Oregon State University

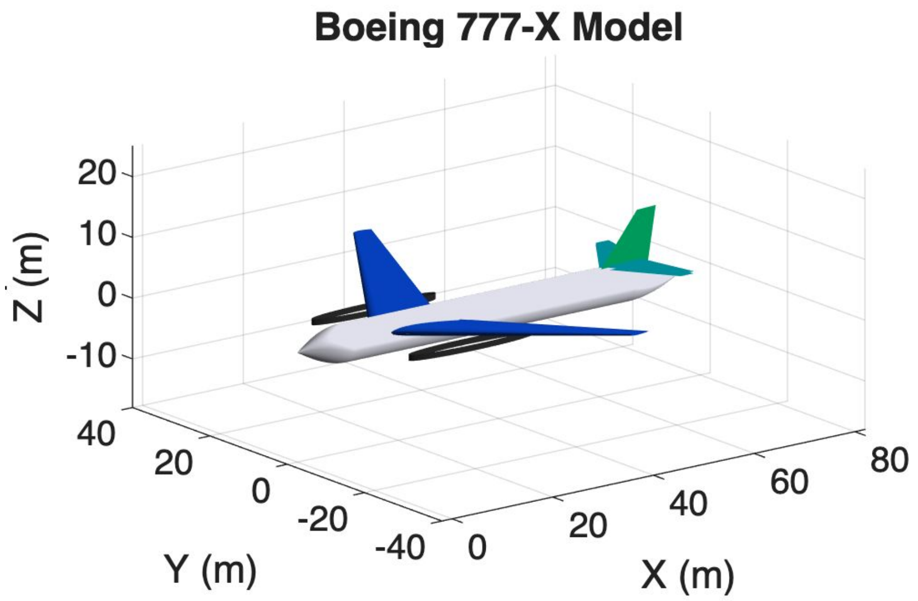
COLLEGE OF ENGINEERING | School of Mechanical, Industrial, and Manufacturing Engineering

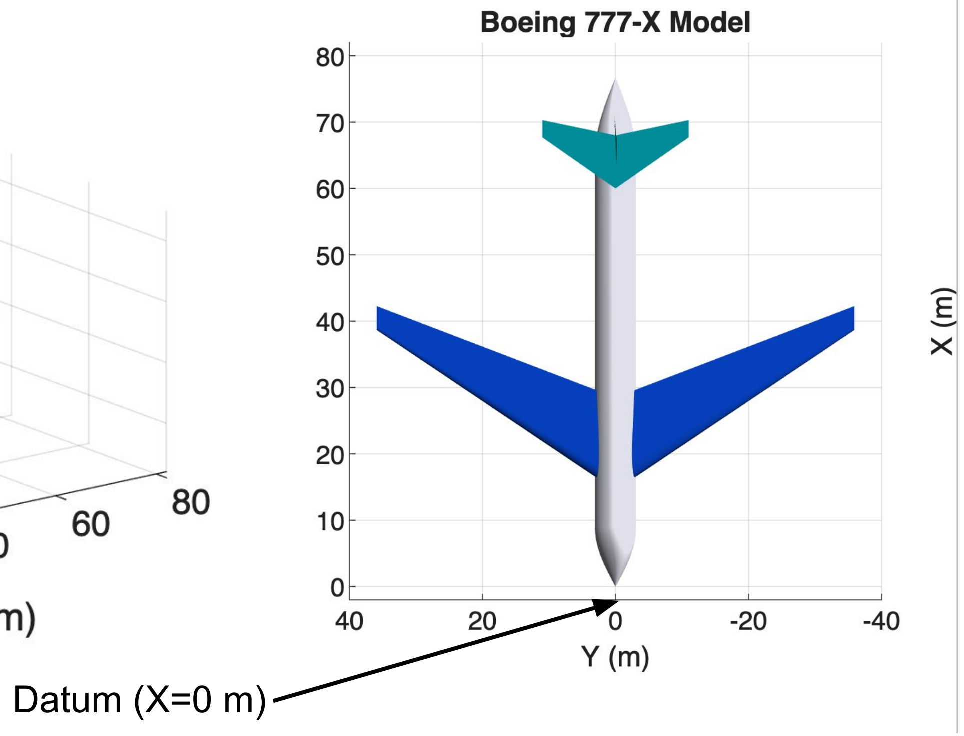
# Boeing 777X

Cahleal Walker, Tristan Powers, Clay Mcleod, Oliver Braitsch

# 3D-Model & Datum

- X→Longitudinal
- Y→Lateral
- Z→Vertical



Oregon State University
College of Engineering

# A. Wing Geometric Reconstruction and Spanwise Chord Distribution

- Geometry extracted from digitized three-view drawing
- Three trapezoidal planforms identified
- Linear chord within each section
- Piecewise chord distribution defined

