Cardmodel design is an opinion of high complexity; small mistakes made in early steps may result in major errors in steps later in the process or even may spoil the whole project.

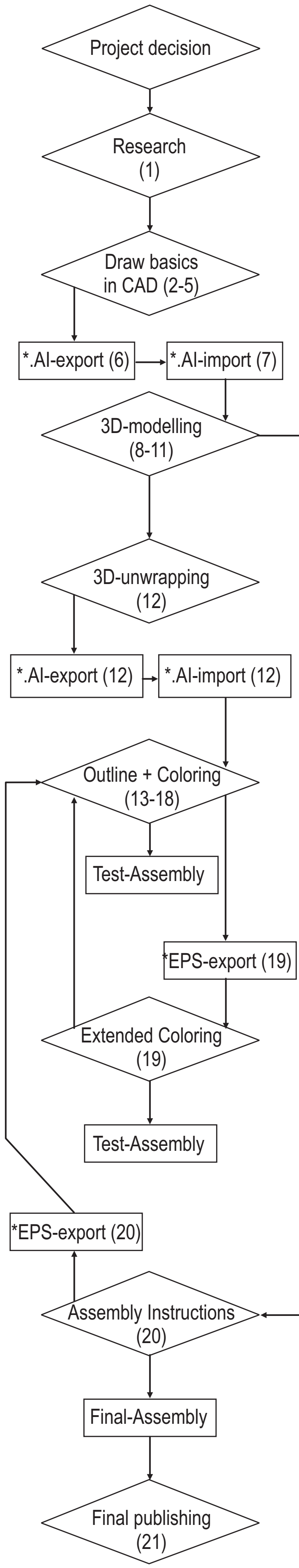
So look at this workflow as being very **general.**

Before a cardmodel design is started, three matters must be stated as being **absolutely essential**:

(1)
You must have in mind a clear vision about »**what to do an how to do**« to achieve a perfect cardmodel of the chosen original.

(2)
You must have also a clear vision about how the finished model must (or will) look like - assembled and in flat sheets. This means to have in mind permanently the complete process from the very first »blank« screen to the printed sheets ready to supply.

(3)
You must be able to handle and use your digital tools at top-level skill. If you are forced to waste brain on **how** to use them, get some training. You only should use your brain about **what** to do!
What's between these cornerstones is what is layed out here:



The tools:

- **Human brain**
- **Records**
- **2D** or **3D CAD application** (I'm using Ashlar Vellum® Graphite® + AutoCAD®)
- **Un-wrapping and modelling software** (I'm using Rhino3D®)
- **Vector-based illustration software** (I'm using CorelDraw® + Illustrator®)
- **Pixel-based illustration software** (I'm using Photoshop®)
- **Publishing Software** (I'm using QuarkXPress® and Acrobat®)

If you're motivated to go ahead and wish to place this workflow beneath your keyboard and start working - then please do so! But don't get too much exited. Maybe it's your first digital design, then the exitement caused by the software capabilities may not compare with the abilities of what you can do at this stage. Choose a small, not too complicated object and give it a try. You may push (virtually) a cone trough an elliptical spheroid - if you can achieve a »cardmodel« of this within - let's say - 12 hours, you're at it. You may then proceed to more sophisticated objects.

You need **as much as possible records** about the object you are about to design. Often you're forced to spend more time in research and studying the original than in designing a cardmodel of it. If you're lucky having plans of the manufacturing company in hand - even these may not be very helpful at least. Indeed they may show the object down to the last screw and bolt - but mostly no »foreign details« like aircraft-engines (because supplied by a different company).

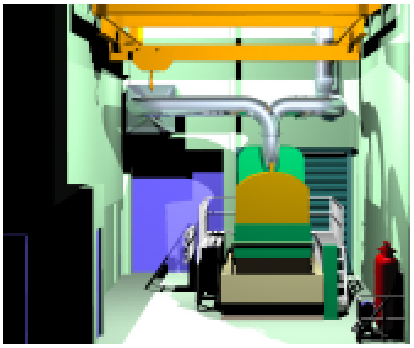
To summarize this: To have as many as possible different records related to the certain object is very important (plans, color-schemes, pictures of exterior and interior etc. etc.). Then sit down and draw your own plan having in mind cardmodel design purposes only.

