# Electra and Electra 60

These diagrams show you how to make the modular sculptures Electra, Electra 60, and, purely for the sake of completeness, the equivalent 24 and 12 module designs.

Electra, or Electra 30, is probably my best known modular design. It dates from 1989 and was somewhat revolutionary at the time because of its use of a mixture of folding geometries. The name Electra is, of course, drawn from Greek mythology, but also references the similarity of the design to one of those, now somewhat outdated, pictures of electrons surrounding a nucleus in their shells.
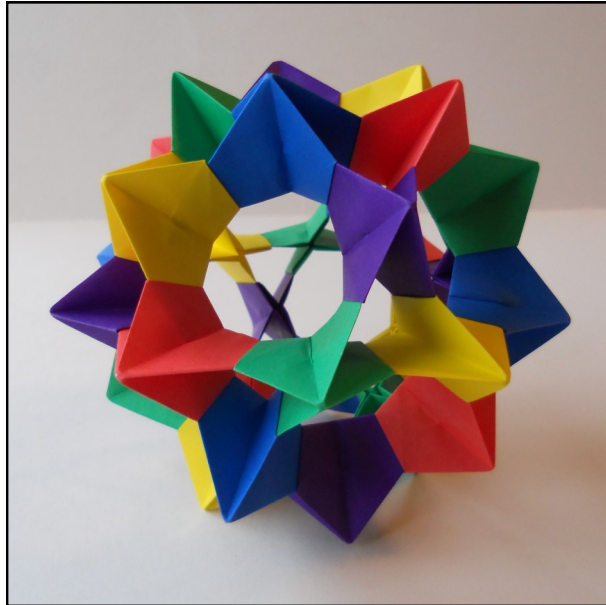
My first Electra was assembled from 30 modules which were folded using standard folding geometry. I soon discovered, however, that the angles of the design, and the strength of the assembly, could be improved by using mock platinum folding geometry to create the angle at which the pockets were set (see pictures 10 and 12). This change of angle not only improved the geometry but also allowed the tab of one module to extend very slightly around the corner inside the pocket of another (see picture 22), thus allowing them to hold together much more firmly, especially during the assembly phase.

The original module now only survives in the 24-piece design, which cannot be made from the hybrid version, and also, unfortunately, in many unauthorised instructional videos on the internet.

In its original form, the Electra module will only make modular sculptures based on polyhedra which have four edges meeting at a vertex. However, it is a simple matter to hide one of the arms away inside the module to produce a three-armed version, or rather, two three-armed versions, one with two tabs and one pocket and the other with one tab and two pockets, which will go together to create sculptures based on polyhedra which have three edges meeting at a vertex. I experimented with this three-armed version at an early stage but found the results unsatisfactory compared to the original designs, preferring a module folded from a hexagon, which has since evolved into my Apollo module. Ian Harrison also experimented with the three-armed module in the early 1990s, but only making, I believe, a few of the simpler possible forms.

In 2002 an article by Ravi Apte was published in the 8th Tanteidan Convention Pack detailing the designs which could be made using the three-armed Electra module, which he had renamed the Universal Vertex Module, some of which required the arms to be set at a wider angle than that of the original design using a 'right about there' fold. Ravi did not know that the three-armed version of the module was already known and had previously been experimented with. His experiments greatly extended the range of designs that had been made from the module and showed that it was not as unsatisfactory as I had previously thought.

I am appending a scan of the pages of Ravi's article to the end of these diagrams.
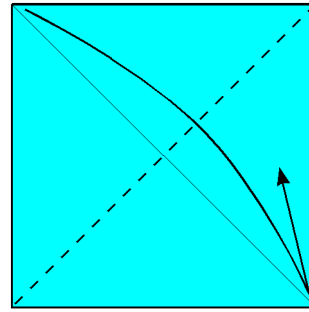
Making Electra

