



Flight Test of Transport Category Airplanes

Heather Ross
787 Project Pilot
Boeing Commercial Airplane
Company

Why We Flight Test

Airplane flight test verification and validation

- Does it work as designed?
- Is it a valid design concept?
 - Provide basic test data and requirements for design
 - Verify that design satisfies requirements
 - FAA/Regulatory certification
 - Manufacturer's design standards

What We Flight Test

- More than just brand new designs
 - Modifications to production airplanes
 - New configurations on current production airplanes
 - Major modifications to existing models
 - 747 Large Cargo Freighter
 - 767 Special Freighter and Boeing Converted Freighter
 - 757 Special Freighter
 - BBJ
- More than just for certification
 - New technology R&D on current production airplanes
 - Manufacturer's design validation prior to certification demonstration
 - Production flights
 - Customer demonstrations
 - Functional check flights

Introduction to Certification

- The FAA and other regulators establishes regulatory requirements for the design and manufacturing of aircraft.
- These requirements are intended to establish an acceptable level of safety.
- In the certification process...
 - The manufacturer shows that they have satisfied all the requirements.
 - When the FAA and other regulators are satisfied that all requirements have been met, they issue appropriate certificates.

Types of Certification

- **Type Certification**
 - The design must meet the standards.
- **Production Certification**
 - The manufacturing processes must accurately and reliably produce products that match the approved design.
- **Airworthiness Certification**
 - Each individual aircraft must match the approved design and be safe for operation.

Type Certificate

- Manufacturer wants to introduce a new design into the marketplace:
 - Produce experimental airplanes
 - Subject it to an intense program of flight and static testing and engineering analyses
 - Prove design complies with certification standards contained in 14 CFR (compliance)
- Once this test program is completed to the satisfaction of the FAA, a Type Certificate is issued for the design (type design)

Production Certificate

- Production Certificate conveys approval of quality and manufacturing systems
- Manufacturer's production facilities and quality assurance program submitted to FAA scrutiny
- FAA must be convinced that production and inspection methods ensure each and every airplane produced conforms to Type design
- Manufacturing under approved production system begins once the Production Certificate is granted



The Production Certificate is usually issued soon after the Type Certificate

Airworthiness Certificate



- Airworthiness Certificate is authorization to operate the airplane
- Inspected for conformity to approved type design
- The changes new to this airplane approved and included in approved type design
- Receives Airworthiness Certificate prior to delivery to customer.

Sequence of a Test Program

Concept development

Application for Type Certificate

Determine Certification Basis

Identify Methods of Compliance

Development and construction

Certification analysis and Test

Company Flight Test

Certification Flight Test

Issue Type Certificate

Certification Requirements

Requirements in the Federal Aviation Regulations

- **Part 21 - Certification Procedures**
- **Part 25 -Airworthiness standards for transport airplanes**
- **Part 33 - Airworthiness standards for engines**
- **Part 36 - Noise standards**
- **Other related regulations**
 - **Operations**
 - **Training**
 - **Maintenance**
 - **Medical**

Part 25 Technical Areas (subparts)

- A- General
- B- Flight
- C- Structure
- D- Design and construction
- E- Powerplant
- F- Equipment
- G- Operating limitations and information
- H- Electrical Wiring
- I- Fuel tank flammability
- App K- Extended Operations (ETOPS)

Commonly Referenced FARs

- § 25.1301 Function and installation.
 - Each item of installed equipment must—
 - Be of a kind and design appropriate to its intended function;
 - Be labeled as to its identification, function, or operating limitations, or any applicable combination of these factors;
 - Be installed according to limitations specified for that equipment; and
 - Function properly when installed.

- § 25.1309 Equipment, systems, and installations.
 - The equipment, systems, and installations must be designed to ensure that they perform their intended functions under any foreseeable operating condition.
 - The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and the occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.

Part 25 Subpart B- FLIGHT

- Consists of all regulations from 25.21- 25.255
- Many include icing and non icing requirements
 - GENERAL- Loads, weight, and cg limits
 - PERFORMANCE- Takeoff speeds, path, distance and run, accel stop, climb (all engine and engine out), landing
 - CONTROLLABILITY AND MANEUVERABILITY- Longitudinal, lateral and directional control, minimum speed control
 - TRIM- Trim
 - STABILITY- Longitudinal, lateral and directional stability (static and dynamic)
 - STALLS- Stall speeds, demonstration, characteristics, warning
 - GROUND AND WATER HANDLING CHARACTERISTICS- Wind velocities (crosswind), taxiing
 - MISCELLANEOUS FLIGHT REQUIREMENTS- Vibration and buffeting, high speed, out of trim characteristics

Methods of Compliance

- While some requirements are quite specific, many are performance-based.
- There can often be a number of possible ways to show that a design complies.
- The FAA publishes guidance material (Advisory Circulars, policies, etc) to provide methods that manufacturers can use to show compliance.
- However, manufacturers can propose other methods.

AC 25-7A



U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

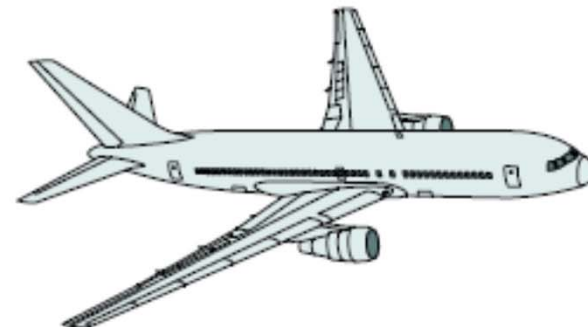
AC 25-7A

DATE: 3/31/98

Most relevant AC used in
flight test:

AC25-7C

FLIGHT TEST GUIDE FOR CERTIFICATION OF TRANSPORT CATEGORY AIRPLANES



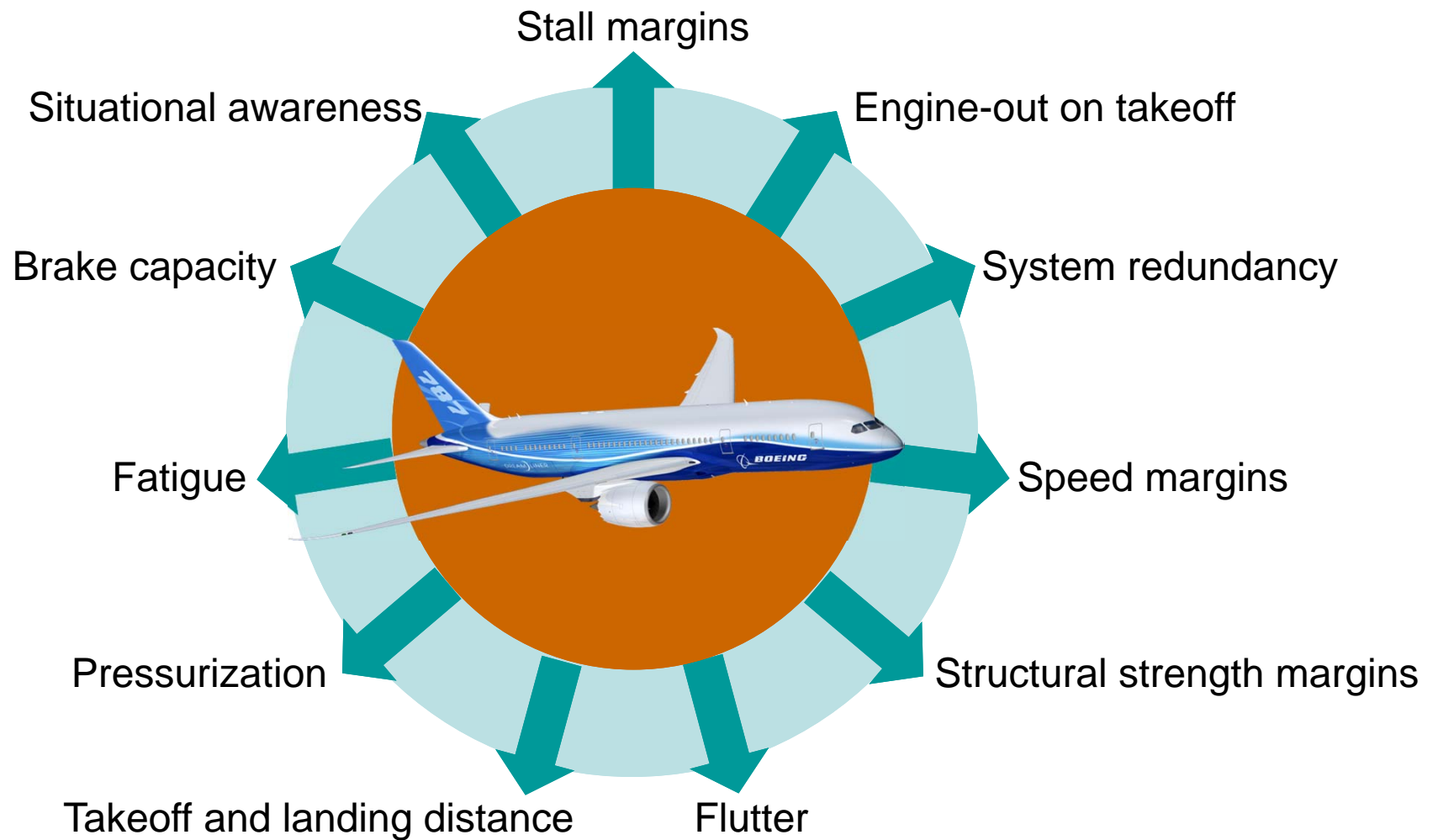
Exemptions

- Requiring strict adherence to every regulation may not always be in the public interest.
 - The law has specific provisions for granting exemptions to regulations.
 - Most importantly, there can only be an insignificant or minor affect on safety.
 - FAA can require mitigating actions to limit the safety impact.
 - There must be a compensating public interest.

