Model of the GAIA Satellite
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For further details about the European Space Agency's GAIA mission, see:
http://astro.estec.esa.nl/GAIA

The GAIA Mission

GAIA will measure the distances of hundreds of millions of stars in our Galaxy. It will also measure their motions through space. By carrying out this remarkable stellar population census, it will provide important information about the structure, the origin and the history of the Galaxy in which we live.

The model is on a scale of about 1:30. The diameter of the extended sunshield and solar arrays is about 9.5 m. The satellite will weigh more than 2 tonnes, and will consume about 2.5 kW of power provided by the solar arrays. It will be launched by an Ariane 5 rocket, and operated at one of the 'Langrange Points' of the Earth-Moon system, at a distance of about 1.5 million kilometers from Earth. Information will be sent back to Earth at about 1 million bits of data per second, throughout its 5-year lifetime.

The satellite rotates around its central axis. As it does so, star light enters the entrance apertures, and reflects off the various mirrors before falling on the corresponding focal plane, where it is detected, converted into electrical signals, and sent to the ground. The baffles on the outside of the tent structure prevent stray light from reaching the instrument. During launch, these baffles are folded flat against the tent structure, and the solar array panels are folded flat against the inclined surfaces of the service module.

The optical bench and mirrors forming the three telescopes will be made of silicon-carbide, a strong lightweight material which will hold the optical elements in a very stable position with respect to each other. The temperature within the instrument areas will be controlled to a very high accuracy. The two astrometric viewing directions will collect observations needed to measure the positions and distances of the stars. The spectrometric instrument will measure their energy distributions and their radial velocities.

You Will Need...

- paper
- scissors or sharp knife for cutting and lightly 'scoring' the lines along which the pieces are folded
- glue (e.g. UHU) and/or double-sided sticky tape
- a spent match stick

General

Download the 9 pages of parts, along with the assembly illustrations, and print on normal paper. A colour printer will give a model with a more striking appearance, but a black and white printer is also satisfactory. Here are some general guidelines:

- cut around the pieces carefully; the final model will benefit from care taken at this stage.
- to give neat folding, use one of the points of a pair of (not very sharp!) scissors, to score lightly all solid lines (including the glueing tabs) unless otherwise noted in the instructions: place the pieces on some cardboard when you do this to avoid damaging surfaces underneath.
- the small outer edges shown with diagonal stripes are 'tabs' for glueing the parts together. The tabs are folded 'downwards', unless otherwise stated.
- before glueing any pieces, put the pieces together first to check that you have understood the assembly instructions correctly.
- areas shown dotted will be glued 'face to face' (this will become clearer as you proceed).
- refer to the illustrations (A–E) as you follow the instructions, to see how the parts are to be assembled.
- where necessary, wait for the glue on the assembled parts to dry before proceeding to the next step.
- as always, use caution with scissors or cutting knife, or supervise young children where appropriate.

Assembling the Service Module and Solar Arrays (Figures A and B)

(1) Cut out the 6 solar array panels (sheet 1). Score only the glueing tabs (not the lines across the middle part of the solar arrays), and fold the tabs upwards, i.e. in towards the coloured side.

(2) Cut out the 18 pieces of the multi-layer insulation panels, or MLI (sheets 2–4). Do not score or fold any of these pieces, or their glueing tabs.

(3) Cut out the 6 pieces of the service module (sheet 5). Score and fold all glueing tabs.

(4) Arrange the 6 service module parts on a flat surface to form a ring, with the 6 shortest edges facing inwards, each of the glueing tabs next to the opposite edge of the adjoining part. They do not form a complete circle. Glue and join the pieces together using 5 of the glueing tabs only. At this time, do not glue or use the final tab to join the ring together at its remaining open edge.

(5) Continuing with the service module ring placed flat, position the 6 pieces of the solar array at the outer edges of the ring. One at a time, glue each tab of the solar array panels, then slide and fix each panel under the corresponding outward facing edge of the service nodule.

(6) Bring the two final edges of the service module together. Glue them in place to form a raised 6-sided pyramid, with the solar panels flat, pointing outwards, and the yellow surface face up.