You will need thirty squares of paper. These diagrams show you how to make Electra using six squares in each of five contrasting but complementary colours.
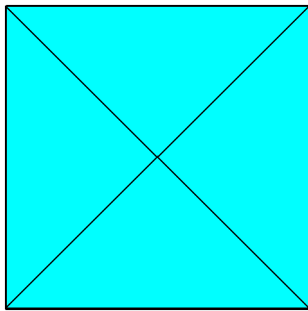
1
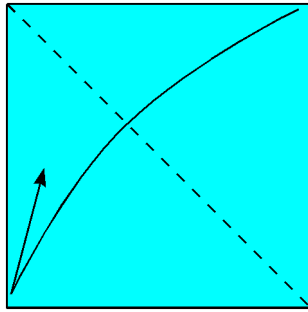
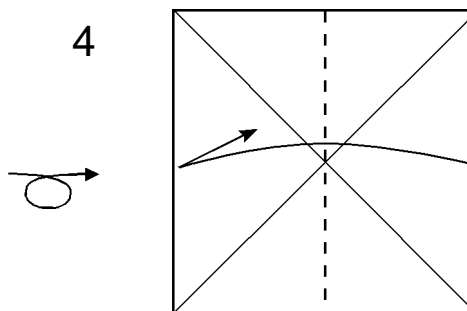1. Fold in half diagonally, then unfold.

2

2. Fold in half diagonally in the opposite direction, then unfold.
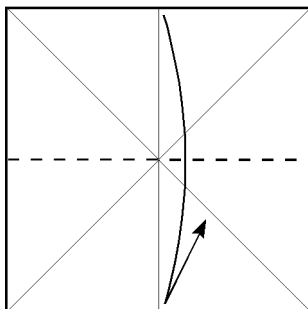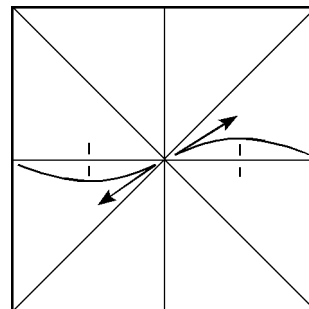
3

3. Turn over sideways.

4

4. Fold in half sideways, then unfold.

5
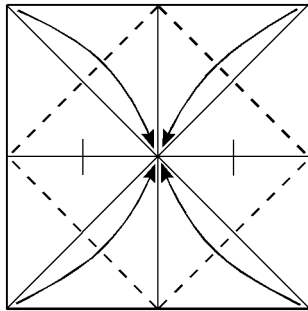

5. Fold in half downwards, then unfold.

6

6. Fold both outside edges into the centre, then unfold, but only make two small creases at the centres of the folds.

7

7. Fold all four corners into the centre.

8
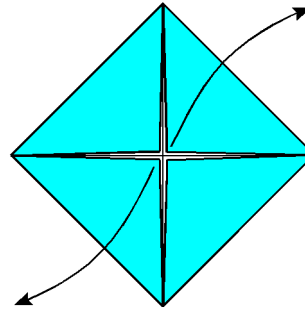
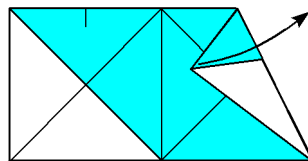8. Open out the top right and bottom left front flaps.

9
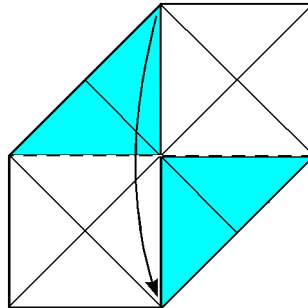
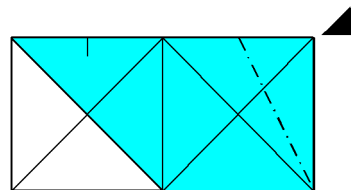9. Fold in half downwards using the existing crease.

10
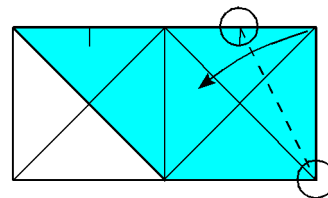
10. Fold the right edge inwards, using one of the short creases made in step 6 to locate the top end of the new crease and making sure the bottom right corner remains sharp.
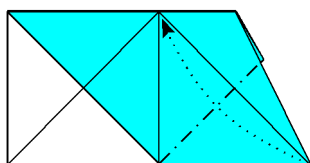
11

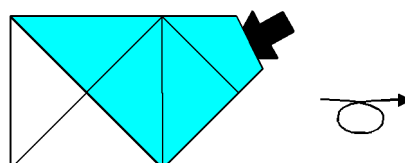11. Open out the fold made in step 10.

