

Recommended Practice

Wind Tunnel Testing — Part 2: Practitioners Volume

AIAA standards are copyrighted by the American Institute of Aeronautics and Astronautics (AIAA), 1801 Alexander Bell Drive, Reston, VA 20191-4344 USA. All rights reserved.

AIAA grants you a license as follows: The right to download an electronic file of this AIAA standard for temporary storage on one computer for purposes of viewing, and/or printing one copy of the AIAA standard for individual use. Neither the electronic file nor the hard copy print may be reproduced in any way. In addition, the electronic file may not be distributed elsewhere over computer networks or otherwise. The hard copy print may only be distributed to other employees for their internal use within your organization.

Recommended Practice

Wind Tunnel Testing – Part 2: Practitioners Volume

Sponsor

American Institute of Aeronautics and Astronautics

Abstract

This recommended practice document is the second part of a two-part series intended to provide test project management and practitioners with best practices that will maximize data value of wind tunnel test projects. Part I is designed to help managers understand the impact of decision making before and during development of a test project and provides key activities to help improve the timeliness and cost-effectiveness of future wind tunnel test projects. Part II provides those responsible for test execution with best practices to employ when preparing for and implementing tests.

Library of Congress Cataloging-in-Publication Data

Recommended practice : wind tunnel testing.

p. cm.

pt. 1. Management volume -- pt. 2. Practitioners volume.

Includes bibliographical references and index.

ISBN 1-56347-650-9 (v. 1) -- ISBN 1-56347-651-7 (Electronic) -- ISBN 1-56347-652-5 (v. 2) -- ISBN 1-56347-653-3 (Electronic)

1. Wind tunnels. 2. Aerodynamics--Research--Standards. 3. Wind tunnel models--Testing--Standards. I. American Institute of Aeronautics and Astronautics.

TL567.W5R437 2003
629.134'52--dc22

2003019165

Published by

American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Reston, VA 20191-4344

Copyright © 2003 American Institute of Aeronautics and
Astronautics
All rights reserved

No part of this publication may be reproduced in any form, in electronic retrieval system
or otherwise, without prior written permission of the publisher.

Printed in the United States of America.

CONTENTS

Foreword	vi
1 Introduction.....	1
2 Aircraft Program Development	1
2.1 Overview.....	1
2.2 Test Development.....	2
2.3 Key Actions Throughout All Phases of Test Projects	4
3 Pretest Planning and Preparation Phase.....	5
3.1 Personnel, Test Requirements, and Facility Selection	5
3.1.1 Team Participants for Pretest Planning and Preparation	5
3.1.2 Test Requirements.....	6
3.1.3 Facility Selection	7
3.2 Development and Management of the Project Plan	8
3.2.1 Test Project Plan Development.....	8
3.2.1.1 Requirements Statement.....	9
3.2.1.2 Basic Work Structure	9
3.2.1.3 Experimental Uncertainty Analysis.....	9
3.2.1.4 Risk Identification and Mitigation	9
3.2.1.5 Safety.....	10
3.2.1.6 Security.....	10
3.2.2 Test Project Plan Implementation and Management.....	10
3.2.2.1 Schedule Development and Control.....	11
3.2.2.2 Budget Development and Control	12
3.2.2.3 Communication and Reporting.....	13
3.3 Test Preparation.....	13
3.3.1 Final Instrumentation Requirements	14
3.3.2 Data Acquisition and Reduction	14
3.3.3 Calibrations.....	15
3.3.4 Pretest Predictions and Historical Data.....	15
3.3.5 Instrumentation Checks	15
3.3.6 Information Management.....	15
4 Model Development and Fabrication Phase.....	16
4.1 Team Participants for Model Development and Fabrication	16
4.2 Conceptual Design.....	17
4.2.1 Model/Test Facility Considerations.....	17
4.2.2 Model Configuration Considerations	18

