2019

System Dynamics and Control

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TOPIC 1: INTRODUCTION

1-1 BASIC CONCEPTS

(A) The System Approach

system: a combination of components acting together to perform a specific objective.
component: a single functioning unit of a system.
MIMO: multiple-input, multiple-output control system.
SISO: single-input, single-output control system.
BIBO: bounded-input, bounded-output control system.

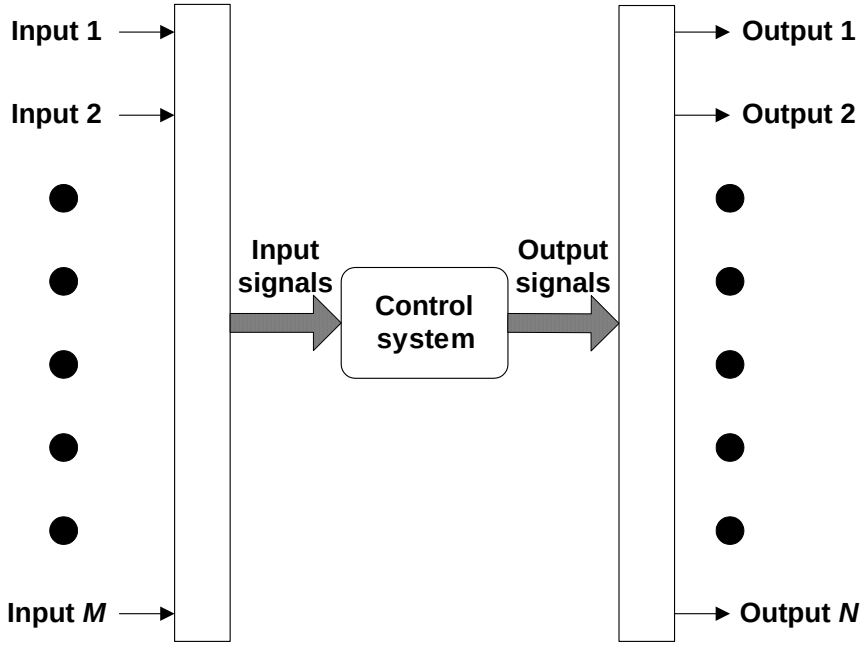


FIGURE 1-1.1 A control system with *M* inputs and *N* outputs.

(B) Model Classification Tree

Dynamic systems *vs* Static systems
Deterministic systems *vs* Stochastic (*or* random) systems
Lumped (*or* discrete) systems *vs* Distributed (*or* continuous) systems
Linear systems *vs* Non-linear systems
Time-invariant (*or* constant-coefficient) systems *vs* Time-varying (*or* variable-coefficient) systems
Continuous-time systems *vs* Discrete-time systems
Simplicity *vs* Accuracy (e.g., 1st-Order Systems vs. 2nd-Order Systems)
mathematical models → differential equations
linear systems → linear differential equations
a. linear time invariant (LTI) differential equations
(*or* linear differential equations with constant coefficients)
b. linear time varying (LTV) differential equations
(*or* linear differential equations with variable coefficients)
non-linear systems → non-linear differential equations
Note: The **Principle of Superposition** applies to linear (both LTI and LTV) systems only.

