Bombardier Aerospace

UP&RT Initiatives

Steve Stowe
Senior Test Pilot
Bombardier Flight Test Center

ICAO Loss of Control In-Flight Symposium
Montreal, Canada
22 May 2014

BOMBARDIER
the evolution of mobility

Forward-looking Statements

This presentation includes forward-looking statements, which may involve, but are not limited to: statements with respect to our objectives, guidance, targets, goals, priorities, our market and strategies, financial position, beliefs, prospects, plans, expectations, anticipations, estimates and intentions; general economic and business outlook, prospects and trends of an industry; expected growth in demand for products and services; product development, including projected design, characteristics, capacity or performance; expected or scheduled entry-into-service of products and services, orders, deliveries, testing, lead times, certifications and project execution in general; our competitive position; and the expected impact of the legislative and regulatory environment and legal proceedings on our business and operations. Forward-looking statements generally can be identified by the use of forward-looking terminology such as “may”, “will”, “expect”, “intend”, “anticipate”, “plan”, “foresee”, “believe”, “continue”, “maintain” or “align”, the negative of these terms, variations of them or similar terminology. By their nature, forward-looking statements require us to make assumptions and are subject to important known and unknown risks and uncertainties, which may cause our actual results in future periods to differ materially from forecasted results. While we consider our assumptions to be reasonable and appropriate based on information currently available, there is a risk that they may not be accurate. For additional information with respect to the assumptions underlying the forward-looking statements made in this presentation, refer to the respective Guidance and forward-looking statements section in the Aerospace section in the Management’s Discussion and Analysis (“MD&A”) of the Corporation’s annual report for the fiscal year ended December 31, 2013.

Certain factors that could cause actual results to differ materially from those anticipated in the forward-looking statements include risks associated with general economic conditions, risks associated with our business environment (such as risks associated with the financial condition of the airline industry and major rail operators), operational risks (such as risks related to developing new products and services; doing business with partners; product performance warranty and casualty claim losses; regulatory and legal proceedings; the environment; dependence on certain customers and suppliers; human resources; fixed-price commitments and production and project execution), financing risks (such as risks related to liquidity and access to capital markets, exposure to credit risk, certain restrictive debt covenants, financing support provided for the benefit of certain customers and reliance on government support) and market risks (such as risks related to foreign currency fluctuations, changing interest rates, decreases in residual values and increases in commodity prices). For more details, see the Risks and uncertainties section in Other in the MD&A of the Corporation’s annual report for the fiscal year ended December 31, 2013. Readers are cautioned that the foregoing list of factors that may affect future growth, results and performance is not exhaustive and undue reliance should not be placed on forward-looking statements. The forward-looking statements set forth herein reflect our expectations as at the date of this presentation and are subject to change after such date. Unless otherwise required by applicable securities laws, we expressly disclaim any intention, and assume no obligation to update or revise any forward-looking statements, whether as a result of new information, future events or otherwise. The forward-looking statements contained in this presentation are expressly qualified by this cautionary statement.

Agenda

- BFTC TEST PILOT UP&RT TRAINING
- INDUSTRY TRAINING FOR STICK PUSHER SYSTEMS

RECENT UP&RT INITIATIVE FOR BFTC TEST PILOTS 2013

Why? Improve the Level of Safety

- Refresher
- Stall Program Prep and Risk Mitigation
- Hard Flying Skills Training (perishable)
  - Liability Insurance Rates

Multiple Solutions Evaluated

Airplane Training Selected

AIRPLANE VS SIMULATOR TRAINING

1. NEED ***REAL "G" FEEL*** – "LIGHT IN THE SEAT" – 1/2 G FOR RECOVERY - ***UNLOAD FOR CONTROL***
2. NEED ***REAL*** SUSTAINED ***ROLL, PITCH, AND YAW RATES***
3. NEED THE ***STARTLE FACTOR*** – REALLY GO INVERTED, REALLY STALL/SPIN
4. BOTTOM LINE: NEED TO TRAIN THE PRIMARY RECOVERY STRATEGY IN A REAL AIRPLANE

Aviation Performance Solutions Selected Extra 300 Platform

- **Negative Training?**
- Doesn’t Replicate Inertias Or Swept Wing Response
- Advantages far outweigh differences
- Experience actual forces and sensations; practice the Proper Response

Training for Stick Pusher Systems

Pusher/Stall ID Device: Experience with Physical Characteristics Valuable … But

Requires Careful Implementation in Full Flight Simulator to Avoid Negative Training and Unintended Consequences

Aero Fidelity Between Shaker and Pusher – Does Not Accurately Reproduce Airplane Response

OEM Concerns

Instructor Knowledge Standards - Correct Recovery Response Must be Used

Recovery Differences at <u>High Altitude</u> (Cruise Altitude)