(7) Collect the 6 pieces of the 5-sided multi-layer insulation panels which have glueing tabs (6 similar pieces do not have glueing tabs). Take one of these, and apply glue to all of its four glueing tabs. Then slide it under one of the 'open' areas between one of the pairs of solar panels. Align it carefully with the 4 corresponding edges of the solar array panels, and press the glueing tabs firmly to hold the piece in place. Repeat with the other 5 similar pieces.

(8) Turn the structure over. Being careful to avoid squashing the raised part of the service module, glue the 12 remaining multi-layer insulation panels into place over the corresponding shapes on the opposite side (hold up to the light to see these more clearly).

(9) Cut out the launch interface panel (sheet 9). Score, and fold the glueing tabs downwards. Insert the piece from below, so that it drops into the central hole of the same size in the service panel. Glue into place, pressing firmly from the inside.

(10) Cut out the closure panel (sheet 5). Score, and fold the glueing tabs downwards. You will now need to make holes, the size of a match stick, through the 6 'bipod' attachment points, shown as the small open circles with a diagonal line. These 6 points will eventually be used as attachment points to hold the telescope assembly to the service module. The easiest way to do this is to first make a small hole with

scissors, with the paper lying (for example) on a piece of old carpet. Then use a spent match to carefully push the correct sized hole through each of the attachment points.

(11) Cut out the six supporting structures, called 'bipods' (sheet 9). Do not score the glueing tabs on these pieces. Roll each bipod lengthways around a spent match stick to form a narrow cylinder. Start with the glueing tab held against the match stick, face outwards. Apply glue to the glueing tab, and press firmly to hold the small cyclindrical tube in place. When secure, push the match out of the middle of the tube. Check that these resulting 'bipod' cylinders fit snugly into the corresponding holes in the closure panel (see previous step).

(12) Put a good spot of glue around the underside of each of the holes in the closure panel, and push the bipods into these holes, one at a time, so that they only just enter the holes—just far enough so that they stay in place. Angle each pair of bipods to point towards each other, so that they stand vertically. The top of each pair will need to be separated by about 1 cm.

(13) Fold the glueing tabs of the closure panel over firmly, doubled back against the closure panel itself. Glue all 6 tabs, and drop the closure panel into place in the centre of the multi-layer insulation panels, shaded surface facing outwards. Position it carefully, then push it firmly into place, again taking care not to squash the raised service module.

The result of these steps should appear as shown in Figures A (from the upper side, showing the closure panel and bipods) and B (from the lower side, showing the service module and solar arrays). Put this assembled section to one side.

Assembling the Tent Structure (Figure C)

(14) Cut out the two main parts of the tent structure (sheets 6–7), the small hexagonal roof part (sheet 7), and the 6 triangular baffle panels (sheets 6–7). Score and fold the corresponding glueing tabs.

(15) There are 3 windows, which are the entrance holes for the telescopes, on these two tent panels. Each of these are to be cut along 3 sides *only*, as shown with the scissor symbols. Score the fourth side of each of these windows lightly. Then fold the resulting flaps outwards along the lower edges. The parts folded outwards form part of the entrance 'baffles' which prevent unwanted light reaching the sensitive detectors inside.

(16) Cut out the 6 triangular parts, and arrange them into three sets of two. Each set should contain one marked 'left' on one of the glueing tabs, and one marked 'right'. Each pair of triangular pieces will be used to hold the baffles at right angle to the side of the satellite. Fold the glueing tabs up or down as indicated on each tab. Score the central line of each triangle also; this will allow the baffles to be folded flat against the side of the satellite. Before glueing the tabs, check how they

are to be arranged. The shaded faces will be on the outside, away from the entrance windows. Glue the 'fold up' tabs in the normal way, but glue the 'fold down' tabs on the *back* side of the tab. Use these pieces to connect the main tent structure with the open baffles. Put the tabs connecting to the satellite *inside* the satellite, and the tabs connecting the baffles *below* the baffles. You can close open and these baffles.

