predominate, and at attitudes where the aircraft's inherently convergent, back-to-normal stability characteristics start producing undamped, divergent responses. It also means flying at energy states where you'll first need to reestablish dynamic pressure and reattach airflow before control can return. We'll emphasize that the underlying aerodynamic conditions—and not merely the aircraft's attitude—determine the inputs necessary to regain control.

As a result of this demonstration approach you'll gain a better understanding of aircraft dynamics, and of the circumstances that actually produce unusual attitudes, than you would if we began our work by placing you in already-developed attitudes and then just coached you through textbook recoveries. To start, we'll tuft the wing to see how airflow, and thus control effectiveness, changes as the aircraft enters and recovers from stalls.

As an additional way of understanding aircraft characteristics, we can also review the flying qualities mandated by FAR certification requirements.

Accidents

Many of the training tasks in our program are drawn from both recent and historically typical unusual-attitude accidents. Some examples are essentially aerodynamic in provocation, like vortex encounters, stalls, and spins. Other accidents stem from mechanical or control system failures. Although the engineering causes of system failures might be specific to aircraft type, there's usually an accompanying aerodynamics lesson that's applicable in general. That's why, for example, we'll have you examine the aerodynamics of rudder hardovers—the bane of the Boeing 737—even if you think it could never happen on your aircraft.

When we practice intentional unusual attitudes, briefed and prepared, it's easy to forget how unintentional attitudes often happen. Sudden catastrophes aside, they evolve. They're often the culmination of a chain of events that typically starts while the aircraft is still under normal control. Problems appear, the workload goes up, the pilot enters an overload state and fails to monitor attitude, and a departure from the normal envelope begins. Pilots who've experienced the alarming physical sensations of spatial disorientation can almost always look back and trace the bad *decisions* that set the seeds.

The National Transportation Safety Board's website www.ntsb.gov contains statistics on loss of control accidents, updates on current investigations, and detailed final reports.

Simulators for Upset Training?

Kinesthesia is the term for the sensation of the body's position, weight, and movement, as conveyed through our muscles, tendons, and joints. Both the vestibular (inner ear) and kinesthetic systems are components of *proprioception*, the general term (although usage varies) for all the non-visual systems involved in providing information on the orientation and movement of the body.

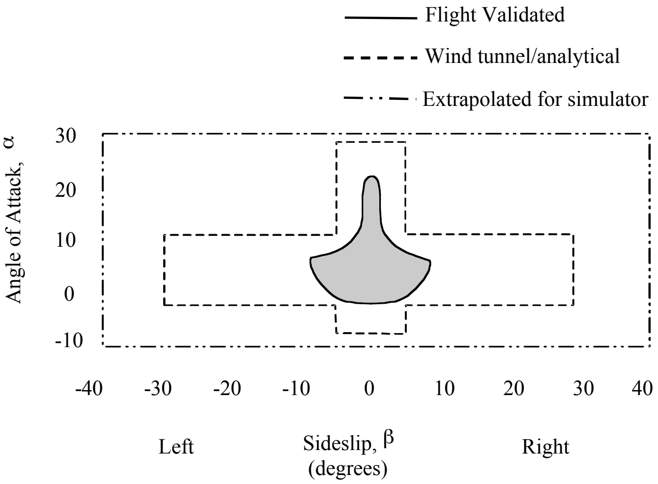
The proprioception of aerobatic flight involves sustained rotation and sustained g forces. But even the best six-degree-of–freedom simulator can only supply momentary cues. You won't feel a continuous 2 g during a simulated 60-degree banked turn, for example.

When a simulator can't provide a reasonably seamless motion environment in which to learn, and toward which to adapt, simulator based unusual-attitude training is limited to drills and procedures. The simulator can't provide equivalent *experience*, as it can in other flight regimes and emergencies involving less extreme motion. And if the simulator gives a false impression of how vision and proprioception match, it may actually lay the groundwork for even greater confusion during unusual attitudes in flight, when visual cues are combined with more challenging proprioceptive inputs than the simulator's motions allowed.

In addition to their limited ability to produce the physical sensations of aerobatic flight, the computers that drive simulators have flight model limitations. Both civilian and military aircraft are flight tested for their intended use, with some additional level of control abuse. Manufacturers of non-aerobatic aircraft are not required to develop actual extreme-attitude flight-test data. It would often be unsafe. As an example, the illustration shows the extent of the 737 flaps-up, flight-validated envelope. Note how combinations of high sideslip and high angle of attack are

737 Flaps Up Alpha/Beta Envelope

Adapted from AURTA, App. 3-D.



avoided. Behavior in these flight regimes simply isn't *known*. According to AURTA, App.3-D.1:

"From an aerodynamic standpoint, the regimes of flight that are usually not fully validated with flight data are the stall region and the region of high angle of attack with high sideslip angle where there may be separated airflow over the wing or empennage surfaces. While numerous approaches to stall or stalls are flown on each model (available test data are normally matched on the simulator), the flight controls are not fully exercised during an approach to stall or during a full stall, because of safety concerns. Also, roll and yaw rates and sideslip angle are carefully controlled during stall maneuvers to be near zero: therefore, validation of derivatives involving these terms in the stall region is not possible. Training maneuvers [in the simulator] in this regime of flight must be carefully tailored to ensure that the combination of angle of attack and sideslip angle reached during the maneuver does not exceed the range of validated data or analytical/extrapolated data supported by the airplane manufacturer."

It's worth noting that this doesn't preclude simulated rolling maneuvers at bank angles and attitudes outside flight-test parameters, but within α/β limits. Again from AURTA:

"Values of pitch, roll, and heading angles, however, do not directly affect the aerodynamic characteristics of the airplane or the validity of the simulator training as long as angle of attack and sideslip angles do not exceed the values supported by the airplane manufacturer. For example, the aerodynamic characteristics of the upset experienced during a 360-deg. roll maneuver will be correctly replicated if the maneuver is conducted without exceeding the valid range of angle of attack and sideslip."

You can see that limitations in the flight model beyond certain α/β values should be taken into account when simulators are used to re-create and study upset accidents. The same caution is necessary when simulators are used to *develop* unusual-attitude recovery techniques—a somewhat abused practice in the past. Be suspicious of simulation at high α and β, especially beyond stall.

But also put the limitations of a non-validated flight model into perspective. An aerobatic aircraft isn't going to "model" precisely the kind of aircraft the AURTA is concerned with, either. In-flight unusual-attitude training is illustrative. It can take you into, and show you how to get out of, all sorts of territory. It produces true sensations. Yet it can only provide for the transfer of general principles and fundamental skills.

Unusual-Attitude versus Aerobatic Training

In typical aerobatics courses you'll learn to fly a standard set of maneuvers: roll, loop, hammerhead, Cuban-eight, Immelmann, spin, etc. It's valuable training and worth encouraging, but not always the best approach for a pilot whose first concern might be to learn unusual-attitude aerodynamics and recovery skills for use in non-aerobatic aircraft.

One problem is that aerobatic training focusing on perfecting standard maneuvers tends to be inherently aircraft-biased in the way muscle memories are developed. Although the basic aerobatic techniques aren't appreciably different between aircraft, if you want to keep your instructor happy, and get the maneuvers right, you'll have to match your control inputs to the characteristics of the trainer you fly. In a very responsive aerobatic aircraft, such as an Extra or a Pitts, a little bit of input will produce a lot of