12

12. Turn the top right corner inside out in between the layers using the creases made in step 10. You will need to reverse the direction of the crease in the front layer.
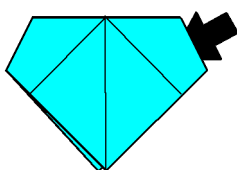
13

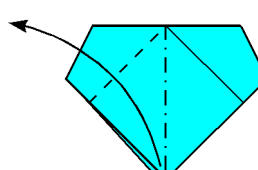**12. Fold the bottom right corner backwards in between the layers using the existing crease.**

14

13. This should have created a secure pocket in the position shown. Turn over sideways ...
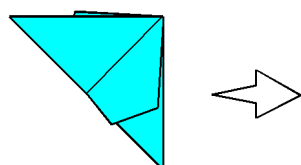
15

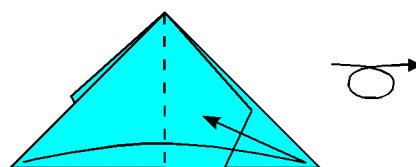**15. ... and repeat folds 10 to 13 on the other half of the paper to create a second secure pocket.**

16

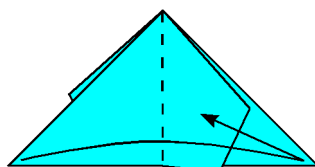**16. Pull the bottom point of the front layer upwards to the left and flatten to look like picture 17.**

17
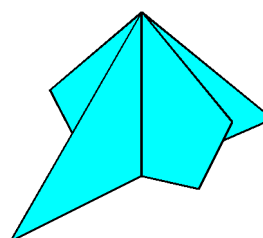
17. Arrange to look like picture 18.

18

18. Fold the left hand front flap across to the right, then unfold. Turn over sideways.
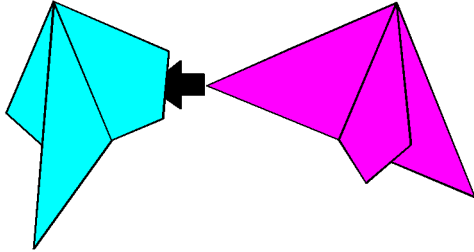
19

19. Repeat fold 18 on the new left hand front flap then bring both short arms out to the side.
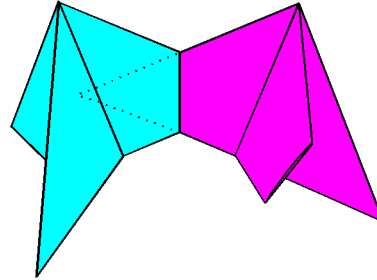
20

20. The module is finished. You will need thirty in all, six in each of five colours.
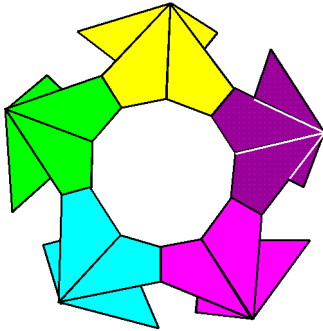
21
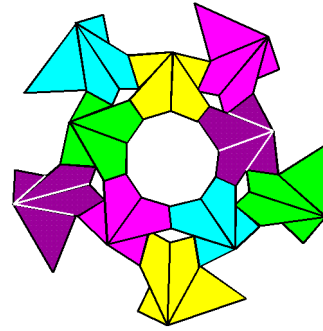

21. Two modules go together like this.

22

22. Because of the angle of the fold made in step 10 the tip of the tab goes beyond the centre crease and becomes trapped by the central fold of the host module.
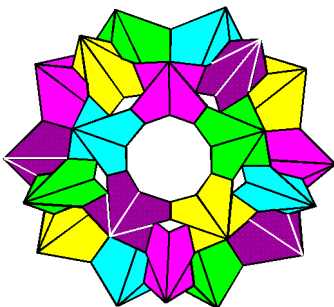
23

23. Begin assembling Electra by putting five modules together to form a five-sided ring like this.

24

23. Add a further five modules to surround this five-sided ring with three-sided rings, keeping to the colour scheme shown.
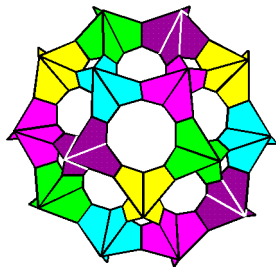
25

25. Continue adding modules until Electra is complete. The underlying structure of Electra is that of an icosidodecahedron. Every five-sided ring is surrounded by three-sided rings and every three-sided ring by five-sided rings. If you keep to this structure as you add the modules Electra will automatically form. The colour scheme can also easily be extended to the design as a whole. Electra also works well when made in a carefully chosen patterned paper.

David Mitchell / Electra and Electra 60

Electra 60

As the name suggests, Electra 60 is a development of Electra 30 that uses twice as many modules. The module is the same as the module for Electra 30.