$$y_0 = 0m \qquad x_{LE}(y_0) = 25.0m \qquad x_{TE}(y_0) = 39.5m$$
$$y_{kink0} = 12.0m \qquad x_{LE}(y_{kink0}) = 31.42m \qquad x_{TE}(y_{kink0}) = 39.90m$$
$$y_{kinkt} = 32.425m \qquad x_{LE}(y_{kinkt}) = 43.37m \qquad x_{TE}(y_{kinkt}) = 45.86m$$
$$y_{tip} = 35.88m \qquad x_{LE}(y_{tip}) = 46.83m \qquad x_{TE}(y_{tip}) = 48.01m$$

$$c(y) = x_{(TE)}(y) - x_{(LE)}(y)$$

$$c_0 = 39.5m$$
$$c_{kink0} = 8.48m$$
$$c_{kinkt} = 2.138m$$
$$c_{tip} = 0.627m$$

$$c_{i(y)} = c_{0,i} + \left(\frac{c_{1,i} - c_{0,i}}{y_{1,i} - y_{0,i}}\right)(y - y_{0,i})$$

$$c(y) = \begin{cases} c_1(y) = 14.5 - 0.502y, & y_0 \le y \le y_{kink0} \\ c_2(y) = 8.49 - 0.293(y-12), & y_{kink0} < y \le y_{kinkt} \\ c_3(y) = 2.49 - 382(y - 32.425) & y_{kinkt} < y \le y_{tip} \end{cases}$$

Oregon State University College of Engineering

# Wing Area and Mean Aerodynamic Chord

- **Mean Aerodynamic Chord**

$$\bar{\bar{c}}_i = \frac{2}{3} c_{0,i} \frac{1 + \lambda_i + \lambda_i^2}{1 + \lambda_i} \qquad \bar{\bar{c}} = \frac{\sum_{i=1}^{3} \bar{\bar{c}}_i * S_i}{\sum_{i=1}^{3} S_i} \qquad \boxed{\bar{\bar{c}} = 9.0\ m}$$

- **Mean Aerodynamic Chord - y location**

$$y_{ac,i} = y_{0,i} + (y_{1,i} - y_{0,i}) \frac{1 + 2\lambda_i}{3(1 + \lambda_i)} \qquad y_{ac} = \frac{\sum_{i=1}^{3} y_{ac,i} * S_i}{\sum_{i=1}^{3} S_i} \qquad \boxed{y_{ac} = 12.683\ m}$$

- **Mean Aerodynamic Chord - x location**

$$x_{macLE,i} = x_{LE,0,i} + (x_{LE,1,i} - x_{LE,0,i}) \frac{1 + 2\lambda_i}{3(1 + \lambda_i)} \qquad x_{macLE} = \frac{\sum_{i=1}^{3} x_{macLE,i} * S_i}{\sum_{i=1}^{3} S_i}$$

$$x_{ac} = x_{macLE} + 0.25\bar{\bar{c}} \qquad \boxed{x_{ac} = 32.263\ m}$$

- **Wing Reference Area**

$$S_{ref} = 2\left[\int_{y_0}^{y_{kink0}} c_1(y)\, dy + \int_{y_{kink0}}^{y_{kinkt}} c_2(y)\, dy + \int_{y_{kinkt}}^{y_{tip}} c_3(y)\, dy\right]$$

$$\boxed{S_{ref} = 512.47\ m^2}$$

- **Wing Wetted Area**

$$S_{half,inside} = \int_0^{y_{fuse}} c(y)\, dy \qquad S_{inside} = 2S_{half,inside} = 85.08\ m^2$$

$$S_{wet} = S_{ref} - S_{inside} \qquad \boxed{S_{wet} = 427.39\ m^2}$$

# Horizontal Tail Parameters

- Geometry extracted from digitized three-view drawing
- One trapezoidal planforms identified
- Linear chord within each section

