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5.0 SKIP ROPE DYNAMICS
The potential severity of skip rope oscillations had been overlooked by NASA and the TSS contractor MMAG. Initially, David Arnold, SAO was alone in pointing out the potential dangers. His contentions based on theoretical arguments and results from SKYHOOK and other SAO simulation tools were contradicted by results produced by MMAG and JSC simulations. Since the MMAG and JSC results seemed to agree with each other and were the most detailed models of the phenomena, those results were assumed to be correct. Still, the theoretical arguments to the contrary were quite strong and convincing. We at CDy conducted an investigation of skip rope dynamics at the request of NASA/MSFC. This was done in collaboration with David Arnold at SAO. Our theoretical analyses and simulation results agreed fundamentally with the SAO observations. Results of this investigation were presented to NASA. A copy of this presentation is included in this report in Appendix E. We and SAO jointly undertook a review of the simulations used by JSC and MMAG to resolve the apparent discrepancy. Their results showed a significant damping of skip rope oscillations, our results showed no such effect. The review was performed with the interested cooperation of these organizations without whose help we could not have proceeded. We first concentrated on the JSC simulation. The tether dynamics models were based on the programs TOSS and GTOSS developed by Dave Lang Associates. Simple run cases were defined to investigate the fundamental property, conservation of angular momentum during tether deployment or retrieval in deep space situations isolated from orbital effects and with such symmetry that the results could be determined entirely from first principles. These results indicated a discrepancy in the TOSS results and pointed to a potential deficiency in the formulation. Arun Misra, working for the summer at SAO in support of David Arnold, was asked to review the formulation of the program and see if he could find a problem. He determined that some terms of the convective derivatives which are required to properly account for tether deployment and retrieval had been left out of the formulation. This seemed to explain the unnatural damping observed in the JSC results because when these terms were added the damping was no longer present. It remained, however, to determine why MMAG results seemed to show the same damping, even though their simulation was formulated independently. As a result of the CDy review of MMAG's Model 3 formulation, it was determined that they also had left out the same type from the convective derivatives from their formulation. Thus, their results were also optimistic with respect to damping of skip rope oscillations and when the correct terms were added the skip rope damping went away so that now all simulations agreed on the amplitude growth of the skip rope oscillation with retrieval. This agreement and resolution of the model discrepancies was not good news for the project but provided warning and set the stage for subsequent activities to eliminate the skip rope oscillations. This activity is necessary if satellite recovery is to be realized at the end of the mission. It is the characteristic of the skip rope phenomenon that its major impact is on the ability to retrieve the satellite to the docked position. It can cause loss of satellite attitude stability and consequent inability to dock if uncontrolled.