BOMBARDIER

the evolution of mobility

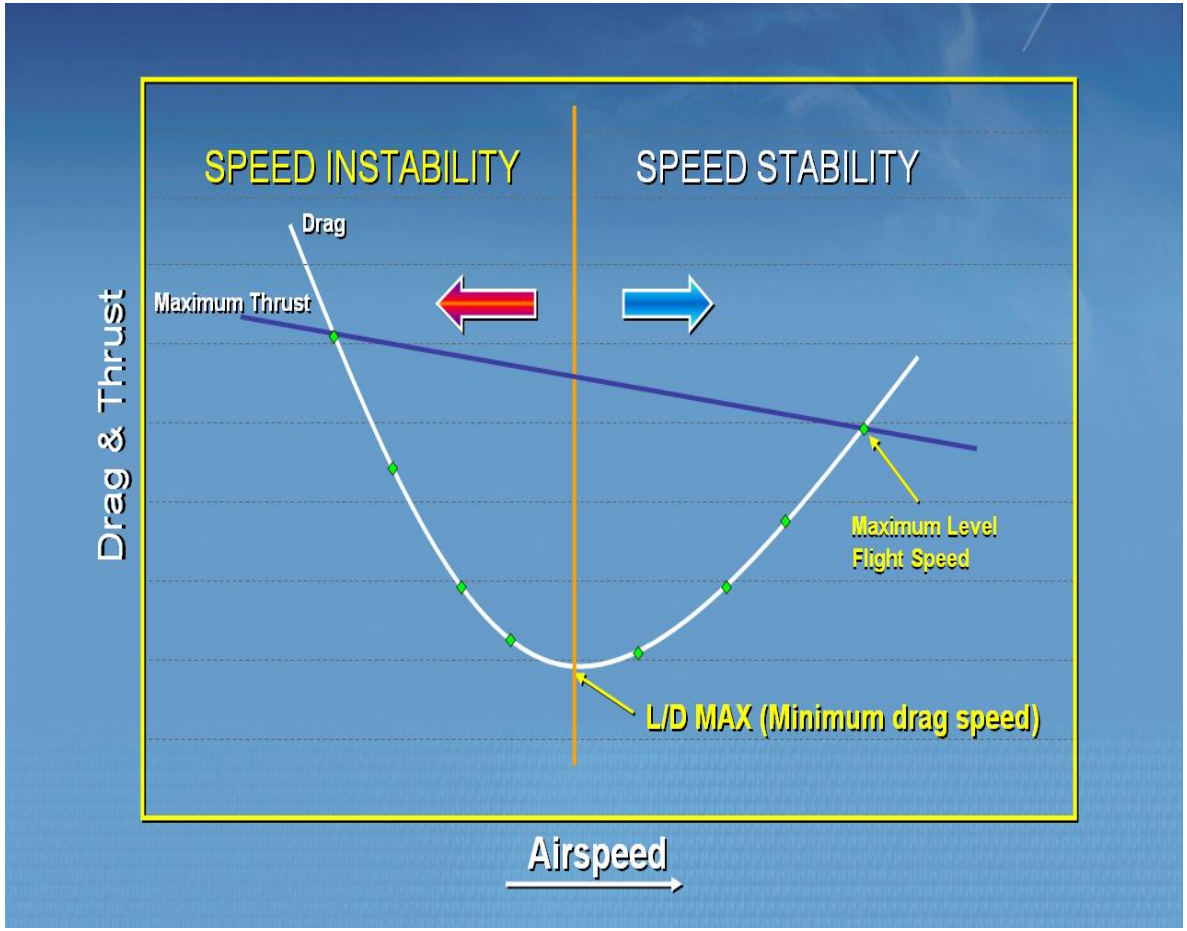
BACK UP SLIDES

- Energy Management Illustration

  Expanding on the Training Aid material from a thrust available vs thrust required perspective

- Bombardier AOA Display

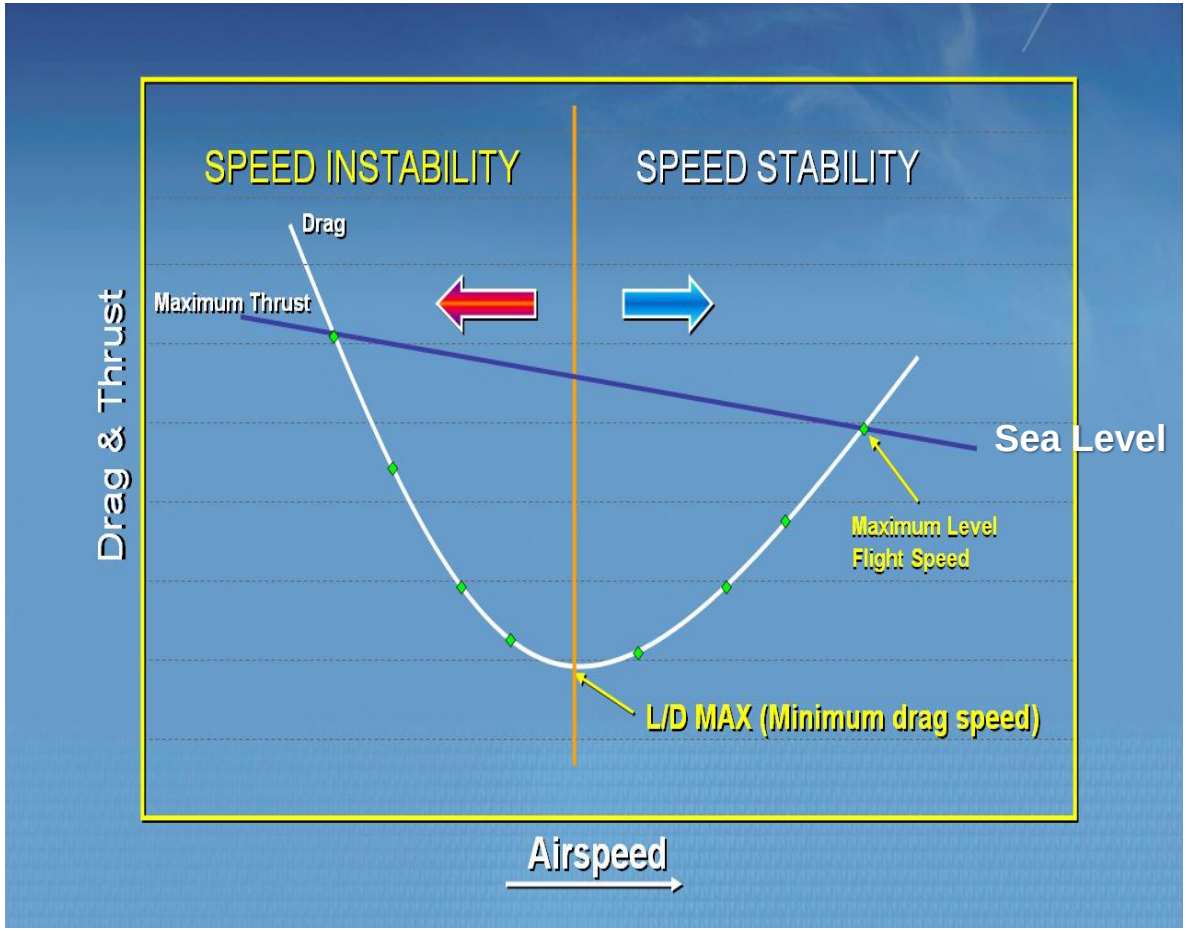
Upset Recovery Training Aid Rev 2
App 3E High Altitude Operations



This is a chart from the Rev 2 appendix on high altitude operations. These slides clarify the real high altitude energy concepts. The white "Drag" line is total drag and also can be referred to as "Thrust Required." The blue line is "Thrust Available." The difference between the blue "Maximum Thrust" line and the white "Drag" line is "Excess Trust."

