ME 163
ENGINEERING AERODYNAMICS

MID TERM EXAM, 14TH OCTOBER 2005
Solution

1. Consider the view of Concorde in the figure attached. Use the dimensions supplied on the figure and an appropriate numerical method to calculate the wing area $S = \int_{-b/2}^{b/2} c dz$**, the aspect ratio** $A = \frac{b^2}{S}$**, and mean aerodynamic chord of the wing planform** $\bar{c} = \frac{1}{S}\int_{-b/2}^{b/2} c^2 dz$**, where** z **is the spanwise ordinate,** $c(z)$ **is the local chord length and** b **is the span.** You need to measure off local chord lengths c as a function of spanwise ordinate z. Do these with a ruler as well as you can. Measure off as many points as are necessary to get an accurate answer. Sample values are in the table below for one half of the wing.

point	z/m	$c(z)/m$	$c^2(z)/m^2$
0	0	27.66	765
1	1.38	27.66	765
2	2.77	20.76	431
3	4.15	17.99	324
4	5.54	13.84	192
5	6.92	11.07	123
6	8.30	8.99	81
7	9.67	6.92	48
8	11.07	4.84	20.1
9	12.8	0	0

Integrate using a trapezoidal scheme. Depending upon whether the values at $z = 0$ are used or not (it's debatable whether that is the wing or not), and how accurately the points were measured off the diagram (limited accuracy), you should get answers of the order of $S = 358m^2$. $A = 1.83$, $\bar{c} = 16m$. These values will be used for part 2. Marks awarded: 15 marks for S, 5 for AR, 30 for $\bar{c}$

2. Concorde was propelled by four Bristol/ SNECMA Olympus 593 turbojets, mounted in pods of two, one pod underneath each wing. Consider a double engine failure on the port (left) side

of the aircraft when in cruise at Mach 2 ($M_\infty = 2$) at 50000ft. In this condition the starboard (right) engines continue to deliver their cruise thrust, but there is then an unbalanced moment about the vertical axis, and so the aircraft yaws anti-clockwise (see the figure) about the vertical axis through the centre of gravity. For safe, controllable flight the yaw angle (i.e. the angle the aircraft makes to the airflow about the vertical axis) should not exceed 2^o. Anti-clockwise yawing moments are produced by the starboard engine thrust and the side force F_{side} on the fuselage (which acts about the fuselage centre-line), while the fin and rudder provide a trimming moment in the opposite direction to set the net yawing moment about the centre of gravity to zero.

The Concorde mass is 140 metric tonnes, and the cruise drag coefficient is $C_D = 0.017$. The dynamic pressure at cruise is $q_\infty = 32480Nm^{-2}$. Note the line of action of the starboard engine pod is $6m$ away from the fuselage centre-line.

Using your answer for the aircraft wing area from part (1), and with the aid of the diagram in the attached figure, determine the following:

(a) The aircraft lift coefficient.

(b) The total engine thrust in normal flight, and hence the thrust provided by the two remaining, functional engines on the starboard side after the engine failure.

(c) The fuselage side force F_{side} due to the aircraft yaw if the rudder and fin side force is a total of $81691N$ acting at a point 92% along the fuselage length.

Answers: (a) Lift=weight. $W = 1373400N$. $L = C_L q_\infty S$, so we find $C_L = 0.118$. (10 marks)

(b) Thrust=Drag. $D = C_D q_\infty S = 197673N$. So $T_{starboard} = 98836N$. (10 marks)

(c) Zero net yawing moment about c.g. Moment arm of fin/ rudder is $21.56m$ from c.g., moment arm of fuselage side force F_{side} is $4.34m$ from c.g.. So net clockwise moment due to fin/ rudder is $1761258Nm$; net anti-clockwise moment is $6T_{starboard} + 4.34F_{side}$. So we find $F_{side} = 269180N$. (30 marks)