$$y_{t0} = 0m \qquad y_{ttip} = 12.28m$$

$$x_{LE}(y_{t0}) = 64.1m \qquad x_{LE}(y_{ttip}) = 73.67m$$

$$x_{TE}(y_{t0}) = 71.7m \qquad x_{TE}(y_{ttip}) = 76.85m$$

$$c_{t0} = 7.6m \qquad c_{kink0} = 2.172m$$

$$c_t(y) = c_{t0} + \left(\frac{c_{ttip} - c_{t0}}{y_{ttip} - y_{t0}}\right)(y - y_{t0})$$

$$\boxed{c_t(y) = 7.6 - 0.422y}$$

$$\lambda_t = \frac{c_{ttip}}{c_{t0}} \qquad \bar{\bar{c}}_t = \frac{2}{3} c_{t0} \frac{1 + \lambda_t + \lambda_t^2}{1 + \lambda_t}$$

$$\boxed{\bar{\bar{c}}_t = 5.39\ m^2}$$

$$S_{t,half} = \int_0^{y_{ttip}} c_t(y)\, dy \qquad S_t = 2S_{t,half}$$

$$\boxed{S_t = 120\ m^2}$$

Oregon State University
College of Engineering

# Weight Configurations and Center of Gravity Analysis Part 1

- Empty (OEW): x_cg=35.87
- MTOW: x_cg=35.84
- Max fuel (no payload): x_cg=35.74 m
- Landing (max payload, min fuel): x_cg=35.92 m

Each Loading Case Satisfies:

$$x_{cg,aft} < x_{cg} < x_{cg,fwd}$$

Assumptions:

1. 3-lumped mass model
2. Chosen longitudinal stations
3. OEW estimated from fraction of MZFW

Given Boeing design weights (Model 777-9)

W_MTOW=351,534 kg ; W_MLW=266,258 kg ; W_MZFW=254,918 kg; W_fuel,max = 197,228 kg

The operating empty weight (OEW) was estimated using published 777-9 technical data indicating an OEW of approximately 400,000 lb (≈181,400 kg) [X]. This value is consistent with 777-9 structural weight fractions and is within 1% of the assumed 0.72·MZFW approximation used in the simplified mass model.

$$x_{cg} = \frac{\sum_{i=1}^{n} W_i x_i}{\sum_{i=1}^{n} W_i}$$

# Weight Configurations and Center of Gravity Analysis Part 2

**Datum: Nose tip**

$$L = x_{MG} - x_{NG}$$

$$x_{cg} = x_{NG} + \left(\frac{R_{MG}}{W}\right) L$$

*with*

$$R_{MG} = W - R_{MG}$$

$$z_{cg} = \frac{t/2}{\tan(\theta_{turn})}$$

$$x_{cg,fwd} = 35.37\ m$$

$$x_{cg,aft} = 36.36\ m$$

$$z_{cg} = 3.00\ m$$

$$\frac{x_{cg,aft}}{\bar{c}} = 4.040$$

$$\frac{x_{cg,fwd}}{\bar{c}} = 3.930$$

Oregon State University
College of Engineering

# Longitudinal Stability Derivatives and Static Margin

$$x_{np} = 36.80\ m$$

$$SM = \frac{(x_{np} - x_{cg})}{\bar{c}}$$

$$SM_{fwd} = 0.159$$

$$SM_{aft} = 0.0489$$

$$C_{m\alpha} = -SM \bullet C_{L\alpha}$$

$$C_{m\alpha,fwd} = -0.827\ rad^{-1}$$

$$C_{m\alpha,aft} = -0.254\ rad^{-1}$$

$$C_{L\alpha,fwd} = 5.2\ rad^{-1}$$

$$C_{m\alpha,fwd} = -0.827\ rad^{-1}$$

$$C_{mq,fwd} = -12$$

$$C_{L\alpha,aft} = 5.2\ rad^{-1}$$

$$C_{m\alpha,aft} = -0.254\ rad^{-1}$$

$$C_{mq,aft} = -12$$

Oregon State University
College of Engineering

# Lateral–Directional Stability Derivatives

- Sideslip angles of 0 degrees and 10 degrees.
- Stability condition met?

$$C_{n\beta} = +0.10\ rad^{-1}$$

$$C_{l\beta} == 0.08\ rad^{-1}$$

$$C_{lp} == -0.50$$

$$C_{nr} == -0.20$$

# Phugoid Mode: Frequency and Damping Ratio

- Evaluated at 77 m/s and at 286 m/s.