MODEL CLASSIFICATION TREE

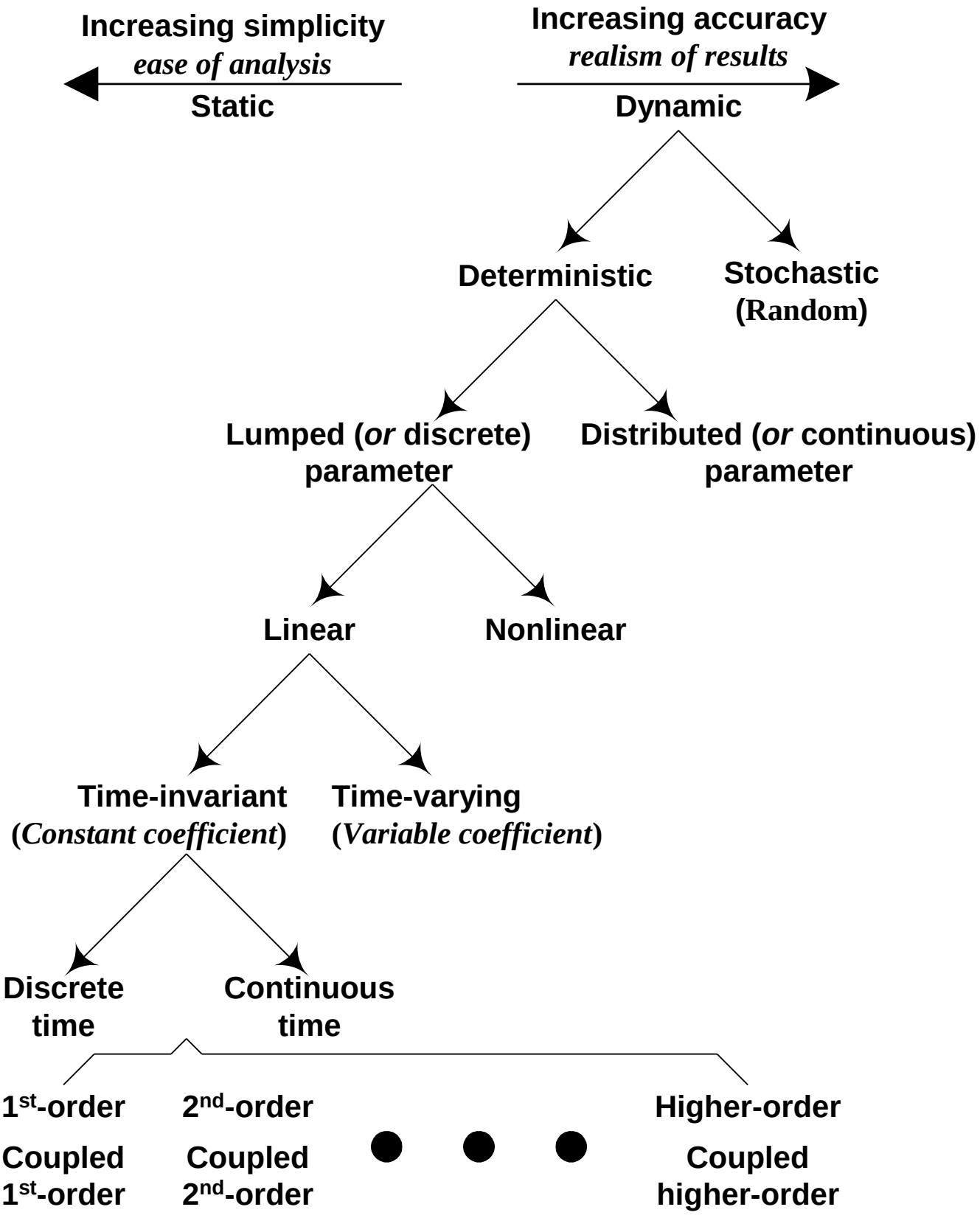


FIGURE 1.2 A model classification tree defining various characteristics in control studies.

(C) The Role of a Controller

1. Each important variable requires its own controller. The interaction between variables calls for coordination between all controllers.
2. ***Regulator*** *for* **regulation problems**: a controller designed to maintain the desired condition in the presence of variations (called disturbance *or* noise) caused by the external environment. This control action is called *disturbance rejection*.
3. ***Servomechanism*** *for* **tracking problems**: a controller designed to bring the system's operating condition to the desired value. This control action is called *servo control*.

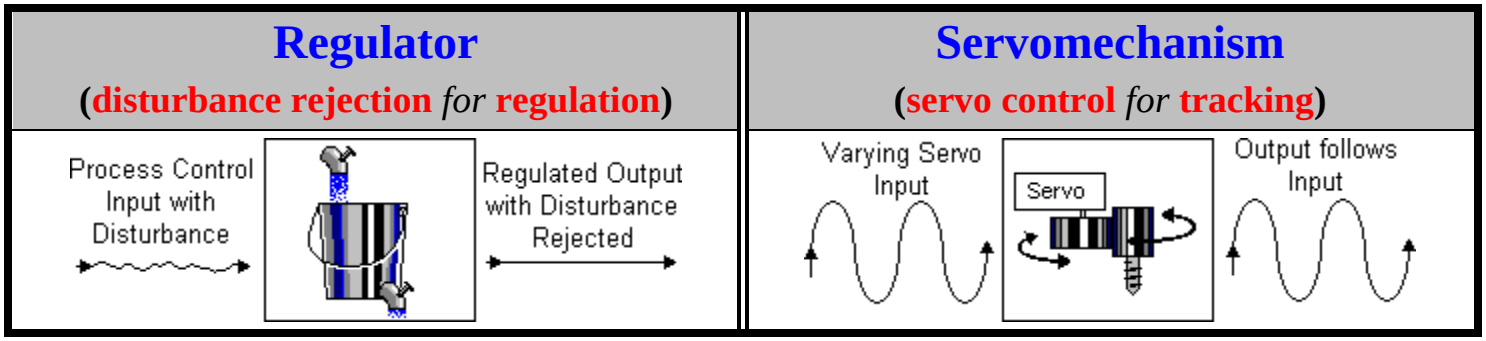


FIGURE 1.4 The role of control: regulator *vs* servomechanism.