The extra work aside, it is equally easy to fold and assemble, equally robust and at least equally as beautiful as the original, much better known, design.

You will need sixty squares of paper. These diagrams show you how to make Electra 60 using twelve squares in each of five contrasting but complementary colours.

Begin by putting five modules together to form a five-sided ring, then add twelve more modules to surround it with four-sided and three-sided rings in the pattern shown here, keeping to the colour scheme shown.
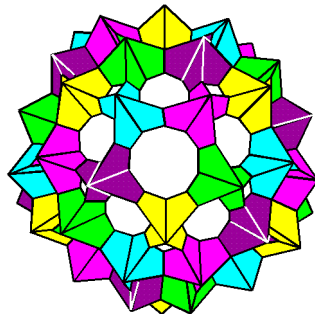

Continue adding modules until Electra 60 is complete. The underlying structure of Electra 60 is that of a rhombicosidodecahedron (see page 13). Every five-sided ring and every three-sided ring are surrounded by four-sided rings. The five-sided and three-sided rings touch at the corners. If you keep to this structure as you add the modules the Electra 60 design will automatically form. The colour scheme shown here can also easily be extended to the design as a whole. Electra 60 also works well when made in a carefully chosen patterned paper.
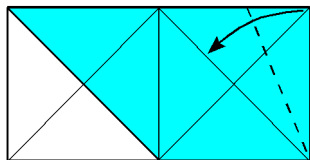
Electra 24

Electra 24 is made using the original Electra module which is folded using only standard folding geometry.

You will need 24 squares of paper. These diagrams show you how to make Electra 24 using six squares in each of four contrasting but complementary colours.

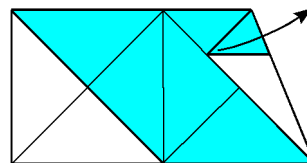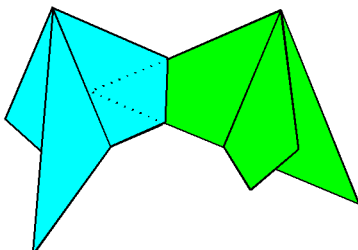Begin by following steps 1 to 9 of the instructions for making Electra 30.

10
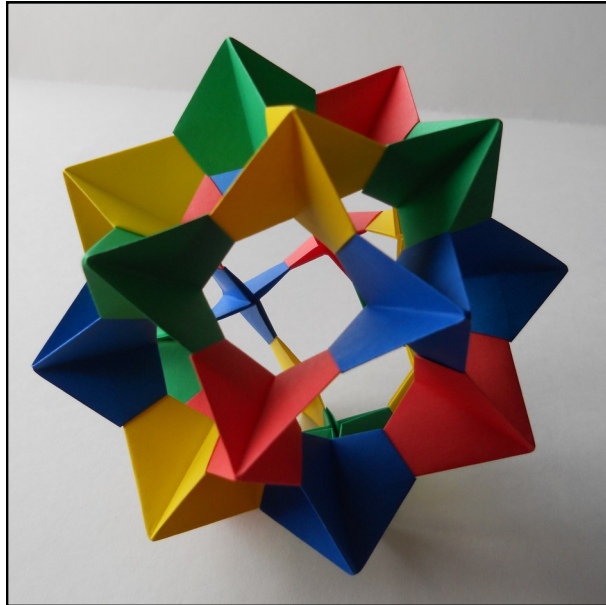
10. Fold the right edge onto the nearest diagonal crease.

11

11. Open out the fold made in step 10, then turn over sideways and repeat steps 10 and 11 on the other half of the paper, then follow steps 13 through 21. Make all 24.

22

22. In this case the tab does not go into the pocket of the host module beyond the line of the centre crease. This means the modules will not hold together so well.
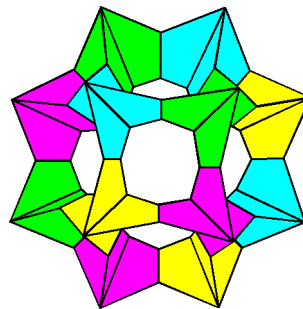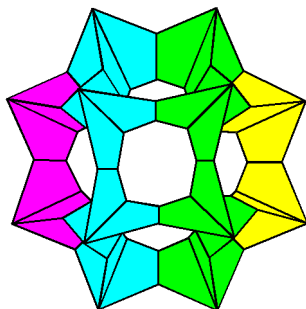
23
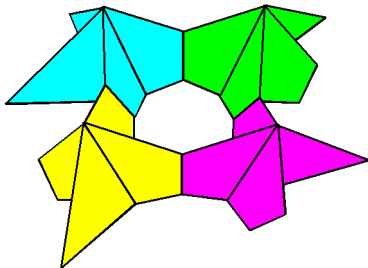
23. Begin assembling Electra 24 by putting four modules together to form a square ring like this.

