transverse oscillations in the two orthogonal directions are considered. For the plate-type flexible member, its motion is represented by superposition of the fixed-free and free-free beam modes. Thus it accounts for transverse as well as twist behaviour. Axial foreshortening effect was purposely omitted. It was found that its contribution is relatively negligible in situations encountered in spacecraft dynamics.

In the section "Absence of Axial Load Effects," Lips mentions axial force and gravity gradient effects. The formulation presented in Ref. 1 is applicable to spinning satellites and accounts for gravity gradient. Lips seems to confuse axial loading and axial foreshortening during vibration.

Lips is correct in noticing the difference between the time rate of change of length and the appendage deployment velocity. In the problem encountered by spacecraft appendages, even extending to 100 m, such distinction is of negligible consequence.

To summarize, the formulation is not an "outline of procedure" but a concrete set of equations valid for a large class of spacecraft with arbitrarily-oriented beam- and plate-type deploying flexible members. It is backed by a functioning numerical algorithm. No paper can provide all the details when complex equations often involve more than a hundred terms. Response results were not given in the paper[1] only because of the constraint of space imposed by the Journal. However, such results have been reported elsewhere.[2-4] Incidentally, the response of plate-type appendages can be quite different. Thus Lips' prediction, ".....it is unlikely that the simulated plate response will appear much different than that of the beam," is off the mark. Further generalization of the formulation accounting for arbitrary, topological tree type additions of structural assemblies, as would be the case during the space station construction, is in progress and will be reported soon.

References

[1]Modi, V.J. and Ibrahim, A.M., "A General Formulation for Librational Dynamics of Spacecraft with Deploying Appendages," *Journal of Guidance, Control, and Dynamics,* Vol. 7, Sept.-Oct. 1984, pp. 563-569.

[2]Modi, V.J. and Ibrahim, A.M., "Vibration/Libration Interaction Dynamics During the Orbiter Based Deployment of Flexible Member," *Proceedings of the NASA/JPL Workshop on Identification and Control of Flexible Space Structures,* edited by C. Rodriguez, San Diego, in press.

[3]Modi, V.J. and Ibrahim, A.M., "Effect of System Parameters on the Dynamics of the Space Shuttle Based Construction of Structural Components," AIAA Paper 84-1988, Aug. 1984.

[4]Modi, V.J., and Ibrahim, A.M., "Dynamics of the Orbiter Based Construction of Structural Components for Space Platforms," 35th Congress of the International Astronautical Federation, Lausanne, Switzerland, Oct 1984, Paper IAF-84-359; also *Acta Astronautica,* in press.

[5]Bainum, P.M., and Kumar, V.K., "On the Dynamics of Large Orbiting Flexible Beams and Platforms," *Acta Astronautica,* Vol. 9, No. 3, 1982, pp. 119-127.

[6]Kumar, V.K., and Bainum, P.M., "On the Motion of a Flexible Shallow Spherical Shell in Orbit," *AIAA Journal,* Vol. 20, Aug. 1982, pp. 1113-1119.

[7]Robertson, D.K., "Analysis of Lateral and Torsional Vibration Characteristics of Beams and Shafts with End Location Rotation Masses," NASA TM 84593, May 1984.

[8]SCOLE Workshop—1984, NASA-IEEE Design Challenge, Compiled by L. Taylor, NASA Langley Research Center, Hampton, VA, 1984.

[9]Balakrishna, A.V., "A Mathematical Formulation of the SCOLE Control Problem: Part 1," NASA Rept. 172581, May 1985.

[10]*Application of Tethers in Space,* Workshop Proceedings, Williamsburg, VA, June 1983, sponsored by NASA Office of Space Flight Washington, D.C., and NASA Marshall Space Flight Center, Huntsville, AL.

