Advanced Composition Explorer (ACE) Paper Model
INSTRUCTIONS

BEFORE YOU BEGIN:

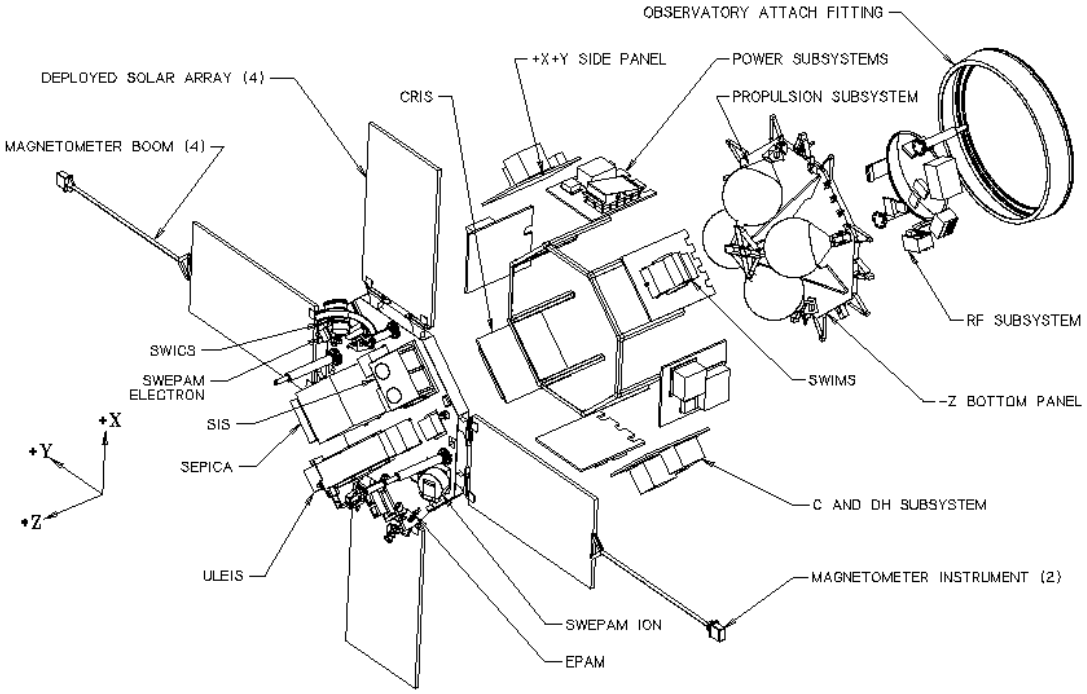
- Read through the instructions thoroughly (to avoid surprises).
- Assembly will take between four and eight hours to complete, depending on your previous experience in paper modelling and the amount of care you want to put in to the model.

SUPPLIES NEEDED:

- Eight (8) sheets of cardstock (≥60 lb. bond) -- may be labeled as "cover weight";
- Sturdy ruler;
- Craft knife (e.g. X-Acto© or equivalent) and/or scissors;
- Glue stick or another form of low-moisture glue (white glue causes parts to buckle and takes a long time to dry);
- Cutting mat or similar surface to cut on (watch out for those tabletops!);
- Thread for hanging; or clear plastic cup with bottom removed for display;
- 18 gauge wire for MAG booms (optional).

NOTES:

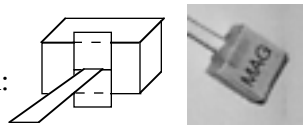
- Avoid cutting out parts before you're ready to assemble that particular portion of the model -- whole sheets are harder to lose than little tiny parts.
- Score along folding lines before cutting out shapes. To score parts, use an empty ball-point pen, or run your craft knife VERY LIGHTLY over the line to be scored.
- Cut out inner shapes (like the triangle within the end of the MAG booms) before cutting the outer edge.
- All tabs for gluing are colored grey.
- In spacecraft terminology, the X, Y, and Z axes are used to designate the top, bottom, and sides of a satellite. +Z is the top, -Z is the bottom, and +/- X and Y refer to left, right, close, and far sides. All of these are labeled on sections of the model to facilitate assembly, and can be seen as well on this exploded view of the ACE satellite:



Advanced Composition Explorer (ACE) Paper Model
INSTRUCTIONS

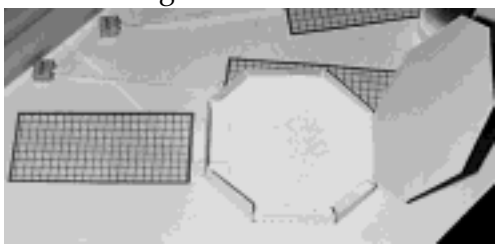
1. Print out the model parts on cardstock.
   - Keep *everything* at the same scale, or the parts won't go together correctly.
   - Make sure the cardstock is compatible with your printer -- office supply stores may have several different types, depending on whether you are using a laser or inkjet printer.
   - If the printer won't accept the cardstock (paper jams or other mishaps during printing), print on regular paper and glue to cardstock or very thin cardboard -- spray glue is ideal for this, as other types may not hold correctly, and might cause the paper to buckle.

2. +Z (top) Assembly:
   a. You may *want* to print the solar panels on blue cardstock (*suggestion* from Larry Deck), or color them in *blue before* cutting them out, for greater realism.
   b. Score along all folding lines (center of solar panels, interior lines on MAG instruments, etc.)
   c. Cut out the solar panels, MAG booms, and MAG instruments.
   d. For solar panels that do not have MAG booms attached, simply fold in half along center line and glue sides together.
   e. For solar panels with attached MAG booms:
      - fold MAG booms in half along fold line, and glue booms together up to the small square at the opposite end. (If you want the booms to be a little more sturdy, put the wire in between the booms and glue.)
      - bend back the small squares 90°
      - assemble MAG instruments, and glue one to each MAG boom as shown:



      - fold the extra portion of the tabs over and glue.
      - glue the other end of the boom to one half of the solar panel, so that the boom will be centered when the panel is glued together. The triangular portion should protrude from the solar panel.
      - Glue the two halves of the solar panel together.

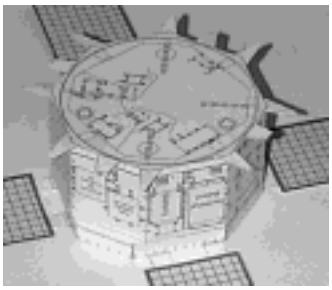
      The solar panels collect sunlight and turn it into usable energy for the spacecraft.
      MAG -- Magnetic Field Monitor -- collects data on the sun's magnetic field, measuring the strength and direction of the interplanetary magnetic field 30 times per second, and calculates patterns of variations. MAG was developed by the Bartol Research Institute in Newark, DE, and by the GSFC, and is a flight spare from the WIND mission. For more information on MAG, please visit the web site at: http://www.bartol.udel.edu:80/~lheureux/ace.html
   f. For the Top Panel:
      - The top panel, when assembled, will form a slightly irregular octagon about 10 cm across and 1 cm high. The upper surface is marked with the positions of each instrument, along with some extra details. The lower surface (with the dotted lines) shows the placement of tabs for the side panels.
      - Score the fold lines on the top panel (these include the perimeter of the central portion, one side of each of the triangular tabs, and the bottom of the sides of the panel).
      - Before cutting out the top panel, cut out the long, thin, black rectangles on four sides of the octagon. These will be where the "feet" of the solar panels fit in.
      - Cut the top panel out, snipping one side of each of the triangles to form tabs.
      - Fold the sides down at 90° angles to the upper surface and glue the sides together with the tabs.
      - Now is a good time to insert the solar panels: spread a little glue on one side of the solar panel tabs, push them through the long rectangular holes, and glue in place.
      - Once the solar panel tabs are dry and secure, fold the lower surface of the top panel down and use the trapezoidal tabs to glue it into place.
      - Through the rest of the assembly, be careful not to bend the solar panels or MAG booms too much; the cardstock can take a little rough handling, but after a while it is more difficult to bend parts back into shape.