24

23. Continue adding modules until Electra is complete. The underlying structure of Electra 24 is a rhombicuboctahedron. Every four-sided ring is surrounded by three-sided rings and every three-sided ring by four-sided rings.
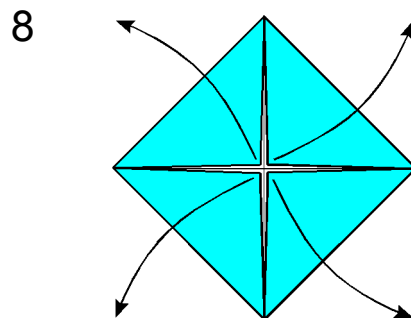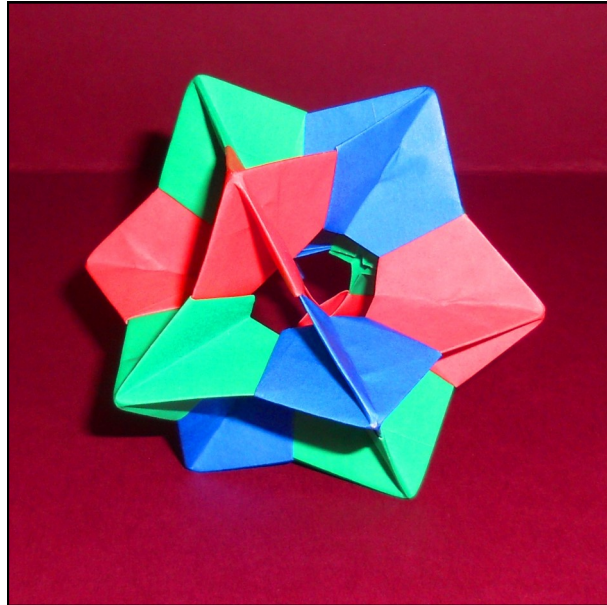
25

25. You could also colour Electra 24 like this.

Electra 12

A 12-piece version of Electra can be obtained by varying the angle at which the pockets are set.

These diagrams show you to make Electra 12 from four squares in each of three contrasting but complementary colours.
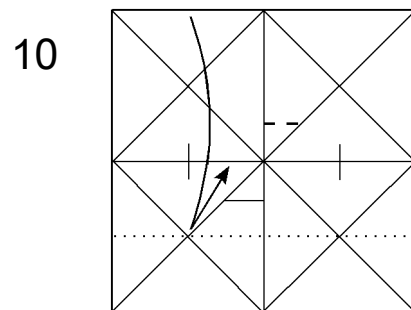
Begin by following steps 1 through 7 of the instructions for Electra 30.

8
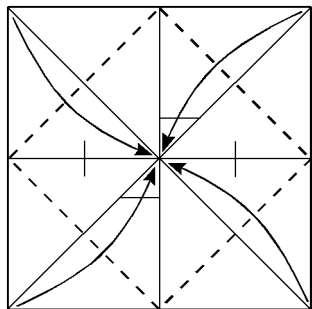
8. Open out all four front flaps.

9
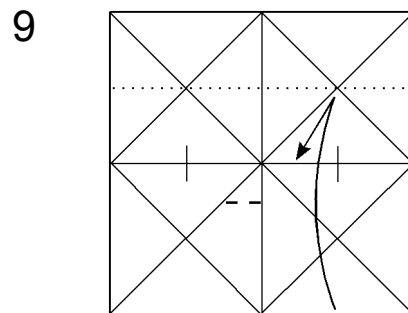
9. Fold the bottom edge upwards to the position marked by the dotted line, make a tiny crease in the position shown, then unfold.
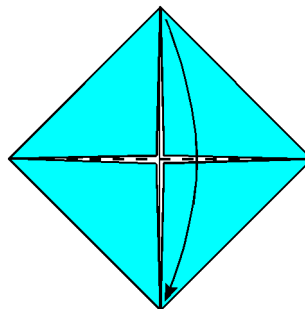
10

