ENAE 484/788D
Problem 8 Solutions
Fall, 2002

a) For 13 flights without a failure, the 80% confidence reliability estimate can be found from $P^{13} + C = 1 \Rightarrow P^{13} = 0.2 \Rightarrow$ $\boxed{P{=}0.8836}$

b) Same equation as above, but demanding a reliability of 0.95 produces a confidence factor of $P^{13} + C = 1 \Rightarrow 0.95^{13} + C = 1 \Rightarrow$ $\boxed{C{=}0.4867}$

c) Crew survival requires that *either* the launch vehicle works *or* the launch escape system works. The likelihood of crew survival is $P(survival) = 1 - \overline{P}(launch\ vehicle)\overline{P}(launch\ escape\ system)$. Numerically, $0.999 = 1 - (1 - 0.95)(1 - P_{LES}) \Rightarrow$ $\boxed{\text{P(launch escape system)=0.9800}}$

d) One failure in 437 missions corresponds to P=436/437=0.9977. Confidence is the probability that the results you got, *and all better results*, would not have happened by random chance. The governing equation in this case would be $P^{111} + 111P^{110}(1-P) + C = 1 \Rightarrow C = 1 - \left[0.9977^{111} + 111(0.9977)^{110}(.0023)\right] \Rightarrow$
$\boxed{C{=}0.02737}$ (*not* very high! Out of curiosity, if you applied the old estimate of 1/72 failures (P=0.9861) to current statistics, you only get a 45.8% confidence in the estimate.)

e) Flying once a month nominally, following a failure with a 9-month down time there will be 9 payloads in the backlog (at 100% retention). You have to fly off the 9 backlogged missions, interspersed with nominal flights, before another failure is expected to show up. Since you plan for 1 failure in 30 missions, you will be nominally resilient if you fly the 9 backlogged missions interspersed with 21 nominal missions. This gives a critical surge rate of 30/21= $\boxed{1.429}$ (You can do this with the equations given in class, too, but I'd rather you think about what is happening than just plug numbers into an equation.)

f) A single computer has a reliability of P. Given an intercorrelation rate of F, the possible outcome probabilities become
All five work: $P^5 = (0.98)^5 = 0.90392$
Four work without intercorrelated failure:
$5P^4(1-P)(1-F) = 5(0.98)^4(0.02)(1-F) = .09223(1-F)$
Three work without either failure being intercorrelated:
$10P^3(1-P)^2(1-F)^2 = 10(0.98)^3(0.02)^2(1-F)^2 = .003765(1-F)^2$
The question asks for the intercorrelation rate F at which the primary system (the sum of the three probabilities above) are equal to the reliability of a single computer.
$0.90392 + 0.09223(1-F) + 0.003765(1-F)^2 = 0.98$ - we can set up a quadratic

equation for (1-F): $0.003765(1-F)^2 + 0.09223(1-F) - 0.076079 = 0$ - this gives (1-F)=0.7988 or a critical intercorrelation rate of $\boxed{F=0.2012}$

g) $P^{111} + 111P^{110}(1-P) + 0.8 = 1$; this is a case where brute force works very nicely, and the answer that comes out is $\boxed{P = 0.9733}$ (which says to expect a failure every 37.5 flights at 80% confidence, which means 4 times out of 5 the results will be *better* than this…)