

# Technical Comments

## Further Comments on "Cost Minimization of a Space System by Multiple Launchings"

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IN a recent Engineering Note, Allen<sup>1</sup> discussed cost minimization of a space system by multiple launchings. Subsequently, Zigrang<sup>2</sup> commented that Allen's expression for losses, deduced from his Eqs. (1) and (2) to be

$$\text{losses} = w_P p (1 + p + p^2 + p^3 + \dots p^n) \quad (1)$$

was in error and that clearly the expected value for losses should be

$$\text{losses} = npw_P \quad (2)$$

where  $n$  is the total number of launchings (including failures) required to place an accumulation of  $W_{PD}$  pounds mass of payload in space,  $w_P$  pounds mass at a time, with a probability  $p$  of failure for each launch.

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In a reply to Zigrang's comment, Allen<sup>3</sup> corrected his Eq. (2), the expression for losses becoming

$$\text{losses} = npw_P [(1 - p^n)/(1 - p)] \quad (3)$$

Allen then stated that the difference between a simplified form of Eq. (3) and Eq. (2) must be due to a failure of Eq. (2) to account for losses of the replaced payloads.

The purpose of this comment is to point out that Allen's new expression overstates losses by the factor  $(1 - p^n)/(1 - p)$ . For example, if  $p = 0.2$  and  $W_{PD}$  and  $w_P$  have values such that  $n = 10$ , Eq. (3) overstates losses by a factor of 1.25. The expected value for losses is clearly given by Eq. (2), because  $np$  is the number of replaced payloads.

In addition, Eqs. (3) and (5) together with the numerical results presented in Figs. 1-3 of Ref. 1 must be revised, since they are demonstrably based on the unrevised version of Eq. (2) of Ref. 1.

### References

<sup>1</sup> Allen, R. W., "Cost minimization of a space system by multiple launchings," *J. Spacecraft Rockets* **1**, 112-113 (1964).

<sup>2</sup> Zigrang, D. J., "Comment on 'Cost minimization of a space system by multiple launchings,'" *J. Spacecraft Rockets* **1**, 447 (1964).

<sup>3</sup> Allen, R. W., "Reply by author to D. J. Zigrang," *J. Spacecraft Rockets* **1**, 448 (1964).

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