(17) Glue and join the two parts of the tent structure together, forming a hexagonal enclosure.

(18) Glue the 6 tabs at the top of the tent structure, and drop the hexagonal closing panel into place, pressing firmly from the inside.

The result of these steps should appear as shown in Figure C. Put this assembled section to one side.

Assembling the Optical Bench and Telescopes (Figures D and E)

(19) Cut out the two parts of the optical bench (sheets 6–7). Score and fold all lines, except for lines marking out the inner dotted areas, and the 2 small glueing tabs at the ends of each of the 6 sections. Glue the two parts end to end with one of the long end tabs, to form a single long strip, which will be folded into the optical bench structure shown in the figure. Ensure that you join them so that the letters on the same 'row' are the same way up.

(20) As before, push small holes into the optical bench at the six locations of the bipod attachment points, shown by the small circles with a diagonal line through them.

(21) Fold and glue each of the six segments of the optical bench in turn, to form a string of six closed 'boxes'. You can press each of these sections flat to fix them securely, before 'opening' out each box again.

(22) Fold these six segments into a hexagonal ring structure, glueing each of the six segments end to end using the two glueing tabs at the end of each section. Do this one section at a time, holding the segments in place until they are secure. Finally glue the two open ends of the ring structure together.

The result is an open hexagonal structure. In the actual satellite, this will provide a light-weight but rigid platform capable of holding the satellite's telescopes. On the lower side are the 3 pairs of bipod fixing points, which will later be joined to the free ends of the bipods fixed to the closure panel (note that the feet of the bipods are more widely separated than the attachment points on the optical bench). Each of the two identical Astro (astrometric) telescopes will occupy a pair of opposite segments of the optical bench. The remaining pair of opposite segments of the optical bench will hold the elements of the Spectro (spectroscopic) telescope.

(23) Cut out and score the 5 parts of the spectrometric instrument (sheet 9). Fold and glue each part separately, forming 5 separate 'boxes'.

(24) Glue the two dotted faces labelled 'Spectro M1 mount' together. Do the same for the two 'Spectro M3 mount' parts.

(25) Attach the part labelled 'Spectro focal plane' to the corresponding part of the hexagonal optical bench, ensuring that the patterned face representing the focal plane faces inwards, towards the centre of the optical bench. Do the same for the part labelled 'Spectro M3 support', ensuring that the face representing the mirror faces inwards, and for the part labelled 'Spectro M1 support' which attaches to the other side of the bench.

(26) Attach the spectro mirror, using the dotted area labelled 'M2 attach' to the optical bench, with the mirror facing inwards, and projecting below the bench, away from the focal plane.

(27) Cut out and score the 10 parts of the two astrometric instruments (sheet 8). Fold and glue each part separately, forming 10 separate 'boxes'. The M1 mirrors are slightly curved, allowed for by the curved shape of the corresponding tabs.

(28) Divide these parts into two identical groups, each group of 5 parts forming one of the astrometric instruments. For each of these two astrometric instruments: glue the two dotted faces labelled 'Astro M1 mount' together. Then attach the face labelled 'Astro M1 support' to the corresponding part of the optical bench, with the M1 mirrors facing inwards, towards the centre of the optical bench. Attach each 'Focal plane', 'Astro M2', and 'Astro M3', to the corresponding parts of the optical bench (labelled 'Focal plane', 'M2', and 'M3' respectively). Make sure that all mirrors and focal planes face inwards, towards the centre of the optical bench. Parts of the M2 and M3 mirrors project below the optical bench, as indicated by the shaded areas of the attachment faces.

