The second paradigm captures process knowledge about the class and instance objects using if-then rules. DMSP rule bases are organized into three types of rules: rules of observation, rules of interpretation, and rules of communication.

Rules of observation have telemetry mnemonics as rule conditions and derived telemetry objects as rule conclusions. Rules of observation are evaluated when the rule conditions receive values from the telemetry server process, either through a polling procedure or through a request for a particular telemetry parameter. Rules of interpretation evaluate derived telemetry objects. Rules of interpretation are evaluated in a forward chaining (data driven) or backward chaining (goal directed) fashion until a diagnosis of an anomalous condition is found. Rules of communication provide information to the user by message passing to the interface server.

Solar Array Drive (SAD) Hangup

The Solar Array is the major source of satellite power. It is the job of the SAD to maintain the orientation of the solar array towards the sun and to transfer power to the satellite subsystems. Due to the polar orbit of the DMSP satellite, the array must rotate continuously about the spacecraft. If the SAD becomes nonoperational, power loss will occur.

A Solar Array Drive malfunction (called a "SAD Hangup") is typical of the types of faults handled by REDMN. The following sections describe what happens onboard the satellite and in SAGE when a SAD Hangup occurs. This scenario is based on a SAD Hangup anomaly generated by the DMSP high-fidelity simulator, and reflects the actual operation of SAGE.

The nominal configuration of the spacecraft dictates that one of the onboard computers is in control of the spacecraft subsystems, but that the other computer is in control of attitude determination. It controls the SAD, as well as torque commands to the reaction wheels. The SAGE user interface indicates by lighted subsystem boxes that Computer 2 is in control, Computer 1 has attitude determination, and the SAD is operating nominally on side 2. The conditions that occur due to a SAD anomalous performance and REDMN actions follow: REDMN switches to the redundant side of the array drive electronics, crosses buses, and makes both of the computers "not OK." The operator is notified of these occurrences by status displays showing "Computer 1 not OK" or "SAD side 1" in red. English messages such as "REDMN has switched ADE sides, crossed buses, and made both SCPs not OK" and "RECOMMEND send ground command to clear SADSWIN in both SCPs" are posted and saved for future use. After the operator is notified of the anomalous conditions and has performed the recommended cleanup procedures, further information about the spacecraft is available from the user interface.

Conclusions

SAGE is an exploration of the issues in designing and building an intelligent satellite operator's workstation. The overall system architecture of SAGE has enabled the rapid development of a flexible system. Although only a prototype, SAGE has proven the value of expert systems technology in the interpretation of REDMN actions.

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Rapid Prediction of Static Stability Characteristics of Slender-Wing Aerospace Vehicles

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Introduction

MOST aerospace vehicles, both civil and military, although designed for hypersonic cruise at low angles of attack, often have to perform maneuvers at high angles of attack from low supersonic to low subsonic speeds. There is, therefore, a need for rapid prediction of the nonlinear high-alpha aerodynamics of slender-wing-aircraft configurations in that speed range.

The complexity of the flowfield on aircraft and aircraft-like configurations that operate at high angles of attack prohibits the use of numerical computational methods for preliminary design. Because of the continual changes in the early design, a purely experimental approach cannot be used either. One needs rapid computational methods to guide the early stages of preliminary design until a firmer design has evolved on which experimental and numerical methods can be applied.

Discussion

A fast prediction method, developed earlier for the unsteady nonlinear aerodynamics of pitching sharp-edged delta wings at high angles of attack,[1] has been extended to include the roll degree-of-freedom.[2] In the present Note, the predicted static lateral stability characteristics are compared with experimental results for slender wing and wing-body configurations.