4.3	Detailed Design.....	19
4.4	Model Fabrication.....	20
4.4.1	Rapid Manufacturing Processes.....	20
4.4.2	Virtual Manufacturing	20
4.4.3	Acceptance Criteria and Noncompliance Documentation	20
4.4.4	Instrumentation Installation.....	21
4.4.5	Model Acceptance.....	21
4.4.6	Handling, Packaging, and Shipping	22
5	Pretest Buildup and Preparation Phase	22
5.1	Team Participants for Buildup Phase	22
5.2	Model Buildup.....	23
5.3	Planning for Installation in the Test Section.....	25
5.4	Final Test Matrix Review.....	25
6	Test Phase	25
6.1	Test Team Communications.....	25
6.2	Model Installation and System Checks	26
6.3	Test Readiness Review	27
6.4	Initial Tunnel Runs	27
6.5	Testing Checks and Documentation	28
6.6	Data Processing.....	29
6.7	Cost and Schedule Management	29
6.8	Test Efficiency Issues	29
6.9	Test Completion Review	30
6.10	Model Removal	30
7	Post-Test Phase.....	31
7.1	Team Participants During the Post-test Phase.....	31
7.2	Hardware	31
7.3	Data	31
7.4	Documentation	32
8	Summary	32
	References	34
	Annex A Example of a work Breakdown Structure (WBS) for a wind tunnel test project.....	35
	Annex B Cost/Schedule Status Report	37
	Annex C Subcontracting Mechanisms for Consideration In Test Projects.....	39
	Annex D Rapid Manufacturing Techniques.....	41
	Annex E Issues Affecting Fabrication Cost and Schedule	43

Figures

Figure 1 Major Phases of a Wind Tunnel Test Project.....	4
Figure 2 Team Makeup During Pretest Buildup	23
Figure B.1 Graphic Presentation of Cost/Schedule Status	38

Tables

Table 1 Examples of Tests Used in Commercial Aircraft Development Programs.....	2
Table 2 Examples of tests used in a high-performance military aircraft development program.....	3
Table 3 Examples of Technical Objectives Stated as Top-Level Goals Versus Detailed Requirements.	6
Table B.1 Definitions Used in a Cost/Schedule Status Report.....	37
Table B.2 Summary of Cost/Schedule Status Report	38

Foreword

The American Institute of Aeronautics and Astronautics (AIAA) Ground Test Technical Committee (GTTC) began looking at best practices associated with test article development as a way to recommend improvements in wind tunnel test efficiency, cost, and cycle time. Early on, it became apparent to the participants of the AIAA working group that trying to separate test article development from overall wind tunnel test process was not a productive and useful activity. The highly integrated nature of the processes, organizations, and personnel involved in wind tunnel test projects require that a broader viewpoint of the wind tunnel test process be evaluated in order to develop successful techniques and methods. The two-part effort, "Recommended Practices for Wind Tunnel Testing," is the result of that evaluation.

Part I was written to provide managers with clear insight into achieving technically focused, cost-efficient, low-risk test programs (which contain multiple test projects) that support the development of aerodynamic vehicles and technologies. This recommended-practices document will help managers understand the impact of decision making before and during the development of a test program and will provide key activities to help improve quality, timeliness, and cost-effectiveness of wind tunnel test projects.

Part II provides additional detail on successful methods for those directly involved in developing and executing individual tests.

Neither volume is intended to be a totally comprehensive document on successful wind tunnel testing. Instead, they represent a compilation of best practices to provide a strong foundation for the successful development of a test program or test effort. While these practices focus on wind tunnel test processes, the information is applicable to many other ground test activities.