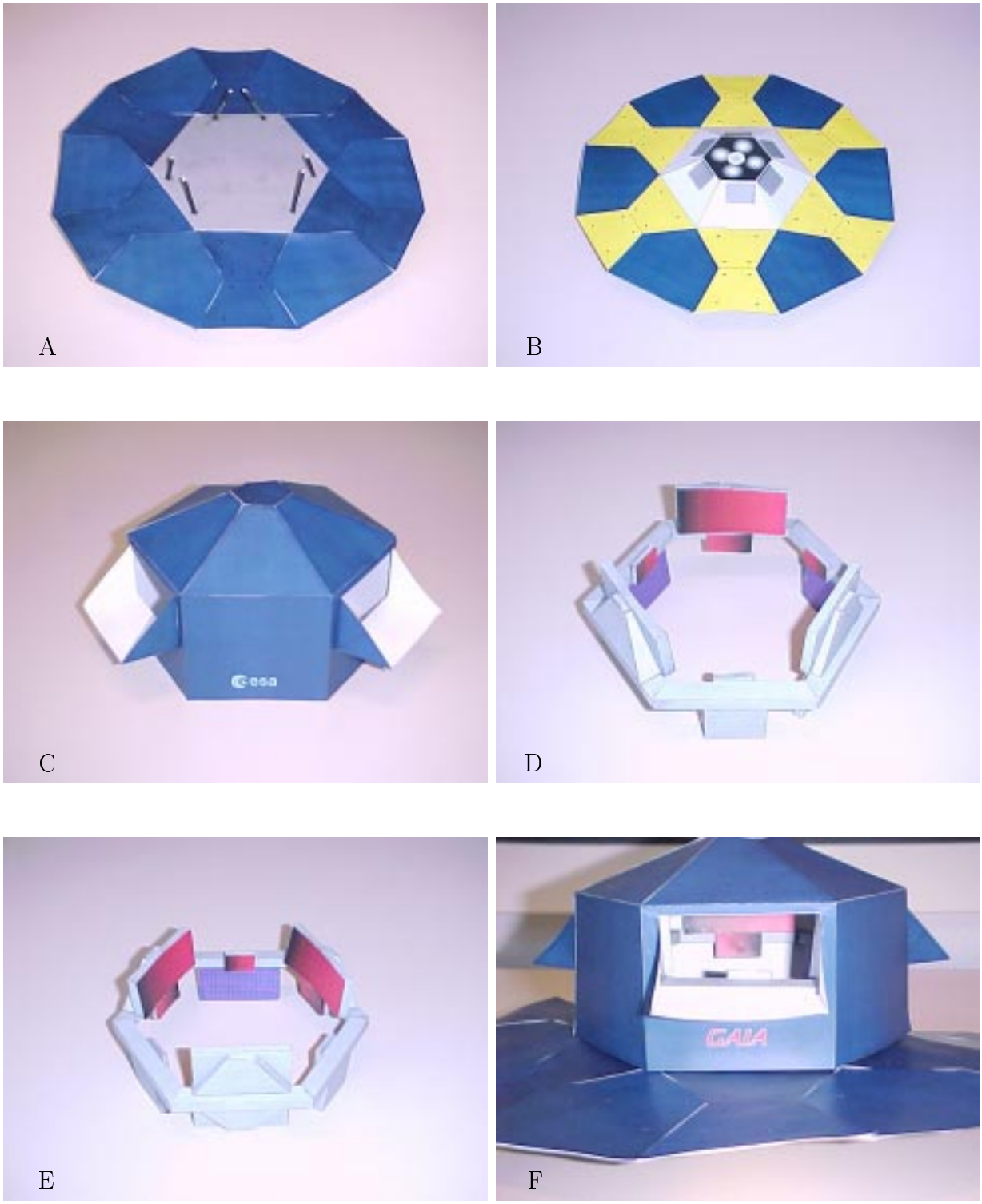
The result of these steps should appear as shown in Figures D and E.

Final Assembly (Figure F)

(29) Position the upper ends of the bipods attached to the closure panel so that they correspond to the position of the attachment points on the lower side of the optical bench. Put spots of glue on the upper ends of the 6 bipods, and attach to the corresponding points on the optical bench.

(30) Drop the assembled tent structure over the optical bench and assembled elements, such that the three entrance apertures allow views across to the three large mirrors above the optical bench, on the opposite side of the ring. Rotate the tent structure by 60° if necessary to achieve this.

The result of the final assembly should appear as shown in Figure F.



Figures A–F: GAIA satellite model assembly