

Appendix C Bibliography

This appendix provides a summary of the material used in doing the work. Not all of the citations included here were explicitly cited in the report, but contain material of interest to people studying the landing gear problem.

C.1. Textbooks

Ashford, N., and Wright, P.H., *Airport Engineering*, 3rd Ed., John Wiley & Sons, Inc., New York, 1992.

Conway, H. G., *Landing Gear Design*, Chapman and Hall, London, 1958.

Currey, N. S., *Aircraft Landing Gear Design: Principles and Practices*, AIAA Education Series, Washington, 1988.

Horonjeff, R. and McKelvey, F. X., *Planning and Design of Airports*, McGraw-Hill, New York, 1994.

Kirschbaum, N., *Aircraft Design Handbook: Aircraft Design Aid and Layout Guide*, VPI Aircraft Design Series, Virginia, 1993.

Niu, M. C. Y., *Airframe Structural Design*, Conmilit Press, Hong Kong, 1988.

Raymer, D. P., *Aircraft Design: A Conceptual Approach*, AIAA Education Series, Washington, 1989.

Roskam, J., *Airplane Design Part IV: Layout Design of Landing Gear and System*, Roskam Aviation and Engineering, Ottawa, Kansas, 1986.

Roskam, J., *Airplane Design Part V: Component Weight Estimation*, Roskam Aviation and Engineering, Ottawa, Kansas, 1985.

Torenbeek, E., *Synthesis of Subsonic Airplane Design*, Delft University Press, Delft, 1981.

C.2. AGARD Reports

AGARD CP 299: *Subsystem Testing and Flight Testing Instrumentation*, October 1980. (N81-29077)

AGARD CP 484: *Landing Gear Design Loads*, October 1990. (N91-28150), see in particular:

- Kempf, G., and Haines, G.H., "Development of Undercarriage Design Loads," N91-28153.
- Krauss, A.J., "Considerations on Optimality of Landing Gear Arrangement and Design," N91-28156.
- Ladda, V., and Struck, H., "Operational Loads on Landing Gears," N91-28158.

C.3. Government/Industry Standards

FAR Part 25 Airworthiness Standards: Transport Category Airplanes, Federal Aviation Administration, Washington, DC, October 1994.

“Standardized Method of Reporting Airport Pavement Strength,” AC 150/5335-5, Federal Aviation Administration, Washington, DC, June 1983.

Aerodrome Design Manual, Part 3: Pavements, International Civil Aviation Organization, Doc. 9157-AN/901, 1983.

1994 Aircraft Year Book, The Tire and Rim Association, Inc., 1994.

Special Design Charts for Concrete Airport Pavement, Portland Cement Association, 1993.

Packard, R. G., *Design of Concrete Airport Pavement*, Portland Cement Association, 1973.

The following aerospace recommended practices have been developed by the Society of Automotive Engineers (SAE) A-5 Aerospace Landing Gear System Committee:

ARP 597 *Wheels and Brakes, Supplementary Criteria for Design Endurance, Civil Transport Aircraft*, April 1991.

ARP 1311 *Aircraft Landing Gear*, January 1995.

ARP 1494 *Verification of Landing Gear Design Strength*, February 1978.

ARP 1598 *Landing Gear System Development Plan*, August 1985.

ARP 1821 *Aircraft Flotation Analysis Methods*, May 1988.

ARP 1934 *Use of Carbon Heat Sink Brakes on Aircraft*, April 1990.

ARP 4243 *Landing Area/Landing Gear Compatibility*, April 1993.