Continuous Safety Program

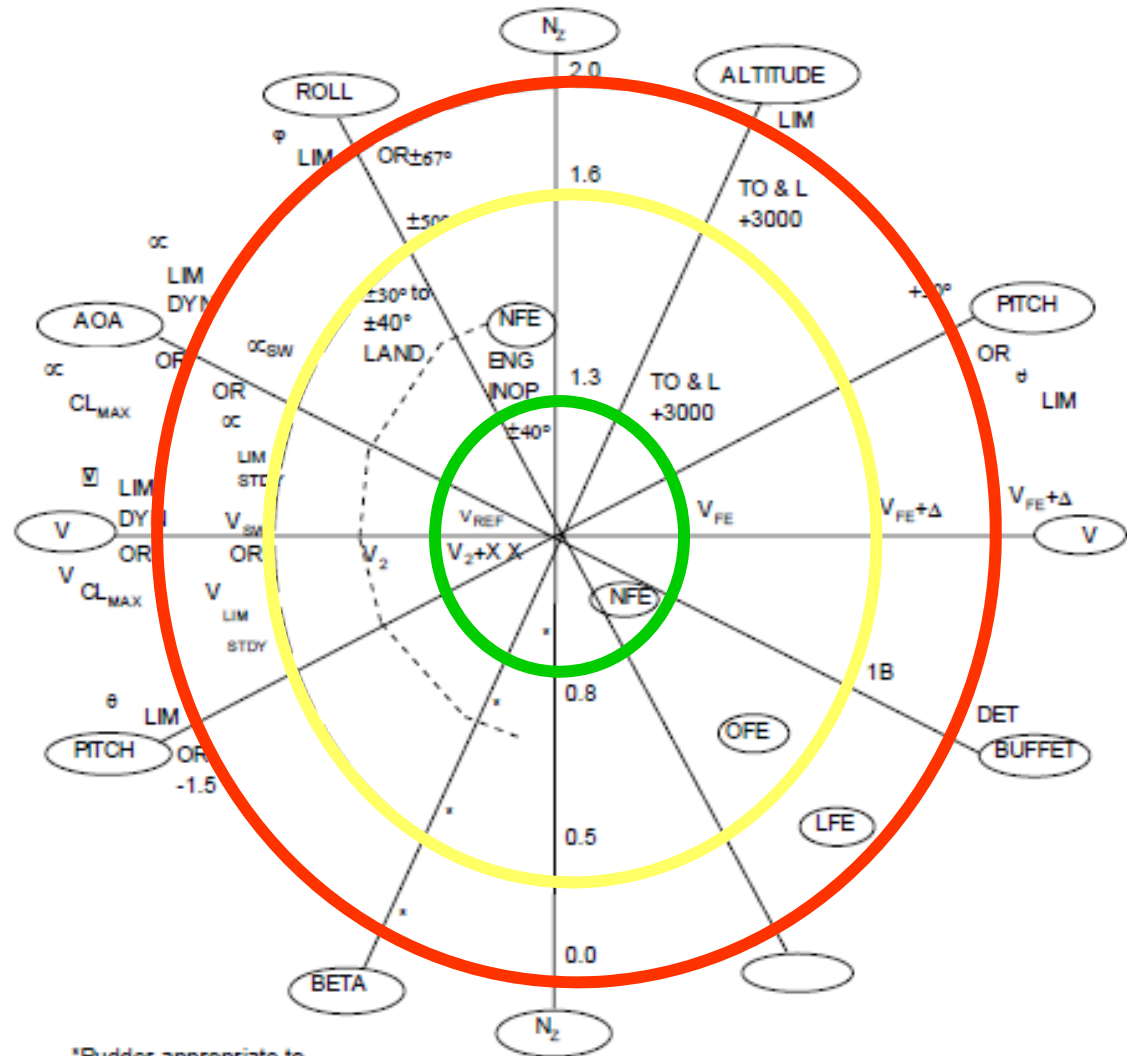
- Type, production, and airworthiness certification are just the beginning of the story.
- Continuously monitor the safety of the fleets.
 - Fix the safety problems found.
 - Improve the level of safety by raising the standards.

Testing the Design Envelope



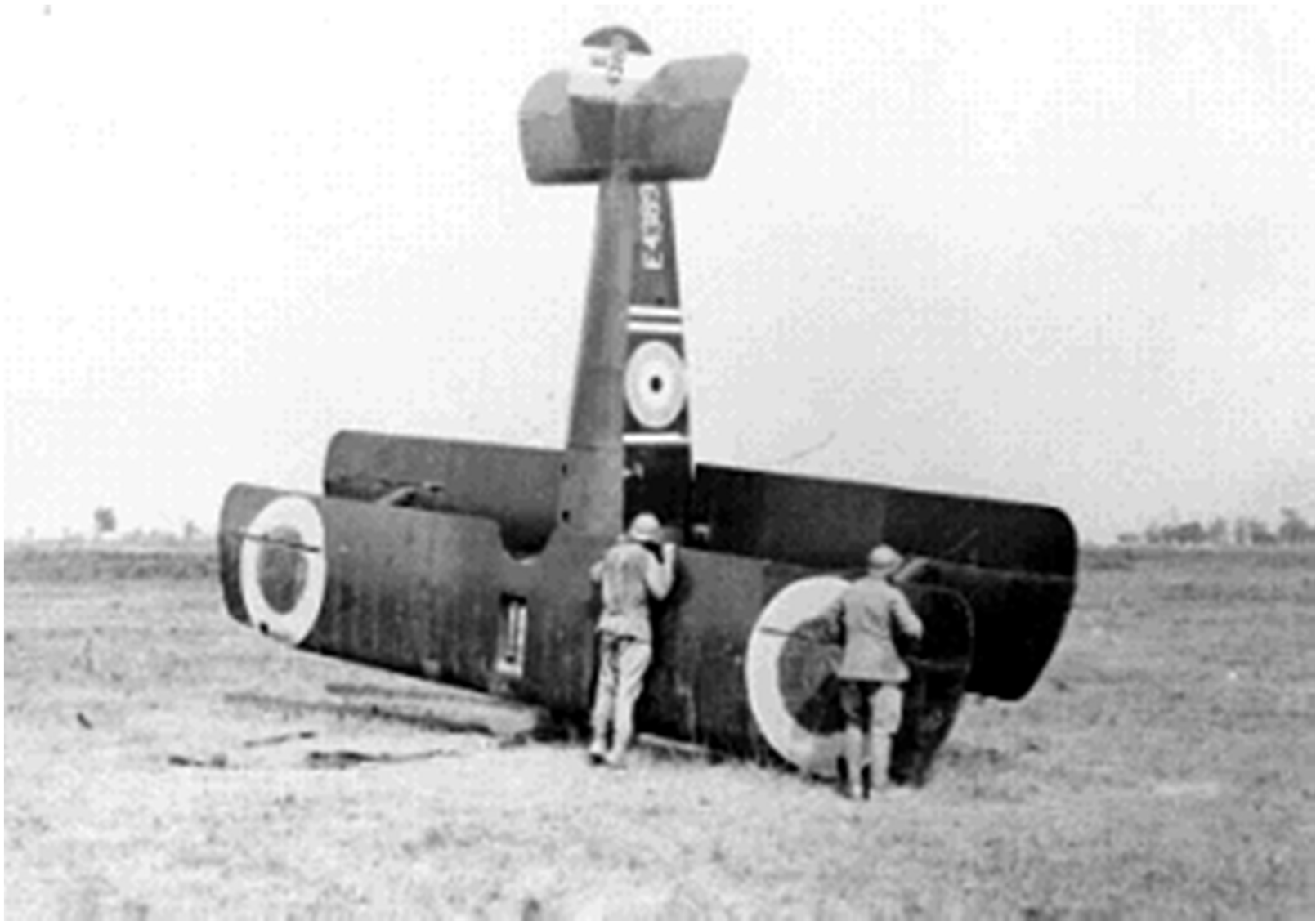
Across the Flight Envelope

- NFE Normal Flight Envelope
- OFE Operational Flight Envelope
- LFE Limit Flight



