



### **Use of Dynamic Distortion to Predict and Alleviate Loss of Control** This work alleviates aircraft loss due to unfavorable pilot/vehicle interactions.

*Dryden Flight Research Center, Edwards, California*

This research has developed and evaluated the specific concepts, termed “Smart-Cue” and “Smart-Gain,” to alleviate aircraft loss of control that results from unfavorable pilot/vehicle system interactions, including pilot-induced oscillations (PIOs). Unfavorable pilot/vehicle-system interactions have long been an aviation safety problem. While the effective aircraft dynamic properties involved in these events have been extensively studied and understood, similar scrutiny has not been paid to the many aspects of the primary manual control system that converts the pilot control inputs to motions of the control surfaces. The purpose of the Smart-Cue and Smart-Gain developments is to redress this neglect, and to develop and validate remedial manual control systems.

The program began with a review of the historical precedent for providing cueing to the pilot via the cockpit controls along with the many control surface rate-limiting alleviation schemes and PIO suppression filter concepts that have been proposed and evaluated over the years. A McFadden hydraulic control

loader capable of generating proposed Smart-Cue forces was integrated with the STI PC-based flight simulator. Candidate mechanizations of the Smart-Cue concept were created, implemented, assessed, and refined through a series of evaluations using guest test pilots. The Smart-Gain concept was developed in response to the Smart-Cue performance during the precision offset landings conducted during the checkout flights. Rapid prototyping of the Smart-Gain mechanization was made via the piloted simulation, and the concept was included as part of the formal flight test evaluations. Five test pilots participated in the Smart-Cue/Smart-Gain evaluations with the Learjet in-flight simulator.

In this work, the “distortion” of interest results from control surface rate-limiting, and is quantified by the surface Position Error, while the “distortion metric” is the Position Lag. A force feedback cue, the constraining function, and/or a command path gain reduction, are created when the Position Error exceeds the Position Lag, or the alerting function. The overall imple-

mentation does, however, require hardware in the form of a back-driven force-feel system included as part of the cockpit manipulator. The feasibility of the Smart-Cue/Smart-Gain approach using a back-driven manipulator implemented in a variable stability aircraft was successfully demonstrated in flight.

The hypothesis stated that the Smart-Cue will change pilot behavior to decrease the chance of adverse pilot/vehicle system interactions. Thus, if this assumption about the pilot-vehicle system was found to be true, then a degraded flight-control system in the presence of dynamic distortions will have improved stability and performance. This hypothesis was found to be true in flight-testing evaluations that replicated high-gain, continuous closed-loop tasks for both cruise and terminal flight operations, especially for those cases that included the addition of the Smart-Gain.

*This work was done by David Klyde, Chi-Ying Liang, and Daniel Alvarez of Systems Technology, Inc. for Dryden Flight Research Center. Further information is contained in a TSP (see page 1). DRC-007-083*

### **Cycle Time Reduction in Trapped Mercury Ion Atomic Frequency Standards**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The use of the mercury ion isotope  $^{201}\text{Hg}^+$  was examined for an atomic clock. Taking advantage of the faster optical pumping time in  $^{201}\text{Hg}^+$  reduces both the state preparation and the state readout times, thereby decreasing the overall cycle time of the clock and reducing the impact of medium-term LO noise on the performance of the frequency standard. The spectral overlap between the plasma discharge lamp used for  $^{201}\text{Hg}^+$  state preparation and readout is much larger than that of the lamp used for the more conventional  $^{199}\text{Hg}^+$ . There has been little study of  $^{201}\text{Hg}^+$  for clock applications (in fact,

all trapped ion clock work in mercury has been with  $^{199}\text{Hg}^+$ ); however, recently the optical pumping time in  $^{201}\text{Hg}^+$  has been measured and found to be 0.45 second, or about three times faster than in  $^{199}\text{Hg}^+$  due largely to the better spectral overlap. This can be used to reduce the overall clock cycle time by over 2 seconds, or up to a factor of 2 improvement.

The use of the  $^{201}\text{Hg}^+$  for an atomic clock is totally new. Most attempts to reduce the impact of LO noise have focused on reducing the interrogation time. In the trapped ion frequency standards built so far at JPL, the optical

pumping time is already at its minimum so that no enhancement can be had by shortening it. However, by using  $^{201}\text{Hg}^+$ , this is no longer the case. Furthermore, integrity monitoring, the mechanism that determines whether the clock is functioning normally, cannot happen faster than the clock cycle time. Therefore, a shorter cycle time will enable quicker detection of failure modes and recovery from them.

*This work was done by Eric A. Burt, Robert L. Tjoelker, and Shervin Taghavi of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-46865*