Figure 1 shows a comparison between predicted and measured[3] lateral stability of a 74-deg sharp-edged delta wing. The agreement is good for $\alpha < 30$ deg. At high angles of attack, the leading edge vortices experience vortex breakdown. The breakdown boundary, determined by experiment,[4] is shown in Fig. 2. At angle of sideslip, the effective sweep angle becomes $\Lambda \pm \beta$ for the two leading edges. As C_{ℓ_β} in experiments usually is determined for $|\beta| \leq 5$ deg, the measurements will be affected by vortex burst when $\alpha > \alpha_{burst}$ for leading edge-sweep $\Lambda - \beta$ in Fig. 2. Thus, the measurements in Fig. 1 should be affected at $\alpha \geq 30$ deg, as $\Lambda - \beta = 74$ deg $- 5$ deg $= 69$ deg in Fig. 2. Thus, the prediction is not expected to agree with experiment beyond $\alpha = 30$ deg, a fact acknowledged by ending the prediction at $\alpha = 30$ deg. The experimental data indicate that vortex burst occurred in the test already at $\alpha < 30$ deg. This is the likely result of support interference.[5]

The agreement between prediction and experiment is certainly satisfactory for pure delta-wing configurations (see Ref. 1 and Fig. 1). However, the current interest is the low-speed aerodynamics of a hypersonic aerospace configuration, such as the one shown in Fig. 3. It can be seen that, aside from the zero shift expected to result from model wing and body camber, not accounted for in the prediction, the agreement with experiment[6] is satisfactory for preliminary design purposes. Again, the deviation at high α, $\alpha \geq 20$ deg, is probably caused by vortex burst, produced by support interference.[5]

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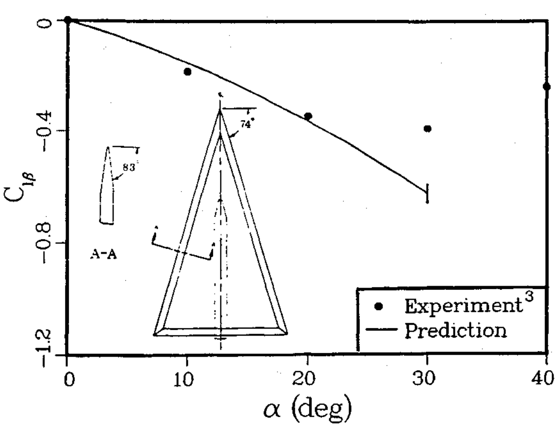

Fig. 1 Lateral stability derivative C_{ℓ_β} of a 74-deg sharp-edged delta wing.

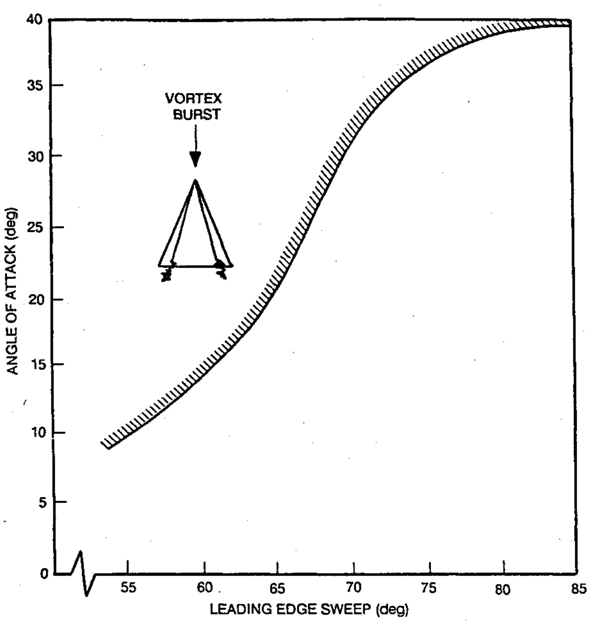

Fig. 2 Boundary for breakdown of leading-edge vortices (Ref. 4).

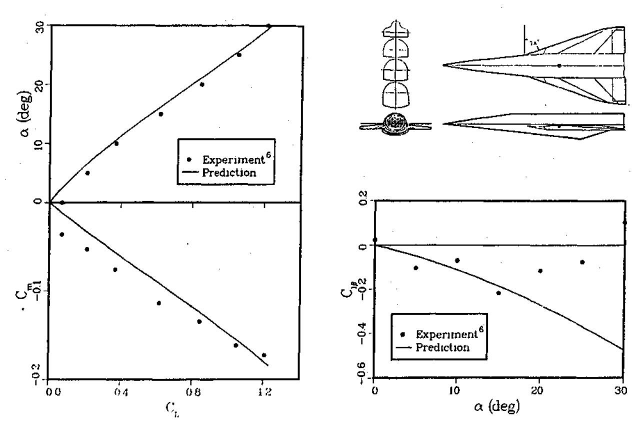

Fig. 3 Aerodynamic characteristics of hypersonic research airplane.