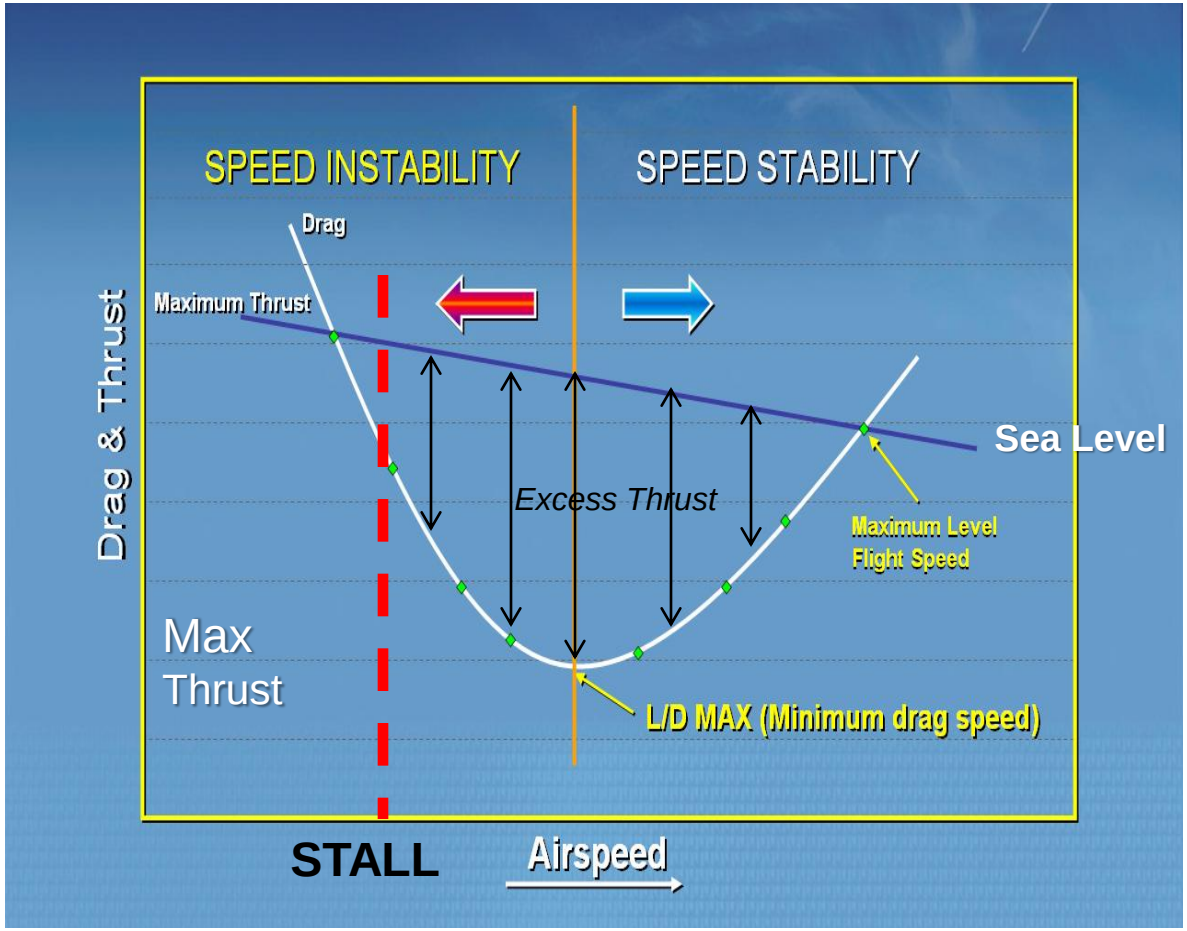
Upset Recovery Training Aid Rev 2
App 3E High Altitude Operations

This Training Aid chart is more appropriate for low altitude



The chart illustrated in Rev 2 is more appropriate for low altitude, for example, Sea Level. Similar to the thrust/drag relationship at takeoff.

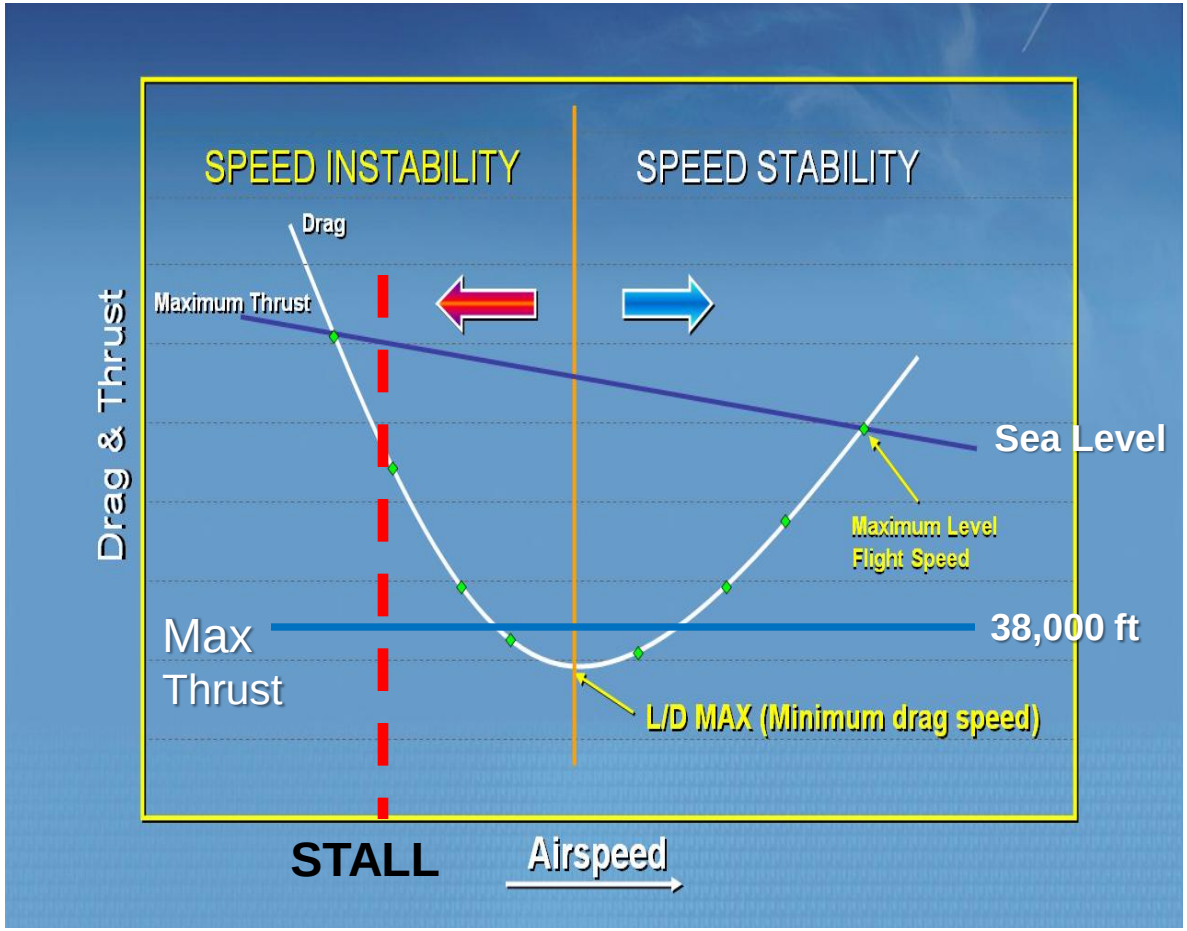
Upset Recovery Training Aid Rev 2
App 3E High Altitude Operations