1st step
Study your records in depth and comprehensively. Then make some hand-drawn isometric and 2D-sketches showing a few important details especially related to the certain model. For example: engine detail or landing gear detail (in case of an aircraft). In the 1st step it's already helpful to figure out details and structure of repetitive items.

2nd step
Draw your **own plan** using your records and the 2D or 3D CAD application. Doing this, it's essential to split down already the item into several **sections**. These sections show how the model »falls apart«.
As these sections have to be »final« at the end, think more than twice. In this step you may work backward and forward as often as you like without causing trouble. To use »construction lines« of the original as section-borders is a good idea.

To do this will also help in achieving section-surfaces with **single concavity!** Only surfaces with single concavity are digitally developeable with the tools described!

Make sure that the outlines of fuselage intersections (aka: bulkheads) are absolut precise - forming a fuselage by only



making an »approach« is a guess and will cause unsatisfying results.

And not to forget: **Draw in the final scale**. To avoid drawing fiddling small detail below material thickness you may place a reference object on your worksheet. The shape of a coin will do. This will help having a permanent feeling about the **real size** of the details in your drawing.

3rd step
Make a 4-view drawing of the item and extract the intersection (or bulkhead) - outlines and place them separately on your worksheet.
Then draw the minor - but all - details from all sides.

If you're using 3D-CAD software, you may think about creating surfaces now - if you do, make sure that these surfaces are compatible to the NURBS-technology of Rhino3D®. (Mostly they're not!) If in doubt, don't make surfaces now.

- **Mesh-surfaces are not developeable in Rhino3D®.**

4th step
Make a break!

5th step
Check the whole drawing and make sure that all dimensions match properly. Anything forgotten?
It could be helpful in this step to place reference points of important decorative elements, f.e. border lines of camouflages, letters, numbers etc. etc. (Of course you may draw these already now, but it'll cause you often double work in the following steps)

Being in the CAD-stage, don't mess around with line-styles, line thicknesses, colors etc. - it's definitely not necesary.

6th step
Export your drawing as *.AI file (Adobe® Illustrator® Format) and save them. You will need them in the next step.

Please note:
The basic functionalities of 2D or 3D-CAD applications and the un-wrapping/modelling software indeed overlap widely in most cases.
If the CAD-software of your choice is AutoCAD® or IntelliCAD® and your un-wrapping tool is Surfmaster®, you do not need Rhino3D®.
If you have no CAD (or only minor skills) don't waste money or time on it - Rhino3D® has enough built-in CAD-capabilities to satisfy all our cardmodel-related needs.

7th step
Import the *.AI-files created into Rhino3D®. Depending on the CAD-software used, you will find your imported drawi ng displayed differently. A 2D-drawing is displayed correctly only in the top-view-window (no z-axis); a 3D-drawing will be displayed correctly in 3D-virtual space.

- **Now you can start the »assembly« of your model in 3D-space.**

Don't forget to add as many reference axis as you like on a certain layer in Rhino; this will make orientation and navigation easier

Imported from 2D-CAD: Rotate, flip or mirror all required elements in the x-y-z-axis directions as needed to form the correct outline shapes (don't mi x with wireframe!) Re-check as often as possible. Make sure that all structures match and fit perfectly. Rhino's default precision is below 1/1000 millimeter.
If you're forced to make corrections, something must be wrong with your CAD-drawing and it depends on your preferences to do the required corrections in Rhino or in the CAD-application.
If you do it in Rhino, your CAD-drawing is of no longer use.
If you go back to CAD, the work already done in Rhino is wasted to a certain extend.

How to proceed in creating surfaces see **step 8.**

Imported from 3D-CAD: check everything in depth and make sure that all structures match and fit perfectly. If you recognize the need of corrections: see above!

8th step
What you should see now in Rhino is a complete »model« in outline-style. It may be important to know that Rhino's *.AI-interface transfers all CAD-curves into NURB-splines - these are very different from the so-called 3D-polylines, mathematically spoken. NURB-splines ensure that all curves **will stay** curves across the whole process - amongst a lot of other features.