10. Fold the top edge downwards to the position marked by the dotted line, make a tiny crease in the position shown, then unfold.
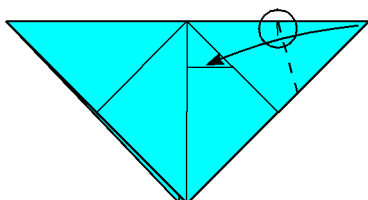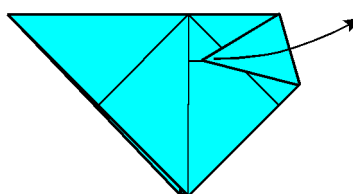
11

11. Remake the folds made in step 7.
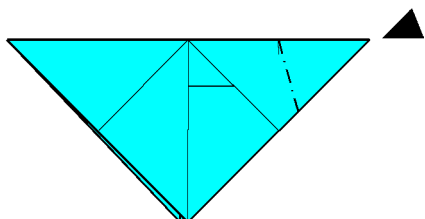

12

12. Fold in half downwards.

13

13. Fold the right corner onto the crease made in step 10 making sure the top of the new crease starts from where the crease made in step 6 intersects the top edge.
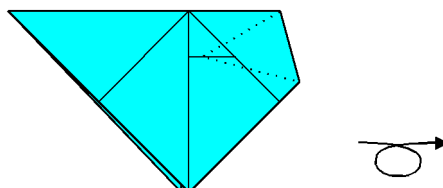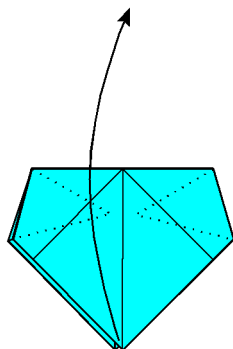

14

14. Unfold.

15

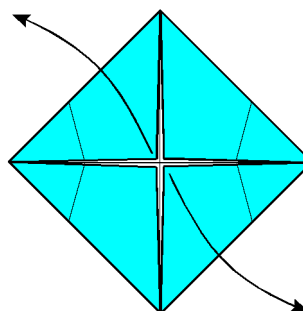15. Remake the fold made in step 13 in between the other layers.

16

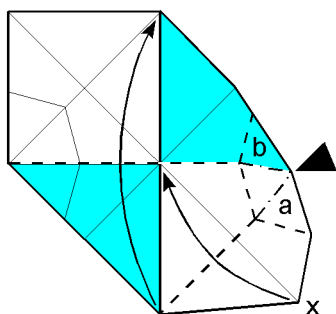16. Turn over sideways and repeat steps 13 through 15 on the other half of the paper.
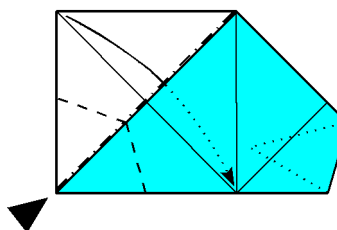
17

17. Open out upwards.

18

18. Open out the top left and bottom right front flaps.
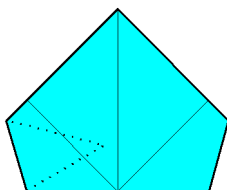
19

19. Remake the fold made in step 15 so that folding point x to the centre and folding the paper in half upwards traps the folds to form a pocket.
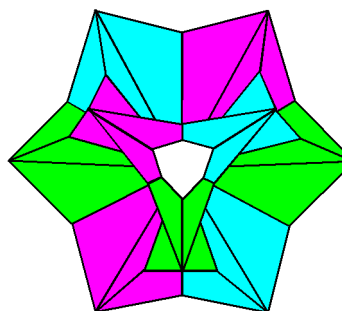
20

20. Repeat fold 19 on the other half of the paper.

21

21. Follow steps 16 through 20 of the instructions for Electra 30 to create the finished module. Make all 12.

22

22. The modules can be assembled to look like this. Electra 12 is finished.

Universal Vertex Module

- The Universal Vertex Module (UVM) is very versatile and can be used to construct many polyhedral structures. Many regular polyhedra have three edges to the vertex. Some have four and some have five edges to the vertex. The UVM lends itself very well to constructing three and four edge vertex structures. Polyhedral structures constructed using 'Vertex' modules require fewer modules than those using 'edge' modules, because the number of vertices in polyhedra are always less than the number of edges. Table 2 shows the various polyhedral structures that can easily be made using the UVM. This work is inspired by the four edge vertex module created by David Mitchell and used in the thirty and sixty piece 'Electra' models.