At takeoff, there is excess thrust available from the time the thrust is set for takeoff. You transition through the red arrow zone shown above on every takeoff. You have excess thrust available from the max level flight speed all the way down to stall. As you climb to altitude, this relationship changes.

Upset Recovery Training Aid Rev 2
App 3E High Altitude Operations

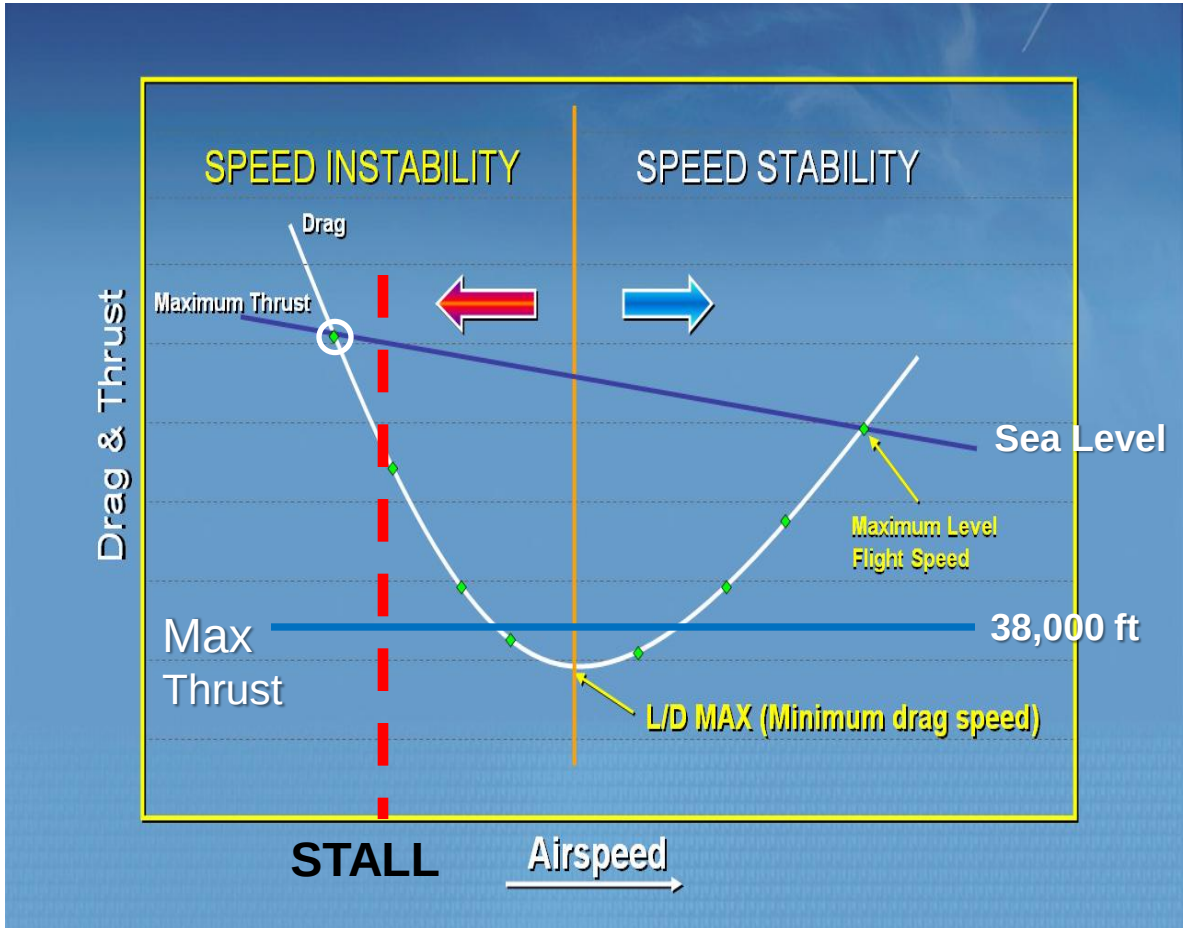
REAL HIGH ALTITUDE



As the airplane climbs, the blue line and the white line merge. The illustration shown above is for simplicity – the max thrust available at FL 380 shown as a straight line; the white thrust required line and the stall line staying where they were. Excess trust is significantly less at high altitude.