C.4. Technical Papers/Reports

C.4.1 Landing Gear Design

O’Massey, R. C., “Introduction to Landing Gear Design,” ASM Paper W70-18.1, March 1970. (extensive data on shock absorber struts, somewhat lesser data on tire scrubbing and materials)

Attri, N.S., and Amberg, R.L., “Advances in Landing Gear Systems,” Paper No. 13, AGARD CP 299: *Subsystem Testing and Flight Testing Instrumentation*, October 1980

Young, D.W., “Aircraft Landing Gears - The Past, Present and Future,” Institution of Mechanical Engineers, Proceedings, Part G, *Journal of Aerospace Engineering*, Vol. 200, 1986, pp. 179-196. (This is an excellent survey for designers to read to get an overview of the problem.)

Veaux, J., “New Design Procedures Applied to Landing Gear Development,” *Journal of Aircraft*, Vol. 25, No. 10, October 1988, pp. 904-910 (This paper describes the use of CAD tools in the landing gear design process, and is not directly germane to the current project.)

Jenkins, S. F. N., “Landing Gear Design and Development,” Institution of Mechanical Engineers, Proceedings, Part G, *Journal of Aerospace Engineering*, Vol. 203, 1989, pp. 67-73.

Tanner, J. A. Ed., *Aircraft Landing Gear Systems*, PT-37, SAE A-5 Landing Gear Systems Committee, 1990.

Greenbank, S. J., "Landing Gear: The Aircraft Requirement," Institution of Mechanical Engineers, Proceedings, Part G, *Journal of Aerospace Engineering*, Vol. 205, 1991, pp. 27-34.

C.4.2 Weight Estimation

Wille, R. H., "Analytical Weight Estimation of Unconventional Landing Gear Design," SAWE Paper 1905, May 1989.

Wille, R.H., "Landing Gear Weight Optimization Using Taguchi Analysis," *SAWE Journal*, Winter 1990, pp. 31-40.

Kraus, P. R., "An Analytical Approach to Landing Gear Weight Estimation," SAWE Paper No. 829, May 1970.

Liebeck, R. H., Page, M. A., Rawdon, B. K., Scott, P. W., and Wright, R. A., "Concepts for Advanced Subsonic Transports," NASA CR-4624, September 1994.

Marsh, D. P., "Theory of Transport Aircraft Weight Fractions," SAWE Paper 1452, 1982.

Elsaie, A. M. and Santillan, R. Jr., "Structural Optimization of Landing Gear Using STARSTRUC," SAE Technical Paper 871047, 1987.

Saelman, B., "Designing Cylinders and Struts for Maximum Strength," *Machine Design*, Vol. 25, No. 8, August 1953, pp. 133-138

C.4.3 Center of Gravity and Load Balancing

Chai, S., Crisafulli, P., and Mason, W. H., "Aircraft Center of Gravity Estimation in Conceptual Design," AIAA Paper 95-3882, September 1995.

Davis, E., "Center of Gravity Envelope Development, 747-400F," SAWE Paper 2200, May 1994. (definitive explanation of 747 cg envelope)

Field, G.G., "MD-11 Design—Evolution not Revolution," AIAA Paper 87-2928, 1987. Contains details of the DC-10 and MD-11 cg range and tail sizing X-plots. Interesting description of the process.

Packing Problem References

Samuel Eilon and Nicos Christofides, "The Loading Problem," *Management Science*, Vol. 17, No. 5, Jan. 1971, pp. 259-268

Samir V. Amiouny, John J. Bartholdi III, John H. Vande Vate and Jixian Zhang, "Balanced Loading," *Operations Research*, Vol. 40, No. 2, March-April 1992, pp.238-246.

This paper has several algorithms for aircraft cargo loading and attainment of a certain balance range.

Kathryn A. Dowsland and William B. Dowsland, "Packing problems," Invited Review, *European Journal of Operations Research*, 56 (1992) 2-14.

Louis A. Martin-Vega, "Aircraft Load Planning and the Computer: Description and Review," *Computers and Industrial Engineering*, Vol. 9, No. 4, pp.357-369, 1985.