3. -Z (Bottom) Assembly:
   a. Cut out the bottom panel shapes (no scoring is required).
   b. You will find that the shapes only fit together in a certain orientation. Glue the two shapes together in this orientation, on their non-printed sides.

   The panel without the balloon-like shapes houses instruments essential to the proper operation of the spacecraft, such as the slam electronics, slam battery, transponders, and other such electronics. The other panel is actually a 2-dimentional representation of the propulsion subsystem: the balloon-shaped objects are actually propulsion tanks, which rest against a pyramid-shaped structure (represented by the large "plus" shape). The spikes sticking out of the -Z panel were used to hold the folded-up solar panels in place against the spacecraft during transport and launch.

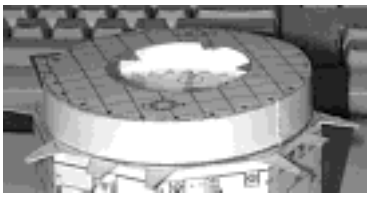
4. Side Panel Assembly:
   a. Score along the inner edges of the tabs, as well as on the lines that separate each individual side panel.
   b. Glue the two side panel sections together to make a ring. *(On the real ACE, the side panels actually slide into a bracket, as shown on the exploded view of the spacecraft, but that was impractical for this model.)*
   c. Fold the tabs at the top of the ring at a 90° angle to the ring, and glue these tabs in place on the top panel, making sure to match up the +X, -Y, etc.
   d. Fold the tabs at the bottom of the ring similarly, and glue them to the corresponding spaces on the +Z face of the bottom panel.



5. Observatory Attach Fitting:
   a. Score along the long horizontal lines of the Observatory Attach Fitting (OAF), as well as on the two tabs on the right side.
   b. To cut out a large series of tabs like those on the OAF, you may find it easiest to use a craft knife, cutting first one side of each tab and then moving the paper slightly to cut the other side:

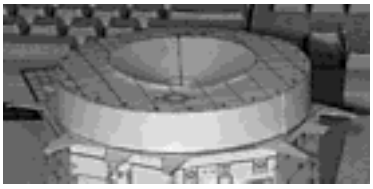
      Step One:  Step Two: 

      For ease of cutting, the two halves of the OAF are "joined" by the row of tabs, but once cut out, you should have two nearly-identical pieces which are then glued together at the ends to form a circle.
   c. Score the tabs on the -Z cover, and cut out the center portion, then the innermost circles of the two O-shaped features (where the -Z low-gain antennas will fit in). Cut out the -Z cover -- you may find that scissors work best to cut out circles.
   d. Fold the tabs of the OAF down, towards the inside, to be at a 90° angle with the circle. Spread glue around the outer edge of the -Z cover. Carefully glue the OAF to the -Z cover, keeping the OAF as perfect a circle as possible.
   e. Now apply glue to the -Z panel, just inside the printed circle, and glue the remaining tabs of the OAF to the -Z panel. (The holes for the low-gain antennas should be approximately along the X axis.) You may need to reach inside the -Z cover to press some of the tabs down.



The Observatory Attach Fitting allowed the spacecraft to attach to the Delta II launch vehicle, as well as providing protection to the electronics and other parts on the -Z panel.

6. High-Gain Antenna (Dish portion):
   a. Cut out the high-gain antenna reflector. Also cut just one side of the wedge, so that when you join the two lines of the wedge, you have formed a cone. The printed side should be on the interior of the cone. Glue the overlap in place.
   b. Apply glue to the five tabs on the -Z cover. Set the reflector into position such that the line is pointed towards the +X low-gain antenna hole.



c. For now, don't glue the high- or low-gain antennas into place; you will be resting the model on the -Z side, and the antennas would just get in the way.

The antennas allow the spacecraft to communicate with scientists back on earth, sending back the gigabytes of data that the instruments generate during operation.