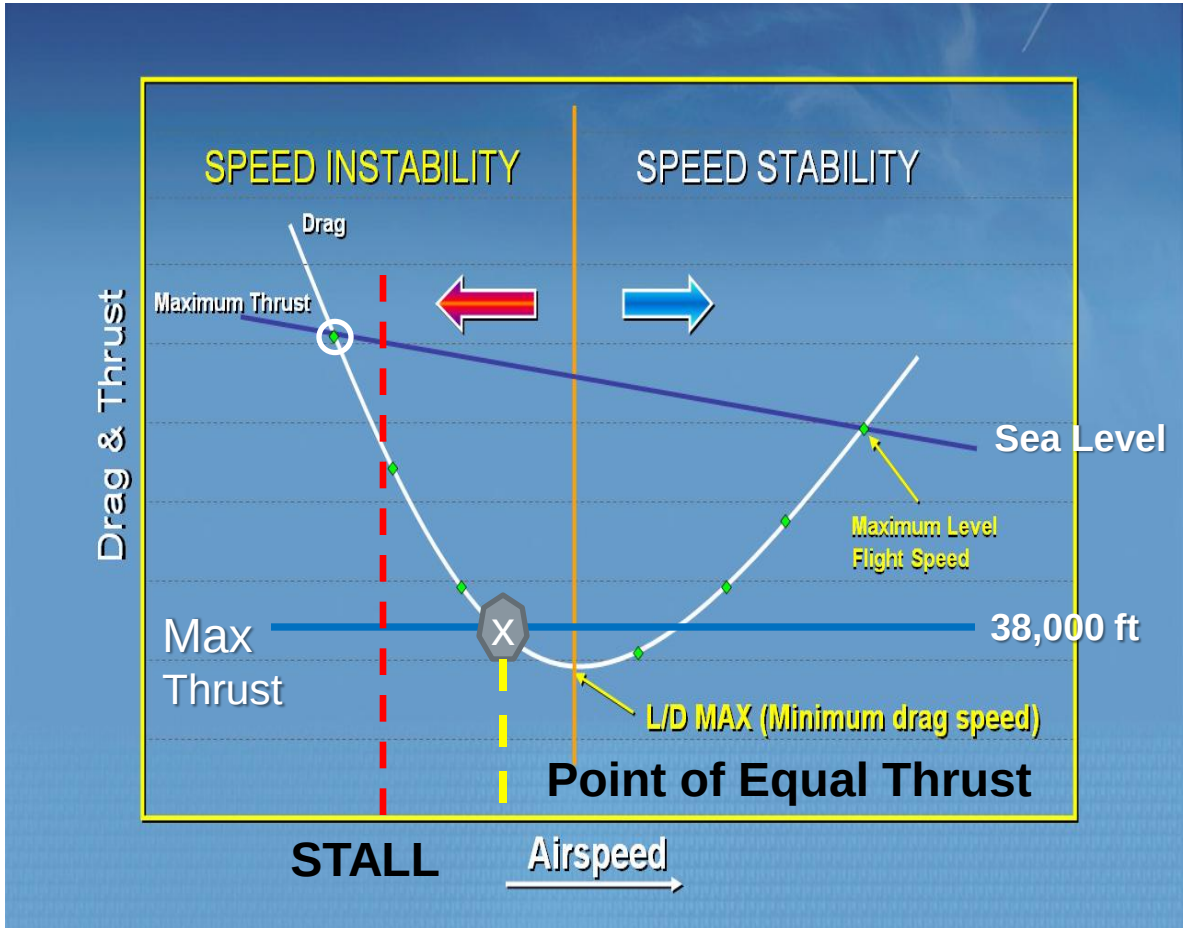
Upset Recovery Training Aid Rev 2
App 3E High Altitude Operations

REAL HIGH ALTITUDE



Note the white circle. At sea level, the thrust required (drag) and the thrust available merge below the stall speed – of no consequence.

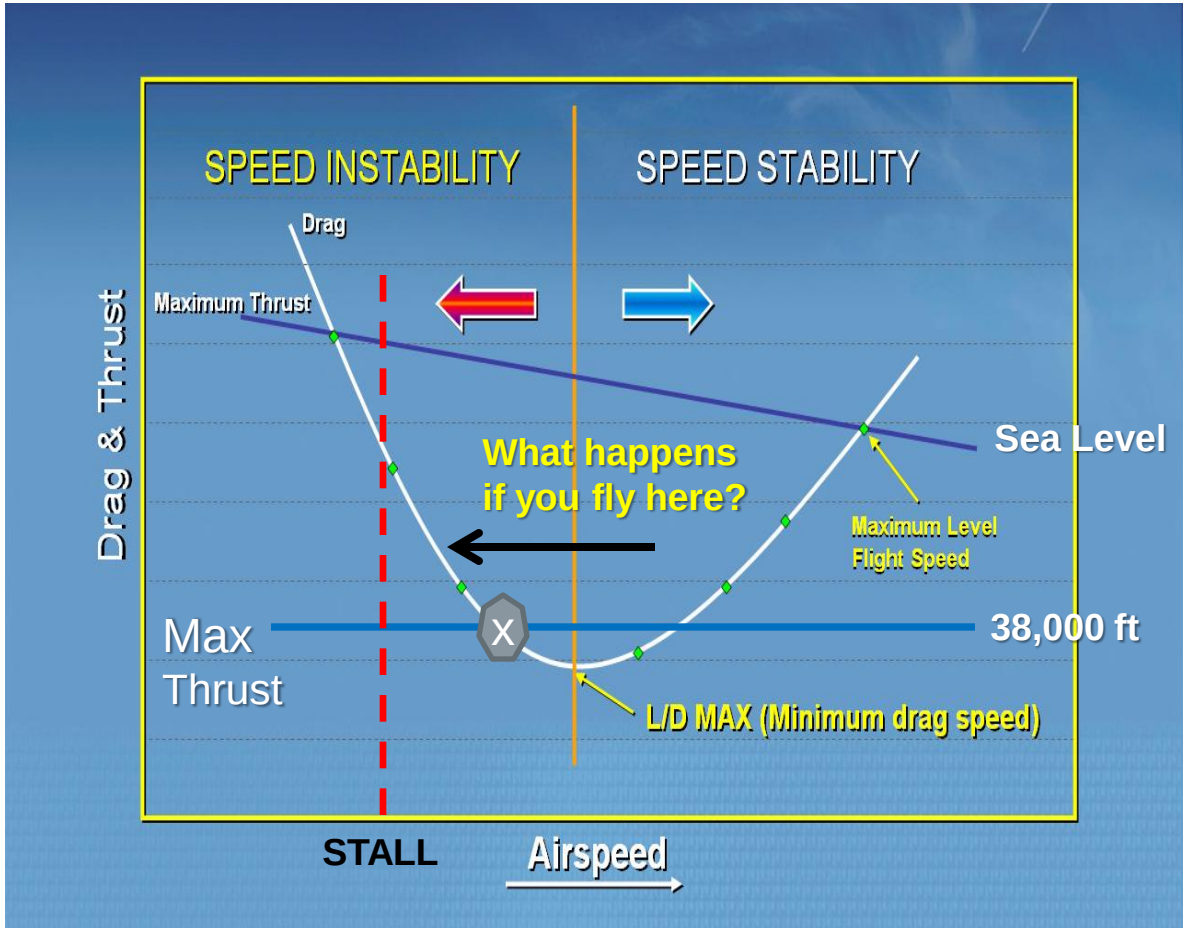
Energy Management Concepts for High Altitude Operations



However, at altitude this point is above stall speed, and can be significantly above stall speed. For simplicity, this point is called the "point of equal thrust" on this illustration. Similar to the term "point of equal power" used in an EASA video on this energy relationship. (see https://easa.europa.eu/essi/egast/ 2008/10/video-on-the-back-side-of-the-power-curve/)