*Rudder appropriate to task/operation/or rudder lock eval

Flight Testing – The Old Way



Validation Process

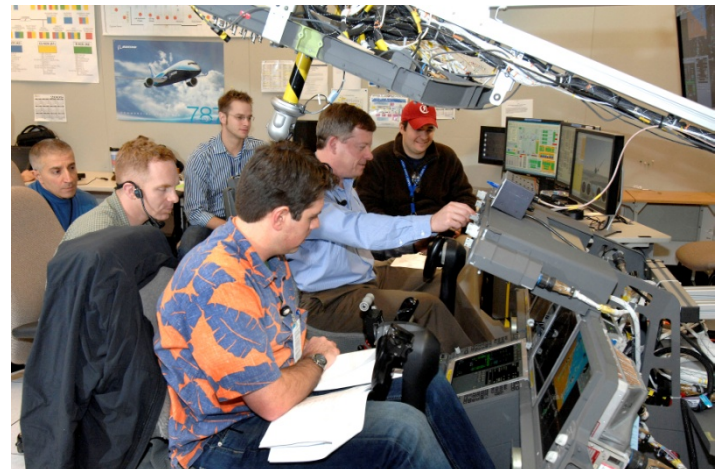
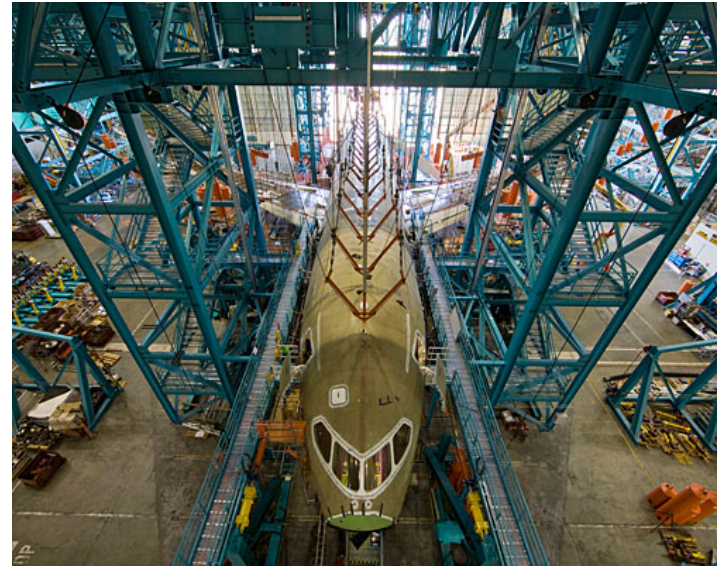


- New airplane
- Major change
- New system
- Modified system
- New part
- Modified part
- No change



Validation Ensures...

- The airplane type design complies with regulations
- The manufacturing process can reliably build the design
- Each airplane built conforms with the design
- Airline can reliably maintain and operate the airplane type
- Flight crews, cabin crews, maintenance crews know how to perform their jobs on this type of airplane



Flight Testing – Using Advanced Technologies



How We Flight Test

Stall Testing- Stall Speeds, Characteristics, Warnings

The purpose of stall testing¹ is:

- To define the minimum inflight airspeeds and how they vary with weight, altitude, and configuration (stall speeds)
- To demonstrate that handling qualities are adequate to allow a safe recovery from the highest angle of attack attainable in normal flight (stall characteristics)
- To determine that there is adequate prestall warning to allow the pilot time to recover from any probable high angle of attack condition without inadvertently stalling the airplane (stall warning)

¹ AC 25-7C Section 6, STALLS

Stall Testing



14 CFR § 25.201

The airplane is considered stalled when the behavior of the airplane gives the pilot a clear and distinctive indication of an acceptable nature that the airplane is stalled.