[11]Misra, A.K., and Modi, V.J., "Dynamics and Control of Tether Connected Two-Body Systems," Invited Address, 33rd Congress of the International Astronautical Federation, Paris, France, Sept. 1982, Paper IAF-82-316; also *Space 2000,* Selection of Papers from the 33rd IAF Congress, edited by L.G. Napolitano, AIAA, 1983, pp. 473-514.

Comment on "To Pursue or to Evade—That is the Question"

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THE purpose of this Comment on the highly intriguing paper cited[1] is to suggest that, assuming that both combatants prefer survival to simultaneous kill, the "pursuer" should sometimes decide *not* to pursue, thereby diminishing the size of the state region leading to sumultaneous kill.

When Fig. 4g, for example, of Ref. 1 is modified by the considerations underlying Fig. 7 there, it appears as in Fig. 1 of this Comment. SK denotes the region (denoted as "Evader's Choice" in the original Fig. 7) where the "evader" (B or A according as the relative position lies right or left of the "role-reversal" line (L)) has time to turn toward the pursuer and achieve a simultaneous kill. The upper boundaries of the SK region are determined (as in the original Fig. 4) by whether or not the evader can escape when *pursued* by the pursuer.

Since the pursuer is here presumed to prefer the evader's escape to a simultaneous kill, it could be advantageous for the pursuer to *cooperate* with the evader and ensure his escape. If so, the outer boundary of the SK region in Fig. 1 should be replaced by a lower boundary related to such cooperation. This is shown in Fig. 2 (for $H=150$ deg, $\beta=2$). To the right of (L), boundary (1) has been repalced by a new boundary (3), passing through the intesection of boundaries (1) and (2). The associated adjoint vectors ∇V_i must be related by:

$$\nabla V_3 = \alpha \nabla V_1 + (1-\alpha) \nabla V_2$$

where the mixing parameter α is uniquely determined by the vanishing of the Hamiltonian $\max_P \max_E \dot{V}_3$.

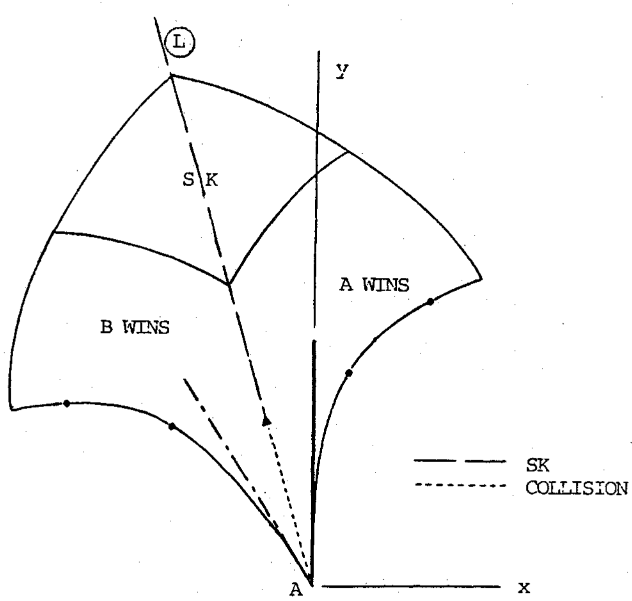

Fig. 1 Outcomes for identical aircraft ($H=150$ deg, $\beta=2$).

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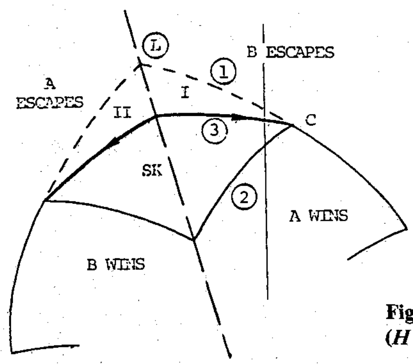

Fig. 2 Reduced SK region ($H = 150$ deg, $\beta = 2$).

For $H = 150$ deg and $\beta = 2$ we find, not surprisingly, that A is turning left on ③ instead of right, as on ①. (For headings $H < 125$ deg, approximately, however, A's switch-function can change sign during the maneuver 3.)