Mr. Mark Melanson, Chairman	(Lockheed Martin Aeronautics)
Mr. Tom Aiken	(NASA Ames Research Center)
Mr. Allen Arrington	(QSS Group Inc./NASA Glenn Research Center)
Mr. Chris Athaide	(Tri Models Inc.)
Mr. Rene Barakett	(Bombardier Aerospace)
Mr. Mark Betzina	(NASA Ames Research Center)
Ms. Jean Bianco	(NASA Glenn Research Center)
Mr. Jim Brunges	
Mr. Steve Craft	(NASA Langley Research Center)
Mr. Roger Crites	(Boeing Company, St. Louis)
Mr. Drew Hope	(NASA Langley Research Center)
Mr. Mark Kammeyer	(Boeing Company, St. Louis)
Mr. Ray Knowis	
Mr. Dan Marren	(AEDC White Oak)
Ms. Laura McGill	(Raytheon Missiles)
Mr. Dave Minto	(Holloman High-Speed Test Track)
Mr. Michel Ouellette	(Bombardier Aerospace)
Mr. Barry Price	(NASA Langley Research Center)

Mr. Al Roberts	(Tri Models Inc.)
Mr. Matt Ruegers	(Boeing Company, St. Louis)
Mr. Lew Scherer	(Northrop Grumman)
Mr. Rob Sheehan	(Northrop Grumman)
Dr. Frank Steinle	(Sverdrup/Jacobs Engr. at Arnold Engineering Development Center)
Mr. Bill Straka	(Penn State University)
Mr. Steven Westmore	(Boeing Company, Seattle)

The skill and leadership of Mr. Cap Catalanotto was critical to the early activities of this work group. Many others also contributed to this document during its development.

The AIAA Standards Procedures provide that all standards, recommended practices, and guides are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. In formulating, revising, and approving standards publications, the Committee on Standards will not consider patents that may apply to the subject matter. Prospective users of the publications are responsible for protecting themselves against liability for infringement of patents, copyrights, or both.

On the recommendation of the Test Processes Working Group, the following knowledgeable individuals reviewed this document and provided valuable critiques. Approval of the document was unanimous.

Mr. Joe Corce	(Boeing Co., St. Louis)
Mr. Steven F. Lieberg	(Boeing Co., Seattle)
Mr. Dave Nestoss	(Boeing Co, Seattle)
Mr. Bill Peters	(Sverdrup/Jacobs Engr. at Arnold Engineering Development Center)

The AIAA Ground Test Technical Committee (GTTC), Mr. Allen Arrington, Chairman, approved this document in July 2002.

The AIAA Standards Executive Council (Phil Cheney, Chairman) approved this document in September 2003.

1 Introduction

The purpose of this recommended practice document is to provide the reader with increased knowledge about planning and executing highly successful wind tunnel tests. First, an overview of the test process is provided, giving a general picture of the origin, purpose, and high-level breakdown of activities that are a part of wind tunnel test development and execution. Secondly, detail is added to the overview to define the full scope of the activities and key considerations. Finally, recommended practices and lessons learned are described.

Part I of this recommended practice looked at test development from a management perspective. This volume (Part II) will provide additional detail that is more useful to participants who develop and execute testing activities. Part II is organized into sections describing activities and best practices during the various stages of test implementation:

- Program development
- Pretest planning and preparation
- Model development and fabrication
- Pretest buildup and preparation
- Testing
- Post-test activities

Part II of this recommended practice document was assembled with guidance from experts (both industry and government) who are responsible for all aspects of wind tunnel testing. Experts from airframe companies (military and commercial), as well as model makers and tunnel operators contributed best practices to help guide test personnel through the implementation and execution of a test project.

2 Aircraft Program Development

Aircraft designs continually push the state-of-the-art in technology. Advances in materials, instrumentation, and onboard computing will continue to allow the design of higher performance, lighter weight aircraft. Consequently, wind tunnel testing has become more sophisticated as demands for improved aircraft performance have increased. Relatively simple aerodynamic tests of early years have broadened to highly specialized testing. Advances in wind tunnel test facilities and techniques are also impacting testing projects by reducing cycle times and increasing the amount, quality, and versatility of the data collected.

