

6). The authors have not ignored "basic difficulties." In fact, they addressed most of these problems: 1) measurement noise and errors were treated in Refs. 30 and 31 of Ref. 1, in which the concept of modal Kalman filters was introduced, 2) actuator location error was not investigated, but in view of the insensitivity of IMSC to actuators locations, this seems to be a trivial problem, 3) modeling errors were considered in Ref. 26 of Ref. 1. The conclusion was that controls designed by IMSC are insensitive to errors in the open-loop eigenvalues, and 4) rigid-body modes present no particular problem. They were included in Refs. 4 and 5.

When the authors use the term "large flexible system" they refer to the order of the system and not to the physical size. But IMSC reduces a system of any order, including infinite order associated with distributed systems, to a set of independent second-order systems. Hence, many of the complexities associated with large-order systems disappear if IMSC is used but persist if coupled control is used. As far as the complexities listed above, the IMSC theory is much further along than the author of the Technical Comment seems to realize.

In conclusion, the authors welcome the opportunity to discuss the merits of IMSC vis-a-vis coupled control. A great many of the points in the three Technical Comments were presented as facts when in actuality they are only personal opinions. Before they can be regarded as facts, they require mathematical substantiation. The various papers by these and other authors, including some of the more recent ones in which experimental work is presented, provide ample mathematical and experimental substantiation of the IMSC method.

### References

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- <sup>2</sup>Meirovitch, L. and Silverberg, L.M., "Globally Optimal Control of Self-Adjoint Distributed Systems," *Proceedings of the Fourth VPI&SU/AIAA Symposium on Dynamics and Control of Large Structures*, Blacksburg, Va., 1983, also *Optimal Control Applications and Methods Journal*, Vol. 4, 1983, pp. 365-386.
- <sup>3</sup>Vander Velde, W.E., and He, J., "Design of Space Structure Control Systems Using On-Off Thrusters," *Journal of Guidance, Control, and Dynamics*, Vol. 6, Jan.-Feb. 1983, pp. 53-60.

<sup>4</sup>Meirovitch, L., Baruh, H., Montgomery, R.C. and Williams, J.P., "Nonlinear Natural Control of an Experimental Beam," *Journal of Guidance, Control, and Dynamics*, Vol. 7, July-Aug. 1984, pp. 437-442.

<sup>5</sup>Shenhar, J. and Meirovitch, L., "Minimum-Fuel Control of High-Order Systems by IMSC," Paper 83-382, *AAS/AIAA Astrodynamics Specialist Conference*, Lake Placid, New York, Aug. 22-25, 1983. To appear in the *Journal of Optimization Theory and Applications*.

<sup>6</sup>Skidmore, G.R., Hallauer, W.L., and Gehling, R.N., "Experimental Theoretical Study of Modal-Space Control," Second Internal Modal Analysis Conference, Orlando, Fla., Feb. 6-9, 1984.

## Errata

### Effects of Time Delays on Systems Subject to Manual Control

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THE following legend was inadvertently omitted from Fig. 11.

Model parameters:

$K_e = 4.2$	$k = 2$
$K_1 = 1.0$	$\omega_n = 6.0 \text{ rad/s}$
$K_2 = 5.0$	$\zeta_n = 0.75$
$T_1 = 2.5 \text{ s}$	$\tau_0 = 0.20 \text{ s}$
$T_2 = 2.5 \text{ s}$	

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