Douglas D. Cochard and Kirk A. Yost, "Improving Utilization of Air Force Cargo Aircraft," *INTERFACES*, 15: Jan.-Feb. 1985 pp. 53-68)

H. Gehring, K. Menschner, and M. Meyer, "A computer-based heuristic for packing pooled shipment containers," *European Journal of Operations Research*, Vol. 44, (1990) pp. 277-288.

Robert W. Haessler and F. Brian Talbot, "Load planning for shipments of low density products," *European Journal of Operations Research*, Vol. 44 (1990) pp. 289-299.

Harold Dyckhoff, "A typology of cutting and packing problems," *European Journal of Operations Research*, Vol. 44, (1990) pp. 145-159.

C.4.4 Pavement Flotation

Dawson, J. L. and Mills, R. L., "Undercarriage Effects on (a) Rigid Pavements (b) Flexible Pavements," *Aircraft Pavement Design*, Institution of Civil Engineers, Proceedings, November 1970.

Bonney, K. V., "Aircraft Development in Relation to Pavement Design," *Aircraft Pavement Design*, Institution of Civil Engineers, Proceedings, November 1970.

Griffis, Jr., M. F. H. and Gamon, M. A., "Aircraft-Pavement Compatibility Study," Report FAA-RD-73-206, Waterways Experiment Station, US Army Corps of Engineers, Vicksburg, MS, September 1974.

Ahlvin, R. G. "Developing a Set of CBR Design Curves," Instruction Report 4, US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, November 1959.

Westergaard, H. M., "New formulas for Stresses in Concrete Pavements of Airfields," *Transactions of American Society of Civil Engineers*, Vol. 73, May 1947, pp. 687-701.

"Landing Gear," *Aircraft Engineering*, Vol. 58, No. 7, July 1986, pp. 3-6.

Pereira, A. T., "Procedures for development of CBR Design Curves," Information Report S-77-1, Waterways Experiment Station, US Army Corps of Engineers, Vicksburg, MS, June 1977.

Cameron-Johnson, A., "The Undercarriage in Aeroplane Project Design," *Aircraft Engineering*, Vol. XLI, No. 2, February, 1969, pp. 6-11

C.4.5 Cost

Dean, E. B. and Unal, R., "Designing for Cost," *AACE Transactions*, 1991

C.4.6 Vehicle Integration

Arcara, Jr., P. C., Bartlett, D. W., McGraw, Jr., M. E., and Geiselhart, K. A., "Technology Benefits for Very Large Subsonic Transports," AIAA Paper 93-1178, February 1993.

Holloway, R. B., Burris, P. M. and Johannes, R. P., "Aircraft Performance Benefits from Modern Control Systems Technology," *Journal of Aircraft*, Vol. 7, No. 6, November 1970, pp. 550-553.

Jayaram, S., Myklebust, A., and Gelhausen, P., "ACSYNT - A Standards-Based System for Parametric Computer Aided Conceptual Design of Aircraft," AIAA Paper 92-1268, February 1992.

McCullers, L. A., "Aircraft Configuration Optimization Including Optimized Flight Profiles", *Proceedings of Symposium on Recent Experiences in Multidisciplinary Analysis and Optimization*, 1984, pp. 395-412 (NASA CP-2327).

Sliwa, S. M., "Economic Evaluation of Flying-Qualities Design Criteria for a Transport Configured With Relaxed Static Stability," NASA Technical Paper 1760, December 1980.

Sliwa, S. M., "Impact of Longitudinal Flying Qualities Upon the Design of a Transport with Active Controls," AIAA Paper 80-1570, 1980.

Garner, P. L., Meredith, P. T., and Stoner, R. C., "Areas for Future CFD Development as Illustrated by Transport Aircraft Applications," AIAA Paper 91-1527, 1991. (contains explicit sensitivity values for the aircraft as a function of gear length)

Eckels, W.E., "Civil Transport Design Methodology," AIAA Paper 83-2463, Oct. 1983. (connects gear tradeoff studies to the total system).