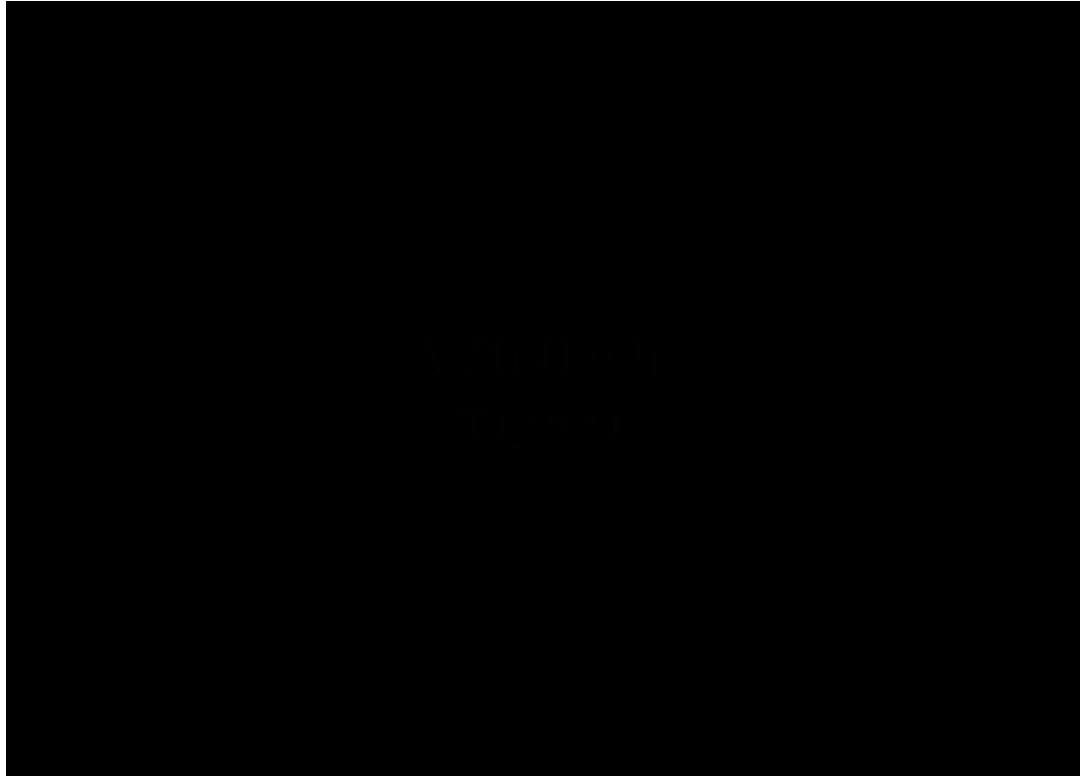
Handling Qualities and Controllability

The purpose of stability testing is¹:

- **To show that any operational maneuvers can be accomplished smoothly with average piloting skill and without exceeding any airplane structural limits.**
- **To show that the control forces are not so high that the pilot cannot safely maneuver the airplane or so light that exceptional pilot skill is required.**
- **To show that the airplane response to any control input is predictable to the pilot.**
- **To show that control forces during power and configuration changes are not excessive.**
- **To demonstrate that a pull force is required to slow and a push force required to accelerate from trim.**

¹ AC 25-7C Section 3, CONTROLLABILITY AND MANEUVERABILITY and Section 5, STABILITY

Wind-up Turn



14 CFR § 25.143

Stick force vs maneuvering load factor must lie within satisfactory limits and must not be so great as to make excessive demands on the pilot strength. Changes of gradient must not cause undue difficulty in maintaining control of the airplane, and local gradients must not be so low as to result in a danger of over-controlling.

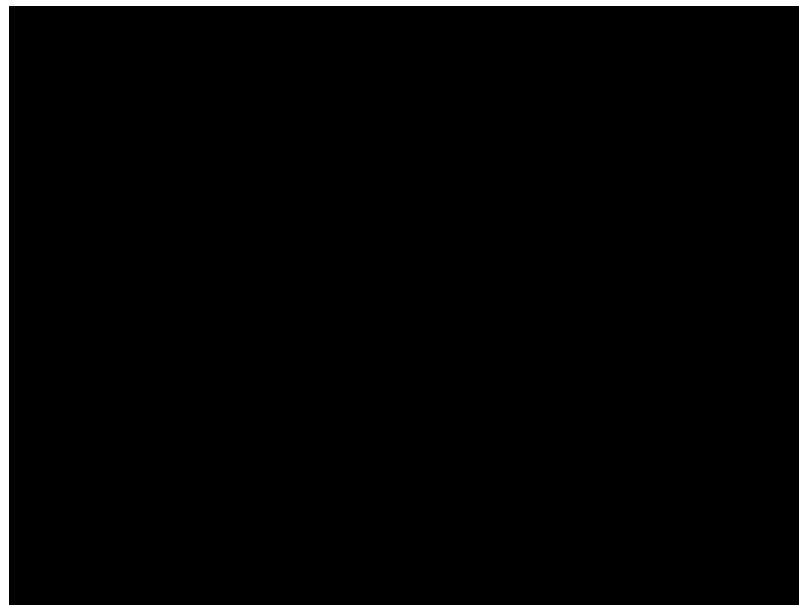
Minimum Control Speed Testing

The purpose of minimum control speed testing is:

- To define the minimum inflight control airspeed during takeoff climb, V_{MC} (V_{MCA})
- To define the minimum ground control airspeed during takeoff ground roll, (V_{MCG})
- To define the minimum inflight control airspeed during approach and landing, (V_{MCL})

¹ AC 25-7C Section 3, MINIMUM CONTROL SPEEDS

Minimum Control Speed- Ground



14 CFR § 25.149

The calibrated speed during takeoff run at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane using rudder control alone (\leq 150 lbs).

Takeoff Performance

The purpose of takeoff performance testing is:

- **To demonstrate configuration satisfies certification performance requirements**
- **To determine takeoff performance parameters required for flight manual**
- **To test a new model airplane - complete series required**
 - **Acceleration parameters, minimum liftoff speeds, rotation rates, takeoff speeds, takeoff distances, and tail contact margins.**
- **Some takeoff tests also required when an airplane undergoes significant changes**
 - **Stretching or shrinking fuselage length, a new takeoff flap deflection or a gross weight increase.**

