Earlier developments in aviation history have driven dramatic changes in finish requirements.

**Boeing Model C**
- 1916

**Boeing 247**
- 1933

**Boeing 707**
- 1957 - 1978

**Linen fabric, wood, and wire:**
- Nitrocellulose lacquer
- Aluminum pigment

**Aluminum Construction:**
- Epoxy and polyurethane enamels
- Hexavalent chromium
- Chemical and corrosion resistance
The 787 Dreamliner has placed a new set of demands on aircraft finishes

- Environmentally compliant coatings
- Extensive use of composite structure
- Globally distributed supplier base
Extensive use of composite structures delivers benefits and drives new challenges

- Lighter
- More durable
- Negligible corrosion and fatigue
- Reduced scheduled maintenance
- Opens new design possibilities
- Presents new finishing challenges

Carbon laminate
Carbon sandwich
Other composites
Aluminum
Titanium
Titanium/steel/aluminum

Composites 50%

Titanium 15%
Aluminum 20%
Steel 10%
Other 5%
Boeing has addressed a range of 787 composite finishing challenges

- Composite fuselage design
  - Epoxy impregnated carbon fibers are wrapped onto smooth tool surface which after curing becomes interior of fuselage

- Caul sheets used to create smooth exterior surface

- “Weave” texture can contribute to orange peel-like appearance

- Challenge is to achieve acceptable finish quality without resorting to fillers and surfacers, which add weight and can lead to cracking problems
Final exterior appearance development for composites requires consideration of many factors:

- Final Exterior Appearance
- Part Design
- Surface Preparation
- Durability
- Cleanliness Detection
- Appearance Inspection/Expectation
- Coating Optimization
- Mold Release Agents
- Surfacing Film Development
- Caul Sheet Development
Partners Across the Globe are Bringing the 787 Together

- **U.S.**
  - Boeing
  - Spirit
  - GE
  - Goodrich

- **Australia**
  - Boeing
  - Mitsubishi
  - Kawasaki
  - KAL-ASD

- **Canada**
  - Boeing
  - Messier-Dowty

- **Asia**
  - Fuji
  - Mitsubishi
  - Kawasaki
  - KAL-ASD

- **Europe**
  - Messier-Dowty
  - Rolls-Royce
  - Latécoère
  - Alenia
  - Saab

**Wing tips**
- Seoul, Korea

**Fixed trailing edge**
- Nagoya, Japan

**Moveable trailing edge**
- Melbourne, Australia

**Tail fin**
- Frederickson, WA

**Passenger entry doors**
- Chula Vista, CA

**Aft fuselage**
- Charleston, SC

**Horizontal stabilizer**
- Foggia, Italy

**Wing**
- Nagoya, Japan

**Nacelles**
- Chula Vista, CA

**Center fuselage**
- Grottaglie, Italy

**Mid forward fuselage**
- Nagoya, Japan

**Forward fuselage**
- Wichita, KS

**Cargo access doors**
- Linköping, Sweden

**Wing/body fairing**
- Winnipeg, Canada

**Main landing gear wheel well**
- Nagoya, Japan

**Center wing box**
- Nagoya, Japan

**Landing gear**
- Gloucester, UK

**Fixed and moveable leading edge**
- Tulsa, OK

**Engines**
- GE – Evandale, Ohio
- Rolls Royce – Derby, UK
Distributed supplier base introduces additional challenges for exterior finishes

- Some sections come fully painted from supplier
  - Wings, engine pylons, horizontal stabilizer
- Final assembly of these sections accomplished in Everett, WA
  - Requires approximately 25,000 pre-painted fasteners (heads only) for assembly
- Over 20 different suppliers applying paint prior to assembly
- Color match issues led to establishment of quantitative color match to standard

![Graph showing delta E vs. topcoat dry film thickness](image-url)
Large aircraft painting introduces more challenges

- Surface preparation and paint application in same hangar
- Manual application of coatings
Numerous factors contribute to final paint appearance

- **Substrate**
  - Layup, surfacer type, caul plate type, etc.
  - Surface prep method
  - Any repairs

- **Painter**
  - Experience
  - Training
  - Preferred technique (gun triggering, gun distance to part, cross coating, etc.)

- **Equipment**
  - Type (AA, Electrostatic, Conventional, HVLP, etc.)
  - Settings (fluid flow rate, air settings, etc.)
  - Equipment maintenance practices

- **Environmental Conditions**
  - Temperature and humidity

- **Process**
  - Paint thickness (target and actual)
  - Overcoat times
  - Cure conditions

- **Paint**
  - Rheology
  - Cure profile
  - Batch to batch color consistency
  - Hide

- **Facility**
  - Air quality and flow patterns
  - Booth contamination
  - Painter access to part
Lab studies of application parameters may or may not correlate with production.

- Charts showing orange peel at different gun to part distance, spray gun type and paint mix age.

![Tension vs Spray Distance (36 in & 18 in.)](image)

![Wavescan Data as a Function of Paint Gun Type and Paint Mix Age](image)
Customers and industry continue to demand more quantitative measurement of appearance quality

- Currently most requirements are qualitative:
  - “The film shall be uniform in appearance…”
  - “It is acceptable to have a slight color variation…”
  - “Cosmetic defects and features shall not detract from the overall appearance of the detail part or assembly…”

- Some quantitative appearance requirements exist:
  - 60° Gloss
  - Waviness
  - Color match to standard (“non-decorative” areas)

- Currently studying additional quantitative measurements:
  - Orange peel
  - Color (decorative areas and special effects coatings)
  - 20° gloss (more sensitive for high gloss coatings)
Each layer of exterior paint system requires unique appearance quality controls

- Need measurement and control at all levels of part completion
  - Substrate (metal or composite)
  - Fillers and surfacers
  - Primers and other undercoats
  - Final topcoat (urethane monocoats, special effects coatings, clear coats)

- Potential defects specific to layer
  - Composite: pits, pinholes, roughness, waviness, resin starvation...
  - Primers and topcoats: blisters, contamination, cracking, craters, crazing, drips, fish eyes, runs, sags, scratches, seeding, solvent pop, wrinkles, overspray, dry spray, mottling, orange peel...
Future challenges require on-going development commitment – Wish List

- Measurement of composite texture ("weave") prior to paint application
- Local shape measurement (depressions, waviness)
- Quantitative measurement of pits and pinholes in composites (unpainted, primed and enameled)
- Quantitative measurement of particle contamination in enamels and primers
Wish List Continued

• Wish List:
  
  • Orange peel measurements on very “peely” surfaces
  
  • Mica and special effect coatings appearance characterization
  
  • Strategy for establishing orange peel requirements for huge palette (hundreds) of customer colors
  
  • What combination of Wavescan parameters best correlates with customer perception of quality finish?
  
  • Paint thickness measurement on composites
  
  • Stand off measurements of color and gloss
Questions ?