Baker, W. R. and Gonzalez, C. R., "Design Considerations for Multi-Wheel Aircraft", 22nd ASCE International Air Transportation Conference, Proceedings, June 1992.

C.5. *Related Articles* (arranged in chronological order)

Brahney, J.A., "Toward the all-electric airplane: electric brakes," *Aerospace Engineering*, Jan. 1989, pp. 17-20.

Smith, B.A., "Decisions to Build the New MD-12X Wing Based on Future Needs," *Aviation Week and Space Technology*, Oct. 8, 1990, pp. 28-29.

"Aircraft Tires: Bias or Radials?" *Aerospace Engineering*, Vol. 11, No. 9, September 1991, pp. 13 -14.

"Technical Advances in Tyres, Wheels and Brakes: Dunlop Keeps Britain in the Forefront," *Aircraft Engineering*, Vol., 59, No. 11, November 1987, pp. 2-5.

Proctor, P., "Super-Jumbos Pose Design Challenges," *Aviation Week and Space Technology*, Feb. 21, 1994, pg. 70.

Mecham, M., "Airport Officials: Superjumbos Mean New Headaches," *Aviation Week and Space Technology*, Vol. 141, No. 21, November 21, 1994, pp. 76-80.

- Mecham, M. and McKenna, J. T., "Cost, Not Size, to Drive Success of Super Jumbo," *Aviation Week & Space Technology*, Vol. 141, No. 21, November 21, 1994, pp. 45-46.
- Proctor, P., "Boeing Refines Designs for 600-Seat NLA," *Aviation Week & Space Technology*, Vol. 141, No. 21, November 21, 1994, pp. 48-53.
- Proctor, P., "Boeing Presses Need for Multinational VLCT," *Aviation Week & Space Technology*, Vol. 141, No. 21, November 21, 1994, p. 75.
- Shifrin, C. A., "New Jumbos, SSTs Face Tough Hurdles," *Aviation Week and Space Technology*, Vol. 141, No. 21, November 21, 1994, pp. 42-43.
- Smith, B. A., "Douglas Awaits Chance to Revive Jumbo Plans," *Aviation Week & Space Technology*, Vol. 141, No. 21, November 21, 1994, p. 57.
- Sparaco, P., "Airbus Weights Four A3XX Versions," *Aviation Week & Space Technology*, Vol. 141, No. 21, November 21, 1994, p. 54.
- Kandebo, S. W., and Dornheim, M. A., "Operability Verified In GE90 Flight Tests," *Aviation Week and Space Technology*, Vol. 142, No. 13, March 27, 1995, pp. 52-54
- Sparaco, P., "Airbus Paves Way for A3XX Megajet," *Aviation Week & Space Technology*, Vol. 142, No. 21, May 22, 1995, pp. 26-27.
- Proctor, P., "Boeing Homes In on Future 747 Design," *Aviation Week and Space Technology*, Vol. 144, No. 6, February 5, 1996, pp. 32-33.
- Fiornio, F., Comp., "Too Big For Your Britches," *Aviation Week and Space Technology*, Vol. 144, No. 21, May 20, 1996, p. 19.
- Sparaco, P., "No Money As Yet In Airbus Jumbo Plan," *Aviation Week and Space Technology*, Vol. 144, No. 25, June 17, 1996, pp. 27-28.
- Proctor, P., "Boeing Poised to Offer Stretched 747 Versions," *Aviation Week and Space Technology*, Vol. 144, No. 27, July 1, 1996, pp. 20-21.
- Smith, B., "Douglas Explores Design Options for Large, Long-Range MD-XXs," *Aviation Week and Space Technology*, Vol. 144, No. 27, July 1, 1996, pp. 43-44.
- Sparaco, P., "Market Upturn Spurs Airbus To Plan New Aircraft Versions," *Aviation Week and Space Technology*, Vol. 144, No. 27, July 1, 1996, pg. 45.