7. +Z Instruments:

(These can be done in any order; here they are arranged as easiest-to-hardest to assemble.)

a. The four rectangular boxes (S^3 DPU, MAG MFI, ULEIS DPU and elect.) are all assembled in the same way as were the two MAG boxes. (DPU stands for "Data Processing Unit" and MFI is the electronics box for MAG.) Once each box is assembled, it may be glued onto the +Z panel.

b. The +Z low-gain antennas are a little tricky to put together because they must be rolled up very tightly (they are rolled into long, thin cylinders). You may wish to print or copy these onto regular paper, or use a 1/8" dowel in their place (credit goes to Larry Deck for this idea). If you are having problems getting the tabs to stick, use a piece of clear tape along the axis of the cylinder. These antennas fit into the +Z panel in the circles you cut out earlier; just push them in as far as they'll go, and friction should hold them in fine. (You may want to wait before pushing them in, though, until the other +Z instruments are in place.)

c. Follow the same sort of procedure with the +Z thrusters (including the use of regular paper or dowels).

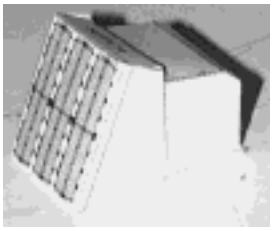
d. **SIS: Solar Isotope Spectrometer**

- Before cutting out the instrument, score along the vertical and horizontal lines that divide the planes of the instrument. Do not score the diagonal lines between the white wedges and the sides of the instrument; there is no fold there.
- Cut the instrument out, and fold along the score lines.
- Glue the tabs into place. The instrument should look like a rectangular box sitting on an angled wedge.
- SIS is positioned on the +Z panel such that it is inclined towards the edge. This gives it the field of view necessary to perform its measurements.

SIS was built to measure the elemental and isotopic composition of the solar wind, in the range of elements between helium and zinc. It was developed by researchers at Caltech, GSFC, and JPL. For more information on SIS, please visit http://www.srl.caltech.edu/ACE/CRIS_SIS/sis.html

e. **SEPICA: Solar Energetic Particle Ionic Charge Analyzer**

- Before cutting out the instrument, score along the vertical and horizontal lines, except for those on the face. The L-shaped tabs that connect to the central (unprinted) rectangle do not actually fold in, so they need not be scored separately, nor should the short connecting line be cut.
- Cut the instrument, and fold along the score lines. The odd-shaped flaps simply glue to the L-shaped tabs without folding the tabs; the rest of them are folded for gluing.
- Glue the tabs into place.
- SEPICA is positioned on ACE with the gratings pointing outward, such that its field of view is unobscured.



SEPICA was built to measure the ionic charge state, elemental composition, and energy spectra of energetic solar ions. It was developed by researchers at the University of New Hampshire and the Max Planck Institute for Extraterrestrial Physics in Germany. For more information on SEPICA, please visit http://www-ssg.sr.unh.edu/tof/Missions/ACE/sepicamain.html

f. **EPAM:**

- The main body of EPAM folds up like a regular box -- just score along the tabs, fold, and glue in place.
- The other shapes represent some of the telescope apertures that EPAM uses to gather data, and are assembled as follows:

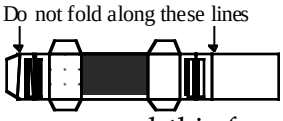
- Score along the vertical lines (next to the triangular tabs).
- Roll the shape such that the larger tab at the top wraps around to the bottom. Glue this tab into place.
- Fold down the triangular tabs, then glue the circles to the tabs.
- Glue the completed telescope apertures to the main body of EPAM so that it resembles the photograph above.

- The darkened box on the surface of EPAM represents another of the five telescopes carried by EPAM, a formation that would have been too small to include on the model.
- EPAM is positioned on ACE such that the face with the two vertical lines on it points outward.