- The number of modules to be used in constructing these polyhedral structures varies from 24 (truncated cube) to 60 (truncated icosahedron) to more than 1000 for icosahedral Buckyballs of order 5 and beyond. For polyhedral models with three edges to a vertex, you always require an EQUAL number of **FFP** (2 flaps and 1 pocket) and **FPP** (1 flap and 2 pockets) modules, where **F** represents a flap and a **P** represents a pocket.

- The technique used to make flaps and pockets can be applied to making modules with different combinations of flaps and pockets. The general principle is that you need to fold as many corners in steps 2 or 12 as you need flaps in the finished module. So, if you need 3 flaps you have to fold 3 corners in steps 2 or 12.

  Every time you repeat steps 3 through 5 you create a flap. (Flap steps)
  Every time you repeat steps 6 through 9 you create a pocket. (Pocket steps)

  Table 1 provides information on configuring these modules. By using a combination of modules shown in table 1, made from different colors (a color for each element, e.g. White for Oxygen, Blue for Nitrogen etc.), you can also make chemical molecular structures, with the number of bonds being represented by flaps and pockets.
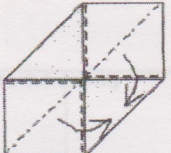
Table 1

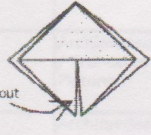| Number of corners folded in steps 2 or 12	All Pocket steps	Flap steps followed by Pocket steps (if any)	Sequence of Flap, Pocket (as needed) & Flaps steps
One	FPPP	FPP	FP
Two (Adjacent)	FFPP	FFP (not recommended)	-
Two (Opposite)	FPFP	FPF	FF
Three	FFFP	FFF	-

Universal Three (3) Edge Vertex Modules (**FFP, FPP**).
Created and Diagrammed by Ravi Apte. Copyright 2002.

2. Fold two opposite corners of the blintz and fold at the creases shown to get a...

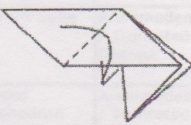1. Crease & unfold two book folds, two diagonal folds and blintz.

12. Fold one corner of the blintz and fold at the creases shown to get a...

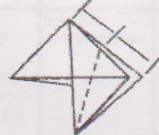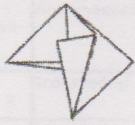13. Preliminary base.

Pull out flap

3. Preliminary base.

Pull out flap

Pocket

Flaps

11. Module **FFP** with two flaps and one pocket is ready.

Pockets

Flap

25. Module **FPP** with one flap and two pockets is ready.

14. Fold down on the valley fold

4. Fold down on the valley fold

5. Tuck flap inside

Assembly is simple. Insert a flap, as far as it can go, into a corresponding pocket of another module. The inserted flap will extend beyond the center line of the receiving module. Fold the flap of the receiving module such that the two modules lock. No glue is required. Keep attaching the other modules in the same way to form triangles, squares, pentagons etc depending on the model you are making (see table 2).

10.

24. Tuck the flap inside, over the first inner layer as in step 19 (See also enlarged figure 10). Use the previously made blintz crease

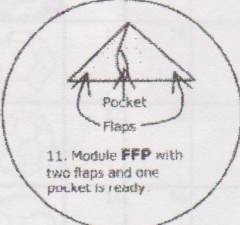15. Tuck flap inside

6. Valley fold as shown

9. Tuck the flap inside, over the first inner layer (See enlarged figure 10). Use the previously made blintz crease

24. Fold along this line to get a lock. Also shown is the hidden part of module.

23. Inside Reverse Fold and swivel the flap as in step 18

16. Valley fold as shown

7. Crease well

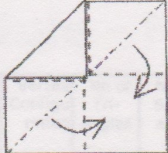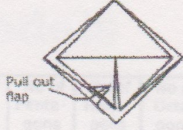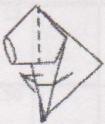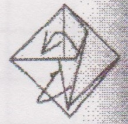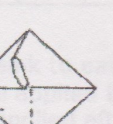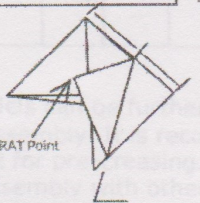8. Inside Reverse Fold and swivel the flap as shown

Fold angles for step 6, 16 & 21
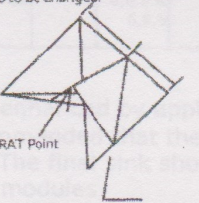
To get the right overall camber (curvature of the model), depending on the number of modules in the model, the angle of the fold in steps 6, 16 & 21 has to be changed.