As test requirements flow from a programmatic level to the finer detail of individual tests, activities and issues associated with the requirements are developed and refined to enable the completion of individual tests. It is often during this flow down that the success or failure of a test effort is determined.

2.1 Overview

As used in this document, an aircraft development **program** refers to the process by which a new aircraft or major derivative is created—from initial concept to production. The test **project** is the portion of the development program when testing is conducted. For this document, the test project will focus on a wind tunnel testing activity. Therefore, each test project is an integrated and important part of the entire vehicle development program.

The phase of a development program has direct bearing on the level of technical requirements for the individual test project. Traditionally, aircraft or technology development programs generally follow three phases:

- Phase 1 is the concept development and risk reduction phase. Initial configuration concepts are evaluated against program goals. Vehicle configurations change quite frequently. Parametric models, with multiple configuration variables, are investigative in nature and high-fidelity simulations are usually not required. The purpose at this phase of the program is to select an initial configuration that will meet developmental goals.
- Phase 2 is the development of the flight vehicle, often referred to as the Engineering and Manufacturing Development (EMD) or Full-Scale Development (FSD) phase. The scope and amount of wind tunnel testing increases dramatically as models are tested throughout the vehicle envelope and simulated flight conditions. Model configurations become more refined as the development phase progresses. Test and model-fidelity requirements increase as aerodynamic, propulsion, and aeroelastic goals are met.
- Phase 3 is the validation phase or production phase. In this phase, the final configuration has or is very close to being frozen, and full-scale production is underway. High-fidelity models with very stringent tolerance requirements are tested to validate aerodynamic, propulsion, and aeroelastic performance predictions. Testing is conducted throughout the proposed flight envelope and flight conditions of the aircraft.

2.2 Test Development

Traditional types of tests and models used for commercial aircraft development are presented in Table 1 and for military aircraft in Table 2. This document is presented from the perspective of testing that supports aircraft development. Other types of flight vehicles, such as missiles, helicopters, rockets, space re-entry vehicles, and V/STOL aircraft, have developed their own unique testing requirements.

Table 1 — Examples of Tests Used in Commercial Aircraft Development Programs

Model Type	Test Goals	Average Wind Tunnel Test Hours ^a
Conceptual Phase		
Low-Speed Force and Moment (High-Lift)	Take-off and Landing Performance and Stability and Control	500–1,000
High-Speed Force and Moment	Cruise Performance High Speed Stability and Control	500–1,500
Development/Validation Phase		
Low-Speed Force and Moment	Take-off and Landing Performance and Stability and Control	250–1,500
High-Speed Force and Moment	Cruise Performance High Speed Stability and Control	250–2,000
Aero Loads Model	Structural Loads	300–800
Flutter Model (Low- and High-Speed)	Flutter Clearance	500
Powered Models	Integrated Propulsion Effects	500–1,500
Icing Models	Icing Effects	500
Isolated Inlets	Inlet Performance	500
^a Test hours, typically described as User Occupancy Hours (UOH), are the time a model occupies a test facility and is able to acquire usable data (includes model change time, but not facility down time).		

Table 2 — Examples of tests used in a high-performance military aircraft development program

Model Type	Test Goals	Average Wind Tunnel Test Hours ^a
Conceptual Phase		
Low-Speed Force and Moment (High-Lift)	Take-off and Landing Performance and Stability and Control	500–1,000
High-Speed Force and Moment	Cruise Performance High Speed Stability and Control	500–1,500
Isolated Inlet and Static Inlet Model	Inlet Conceptual Design	200–700
Static Exhaust Model	Nozzle Performance	200–500
Development/Validation Phase		
Low-Speed Force and Moment	Take-off and Landing Performance and Stability and Control	250–3,500
High-Speed Force and Moment	Cruise Performance High-Speed Stability and Control	250–3,500
Aero Loads Model	Structural Loads	300–1,000
Flutter Model (Low- and High-Speed)	Flutter Clearance/Aeroelastic Effects	800–1,000
Inlet /Airframe Model	Integrated Inlet Effects/Inlet-Induction System Performance	500–1,500
Weapons Separation Model	Safe Store Separation/Accurate Delivery of Weapon	2500–5,000
Spin Models	Spin Recovery	500–2,000
Jet Effects Model	Effects of Exhaust on Aircraft Performance/Stability and Control	500–1,000
^a Test hours, typically described as User Occupancy Hours (UOH), are the time a model occupies a test facility (including installation and removal) and is able to acquire usable data (includes model change time, but not facility down time).		