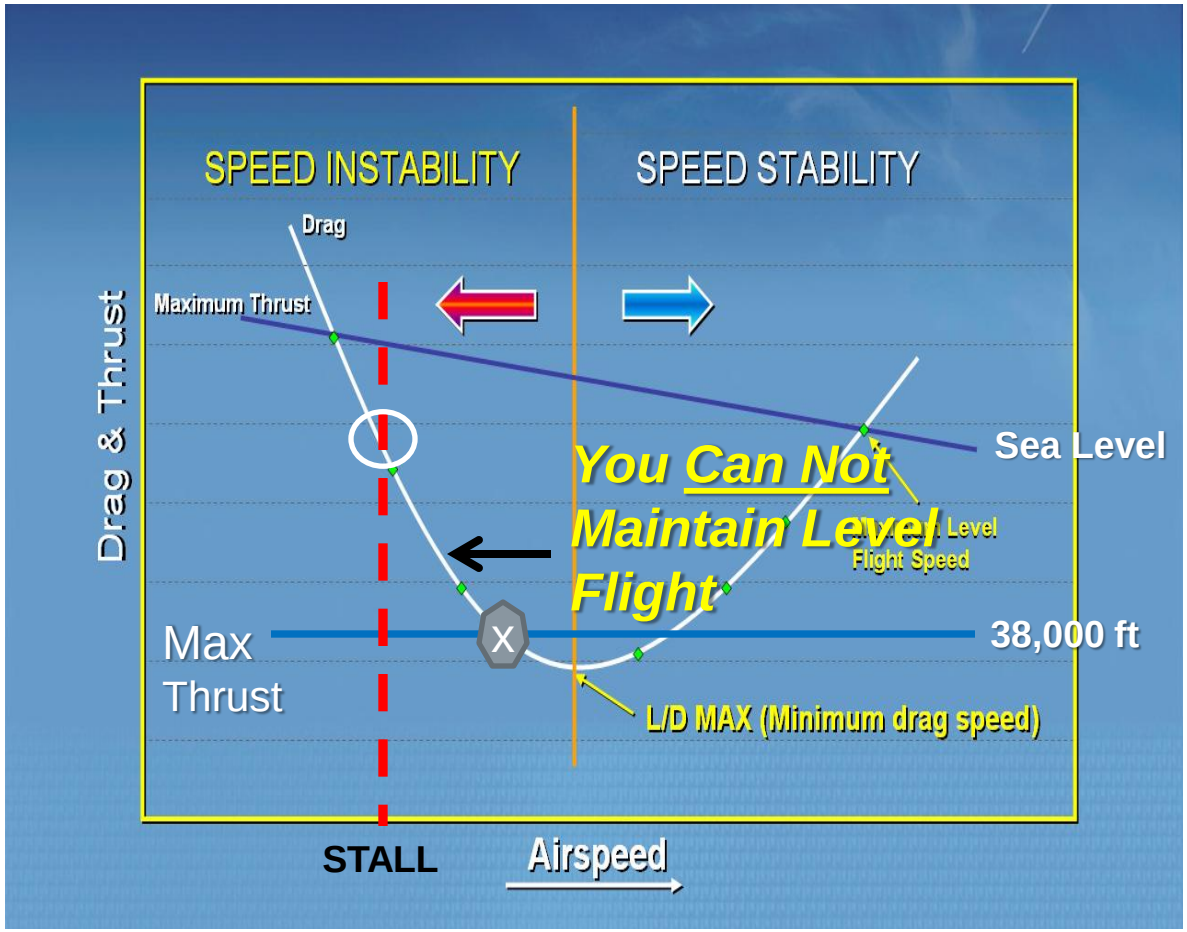
BOMBARDIER
the evolution of mobility

Energy Management Concepts for High Altitude Operations



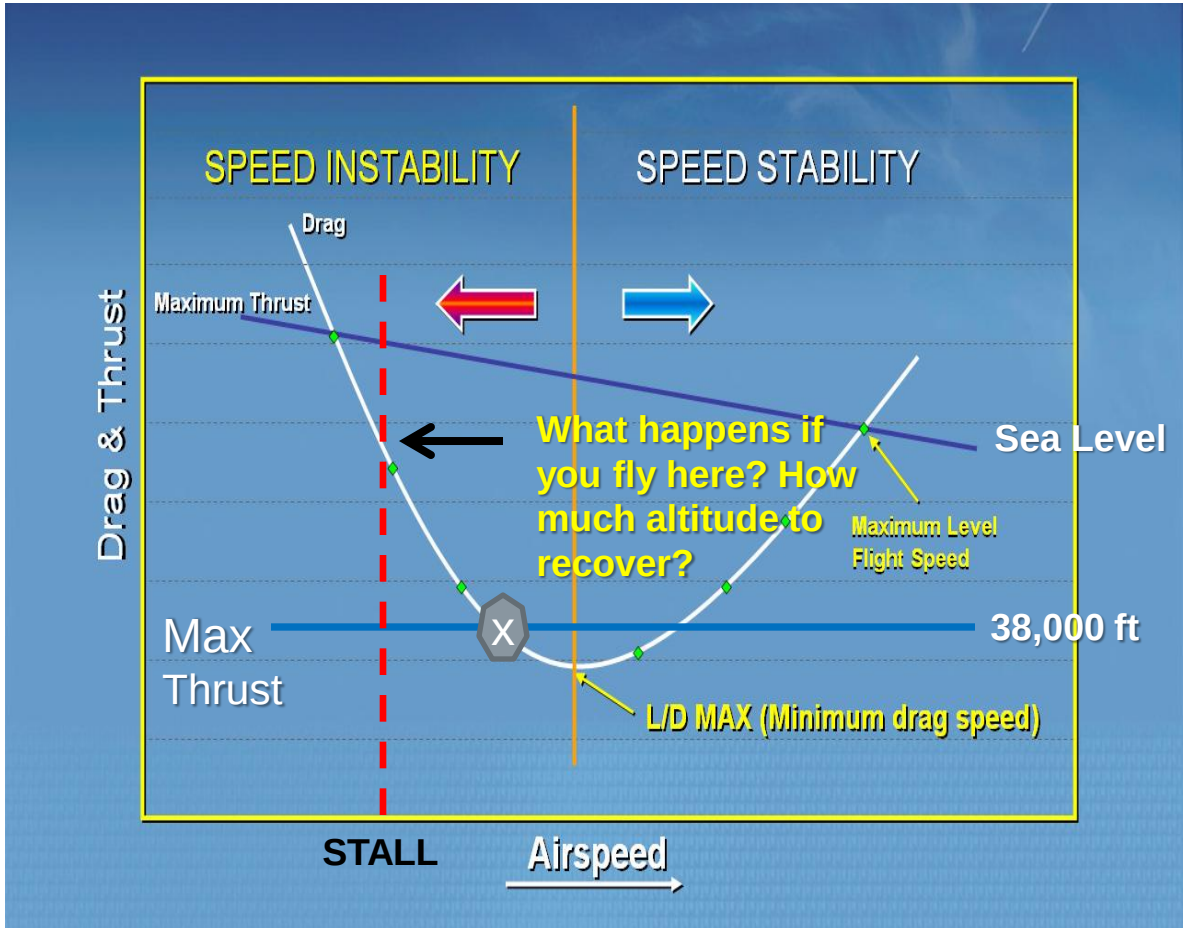
What happens if you fly at a speed (Mach) below the point of equal thrust? For example, climbing well above Opt Alt in Vertical Speed at say 1500 ft/min due to weather – in effect trading airspeed for altitude.