C.6. Aircraft Data

Aircraft Type Certification Data Sheets and Specification, Vol. 3: Large Multiengine Aircraft, Federal Aviation Administration, Washington, DC, 1985.

Aircraft Data for Pavement Design, American Concrete Pavement Association, 1993.

Special Design Chart for Concrete Airport Pavement: Boeing 727, Portland Cement Association, 1994.

Airplane Characteristics for Airport Planning, 737-300, 737-400, 737-500, Boeing Document D6-58325-2, Boeing Commercial Airplanes, Seattle, Washington, September 1988.

Airplane Characteristics for Airport Planning, 747-400, Boeing Document D6-58326-1, Boeing Commercial Airplane Company, Seattle, Washington, March 1990.

Airplane Characteristics for Airport Planning, 777, Boeing Document D6-58329, Boeing Commercial Airplane Company, Seattle, Washington, February 1992.

Boeing B737-130 Weight and Balance/Control and Loading Manual, Boeing Commercial Airplane Company, Seattle, Washington, 1985.

Boeing Group Weight Statements, Boeing Commercial Airplane Company, Seattle, Washington.

Anon., *MD-80 Component Weight Breakdown*, McDonnell Douglas, 1987.

Green, W., Swanborough, G., and Mowinski, J., *Modern Commercial Aircraft*, Portland House, New York, 1978.

Lambert, M., Ed., *Jane's All The World's Aircraft*, Sentinel House, United Kingdom, 1972-1994.

C.7 Simple Landing Gear Dynamics Models for Insight.

Flügge, W., "Landing-Gear Impact," NACA TN 2743, October 1952. This is a classic for insight. It provides a simple dynamic model of the landing gear as a spring-mass-damper. I actually think the equations are a tad oversimplified since today they would be solved using computational methods. An example analysis of the metering pin is included. The report also includes the analysis of the landing gear hitting a step in the pavement. Curiously, the design community does not use this first principals analysis to do the design. Probably the analysis is not complete enough for actual design.

Abramson, H. Norman, *An Introduction to the Dynamics of Airplanes*, Dover Publications, New York, 1971. pp. 134-139. This is the book that led me to the Flügge reference. Some other references are also cited.

von Mises, Richard, *Theory of Flight*, Dover Publications, New York, 1959, pp. 483-488. This is another, slightly different, basic analysis of the landing impact problem.

C.8 Historical (pre 1970) and Miscellaneous

Liming, R. A., "Analytic Definition of a Retractable Landing Gear Axis of Rotation," *Journal of the Aeronautical Sciences*, January 1947, pp. 19-23.

McBrearty, J. F., "A Critical Study of Aircraft Landing Gears," *Journal of the Aeronautical Sciences*, 16th IAS Annual Meeting, Proceedings, May 1948, pp. 263-280.

McBrearty, J. F. and Hill, D. C., "Landing Gear Strength Envelopes," *Journal of the Aeronautical Sciences*, IAS Los Angeles Meeting, Proceedings, May 1948, pp. 229-234.

Russell, A.G., "Some Factors Affecting Large Transport Aeroplanes with Turboprop Engines," *Journal of Aeronautical Sciences*, Vol. 17, No. 2, Feb. 1950, pp. 67-122.

Carter, K.S., "The Landing Gear of the Lockheed SST," SAE Paper 650224, 1965.

Stanton, G., "New Design for Commercial Aircraft Wheels and Brakes," AIAA Paper 67-104, June 1967.

Ridha, R. A., "Minimum Weight Design of Aircraft Landing Gear Reinforcement Rings," AIAA Paper 68-328, March 1968.

Collins, R. L. and Black, R. J., "Tire Parameters for Landing Gear Shimmy Studies," AIAA Paper 68-311, April 1968.

Firebaugh, J. M., "Estimation of Taxi Load Exceedances Using Power Spectral Methods," *Journal of Aircraft*, Vol. 5 No. 5, September 1968, pp. 507-509.