Each aircraft or flight vehicle will have unique requirements in regard to the type and amount of wind tunnel testing it needs. Individual test projects during the flight vehicle development program have three main drivers:

- Data requirements
- Cost
- Schedule

Defining data requirements and when that data is needed are of utmost importance at the start of a program. This will establish and guide specific test project requirements and goals. Accordingly, the next two drivers, cost and schedule, are directly related to the selection of test hardware and test facilities. Wind tunnel test planning must carefully consider “how much” testing and fidelity are required to accomplish the stated goals. This is the starting point for individual test project development.

Individual test projects typically contain the following five key phases and activities:

- **Pretest planning and preparation** — Transition from program requirements to detailed test requirements, development of detailed plans, and preparation for testing

- **Model development and fabrication** — Planning and implementation of model-specific activities in preparation for testing
- **Pretest buildup and preparation** — Configure the test facility and install the test article in preparation for testing
- **Test** — Conduct testing
- **Post-test** — Evaluation of test results, documentation of test events, cleanup of test hardware, and final documentation, including lessons learned

The phases of a test project are shown in approximate chronology in Figure 1. Sections 3 through 6 describe in further detail the activities associated with these phases.

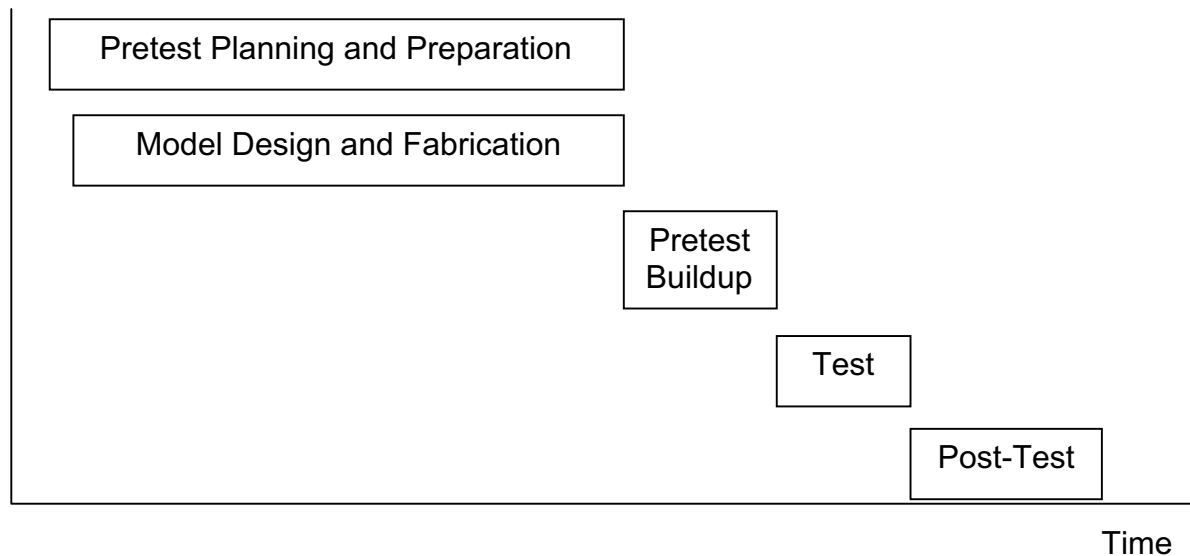


Figure 1 — Major Phases of a Wind Tunnel Test Project

As illustrated in Figure 1, most activities in the first two phases (pretest planning and preparation, and model design and fabrication) occur almost concurrently. Because many activities happen during the same time period, it puts significant stress on all involved. Many of the considerations discussed in later sections are described to illustrate the complex nature of the interactions of activities involved in testing.

