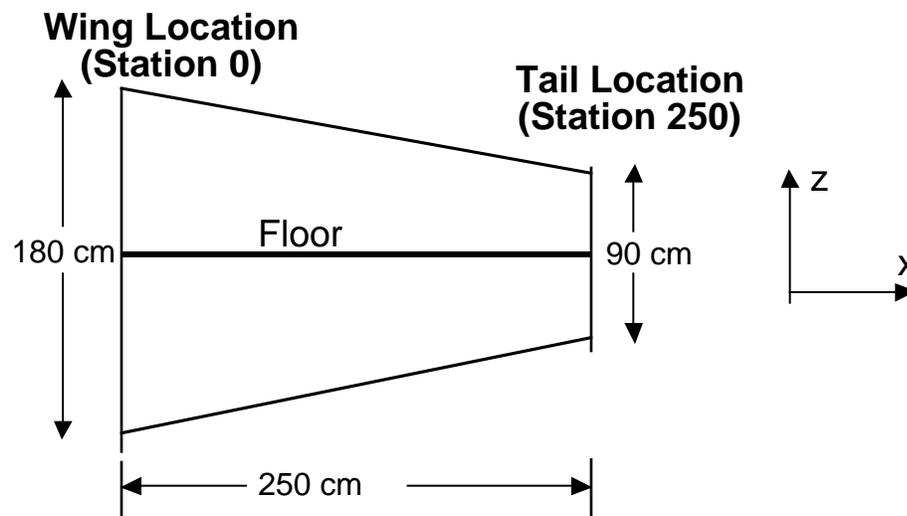


**DESIGN PROBLEM #4**  
(and...HOME ASSIGNMENT #9)

You and your team of colleagues are employed as structural engineers at Small-Planes-R-Us, Inc. The board of directors has committed the company to producing a new small two-seater airplane. Your engineering manager is responsible for the fuselage design and specifically assigned your team to work on the aft fuselage between the wing and the tail. She has asked you to submit a preliminary design for this section of the fuselage in about three weeks. The aerodynamics group has decided to go with a circular cross-section and it is divided into two regions by a "floor" to attach some instrumentation as specified by the avionics group. The preliminary sizing work has defined the diameter of the cross-section near the wing region (aft fuselage station 0) to be 180 cm, and at the tail connection point (aft fuselage station 250) the diameter is 90 cm. The length of this section is 250 cm.

FIGURE 1 Side view of aft fuselage.



You have been asked, specifically, to make recommendations for the areas and materials to be used for the stringers and the thicknesses of the floor and skin of the fuselage. This is to help your engineering manager prepare for a "Design-Build Team" meeting where representatives from the various aspects of the engineering divisions as well as manufacturing and marketing representatives will confer to better define the design.

The preliminary sizing and configuration work has defined a cross-section for the aft fuselage. This configuration consists of skins connecting four stringers: one at the top of the fuselage, one at the bottom, and one on each side of the floor at the floor level. In a discussion with your group, your manager has provided you with the following information as well as the accompanying figures:

**FIGURE 2 Cross-section dimensions.**

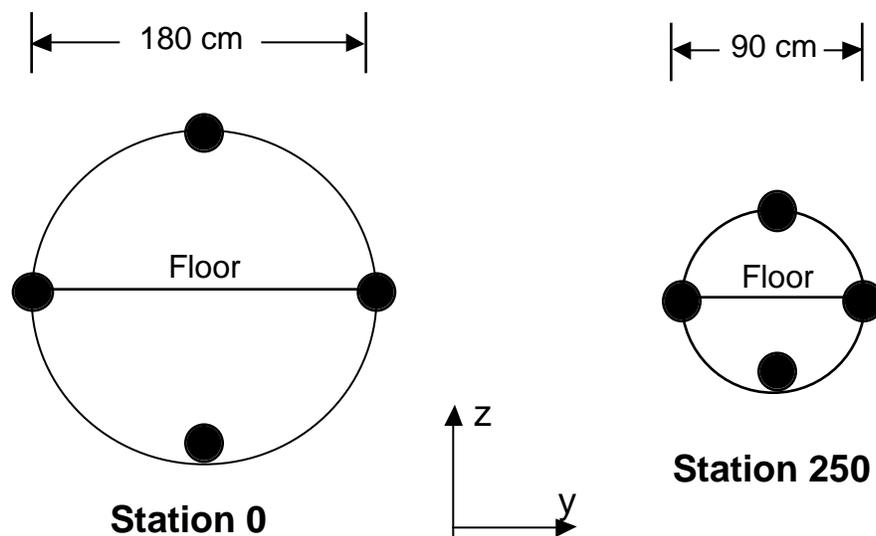
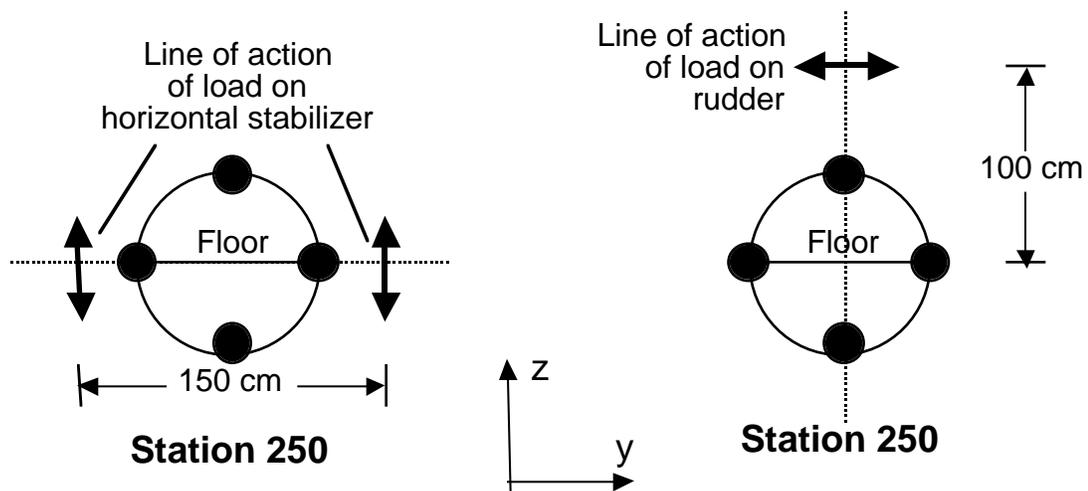


FIGURE 3 Lines of action of loads.



### Preliminary assumptions

For the purposes of preliminary design, the following assumptions can be made:

- The stringer can be made of two possible materials: a highly-unidirectional-oriented graphite/epoxy laminate using premanufactured rods from a relatively new process from a company in Rhode Island (see attached article) or aluminum. However, due to manufacturing considerations, all stringers should be made of the same material. Furthermore, each stringer cross-section is to remain constant along the entire length of the aft fuselage.
- The skins will be made of 7075-T6 aluminum. Minimum gage thickness is 0.3 mm. A good "first guess" is that all the skins are of the same thickness. The floor thickness has been initially set at 6 mm (Someone else is doing the specific design of the floor which will include local stiffeners. These local stiffeners can be ignored in your work.)
- It is sufficient to assume that only the four concentrated stringer areas contribute to bending stiffness while the skins are only effective in shear.
- Symmetry of the structure is to be assumed in the preliminary design due to aerodynamic considerations and due to the fact that loads could switch directions depending on the conditions of the flight. The lines of symmetry are the floor and a line drawn perpendicular to the floor through the fuselage center.

- The aft fuselage may be considered as a cantilevered beam clamped at station 0. There are rigid frames to maintain the cross-section at regular intervals. You are not being asked to worry about the frame location and design at this time.
- Buckling is not to be considered at this stage but will likely be an important consideration in the next stage of the design.