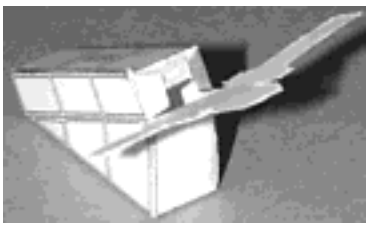
EPAM was built by researchers at Johns Hopkins University's Applied Physics Laboratory (JHU/APL), and is a flight spare of an instrument built for the Ulysses mission. For more information, please visit http://www.gsfc.nasa.gov/ace/epam.html

g. **ULEIS: Ultra-Low Energy Isotope Spectrometer**

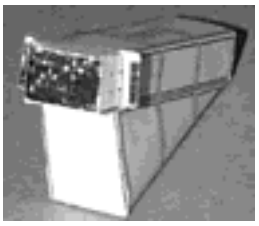
- Take care when scoring this model that you score only its actual faces -- in the lower part of the instrument, each face is divided into three sections, but those are there only for the pretense of accuracy, and are not to be folded or cut out.
- Score along the vertical lines, except for those indicated in the picture. Score also along the horizontal lines, and those bordered by tabs. Only one diagonal line (plus the tabs) will be scored: note that on the right side of the instrument, there are two actual faces, one of which is wider than the other. Score around this face only: the other diagonal face, and the wedge-shaped one, form a single face when folded, as may be apparent in the photograph (of the actual instrument) above.



- Carefully cut out the instrument, remembering to cut slits between the diagonal faces at the bottom and the tabs that will connect them to the smaller rectangle adjacent to them.
- To glue the instrument together, begin with the lower half. The lower half should resemble the base of the instrument as shown in the photograph -- like a rectangle on which one end has been enlarged. You will not use the three top diagonal tabs until after the next step; only the tabs on the lower end, the large diagonal one, and the two on the middle connecting piece should be glued at this time.



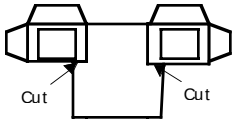
- The top section folds together like another, separate box. The unprinted rectangle forms the bottom, while the tiny rectangles with black rectangles printed on them jut out from the sides of this box, along the bottom plane. (This can be seen to some extent in the photograph.)
- Once that box is finished, it can be glued to the tabs leftover from before the previous step.
- ULEIS is positioned on ACE with the small black box -- the portion that collects particles -- pointing outwards.



ULEIS was built by researchers at the University of Maryland, in conjunction with JHU/APL. For more information on ULEIS, please visit http://sd-www.jhuapl.edu/ACE/ULEIS/

h. **SWEPAM (Solar Wind Electron, Proton, and Alpha Monitor) ION**:

- SWEPAM is one of the trickier instruments to put together here. Don't let that discourage you, though -- it's certainly do-able!
- First (repeat after me) score along the fold lines. Of the lines on the upper section of the main body, only the outside vertical lines should be scored (where it meets the tabs), but all of the horizontal ones can be.
- On the lower section, score all vertical and horizontal lines, and cut through the small lines indicated at right. Also score the diagonal lines deliniating the tabs, as shown in the photograph.



- To fold the instrument, follow the diagrams below:

- For the cylindrical portion, score the tabs, roll up the cylinder, and glue the circular flap down. Apply glue to the other tabs, and set the cylinder on the slanted portion of the instrument.

i. **SWEPAM Electron**:

- The box-portion of SWEPAM electron is constructed in the same manner as SWEPAM ion. The long, striped face actually represents the cylindrical portion shown in the photograph.
- To construct the cylindrical portion, wrap the striped face into a circle, and glue the tab to the bottom portion. The tabs on the rounded face should facilitate shaping the cylinder.

SWEPAM was built by the Los Alamos National Laboratory in New Mexico. It is built from the spare solar wind electron and ion analyzers from the Ulysses mission, with selective modifications and improvements. For more information on SWEPAM, please visi http://swwwepam.lanl.gov/

j. **SWICS: Solar Wind Ion Charge Spectrometer**

- SWICS look daunting, but don't despair; it's the last of the +Z instruments and the worst one you'll have to assemble.
- Score along all lines except the dotted line and the circle seen on the uppermost wedge-shape (which are merely placement guides).
- Cut the instrument out as shown (the picture is backwards due to a change in this version).
- Fold and glue the funny-shaped pieces as shown.
- Roll up the lower section (as with the telescopes on EPAM) and glue; roll up the separate cylinder and glue it together, then glue it to the circle on the main body.