During these phases, the mix of necessary personnel will evolve as the focus changes during pretest planning and preparation, model development and fabrication, pretest buildup, testing, and finally post-test activities. The dividing lines and overlap of the various activities are not precise or as easily defined as shown, but for the purposes of this document, information and key personnel will be discussed according to the phases shown.

2.3 Key Actions Throughout All Phases of Test Projects

Three critical actions are common throughout all phases of a test project. First, getting the right personnel (with appropriate authority to act) involved early helps ensure that all details and tasks are correctly planned and executed (nothing is overlooked). Secondly, organizing the personnel using a team-based model gives structure to the activities of individual participants. Finally, constant attention to the importance of communication (throughout the assembled team) gives those with the right skills the opportunity to perform at the highest level.

There is a great deal of work that must be addressed in the early stages of a test project, such as selecting and scheduling tunnels, setting up contracts with outside vendors, and selecting test equipment. It is important that those with detailed knowledge be involved in the early stages of a test project.

Organizing the participants using a team model provides a strong working structure for participation, decision-making, and project management. While this document does not provide a tutorial on the various methods of team-based organization, it does illustrate the basic functions the team should perform during the various phases of the project. Throughout this document, it is assumed that a team lead with overall authority is in place. Recommendations on team structure are provided during the critical test buildup and testing phases. Finally, regular communication between the team members is absolutely critical. Information should be disseminated throughout the entire team for the duration of the project. Remember that the personnel involved with a test project will change over time as the project moves from one phase to the next (as illustrated in Figure 1). Because of this, communication with team members associated with each test element is crucial throughout the project to ensure that vital information is transferred effectively as the project progresses.

3 Pretest Planning and Preparation Phase

Planning and preparation are critical to the ultimate success of any test project. When lead time is short, there is a tendency to abbreviate these steps and progress directly to implementation. However, investing time and resources to properly plan a project and prepare for testing will invariably pay off in terms of lower cost, reduced cycle time, and higher data quality.

Pretest planning and preparation embodies the following key areas:

- Selecting personnel, test requirements, and the facility
- Developing and managing the Project Plan
- Preparing to test

Work in each of these areas is an iterative process. As a test project develops, new information may require adjustments to the initial plan; however, laying the groundwork properly can minimize the impact of these adjustments.

3.1 Personnel, Test Requirements, and Facility Selection

The first item to be addressed in pretest planning is the creation of the test team, determination of the test requirements, and selection of the test facility. Each of these items will affect the others. Key requirements could eliminate some facilities from consideration, or conversely, a facility selected for one set of capabilities may not support other test requirements, so a trade-off may be required. In addition, the availability of expert key personnel must be considered when selecting facilities.

3.1.1 Team Participants for Pretest Planning and Preparation

During pretest planning and preparation, the key participants typically include the following:

- Customer (principal user of the test data)
- Lead test engineer
- Lead model designer
- Facility test engineer
- Fabrication engineer or foreman

Throughout this document, the customer is defined as the principal user of the test data, who converts the data to aircraft design or design validation information (such as aircraft aerodynamics, performance,

installed propulsion effects, etc.) Customer, in the context of this document, is *not* the program management team or primary user of the aircraft or flight vehicle.

Identifying the responsible test team is a task that is often left until late in the planning process. The test participants must be identified as early as possible so they can participate in all planning aspects. The most common failure in project planning and implementation is a breakdown in communication. Because communication is a critical aspect of this phase, a communication plan must be established to ensure that all team members are involved in planning and that their knowledge and experience are included in the decision-making process.