Does A risk defeat by adopting a cooperative stategy when the position is in the escape zone I, which was part of the simultaneous kill region in Fig. 1?

The answer is no. Suppose B turns toward A but A, for a while, turns away from B. The position will now move towards the (reduced) SK region and may even cross the line Ⓛ. However it cannot reach B's win region without passing through the SK region. A of course, will turn toward B before B's win region is reached.

Starting in zone I, B should, of course, turn away from A, so that if A cooperates the path will move to the right and pass above corner C, after which B can escape no matter what A does. If B sees that the path is going to pass below C, because A has not cooperated, he must, of course, turn toward A before A's win region is reached, and a simultaneous kill results. Identical considerations apply to zone II, with the roles of A and B interchanged.

Reference

[1]Merz, A.W., "To Pursue or To Evade—That is the Question," *Journal of Guidance, Control, and Dynamics,* Vol. 8, March-April 1985, pp. 161-166.

Reply by Author to J.V. Breakwell

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WITH regard to the preceding Comment on Ref. 1, optimization problem solutions normally require the performance criterion to be specified a priori, but the air combat problem can be solved in this way only for "set-up" initial geometries, when the roles are apparent. More generally, the min-max interests of the pilots, and the corresponding solutions, depend on the state itself, as shown in Fig. 2 of the Comment. This solution seems to answer long-standing practical criticism of the differential-game modeling of the air combat problem, in that the offensive and defensive interests of both pilots are generally present. Barriers separating different closed state regions are found, and these solutions are comprehensive in that realistic *options* of the nominal evader are identified, together with corresponding tactics of the nominal pursuer.

Reference

[1]Merz, A.W., "To Pursue or to Evade—That is the Question," *Journal of Guidance, Control, and Dynamics,* Vol. 8, March-April 1985, pp. 161-166.

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Book Announcements

BILLINGS, S.A., GRAY, J.O., and **OWENS, D.H.,** editors, ***Nonlinear System Design.*** Peter Peregrinus, Stevenage, England, 1984, 192 pages. $32.00.

Purpose: This text has ben conceived in the belief that sufficient material is now available in applications areas where nonlinear effects are dominant to make an up-to-date state-of-the-art overview useful both to researchers in the field and to industrial users. The text aims to present techniques for coping with nonlinearities in control systems at all stages of the design process.

Contents: An overview of nonlinear systems theory (D.P. Atherton). Identification of nonlinear systems (S.A. Billings). Stability criteria for nonlinear systems—a survey (P.C. Parks). Frequency domain methods in the analysis and stability of nonlinear feedback systems (C.J. Harris, R.K. Husband). Stability and performance deterioration due to modeling errors (D.H. Owens, A. Chotai). Harmonic analysis of nonlinear feedback systems (J.O. Gray, L.S. Brown). Optimization-based design of nonlinear control systems (D.Q. Mayne). A design methodology for nonlinear systems (G.T. Russell). Nonlinear analysis and modelling during the development of an aircraft incidence limiting system (C. Fielding). The implications of the control surface actuation system on flight control system design (B. Gee). Some nonlinear design aspects of position control systems and regulators (P. Bowler).

CASTI, J.L., International Institute for Applied Systems Analysis, ***Nonlinear System Theory.*** Academic Press Inc., New York, 1985, 261 pages. $45.00.

Purpose: This text has been written as a reference guide to the current status of certain aspects of nonlinear system theory and, as such, is not an introductory text. The mathematical approach is algebraic and geometric in nature, thereby avoiding methods of classical and functional analysis. Finally, some aspects of nonlinear system analysis have been omitted by design. These include systems defined by partial differential equations, systems with differential delay, and stochastic systems.

Contents: Perspectives and problems of nonlinear system theory. Mathematical tools of nonlinear system theory. A modern view of linear system theory. Reachability and controllability. Observability, realization, and estimation. Stability theory: singularities, bifurcations, and catastrophes.