SWICS was built by the University of Maryland and the University of Bern, Switzerland. It is a flight spare from the Ulysses mission. For more information, please visit http://space.umd.edu/umd_sensors/uls_swics.html

k. **Positioning the +Z Instruments**:

- To place the +Z instruments in their proper positions, match the label on the base of each instrument to its corresponding label on the +Z panel, or consult the photograph at right.

The instruments on ACE are all positioned so that they have the best field of view for the data they collect. For example, SEPICA is positioned essentially such that it is not facing the sun directly, but rather can sample data that is accelerated by the solar wind without being overwhelmed by solar ions.

8. <u>Side Panel Instruments</u>:

a. There are eight rather nondescript boxes included with the model; these are optional parts, as their purpose is functional rather than strictly scientific. However, ACE could not fly or collect data without them, so they are included for completeness. Each one is labeled according to its function, and those labels are also placed on the spacecraft panels, so you will know where to place them. They are all assembled in the same manner as MAG, the DPUs, and other small boxes.

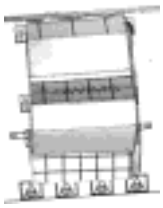
b. **CRIS: Cosmic Ray Isotope Spectrometer**

- This instrument is represented as a simple box shape, and is assembled in the same manner as other boxes. There are only six faces, so study the instrument somewhat carefully before scoring -- most of the lines are purely cosmetic and will not be folded.
- Beyond this, CRIS is quite simple to assemble. It is shown in place in the photograph at right.

CRIS was developed at Caltech, GSFC, JPL, and Washington University at St. Louis. For more information, please visit http://www.srl.caltech.edu/ACE/CRIS_SIS/cris.html

c. **SWIMS: Solar Wind Ion Mass Spectrometer**
   - SWIMS looks a little complicated on the page, but don't be frightened; it's just a matter of folding the long segment correctly.
   - Score the model on the horizontal lines that divide planes on the long segment. There will be nine planes in total; two of them are too small to include tabs, but should be folded to insure that the instrument is assembled correctly. Also score the lines at the base of each of the tabs on the lower section, and the vertical lines to the right and left of the labeled center piece.

   - Cut the model out and fold the strangely-shaped faces forward (print side out). To glue the instrument together, apply a little glue to each pair of tabs as you come to it (to avoid a mess), and simply fold the long section to fit the contour of the strangely-shaped faces.
   - SWIMS is shown half-done, and completed in its position on ACE, in the photographs here.



SWIMS was built by the University of Maryland and the University of Bern, Switzerland. It is a copy of portions of the CELIAS experiment form the SOHO mission, with slight changes to optimize it for ACE. For more information, please visit http://www.gsfc.nasa.gov/ace/swims.html

9. -Z Finishing Touches
   a. Very carefully cut out the High-Gain antenna (leftover from the Observatory Attach Fitting assembly). You may want to apply tape to the long, thin struts before cutting out the antenna, to prevent them from tearing.
   b. Fold the ends of the struts up just slightly, and glue them to the small, black rectangles on the edges of the antenna dish.
   c. The -Z low-gain antennas are assembled in the same way as the +Z low-gain antennas were, and are inserted into the holes in the -Z cover.

10. In reality, not many of the faces of ACE are actually seen, as the structure is covered with a thermal blanket, leaving only the instrument sensors uncovered. I think the model is more impressive when you can see all the little details, but if you want real accuracy, you may want to cover the model with tissue paper. Pictures of the covered satellite are available at http://www.gsfc.nasa.gov/ace/gallery.html (along with many other ACE-related graphics and such), so scroll down and take a look if you want to cover the model.

11. To hang the model, cut a piece of thread about 1 meter (36 inches) long, and tie the ends together to create a loop. Holding the loop in the middle to make two smaller loops, pass one loop around each of two opposite solar panels. Tie a knot in the middle, and hang your model from another string. Alternately, you may cut the bottom off of a clear plasic cup, and place the spacecraft on it.

12. Carefully pat yourself on the back: you've now finished with your construction of the Advanced Composition Explorer model, and hopefully learned about the spacecraft in the process.

Model and Instructions Completed on 25 January, 1999
Revision Two Completed 22 February, 1999
Jan Andrea Heirtzler, UNH Space Science Group
