ENAE 483/788D LECTURE #09 (RELIABILITY) PROBLEMS – FALL, 2023

(1) NASA flew 13 Saturn V vehicles with no failures. At an 80% confidence level, what reliability could they claim?

$$R^{13} + C = 1 \Longrightarrow R = (1 - C)^{\frac{1}{13}} = (0.2)^{\frac{1}{13}} = \boxed{0.8836}$$

(2) The Space Shuttle flew 135 times with two failures. What reliability could NASA claim for the shuttle at a 75% confidence level?

Confidence is the likelihood that you would have seen the expected outcome or any of all possible better outcomes, so for two failures out of 135 launches:

$$R^N + NR^{N-1}(1 - R) + \frac{N(N-1)}{2}R^{N-2}(1 - R)^2 + C = 1$$

$$R^{135} + 135R^{134}(1 - R) + \frac{135(134)}{2}R^{133}(1 - R)^2 = 0.25$$

Solve numerically in Excel or Matlab to get that the shuttle 75% confidence reliability is $\boxed{0.9711}$

(3) Your launch system is focused on low cost, high flight rate, (relatively) low reliability access to orbit. Assume you have, on average, one failure every 20 flights. You normally fly 24 missions/year, but could fly 36 missions per year if you had to. Assuming no flights in the backlog are lost to the competing launch systems, what is the maximum down time you can allow to ensure a marginally resilient system?

$$\frac{Srkd}{S-1} \leq m \Longrightarrow d \leq m\frac{S-1}{Srk} = 20\frac{1.5-1}{1.5(24)(1)} \Longrightarrow d \leq \boxed{0.2778 \text{ yrs=3.33 months}}$$

(4) You want to specify a computer for use on a three-year mission to Mars. You'd like to have at least an 80% reliability for a single unit. What MTBF should you look for to achieve this reliability?

3 years = 26,280 hours

$$R = e^{-\frac{t}{MTBF}} \Longrightarrow MTBF = -\frac{t}{lnR} = -\frac{26,280}{ln(0.8)} = \boxed{117{,}800 \text{ hrs}}$$

(5) You're designing a system of three flight control computers, of which two must work for mission success. What is the maximum rate of intercorrelated failures you can accept to have a system reliability at least as high as a single computer (= 96%)?

Reliability of single computer = R

Reliability of three computers with one acceptable failure = $R^3 + 3R^2(1-R)(1-f)$ *where* f *is the intercorrelated failure rate. Setting the two equal gives*

$$R = R^3 + 3R^2(1 - R)(1 - f) \Longrightarrow 1 - R^2 = 3R(1 - R)(1 - f)$$

$$\Longrightarrow f = 1 - \frac{1 - R^2}{3R(1 - R)} = 1 - \frac{1 - 0.96^2}{3(0.96)(1 - 0.96)} = \boxed{0.3194}$$