3.1.2 Test Requirements

The test project must have clear objectives and requirements that have been mutually agreed upon by the customer and the test team. Although most objectives will focus on the technical aspects of the aircraft development program, they should also address cost and schedule implications. Depending on the wind tunnel test experience of the customer, technical objectives may be stated as top-level goals or as detailed requirements. Examples of the relationship between the two are listed in Table 3.

Table 3 — Examples of Technical Objectives Stated as Top-Level Goals Versus Detailed Requirements.

Top-Level Goals	Detailed Requirements
Data Accuracy / Repeatability	Model Fidelity
	Data System Accuracy / Repeatability
	Sensor Speed and Accuracy / Repeatability
	Accuracy / Repeatability of Model Positioning System
	Uniformity of Flow Field
Reynold's Number	Model Size
	Mach No.
	Flow Environment (Pressure, Flow Medium)
Volume of Test Points	Ranges of Model Travel
	Frequency of Data Acquisition
	Model Configurations
Visualization Requirements	Facility Capability for Schlieren, Laser Doppler Velocimetry, Pressure-Sensitive Paint, etc.
Format Requirements	Test Data
	Model Design Data

Frequently, more than one customer will ultimately use the test data (e.g., design engineers, computational fluid dynamics developers, etc.). Therefore, the requirements may be a compromise or collaborative effort. The team (including multiple customers) should work together to identify opportunities for consolidating model and test requirements. Often requirements may take the form of a preliminary run schedule, which indicates Mach range, attitude range, number of configuration changes, and the number of runs at a minimum.

There are many potential problems that can arise during the development of requirements. The biggest threat to managing any test project is "requirements creep" or changing requirements as the project progresses. Although it will never be eliminated, having the customer work through the requirements as a team member is a good first step in controlling "requirements creep."

When project objectives and requirements are established, trade studies should be performed to determine the most cost-effective experiment design. This is typically an iterative process. These studies include determining model size (or scale), model configurations, instrumentation, and test facilities. Initial

aircraft analysis and computational fluid dynamics (CFD) can assist in making model hardware and scaling decisions such as model loading, support system optimization, and wall effects evaluation.

3.1.3 Facility Selection

Numerous considerations must be evaluated when selecting a wind tunnel for a specific test project. The selection of the test facility will influence every aspect of the test project, from cost to final data quality. Many points that must be considered are listed here:

- **Test section size** — This will establish possible model size. The general trend is to maximize model size for a given tunnel. This can, however, lead to large wall corrections that could compromise the data.
- **Tunnel operating conditions** — Will the tunnel operating range match desired data test goals? This includes Mach number and Reynolds number. Can tunnel test conditions be varied?
- **Tunnel flow quality** — Will the tunnel flow quality meet test goals? Uncertainty analysis of test parameters will help make this determination. Tunnel flow qualities are typically determined in ideal circumstances (no model) and should be viewed as best “possible”.
- **Tunnel costs** — This includes pretest setup, test, and post-test costs. Can lower cost facilities be used and still meet test objectives? Productivity of each tunnel should also be evaluated. Some facilities may be lower in cost on a per-hour basis, but not obtain the same amount of data per-hour as another tunnel (with a higher per-hour rate). Cost of the tunnel, coupled with the cost of the model selected, should be evaluated. Previous experience with a facility’s ability to predict or perform to cost is also an important consideration.
- **Tunnel availability** — Many facilities have full schedules. Initial planning far in advance might be required to obtain test time in a desired tunnel. Tunnel availability may remove some facilities from consideration.
- **Data acquisition capability** — What are the data acquisition capabilities of each tunnel being evaluated? Does a user have to bring his/her own data acquisition, along with support personnel, to the site? Can the data be provided directly to the user via a Web site or other means?
- **Data reduction and analysis** — What are the capabilities of each tunnel for supplying reduced data in near- or real-time while the test is in progress? What data analysis (such as plotting) capabilities are available during testing? What corrections will have to be applied for such things as test section flow quality, model support interference, wall interference, or test article geometry, and are these corrections in place at the facility?
- **Instrumentation** — Is the necessary instrumentation available to support test requirements (e.g., balances, optical access, etc.)?
- **Experience** — Does this tunnel have a proven history of successfully executing the type of test requested? Are past performance records available that indicate how the tunnel handles a particular type of test? What lessons were learned from past experiences?
- **Personnel support** — Are knowledgeable experts available to assist in interpreting test results? Are on-site model design and fabrication services available? Do tunnel personnel have experience with the required type of testing?
- **Support hardware** — Does the tunnel have existing hardware that is available for use? New model hardware, such as support systems, can be very costly, and if necessary, must be part of the overall evaluation.
- **Security** — Can tunnel and tunnel personnel meet program security requirements? Security clearances are often a long-lead issue that must be addressed.

