the aileron-rudder crossfeed transfer function can be represented adequately by a first-order lead-lag network. This assumption is not generally valid, and in some cases the magnitude of the μ parameter resulting from the assumption implies quite different rudder coordination from that actually required to restrain sideslip to be zero.

2) It is shown that the following rudder control law will constrain sideslip to be essentially zero during rolling and turning maneuvers.

$$\delta_{rc} = \frac{\delta_{rc}}{\delta_{AS}}\delta_{AS} + \frac{\delta_{rc}}{p}p + \frac{\delta_{rc}}{\phi}\phi$$

The gains in this control law can be evaluated by setting the coefficients of $N^{\beta}{}_{\delta_{AS}}$ to zero.

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C80-011

Reply by Authors to C. R. Chalk

Roger H. Hoh* and Irving L. Ashkenas†

Systems Technology, Inc., Hawthorne, Calif.

IN the Calspan critique, an example configuration is used to question the viability of the μ parameter. This reply is presented in rebuttal and also to illustrate proper application of the parameter.

As discussed in the paper, the numerators of the aileron-rudder cross-feed cannot be generalized. To overcome this, a two point curve fit of the rudder time response was suggested as a way to define μ in the frequency range of interest. Such lower order equivalent system (LOES) approximations to complex higher order systems (HOS) have shown considerable promise as a method of specifying handling qualities criteria (see Refs. 1 and 2). In fact, the referenced works have shown that an HOS which cannot be fit by an LOES form is predictably unsatisfactory to the human pilot.

Coming back to μ, it must be understood that the corresponding first order LOES form does *not* represent an assumption that *all* airplanes respond in this manner. Rather it implies that:

1) Responses which can be adequately fit by the LOES form can be classified as acceptable or unacceptable according to values of μ and $N_{\delta_w}/L_{\delta_w}$ or $\delta_r(3)$.

2) Responses which are higher order in nature and cannot be fit by the first order LOES form in the frequency range of control will be unacceptable to the pilot.

The example cited in Mr. Chalk's critique (an early version of the YF-16) turns out to be quite interesting in terms of lending additional insight into application of the μ parameter. In this case the required rudder time-history to coordinate is extremely complicated and not well matched by the lower-order equivalent system defined by μ, as shown in Fig. 3 of the technical comment. The extreme mismatch between the HOS and LOES precludes even a cursory evaluation of μ. However, the complex nature of the required rudder to coordinate a step aileron input would in itself lead one to suspect very poor pilot opinion of heading control. While Mr. Chalk was not able to produce a pilot rating for this configuration, it is well known that the original version of the YF-16 was an extremely poor airplane (pilot ratings of 9 and 10). These results, rather than invalidating μ, actually provide the first available data which tend to support the assumed extension of the results of Refs. 1 and 2, i.e., that complex higher order responses are unacceptable to the pilot.

Finally, Mr. Chalk states that "crossfeed of aileron stick through a shaping network is an idealization that does not properly represent the task the pilot must accomplish." We could easily take issue with this statement by noting the lack of positive evidence experimentally quantifying the pilot's auxiliary rudder activity, e.g., in describing function or other terms. However, what seems most significant is the characteristic shape and magnitude of the rudder required to coordinate stick inputs, no matter how the pilot manages to generate it. If the magnitude is large, or the shape complex, he will not like it. In fact, he may not use the rudders at all, in which case the complex shaping or large magnitude required will show up as a lack of consonance between bank angle and yaw rate.

As noted by Mr. Chalk, some of the ψ_β values used in the paper were in error. This issue was covered in correspondence between Calspan and STI nearly two years ago. However, correcting these points has no effect, considering all the available evidence, on our basic conclusion that the $\Delta\beta_{max}$ parameter is overly conservative—a conclusion in line with Mr. Chalk's (Ref. 3) "thought that the $\Delta\beta/k$ requirement is in need of revision...." Rather than "revise" it, we devised a different and perhaps a better set of correlating parameters; whether better or not would be an issue more worthy of consideration than worrying about inadvertent data handling errors which do not affect the final result. In connection with such errors, as noted in Ref. 4, the tendency to miscalculate ψ_β is perhaps an inherent deficiency in the parameter. Witness the discrepancies for the values of ψ_β listed in Table 1 for the same flight conditions which appear in two separate Calspan authored reports.

No attempt has been made to determine which of these represents the "correct" values of ψ_β.

Table 1 Discrepancies in calculated values of ψ_β

	ψ_β, deg	
Configuration	Ref. 5	Ref. 6
2P2	−295	−254
3N0	−189	−224
3P2	−344	−290
4P2	−332	−208
12A2	−207	−159
12A1	−210	−167
12P2	−356	−291

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*Senior Research Engineer.

†Vice President and Technical Director. Fellow AIAA.

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