For the aerospace-plane-like configuration in Fig. 4, the predictions are also found to be in satisfactory agreement with experimental results,[7] at least for $\alpha < 15$ deg. At $\alpha > 15$ deg, both the in-plane and out-of-plane aerodynamic characteristics show the effects of premature vortex burst, the expected result of high-alpha support interference.[5] Similarly, good agreement between prediction and experiment[8] is shown in Fig. 5 for a hypersonic boost-glide vehicle.

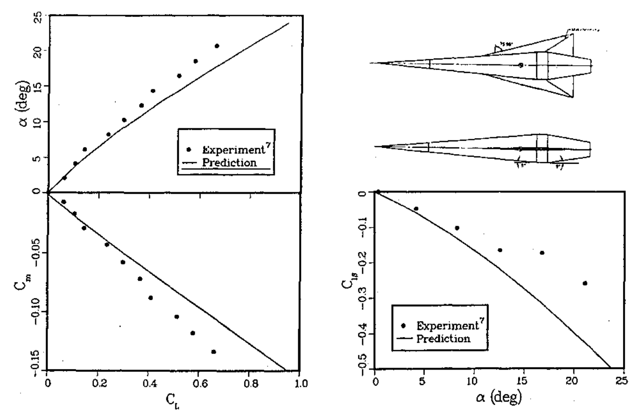

Fig. 4 Aerodynamic characteristics of a slender wing-body aerospace vehicle.

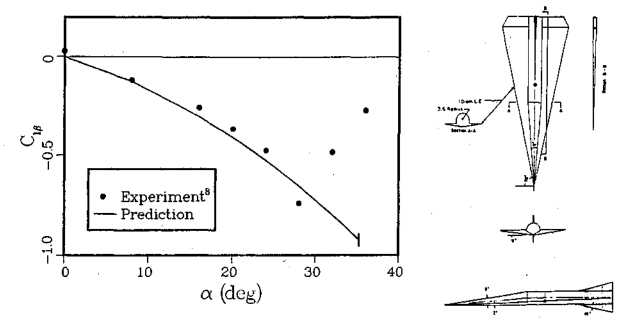

Fig. 5 Subsonic lateral stability characteristics of a hypersonic boost glide vehicle.

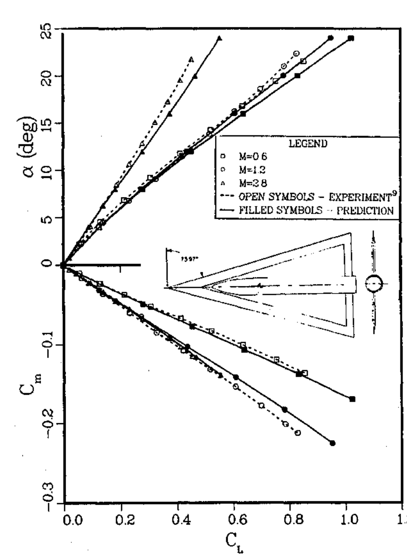

Fig. 6 Effect of Mach number on delta-wing aerodynamics.

All the comparisons made so far have been with low-speed test results. The prediction method is valid up through the transonic and low supersonic speed region. The only requirement is that the crossflow conditions at the leading edge remain subsonic, i.e., $M < \operatorname{cosec} \Lambda$. That means $M < 3.6$ for the 74-deg swept delta wing in Fig. 6. The agreement between prediction and experiment[9] is certainly satisfactory for preliminary design purposes. The same can be said about the comparison at transonic speeds for the Viking configuration[10] (Fig. 7).