Now create **surfaces** using the outline curves as reference and Rhino's different surface tools - there are plenty. You will have to work out which of the surface-tools supply the best results. In most cases the **<loft>-command** will do.
You must take care that all surfaces are of **single concavity** - as said before. The <loft>-command supports this by showing a dialogue-window from where you may choose different styles of surfaces, combined with a pre-view feature.
If you're happy with the preview, comfirm the suggestion. If a satisfying surface cannot be achieved by lofting, try other surface tools. If you're basic drawing is OK, **there is** a surface tool wich will deliver the expected result.
Creating proper surfaces may cause heavy workload and time-consuming trial-and-error phases. Don't get bored! The result will be worth all efforts.

Rhino contains different analysis-tools. Feel free to check them out. Mark-up a single surface and try the curvature-analysis. The displayed window will leave no doubt about the concavity of your surface.
Don't hesitate to perform as much as possible test-unwrappings already in this step.

9th step
Make a long break!

10th step
An intermission:
What you see after having created all surfaces is something what looks rather similar to an assembled cardmodel - without any color and decoration.
Depending on the chosen view-option you can see your model with opaque-surfaces, in wireframe-mode or in pre-rendered mode. Having no color attached to any surface, the latter will not differ very much from the opaque view.

You should learn to organize your work in Rhino by the extensive use of layers, different line colors and/or surface colors. (If this hasn't been done already in the CAD-stage.) To be familiar with this, helps a lot in having a continuous and structured overview about what you do. These »object properties« are managed by using the <F3>-key and the connected dialogue-boxes which are opened after hitting the <F3>-key.

At this stage it must be pointed out that **for cardmodel purposes** it is absolutely useless to fiddle around with colors in Rhino - with the only exception to use colors for internal organisation. Forget about line-styles and thicknesses - Rhino is not able to handle those.
(Indeed there is a Rhino-3rd-party-plugin named Lino®, which is »suspected« to handle line-styles and thicknesses, but not to a satisfying extend in the present version.)

11th step
Add formers and reinforcement-structures to your 3D-model depending on the model's sections and matching the sequence of assembly.
If it is necessary to add formers at positions different from your earlier »bulkhead«-outlines, make a flat surface (big enough) and place it at the position required. Trim away the outer areas of this surface using the model's surface as border.
Make sure that every additional former is in it's correct place.

Now you should draw your attention to some intersection-topics of your model. Those areas where certain structures or surfaces intersect with other structures or surfaces. The extensive use of the <trim> and <split> tools of Rhino is required in those cases. Maybe - in case of an twin-engine aircraft - you've designed the engine gondolas as closed surfaces. Placed in correct position relatively to the wing(s) you'll clearly see where they overlap (»intersect«).
The use of <trim> and <split> »opens« the gondola propely.
This basic technique applies to all intersections that the model may contain. You may use any geometric shape drawn aside the model to make intersections and/or openings on the model's surface. Use the <backdraw> function of Rhino to apply those shapes onto the model's surfaces - then use <trim> and <split>.
The extensive use of the <mirror> and <flip> function is also highly recommendend.

12th step
Make sure that you're satisfied with your work before you will start the final unwrapping work.
It must be pointed out that Rhino in version 3.0 is not able to handle material thicknesses.

- **The theoretical thickness of any surface in Rhino is »zero«.**

Indeed it is possible to create volumetric shapes from any surface by creating parallel surfaces in a distance which is equal to the material thickness. Besides the fact that it will complicate your work, it doesn't help - volumetric shapes are not developable.
To »work-around« the missing material-thickness tool, it is highly recommended to start the unwrapping work with all outer surfaces of the model.
Then work step-by-step through all internal structures, shapes and surfaces and reduce them in size by the thickness of

the material chosen. Indeed this is challenging and requires some experience beyond basic level.

• **Now work through all your unwrapping.**

Every unwrapped surface is placed at position »zero« of the x,y,z-world-axis of Rhino.