$1.1V_{stall}$ = 77 m/s

$\frac{C_L}{C_D}$ = 17N,ph

$\omega_{n,ph} = 0.18\ \frac{rad}{s}$

$\zeta_{ph} = 0.0294$

$V = 286\ \frac{m}{s}$

$\frac{C_L}{C_D} = 19$

$\omega_{d,ph} = 0.0485\ \frac{rad}{s}$

$\zeta_{ph} = 0.0263$

Oregon State University
College of Engineering

# Landing Gear Loads, Stability Angles, and Tire Sizing

## Ground Loads & Stability

- Max main: 3.53 MN
- Max nose: 0.30 MN
- Tip-back: 46.4°
- Turnover: 61.0°
- Stable for all CG cases

## Tire Sizing (Load-Based)

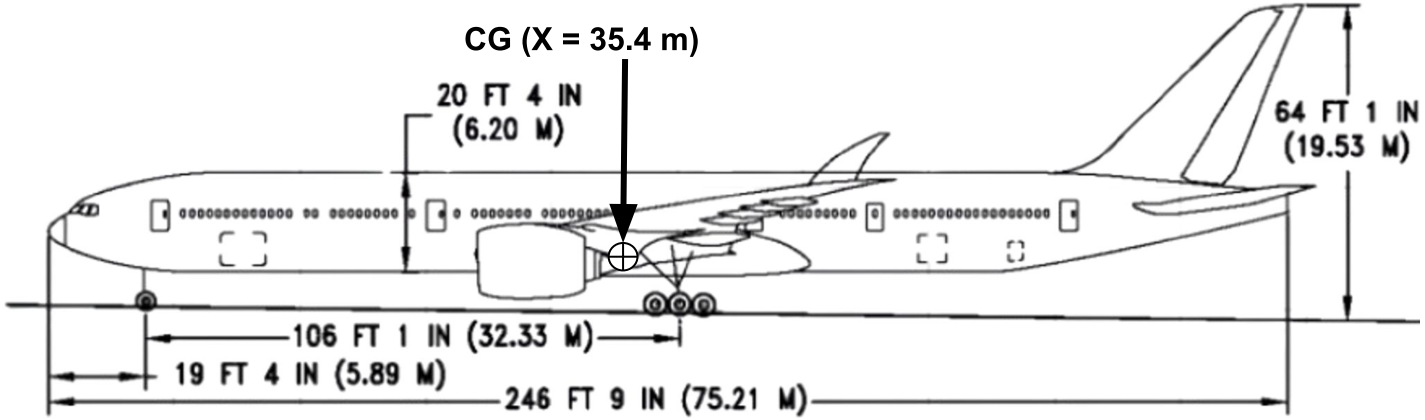
- Main tire load: 294,000 N
- Nose tire load: 152,000 N

Actual
- Main: 52x21.0 R22
- Nose: 43x17.5 R17

## Wheel Sizing via Braking Energy

$$KE_{braking} = \frac{1}{2} * \frac{W_{landing}}{g} * V_{stall}^2$$

- KE per main wheel: 64.3 MJ
- Required diameter (large transport curve): 24 in
- Actual main rim: 22 in



Oregon State University
College of Engineering

# References


[1] Boeing Commercial Airplanes, “777-9 Airplane Characteristics for Airport Planning,” Rev. E, Boeing, 2023.

[2] “Tire Specifications,” Data-Section-2022, https://www.goodyearaviation.com/resources/pdf/Data-Section-2022.pdf.

[3] “Boeing777XTechnicalSpecifications,”SimpleFlying[onlinearticle],URL: https://simpleflying.com/boeing-777x-variants-differences/ [retrieved 1 March 2026].

[4] “777X,” 777X family, https://www.boeing.com/commercial/777x.

[5] “Boeing 777 Flight Manual ,” Internet Archive, https://archive.org/details/Boeing777FlightManual&ved=2ahUKEwjTxaDGpZGSAxUunSYFHUAoG6MQFnoECC8QAQ&usg=AOvVaw1RAZzGyPtF3GOhmNBos-er.