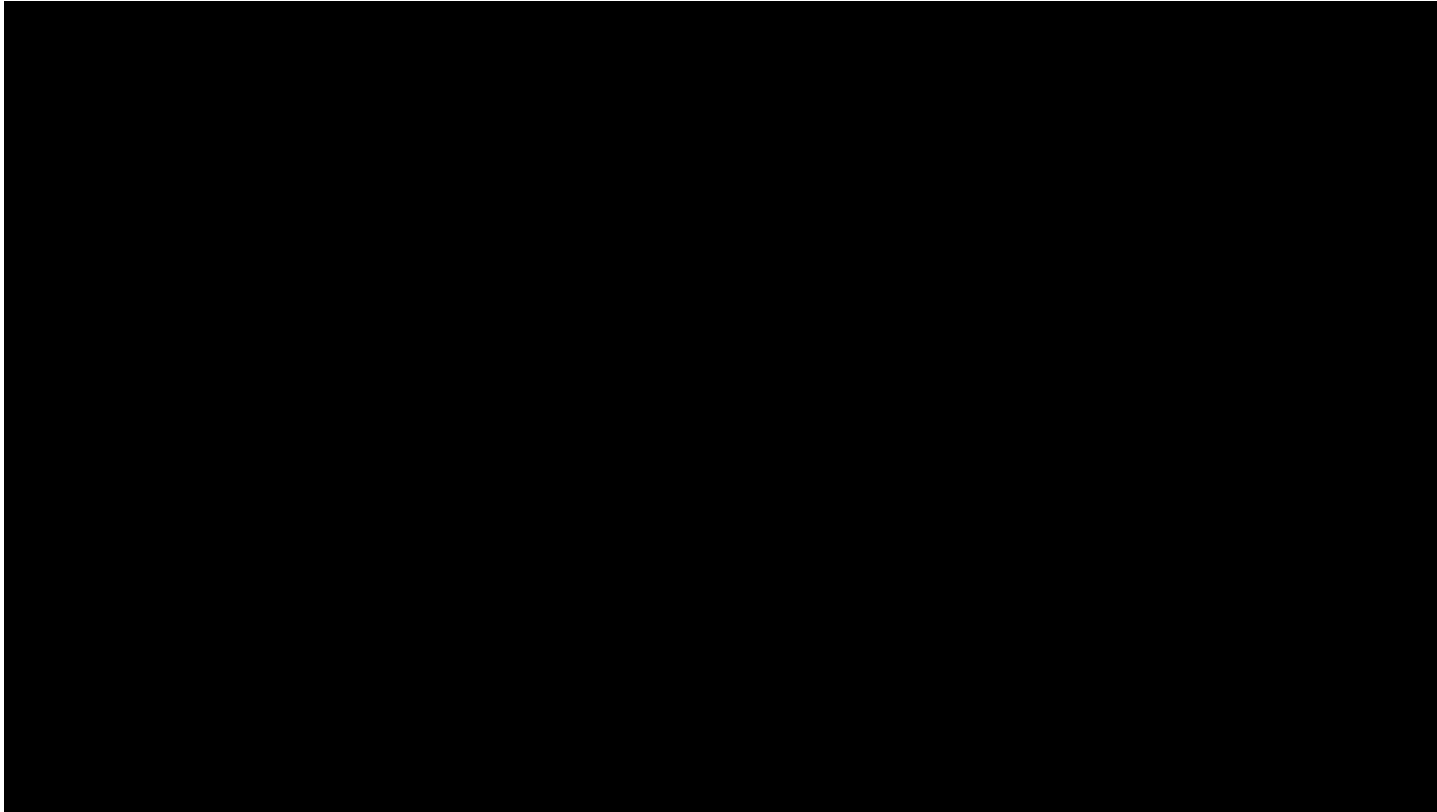
Takeoff Performance- Abuse Takeoff (Rapid Rotation)



[14 CFR § 25.107](#)

Reasonably expected variations from established procedures may not result in unsafe flight characteristics or marked increase in takeoff distance.

Takeoff Performance- Minimum Unstick (V_{MU})



14 CFR § 25.107

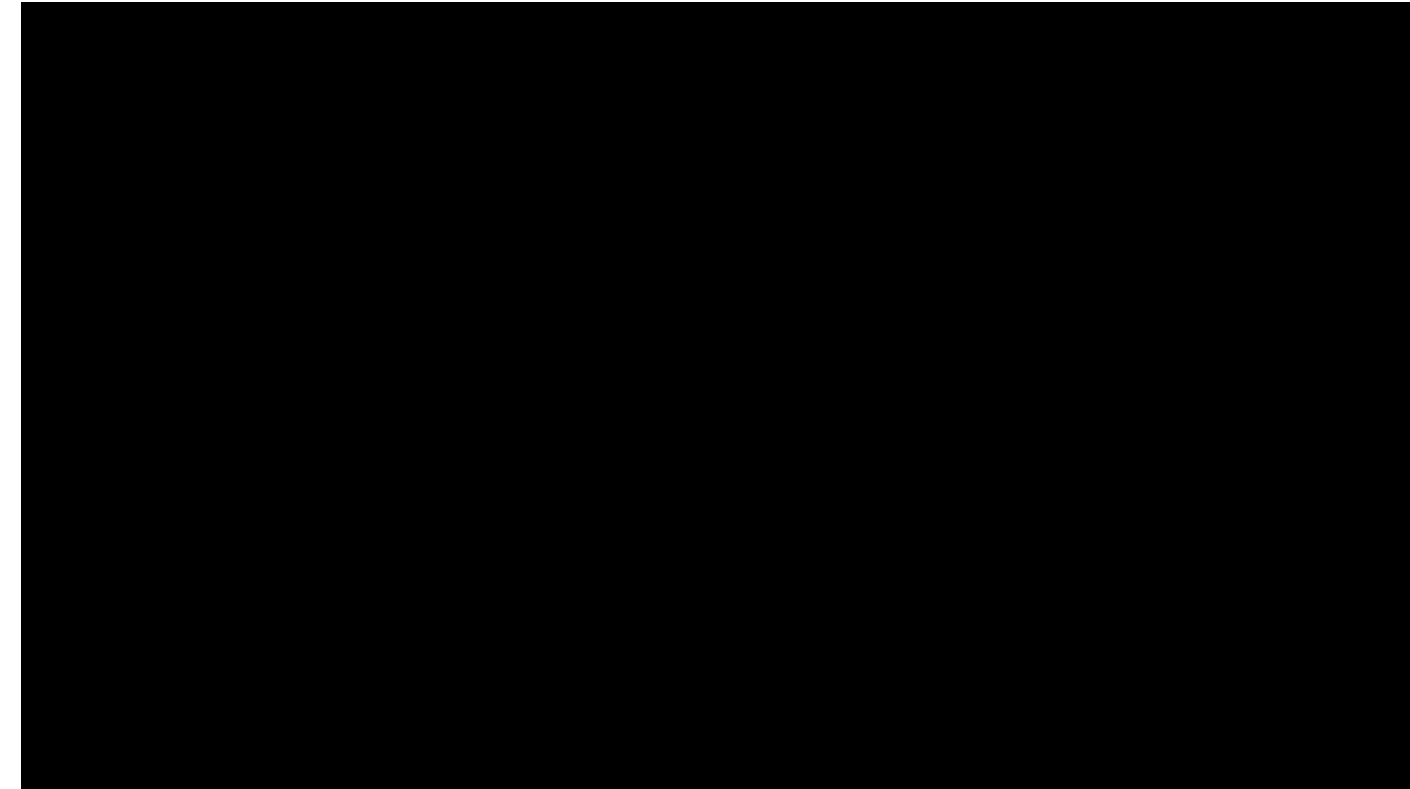
V_{MU} - Minimum speed at which airplane can safely lift off and continue takeoff. The speed at which the weight of airplane is completely supported by aerodynamic lift and thrust forces.

