

# *Aircraft Performance, Stability and Control with Experiments in Flight*



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## **Module-1**

### **Lecture-1**

#### **Introduction**

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# Introduction

## Introduction to Flight Mechanics

The important/relevant topics in flight mechanics are to be familiarized with, before conducting any experiment. Atmospheric flight mechanics encompasses two major disciplines; namely performance and flight stability and control, as shown in Figure 1.

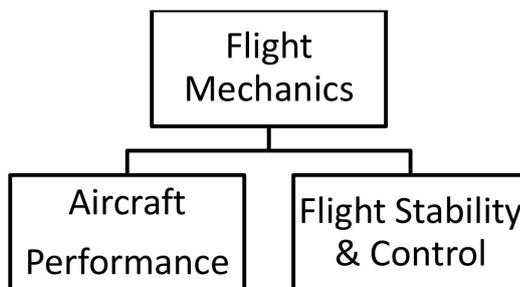


Figure 1: Flight mechanics: Classification

1. **Aircraft performance:** mainly deals with the estimation of performance characteristics such as range, endurance, rate of climb, etc.
  - (a) **Range:** The total distance that an aircraft can travel on a given full tank of fuel.
  - (b) **Endurance:** The total time that an aircraft can stay in air for a given tank of fuel.
  - (c) **Rate of climb:** The rate of change of altitude of an aircraft in flight.
2. **Flight Stability and control:** deals with the handling qualities of an aircraft under the influence of external forces and/or internal forces.

## Warm up

*What does the term “experiment” imply in engineering and physical sciences?*

*“In engineering and other physical sciences, experiments are used to test theories and hypotheses about how physical process work under given conditions”*

For successfully conducting any experiment, the following preparations are required:

1. Conduct initial research/studies on the topic of interest/research problem.
2. Postulate the problem/exercise/hypotheses to be tested based on initial research findings.
3. Design appropriate experiment(s) to test the hypotheses/theories associated with the problem/exercise.
4. Record the data and other details.
5. Replicate the experiment to validate and verifying the findings.
6. Document the process, data and findings as a technical report.

## Target audience

*The target audience of this course is upper level undergraduate and graduate students, along with practicing engineers.*

This course is structured in the following manner:

1. Introduction to various aerodynamic and flight dynamic models routinely used to estimate performance characteristics of an airplane in flight.
2. Introduction to the concept of aircraft stability and control.
3. Development of analytical expressions for estimation of neutral point (stick fixed and free) and maneuvering point (stick fixed and free).

4. Description of experiments (flight maneuvers) and associated theories/hypotheses that are typically tested.
5. Familiarization of various sensors used to acquire flight data such air relative speed, angle of attack, side slip angle, linear & angular accelerations, etc.
6. Acquisition and analysis of flight data.
7. Accept/reject the hypotheses and draw appropriate conclusions.
8. Technically report writing.

## Flight testing

**PURPOSE** : Broadly speaking, flight testing of aircraft may be conducted for various purpose in mind.

**Acceptance Flight Testing** : To determine the actual characteristics of aircraft and to compare it with the computed / predicted or with that claimed by the manufacturer. Such test may be conducted by :

1. Airline operator
2. Airforce
3. Prospective owner
4. Prototype testing by manufacturer himself

*Overhauled airplanes may also need to conduct tests for obtaining flight airworthiness certificates.*

The procedures for flight testing are basically same irrespective of the purpose of it being acceptance testing or research and development testing. The major differneces lie only in the manner in which the final corrected data is presented.

**Flight Test Program** : The major steps involved in any flight test programs are :

1. Develop plan & establish objectives
2. Theoretical estimates of results to be obtained from flight testing
3. Determine mass characteristics

4. Instrumentation
5. Design and perform flight maneuver
6. Measure and record data
7. Pre-process data
8. Analyse data
9. Evaluate results
10. Present results

A statement of the objectives is the first element of any test plan. The statement must be :

1. Concrete
2. Include acceptable forms of the results

*The aim is to design the test program to provide the desired results for the least cost in time and money within the limitations of available manpower and equipment*

***Example:***

Let us consider an example where stick fixed and stick free longitudinal static stability characteristics are to be studied. To define the objective more precisely, we say :

*“To obtain the location of stick fixed and stick free neutral points from some fixed reference point”*

Let us see what needs to be known :

While preparing for the experiment we need to

1. Know the longitudinal static stability theory of aircraft.
2. Know how to relate this theory to flight test technique for obtaining the desired results.
3. Obtain some pre-flight data; c.g. location
4. Identify the instrumentation requirement, say elevator position, stick force, airdata (speed, altitude, outside air temperature).

5. Calibrate ground and flight instruments.
6. Have airborne data acquisition system or system to telemeter data to ground station.
7. Identify the flight maneuver and convey the same to the pilot and instrumentation (recorder) team.
8. Check if any pre processing of data is required or not (say, correction for fuel burnt and it's effect on c.g. location)

*Analysis is carried out to evaluate results and these are finally presented in the form as stated in the objectives of the test plan*

### **Preflight Data :**

We need to collect some data before the test begin. These primarily include predicted **aerodynamic characteristics**, **aircraft mass characteristics** and **atmospheric conditions**. Of course, we need a thorough understanding of the instrumentation system and aircraft control system.

### **Predicted Aerodynamic Characteristics :**

There are many purpose for which we need predicted values of what we wish to determine from flight testing. The objective itself may be validation of such predicted values. We need this information for test maneuver design. Predicted values could be obtained from:

1. Analytical relation
2. CFD computation
3. Wind tunnel test

The wind tunnel data must be properly transformed into a form suitable for our analysis. Care is also to be exercised to ensure that the predicted values and flight test results have used the same geometric values like ; area, span, chord and also values are defined with respect to the same refernece point.

### **Aircraft Mass Characteristics:**

The aircraft mass characteristics relevant to rigid body motion are :

1. Weight
2. Center of gravity
3. Moment of inertia

Weight and longitudinal center of gravity position are easy to measure and are routinely monitored. This is a routine maintenance activity approved by civil aviation airworthy organisation. Determination of moment of inertia and vertical and lateral C.G. positions require special tests.

1. Flight test plan should provide for accurate monitoring of the mass characteristics throughout the flight test program.
2. In preparing for each test flight, it should be checked that all the required mass data is available, because it is not possible to reliably re-construct mass data once the aircraft is handed over.
3. If we have inaccurate mass data, we will have inaccurate test results, so **mass data** deserves some care and attention to detail as the **flight instrumentation system**.

### **Common source for mass data collection**

The common source of mass data is ground based measurement.

1. The weight and the longitudinal and lateral components of the C.G. can be accurately measured by scales under each wheel.
2. Swing test measure the moment of inertia, using springs with known spring constants.
3. A second good source of mass data is manufacturer's records of component build up. These records can give total aircraft moment-of-inertia data that are more accurate than those from swing test.

## **Reference material**

Much of the lecture material is taken from these books:

1. Anderson, John D. "*Introduction To Flight*." : McGraw-Hill, 1978.
2. Phillips, Warren F. "*Mechanics Of Flight*." : J. Wiley, 2004.
3. Nelson, Robert C. "*Flight Stability And Automatic Control*." : McGraw-Hill, 1989.
4. Napolitano, Marcello R. "*Aircraft Dynamics*." : J. Wiley, 2012.
5. Perkins, C.D. & Hage, R.E., "*Aircraft performance, stability and control*." : J. Wiley 1949.