I found out that the sequencial positioning of unwrapped parts in Rhino is complicating the work with any additional part unwrapped. So mark-up the unwrapped part in the top-view window of Rhino and export it as *.AI file instantly. A dialogue box will ask you about converting the dimensions, make sure that Rhino-units equals your chosen measurering environment. F.e. 1 Rhino-Unit = 1 millimeter.
Save the exported *.AI file to a certain folder and delete the unwrapped part from Rhino.

Open your vector-based illustration software (in this workflow I'll describe Corel procedures), create the required sheet size (save the file!) and import the *.AI-file.
Place it at any position you like - but **don't scale** it!
Be aware that the *.AI-export interface of Rhino transports also layer information. So keep an eye to the object-manager window of Corel.
If you don't structure your Corel work also straight and clear, you will get messed up soon.
The imported *.AI-file is a mix of grouped and combined lines and curves, displayed with default line-width. To avoid any loss of a detail, make a group - and leave the unwrapped structure as it is for the moment.

Leave Corel open and return to Rhino.

Unwrap the next surface in Rhino, export it as *.AI-file, make an import to Corel . . . and so on.
To attach part's numbers in Corel to the certain parts immediately after importing is a good idea. You may also arrange the parts roughly on the sheetsize.

It is highly recommended to concentrate on purely the unwrapping, exporting and importing work in this stage. If you »work« too much in both softwares simultaneaously, you may be confused by the completely different user interfaces.

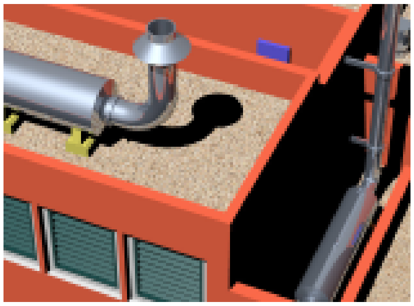
Step by step your Corel-worksheet gets filled with unwrapped parts. When the whole model is unwrapped and brought to Corel completely, discontinue your Rhino work, but don't delete any detail from your 3D-work - you will need it again for the assembly instruction latest.

13th step
If the following steps will not bring up the need of major corrections, your further work on the flat cardmodel sheet is in Corel only.

What you see in Corel up to now is a number of unwrapped parts, more or less properly arranged.
Select all parts, shapes, lines and curves, apply the line property 0.1mm (a good compromise) and the line colour black.
Add all required tabs, joiner-rings and joiner-stripes if they haven't been brought from Rhino already.

Print out your work on your preferred material and printer and make a test assembly.

This first test assembly is the **most important** one. At this stage not too much as happened and it it's quite easy to eliminate any error.



It's up to the designers decision to work out all corrections in Corel or go back to Rhino, make the corrections there and repeat the unwrapping, exporting and importing. Personally I prefer the latter.

If major corrections had been applicable it is essential to make a new test assembly.
Supposing that everything fits perfectly after the test-assembly, corrections and another test assembly, we now move to step 14.

14th step
Now arrange all your parts on the Corel worksheet properly with high precision. Make sure that the sheet is »filled« by arranging the parts keeping an eye on »optical attraction«.

15th step
Un-group and de-combine all structures on your Corel worksheet!

16th step
Apply all required line styles to your parts, define scoring lines and border lines of areas where different parts have to be glued to one another. Make sure that all lines appear in the required color - mostly black.

17th step
Create the coloring by duplicating certain structures, combine the duplicated curves, close all knots and fill with color. Attach the same colour to the duplicated structure's outlines.
Move the colored structure back to the original outline structure and arrange it beneath **- this is important**. The black outline of the source object **must** maintain above the colored structure.
You may use different layers in Corel to organize black outlines and colored structures.
(If you wish to <group> black outlines together with colored shapes being on different layers, you will then find the group placed on a single layer!)

Work trough the coloring job of your whole model. The abilities of Corel are nearly un-limited. You even can create the finest camouflages with Corel.