Landing Performance

The purpose of landing performance testing is:

- **To determine landing performance parameters required for flight manual**
- **To demonstrate configuration satisfies certification performance and handling requirements**

Landing Performance



14 CFR § 25.125

The horizontal distance necessary to land and to come to a complete stop from a point 50 feet above the landing surface must be determined.

Limit Wind Conditions

The purpose of limit wind conditions is:

- **To demonstrate takeoff and landing conditions can be performed with**
 - **Crosswind of no less than 20 kts (at 90 degrees)**
 - **Tailwind of 15 kts**
- **To demonstrate autoland testing with**
 - **Headwind > 25 kts (target 40 kts)**
 - **Crosswind > 25 kts (target 40 kts)**
 - **Tailwind >15 kts (target 25 kts)**
- **Also, to assess airplane handling qualities**

Cross Winds



14 CFR §25.237

A 90-degree cross component of wind velocity, demonstrated to be safe for takeoff and landing, must be established for dry runways and must be at least 20 knots.

Brakes Testing

The purpose of braking performance testing is:

- **To determine brake performance to support airplane takeoff and landing field length requirements.**
- **To determine distance and brake energy required for an airplane to come to a full stop from either a Rejected Takeoff (RTO) or a performance landing.**
- **To determine airplane deceleration capability resulting from the use of the autobrake system.**

Refused TakeOff (RTO)



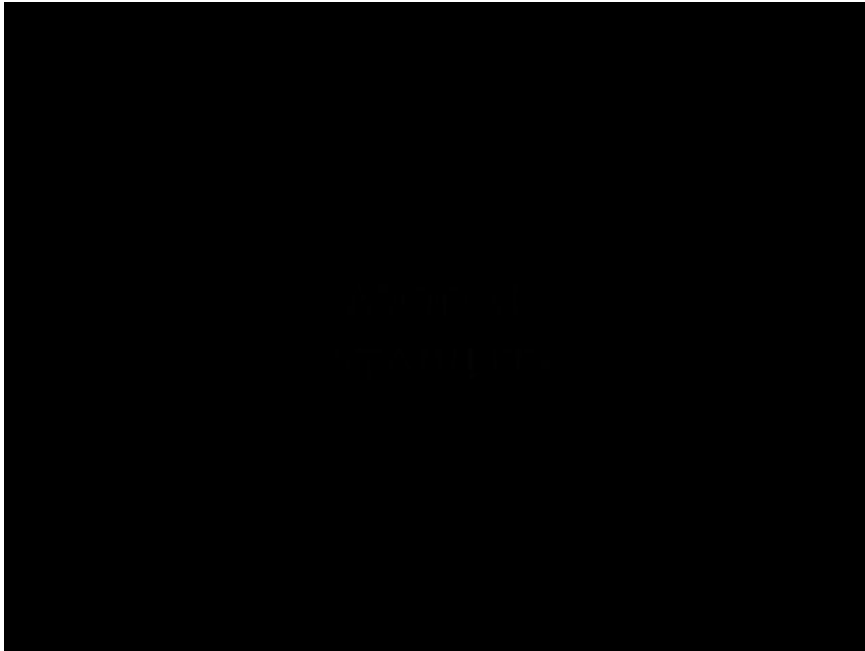
[14 CFR § 25.109](#)

The sum of the distances necessary to accelerate the airplane from a standing start with all engines operating to the highest speed reached during the rejected takeoff, assuming the pilot takes the first action to reject the takeoff at the V1 for takeoff from a dry runway come to a full stop on dry runway.

Flight Test Data used for Other Than Certification Purposes

- **Flight tests to establish initial airworthiness/clear the flight envelope**
- **Company validation of certification conditions prior to regulatory demonstration flight tests**
- **Data gathering for Airplane Flight Manual**
- **Validation of contractual agreements- NAMS**
- **Gathering flight test data to build airplane simulation database**