Energy Management Concepts for High Altitude Operations



If you level off here, and you try to maintain level flight, you will slow down – even if it is slowly - to the white circle where stall speed and thrust required merge. Your PFD low speed cues may not show this energy management issue when you first leveled off. If you continue to maintain altitude, you will stall.

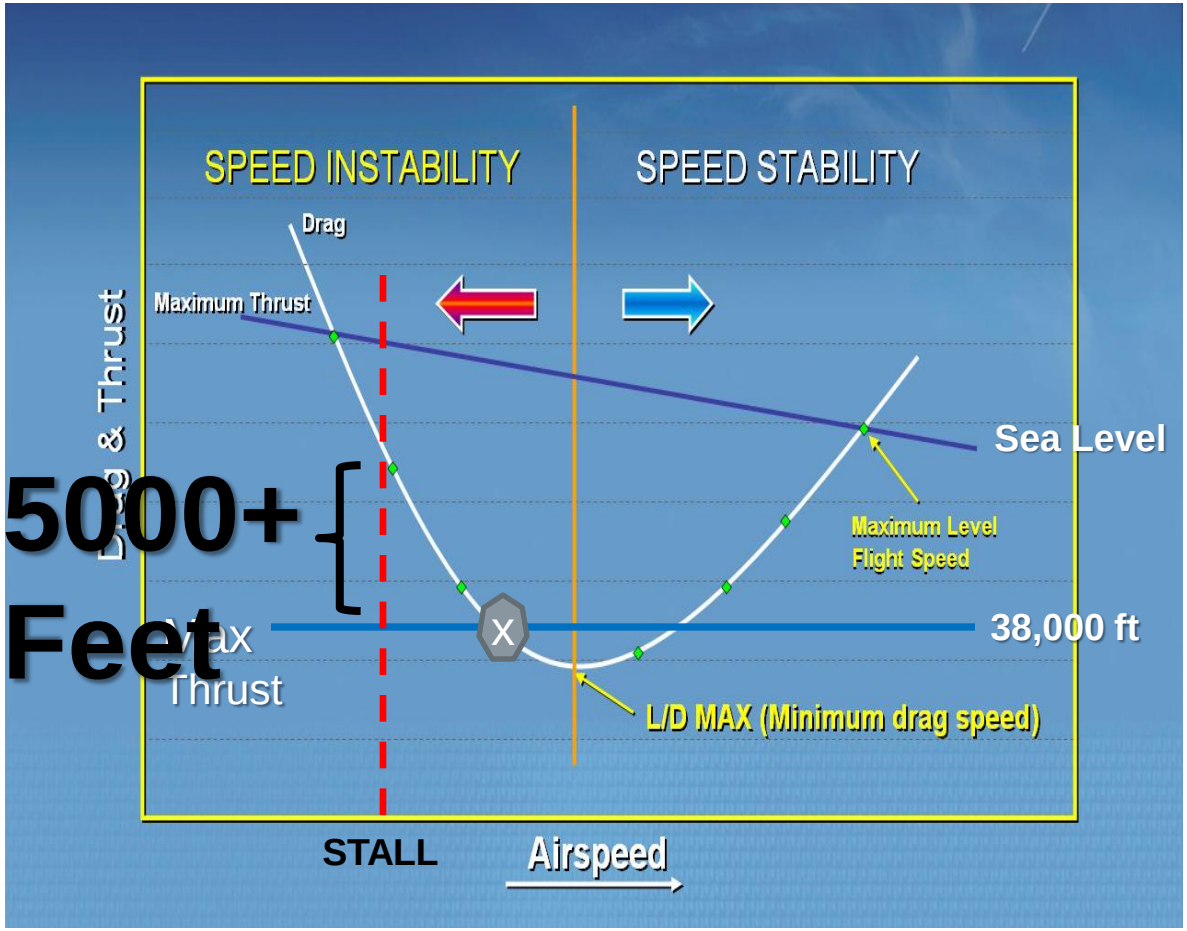
Energy Management Concepts for High Altitude Operations



If you maintain altitude until stall warning (shaker), it takes considerable altitude to recover. The recovery is two parts: break the AOA, then accelerate to above the equal thrust point.

BOMBARDIER
the evolution of mobility

Energy Management Concepts for High Altitude Operations



To reduce the AOA and recover to positive thrust available energy state may take over 5000 feet from a stick shaker event at high altitude. (The energy state moves to a different thrust available vs thrust required "chart" at a lower altitude.)

BOMBARDIER
the evolution of mobility

Bombardier AOA Display

(Challenger 350 Shown)

FL 430 M 0.79 AOA < .4

APPROACH VREF AOA .6

BOMBARDIER
the evolution of mobility

Slide 4

Existing contract with APS for production/customer support pilots = LeadingEdge program. Initial and recurrent every 60 months. Aviation Performance Solutions.

BFTC Test Pilots are highly experienced. Many with extensive new aircraft envelope expansion/stall test experience. Many former military jet fighter background. But recency of advanced maneuver training was low. Even highly experienced test pilots need refresher to practice the hard skills necessary for unexpected aircraft behavior, stall recoveries, etc. Had new aircraft programs – CL 350, C-Series, Learjet 85; desired crew prep as risk mitigation. A side business case was potential lowering of BA pilot liability insurance rates, in negotiation.