What I find essential to explain additionally is - if you're intention is to publish your model offset-printed - to create a high resolution PDF from time to time during the coloring job. (2400 dpi / CMYK). Check the PDF carefully - sometimes Corel in combination with postscript-printer-drivers creates strange and unexplicable pixel-effects. If you observe this, check the certain colored part in Corel. Mostly unwanted effects occur, when objects filled with a shaded transparency are placed above an object with solid color or shaded color.
In case your certain cardmodel-project consists basically on color-overlay techniques described above, please see step 19 to learn how to handle those.

When the coloring job is finished and you're happy with it, make a printout and a test-assembly. Mostly to make sure that all color-borders match properly. Make the necessary corrections, if any.

18th step
Apply the complete numbering in sequence - avoid to miss out a number in the sequence, because this may confuse the modeler. Add required symbols and wording. After a final check your cardmodel is ready for publication - but wait! The assembly instruction is still missing. This topic is described in step 20.

19th step
As pointed out in step 17, the need of »extended« coloring may exist. Mostly to prevent unwanted pixel-effects caused by strange behaviours of Corel and postscript-devices, also to take advantage of addional weathering-effects.

Now pixel-based software enters the field. In this workflow I'll describe Photoshop procedures.
In principle you'll export your Corel drawing into Photoshop, but you'll have to decide at first wether to export the complete drawing or export the colored shapes only. The latter will »leave« every outline, number, symbol, text etc. on the Corel worksheet. Both alternatives have their advantages and dis-advantages - it depends on your certain model concept and your working preferences. So you'll have to find out what fits more into your workflow on your own.

Now export your Corel shapes into photoshop by creating an *.EPS file. The *.EPS export interface of Corel will not ask you about resolution and color. (Corel itself and the EPS-format are both vector based!)

Open the saved *.EPS-file in Photoshop. Photoshop **now** asks you for resolution and color. Set resolution not below 300dpi and the color-mode must be CMYK.
Photoshop now creates a pixel-image of the EPS-file. Depending on the dimensions of the drawing you've exported as EPS, the chosen resolution and the resources of your hardware, this may take a while.
(To increase the performance of Photoshop go to the preference-settings of Photoshop and make sure that the temporary swap-file of Photoshop is not filed on the same physical hard-drive as the application is stored itself; a non-physical, but different partition of the same harddrive does not help.)

Check the displayed image carefully in terms of precise display of the thin outlines (if you had exported them).
If you're not satisfied, close the file and open the EPS file again with higher resolution. Repeat this by increasing the resolution until you're satisfied.
It must be pointed out also that the filesize Photoshop is building up, may become dramatically huge - compared with the EPS source file.

Now make extensive use of all the numerous and wonderful Photoshop-tools to polish up the coloring of your model parts. Create or upgrade all your shadings and transparent color areas, add weathering and anything you may think about. Ready and everything looks perfect? Great!
Then file your image first in *.PSD format and then in *.EPS format. The *.PSD-format will save a file on which you may continue or extend your work later, if required.
(The *.TIF-format is not recommended here because of it's huge file size and it's limited abilities in terms of the prepress process for offset-printing)

Now the »new« EPS-file can be placed on your original Corel worksheet. You will recognize that EPS-files are displayed rather crude when placed in Corel. That doesn't matter, because it's common practice to create high-resolution PDF-files before any printout of Corel files containing EPS-files.

Having described extended coloring, the description of designing a cardmodel is finished. I would like to recommend a final test assembly from the final coloring. This is your master-piece and reference-model - not at least for taking pictures.

20th step
The assembly instruction in my opinion is as important as a precise cardmodel design itself. You may find out that creating a perfect assembly instruction may cause the same workload as the model-design.
At first take the effort to lay down what may be called a »story board«. A sequence of quickly handdrawn sketches, showing in basic everything what's essential to achieve a prefect assembly instruction for the modeler. Early basic sketches (see 1st step) may assist. Only when you're happy with your story board, proceed.

There are two alternative ways to use the software tools described in this workflow to create proper assembly instructions:

Quick'n'dirty
You need again Rhino for this. It is assumed that the render-plugin Penguin® is installed on your system. Penguin® is a raytracing tool which supplies cartoon-

like renderings with sharp outlines. Experienced users will achieve stunning results.