Modal Suppression Testing



14 CFR § 25.251 Vibration and buffeting.

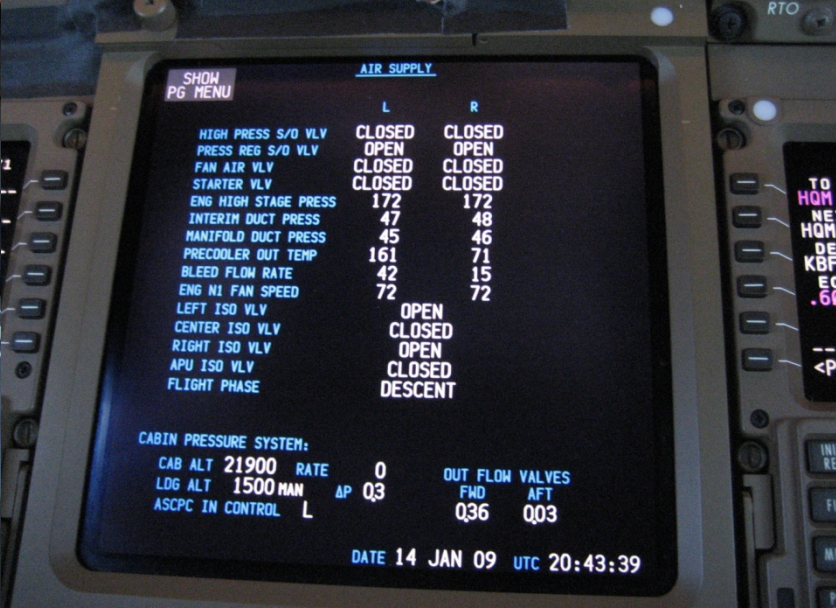
(a) The airplane must be demonstrated in flight to be free from any vibration and buffeting that would prevent continued safe flight in any likely operating condition.

(b) Each part of the airplane must be demonstrated in flight to be free from excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF} .

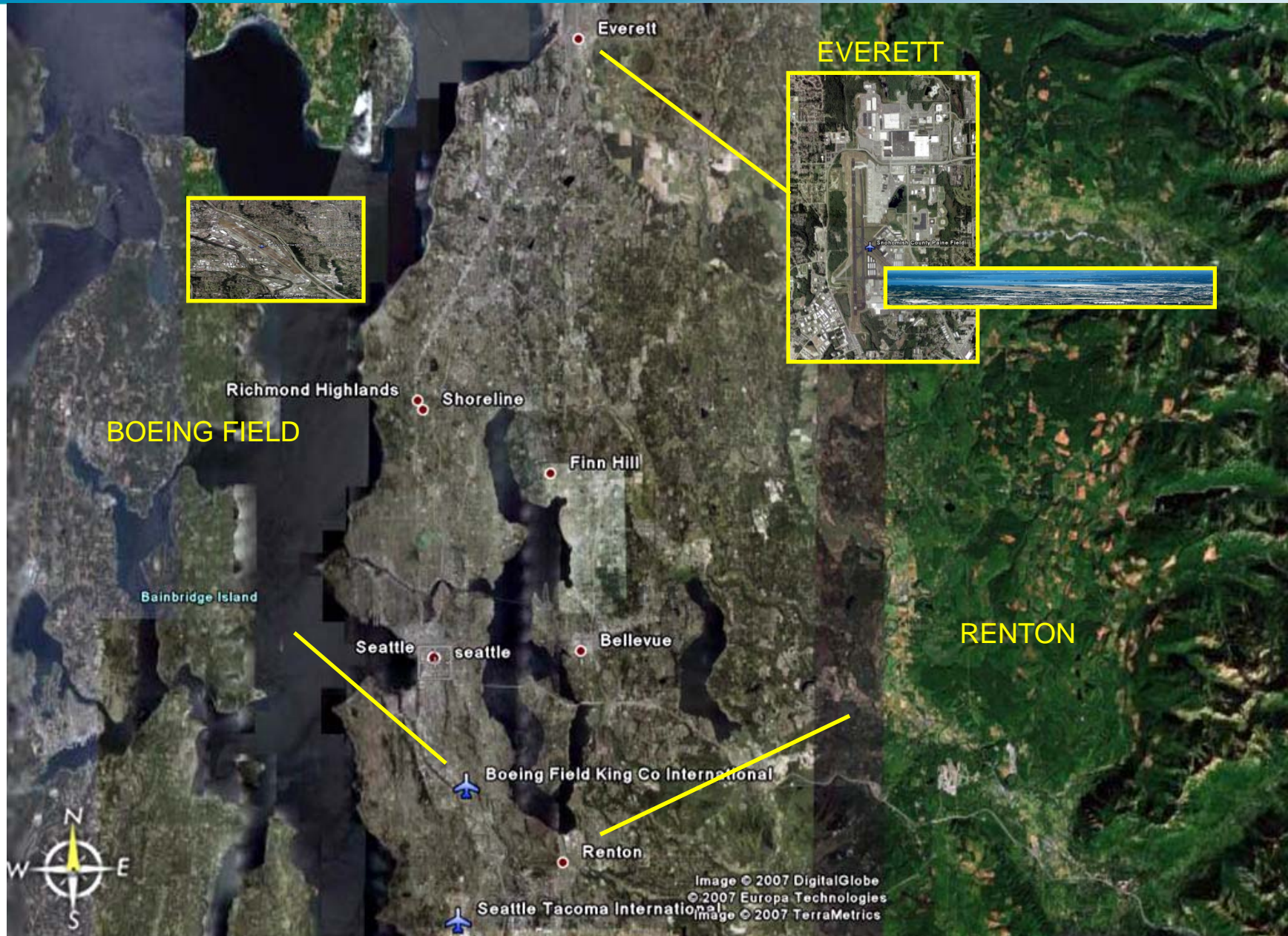
Ground Effects



Cargo Smoke Testing



Flight Testing Around Washington State



Flight Testing in the US

- **Edwards AFB, CA**
- **Victorville, CA**
- **Roswell, NM**
- **Glasgow, MT**
- **Moses Lake, WA**
- **Colorado Springs, CO**
- **Kona, HI**

Roswell, NM



And Around the World - Longyearbyn



La Paz, Bolivia



Thank You

Any Questions?

heather.p.ross@boeing.com