### Preliminary material information

The following material properties have been furnished by the materials department:

Material	$E_L$ [GPa]	$\nu_{LT}$	$\sigma_L^{\text{allowable}}$ [MPa]	$\tau_L^{\text{allowable}}$ [MPa]	$\rho$ [g/cm <sup>3</sup> ]
Gr/Ep laminate	110	0.4	500	----	1.54
Aluminum	70	0.3	350	180	2.80

- Further questioning of the materials department yields a working shear modulus of the graphite/epoxy laminate of 6.0 GPa.
- The material allowables are valid in both tension and compression. These represent values that have been reduced from mean material ultimates due to statistical and other considerations.
- The cost per manufactured pound of graphite/epoxy structure is \$150. The cost per manufactured pound of aluminum structure is \$70.

### Preliminary load information

The loads on the aft fuselage are primarily due to the lift loads on the horizontal stabilizer and the rudder/vertical stabilizer. (The fuselage is not pressurized.) The loads can be considered to act at a point. There are three types of loads at the tail location (station 250) which may be considered to act separately for the purposes of preliminary design:

- The first load condition is at take-off and consists of a symmetric 2500 N load on each horizontal stabilizer acting in the negative direction at a distance of 75 cm from the center of station 250.

- The second load condition is an anti-symmetric maneuvering load of 1000 N per horizontal stabilizer. These loads also act at a distance of 75 cm from the center of station 250.
- The third load condition is again a maneuvering load. This consists of a load of 1000 N on the rudder. This acts 100 cm above the plane of the floor at station 250.

### Preliminary design criteria

A preliminary assessment of usage has been conducted based on historical data as well as a survey of past and potential customers. The following design criteria for the aft fuselage have been initially set:

- Under normal conditions, the bending deflection in the z-direction at station 250 must not exceed 1% of the length of the fuselage between stations 0 and 250.
- The twisting at the tip must not exceed  $1^\circ$  under normal operations.
- An ultimate factor of safety of 1.5 is to be employed when considering the operating loads/stresses in comparison to the material allowables.

### The Job

Your group's job is to provide the complete specifications of your preliminary design, with dimensions of all the areas involved, material used, and the weight and cost of the resulting structure. You should highlight any key tradeoffs such as that between weight and cost that would result by this choice of design and provide suggestions pertaining thereto.

### How and What...

This assignment is divided into two parts. The first part is **Home Assignment #9** and is a separate document handed out with this document. This assignment poses a general stiffener-skin configuration similar to those to be considered in Design Problem #4. Your team is asked to determine the cross-section properties of the configuration and the stresses and deflections that arise

under several different loading conditions. This part of the work is **due on Lecture 43**.

This work serves as the appendices to your memo that you need to provide your supervisor in this Design Problem #4. The specific calculations in Home Assignment #9 serve as the base work on which to base engineering judgements in the design considerations. In order to be sure that each team has equal capability in this regard, *solutions for Home Assignment #9 will be posted on the 16.20 website on Lecture 43, during the latter part of the day.*

For Design Problem #4, you are to provide an internal memo to your engineering manager detailing your design. This should include the dimensions for each of the cases, the associated costs, and any interesting items that arise in considering the designs. Important tradeoffs should be highlighted and reasons for the final recommendation clearly indicated.

No appendix is needed in this case since your engineering manager has already received your basic analysis technique (i.e. Home Assignment #9). However, this internal memo should contain descriptions of the methodology you used in arriving at your design. Since this is an internal memo, it is less formal than those written for outside customers, especially since this is a preliminary design exercise. Your engineering manager will then use this memo in preparing for the Design-Build Team meeting. It would help your manager if there were a clear summary up front followed by the full description.

This part of the work, Design Problem #4, is **due on Lecture 46**.