- **Data quality/information quality** — Does the tunnel have an established capability to produce quality data? What combination of tunnel, model, and instrumentation provide the desired data quality? What information management system is in place?
- **Contractual agreements/liability** — How are the formal relationships established? Are the legal aspects of performing a test understood, and is the risk of unfavorable contract terms low? How long will it take to have contracts approved? Who is liable for damage to the facility in case of a model failure? Is export or import documentation required? Are proprietary or Memorandums of Agreement (or similar documents) in place?

3.2 Development and Management of the Project Plan

After the initial planning has been established, the next step is to develop and execute a detailed test Project Plan. This plan is the blueprint used to successfully complete the wind tunnel test project. As illustrated in the following sections, the plan is an all-encompassing document that requires input from the entire team to be meaningful and useful. The Project Plan is a living document, in that it will change to reflect changes in the scope of the test requirements or other aspects of the test project. The Project Plan is used to document all planned activities, assumptions, task assignment and responsibilities, tolerances and fidelity requirements, and expected outcomes.

The form of the Project Plan is not important, but the act of creating a detailed action plan provides a baseline for all participants and provides documented expectations for implementation. The Project Plan implies a commitment made between the team members once the plan has been established and approved. The commitment is that team members will complete their assigned duties as agreed upon in the plan. The Project Plan is also an important tool for the project leader in further defining the details of the test project and for managing the tasks, costs, and schedule associated with the test.

3.2.1 Test Project Plan Development

Developing the Project Plan is a team activity. It begins with evaluating the project requirements (technical, cost, and schedule) and identifying areas where additional information is required (such as facility schedule, procurement and fabrication lead-times, resource availability, model-to-facility interfaces, material costs, and labor) and culminates in an integrated schedule of tasks.

This activity serves two purposes. First, it develops a common understanding among the team members about the tasks to be accomplished. Secondly, it provides a road map for the team to follow and assists when making adjustments as the project develops. There are numerous software tools available to assist in this aspect of project planning, most provide the capability to produce and maintain detailed project schedules. In most cases, significant training and experience are required before the full capability of the software can be realized. Ultimately, success of the plan will depend on the depth and breadth of the content and not the sophistication of the tools used.

Project planning is not complete until the plan has been documented in a format available to all team members. It is vital to the success of the plan that all team members have an opportunity to review the plan and concur on the tasks, costs and schedules that have been listed. It is also very important that the plan be kept current. Modifications to the plan can be expected, but any changes must be carefully controlled. A well-defined process must be established for submitting, reviewing, approving, and incorporating potential changes. Any cost or schedule impacts from the changes should be negotiated before proceeding with the amended plan, and the entire team, including the customer, must understand and agree on the changes. An amended Project Plan should continue to serve as a communication tool to keep the team informed and involved in the project.

The Project Plan should include the items described in Sections 3.2.1.1 through 3.2.1.6 below. They have been separated to demonstrate the importance of each. However, they are highly dependent on each other. Decisions made in one area can have major impacts on several others. The descriptions provided focus primarily on the informational content of the major sections of the plan. The order in which