Open your 3D-model in Rhino, switch the perspective window to full-screen mode. Save the Rhino-file using a different name to keep the untouched file for further use. Then rotate and zoom your model until your happy with angle of view and focus. To reduce virtual perspective distortion, go to the window-preferences and set the camera-focus to 80 appr. (focus of more than 100 will result in a not very realistic »parallel«-perspective; focus of less than 50 will result in also a not very realistic »fish-eye« -perspective.)

Make Penguin® your present renderer. Go to the render-preferences dialogue and leave the settings as they are.

Start the render-process. The result may be called a test-rendering, because it will show you a possible result in basic. Then increase the resolution step by step and increase also the quality settings to maximum. After each change make a rendering. The most satisfying settings keep in mind, write them down or file them in the render-invironment file.

The final rendering should be saved as TIF-file!

As you have started your rendering with the complete 3D-model, you must virtually disassemble your model step-by-step following your story board and make renderings of each step. Each with the same settings. At the end you should have a bundle of TIF-files matching your story board.

Open every TIF-file in Photoshop, change the color-mode to grey-scale (Rhino files rendered pictures in RGB, as we don't use colors in Rhino, there's no need for RGB).

Save to *.EPS in Photoshop. Then bring the EPS-files to a new Corel worksheet, arrange them, add numbers, symbols and wording. Create a high-resolution PDF and check everything.

(If you don't have available Penguin®, then the built-in Rhino renderer will also help. Similar to the high-end raytracing render tool Flamingo®, the built-in renderer supplies shaded renderings. Play around with it, set lights etc. and see what will happen. If you have Flamingo® you're lucky - it opens the high-end photo-realistic world. But this would be a completely different workflow!)

The way of »precision«

Alternatively you may use this procedure if you like precise outline drawings for your assembly diagrams.

You need again Rhino for this. The benefit is that you don't need any render-tool. You may concentrate on your geometric work.

Open your 3D-model in Rhino, **do not** switch the perspective window to full-screen mode. Save the Rhino-file using a different name to keep the untouched file for further use. Then rotate and zoom your model until your happy with angle of view and focus. To reduce virtual perspective distortion, go to the window-preferences and set the camera-focus to 80 appr. (focus of more than 100 will result in not very realistic »parallel«-perspective; focus of less than 50 will result in also not very realistic »fisheye«-perspective.)

Now use <_make2D> from a Rhino tool box - or type it on the command-line. Rhino then calculates the chosen view and creates a perefect 2D-drawing without any hidden line and without those ISO-lines of the surfaces.

The result is displayed in any window and already marked-up - make the **top-view window** being the active window and export the 2D-drawing as *.AI-file instantly.

As you have started the 2D-creation with the complete 3D-model, you must virtually disassemble your model step-by-step following your story board and make 2D-drawings of each step. Each with the same settings. At the end you should have a bundle of AI-files matching your story board.

Import all these AI-files to Corel. You will find that the 2D-drawings consist of numerous lines and curves you can work on indepently in Corel.

Do all your preferred Corel work with these 2D-drawings, add numbers, symbols, wording and colored areas as you like until you've achieved a perfect and satisfying assembly instruction.

21st step

It doesn't matter at all what your publishing purposes are, in any case choose postscript software-devices for the output. If you like to make available a small, simple and free model on the internet, create a low resolution PDF-file.

Alternatively create high-resolution PDF-files if you're model is printed in offset-technique and published commercially.

The use of a commercial Publication Software f.e. QuarkXPress is useful; Adobe® Acrobat® is recommended.

Never give away unlocked PDF-files or even your original source data.

Epilogue

You should have found out quite early that using Rhino3D® for cardmodel design purposes makes use of less than 5% of Rhino's features. The »real« purpose of Rhino is free-NURBS-modelling and the creation of photo-realistic virtual 3D-reality.

This workflow never even »touched« those features.

Therefore a possible future workflow may contain how to create JPG-files from the flat model-parts in Corel and wrap around these so-called »decals« on the 3D-surfaces of our model in Rhino. Extended with additional lighting, weather, sun, sky, material-effects, environment etc. etc. we are able to re-create a hyper-realistic picture of our card-model without cutting and getting sticky fingers.

Thank you
for your attention.