22. Crease well

17. Crease well

21. Valley fold as shown

18. Inside Reverse Fold and swivel the flap as shown

RAT (Right about there)

RAT Point

RAT Point

For models with less than 30 modules

For models with MORE THAN 30 and less than 60 modules

For models with MORE THAN 60 modules

The angle subtended by the fold line needs to become greater as the number of modules increases. The important thing to note is that a small portion of the fold must extend beyond the center line so that the folding lock can occur.

20. The first pocket is done. Turn the left flap to the back, along the crease

19. Tuck the flap inside, over the first inner layer (See enlarged figure 10). Use the previously made blintz crease

Universal Vertex Module

Table 2

| Name of the Solid	Family	Picture	No of Faces	No of Edges	No of Vertices equals no of Modules	No of Edges to a Vertex	Vertex Configuration	No of Tri-angles	No of Squares	No of Penta-gons	No of Hexa-gons	No of Octa-gons	No of Deca-gons
Triacontrahedral BuckyBall Order 3	Triacontra-hedral		92	270	180	3	6,6,5 & 6,6,6			12	80		
Truncated Octahedron	Archimedean / Truncated Platonic		14	36	24	3	6,6,4		6		8		
Truncated Icosahedron / Soccer Ball	Archimedean / Truncated Platonic		32	90	60	3	6,6,5			12	20		
Truncated Cube	Archimedean / Truncated Platonic		14	36	24	3	8,8,3	8				6	
Truncated Dodecahedron	Archimedean / Truncated Platonic		32	90	60	3	10,10, 3	20					12
Truncated-cuboctahedron	Rhombic Archimedean		26	72	48	3	4,6,8		12		8	6	
Truncated Icosi-dodecahedron	Rhombic Archimedean		62	180	120	3	4,6,10		30		20		12
Icosi-dodecahedron (Dual of Icosihedron and Dodecahedron) Mitchell's Electra 30	Special Archimedean		32	60	30	4	3,5,3,5	20		12			
Rhombicosi-dodecahedron - Mitchell's Electra 60	Rhombic Archimedean		62	120	60	4	4,3,4,5	20	30	12			
Icosahedral BuckBall order 2	Icosahedral		122	360	240	3	6,6,5 & 6,6,6			12	110		
Icosahedral BuckBall order 5	Icosahedral		752	2,250	1,500	3	6,6,5 & 6,6,6			12	740		
Triacontrahedral BuckyBall Order 2	Triacontra-hedral		42	120	80	3	6,6,5 & 6,6,6			12	30		

- The finished models can be further enhanced by applying a sink to each module before assembly. It is recommended that the sink be applied between step 1 and step 2 for pre-creasing. The final sink should be applied after step 11 and before assembly with other modules.
- Medium weight paper (20-24 lbs, 70-80 Grams/Sq.Meter) from 3" to 6" (75mm to 150mm) works best. A sixty piece structure assembled from 3" paper results in a finished model of diameter approx 5" (125mm).

Universal Vertex Module – Models
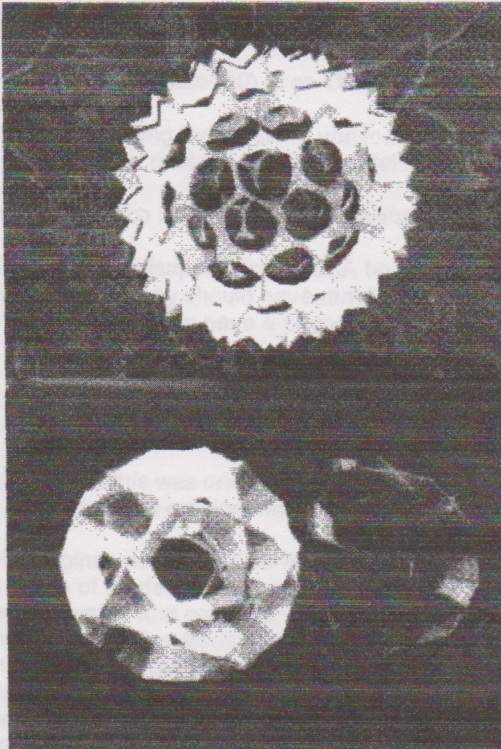
Model of a Carbon 180 molecule (C180) using 180 three edge vertex modules

An 'Electra 30' using the sunk version of the module

A model of the Truncated IcosiDodecahedron using 120 three edge vertex modules

A model of the Truncated Dodecahedron using 60 three edge vertex modules