The purpose of this Note, besides advertising the utility of the fast prediction method,[2] is to illustrate that one must be aware of the fact that vortex breakdown, which has a dramatic influence on high-alpha aerodynamics, can be affected greatly by support and wind-tunnel wall interference.[5,11] As a general

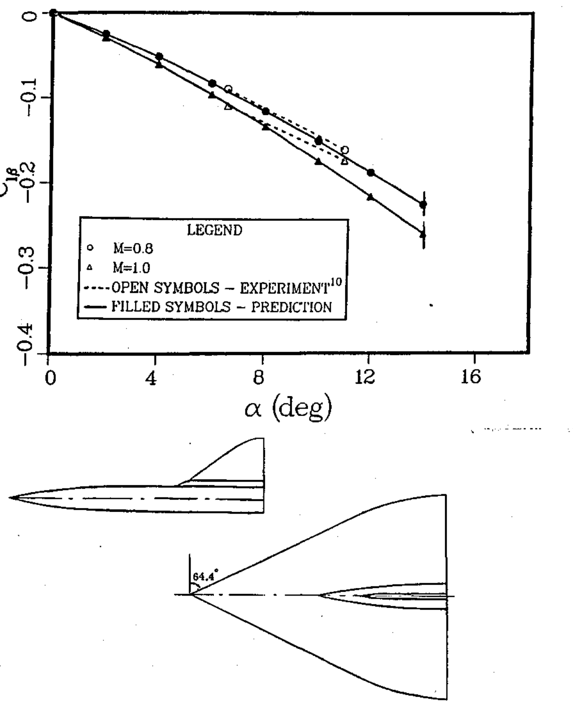

Fig. 7 Transonic lateral stability characteristics of the Viking configuration.

rule, one should therefore avoid "tuning" one's predictions to agree with experimental results obtained in ground test facilities.

Acknowledgment

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Titan Improvement Study: Hydrogen Core Stages

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Introduction

THE Titan launch vehicle has had a long and successful history of placing both manned and unmanned payloads into orbit. It has been used for low Earth orbit (LEO), geosynchronous Earth orbit (GEO), and interplanetary launches. Several upper stages have been used but the Centaur is the upper stage that provides the greatest capability. The core stages have been used with and without the solid-rocket motors, and two sizes of solid-rocket motors have been developed. Titans have been launched from the east coast into easterly orbits and from the west coast into polar orbits. Except for the Saturn vehicles, which are no longer in use, the Titan has the greatest payload capability of any expendable launch vehicle in the free world.

As needs for greater payload capability or reduced costs appear, improvements of the Titan launch vehicle should be considered as an alternative to new designs. An incremental approach to improvements has the advantages of incremental development costs, confidence in the performance of the parts continuing to be used, and increasing production rates of the parts being used by both the new version and versions continuing in the inventory. The Titan is a good candidate for improvement because the core stages use storable propellants, which are toxic, expensive, and less energetic than hydrogen and oxygen.

Two possible improvements to the Titan/Centaur were considered, as shown in Fig. 1. First, a new hydrogen/oxygen stage II was studied that replaces both the Core II and the Centaur. Next, a new hydrogen/oxygen stage I was considered that replaces the current Core I stage. The new stage II was also examined as an orbit transfer vehicle for use with a new launch vehicle.

This study was conducted as part of continuing studies of advanced rocket engines. The Titan improvement could be one of several justifications for a new hydrogen/oxygen rocket engine with 500–1000 kN thrust.

Standard Titan/Centaur Capability

The ideal-velocity capability of the Titan/Centaur was calculated for various payloads, based on data from Ref. 1. The results are shown in Fig. 2 in an accumulative fashion. The solid rocket motors provide between 2.1 and 2.4 km/s of ideal velocity. The Core I stage adds about 2.4–3.0 km/s. The Core II stage contributes about 2.7 km/s with no payload and about one-half as much with a payload of 32 Mg. The Centaur provides over 8.8 km/s with no payload, but this decreases rapidly to less than 1.5 km/s with a payload of 32 Mg. The Centaur stage is not used for payloads over 7 Mg.

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