These skills are perishable – research shows two years. Establish and Maintain Upset Recognition, Avoidance, and Recovery Skills.

Evaluated the National Test Pilot School URT program – Impala; Calspan URT with Bonanza F-33 and Learjet Variable Stability In Flight Simulator, Aviation Performance Solutions Emergency maneuvering training with extra 300, plus a number of fixed base simulators.

Quickly down-selected to actual airplane training being the solution. Top end = Calspan – side by side, vari-stab can program to fly like any airplane; expensive. NTPS good program. APS was most effective cost-benefit business case for our needs.

Next slide: why did we select aircraft not sim training?

Slide 5

AOA control is paramount – "ALPHA is a Greek named Control: Unload for Control" (F-4 training video). Need real "g" to train the "unload for control" strategy; to "light in the seat" about 1/2 g, not zero or negative g. Can't reproduce "light in the seat" in FSTD (Centrifuge simulators can but high cost/low capacity issues for operator training purposes.)

A full flight simulator, mounted on telescoping rods attached to a floor, can't physically reproduce sustained pitch, roll, or yaw rate rates. Current sims for operator training have little post stall fidelity of response. OEMs may have data. Hopefully improvement of simulator aero models will be a step in the right direction but still limited physically in giving real sensations to the trainee, especially those that are potentially disorienting (high roll rates, inverted, nose slice).

Speaker's Notes Pages

Slide 6

APS program selected – academics and 4 flights.

Re "Negative Training" issue – of course there are significant differences: prop, tandem seating, straight wing vs swept wing characteristics. While it does not replicate the inertias and handling characteristics of a typical business or commercial jet, it does provide appropriate education, train the proper response, and allow the student to experience the actual forces and sensations of an upset. And it does it better than a fixed base simulator in the exact type. And is cost effective.

Note there is an option for adding a CRJ simulator session at the vendor's Mesa, AZ site. Option after the flights to practice skills as a crew.

Startle factor far more real in airplane (can do a better job of "surprising" FSTD trainees but they won't be "scared"); no "fear" in a sim – can always go on motion freeze and go on a coffee break. An airplane is different - real "fear" factor.

Bottom line: Experience actual g forces and sensations, startle/pucker factor of really having to get it right.

Learn – or relearn and practice - the response – unload for control – to the instinctive level.

Speaker's Notes Pages

Slide 7

As OEM, not advocating training customers to disregard stall warning (shaker or natural buffet) and allow further decrease of airspeed/increase of AOA, which will increase the likelihood of loss of control. But accidents – Pinnacle, Colgan - have shown the line pilot response is to fight the pusher. The data shows exposure to pusher events may be warranted. Pusher Stall ID device similar to others – Boeing Elevator Feel Shift, Envelope Protection Systems. Pusher is an abrupt nose down movement of the control column. Pilot should not "fight" this – Pinnacle case. Pusher preceded by shaker with appropriate Part 25 stall warning margins. Shaker is "artificial buffet onset;" pusher is artificial "CL Max" – "g break."

Comments here similar to recommendations of the SPAW ARC - Stick Pusher and Adverse Weather Aviation Rulemaking Committee.

Part 25 specifies margin between Stall Warning (Shaker) and Stall ID (Pusher). Recovery from Warning (Shaker) not same as recovery from Stall ID: Although "Upset Recovery Training Aid Rev 2" states "Effective stall recovery requires a deliberate and smooth reduction in wing angle of attack." – the actual Pusher is not "smooth." Valuable to experience how it feels. At the Stall ID AOA, AOA must be reduced immediately.

Sim fidelity Post Shaker may be unrepresentative. OEMs have data. Non-linear and non-repeatable – or at least highly variable – airplane response. Changes to Sim aero model may help, a step in the right direction.

Sim Instructor knowledge standards – examples of IP giving incorrect recovery strategy from Pusher – eg, roll wings level first – vs Unload for Control. Some IPs are still emphasizing minimizing altitude loss during approach to stall training; often focus on precise set up airspeeds, altitudes, and thrust settings which detracts from the learning objective; probably should not have test standards – maybe pass/fail.

Low altitude – immediate thrust response and able to loose less altitude in recovery than high altitude ; high altitude – slow thrust response and recovery is two parts: AOA/Stall recovery + accelerate in a descent until airspeed is above the "backside of the power curve" – may take 5000 – 8000 ft.

Train the Trainers first; need agency oversight.

High altitude doesn't mean some altitude we rarely go to – it means everyday cruise altitude. There are differences in recovering from a stick shaker or pusher at high altitude – aero characteristics and low thrust available – buffet before shaker – "time" between shaker and pusher - "tuck under": need to quickly check back on the control column after the pusher to avoid neg g – a Part 25 certification requirement issue – but operationally, neg g better than secondary stall. And it takes a lot of altitude to recover – two parts: break the AOA "UNLOAD FOR CONTROL" Alpha is a Greek named Control – it should be trained to the point it is "instinctive" to unload – then the recovery to level flight, at a speed above the "equal thrust point" = Thrust available equal or greater to thrust required.

High altitude training – Classroom and Simulator – need to be improved. (See Back Up slides)

Better than Not Training Pusher at All

Back Up Slide 17

Why You Can Not Maintain Level Flight - It's Newton's fault: F = mA … and your "F" is negative, of course your "m" can't be, and since the equation is equal, your "a" is negative … you are going to slow down if you maintain level flight … and you are going to stall if you continue to maintain level flight.

You have to descend (exchange altitude for airspeed) to accelerate to or beyond the point of equal thrust. The "descent" is actually a reduction of Angle-of-Attack – reducing the Lift – and Induced Drag – such that Thrust Available is Greater than Drag at that reduced AOA.

A rule of thumb (Challenger 350) above 40,000 ft is to stay above M 0.65 and in climb, stay below .4 on the AOA indicator.

Back Up Slide 18

If you maintain altitude until stall warning (shaker), it takes considerable altitude to recover. The recovery is two parts:

1) Break the AOA - "UNLOAD FOR CONTROL" and note that unlike what you may have been taught in the simulator in the past, you can not "power out" of the stick shaker in level flight because you were already at full thrust.

2) Then the recovery to level flight at a speed above the "equal thrust point." This requires trading altitude for airspeed which will, unlike low altitude where you have considerable excess thrust at stall speed, take thousands of feet.