(D) Examples

D.1 A computer-controlled boiler-generator system

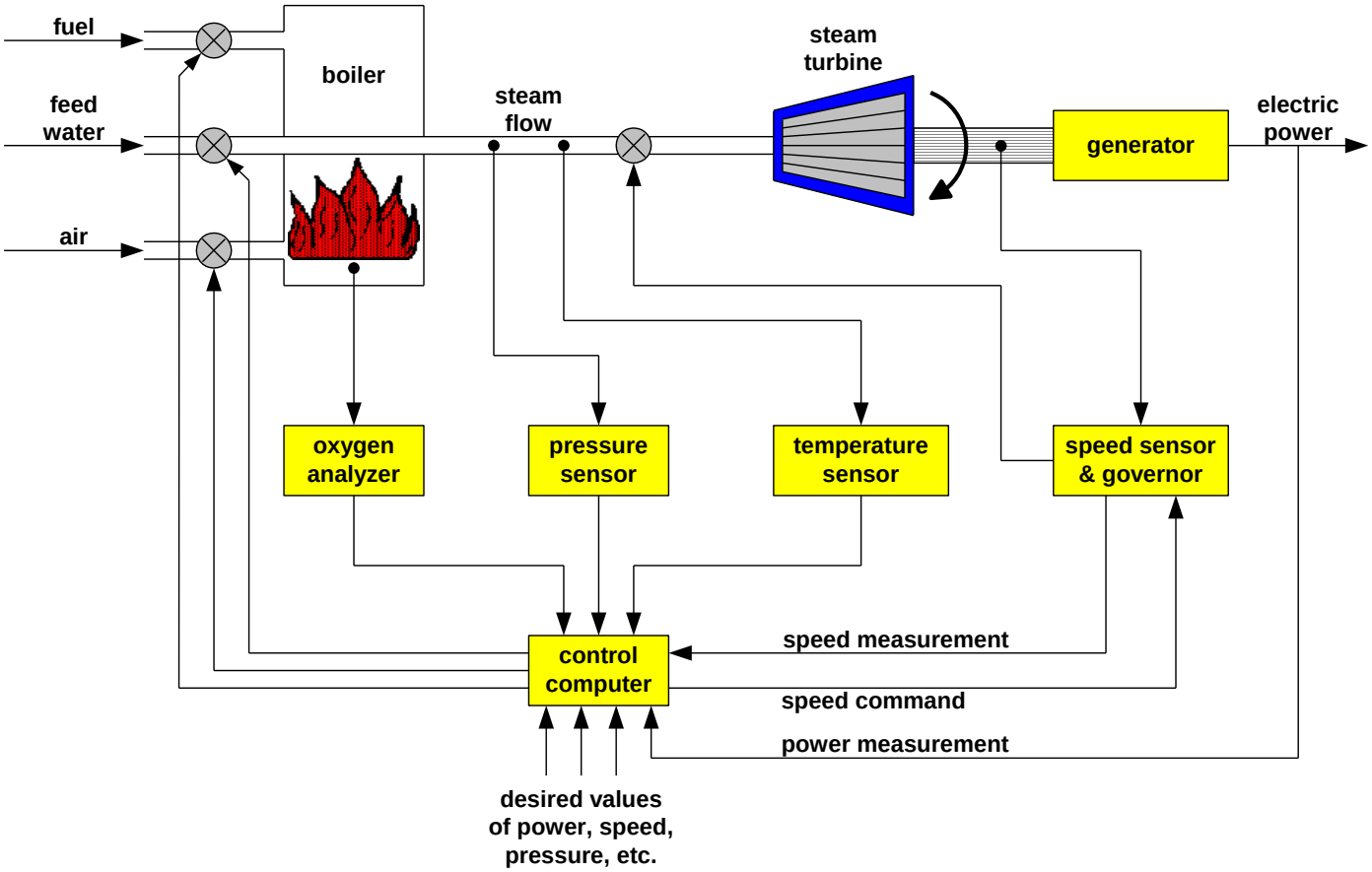


FIGURE 1.5 A computer-controlled multiple-input/multiple-output boiler-generator system, modified from Palm [1].

D.2 A pressure regulator used in fluid level-flow systems

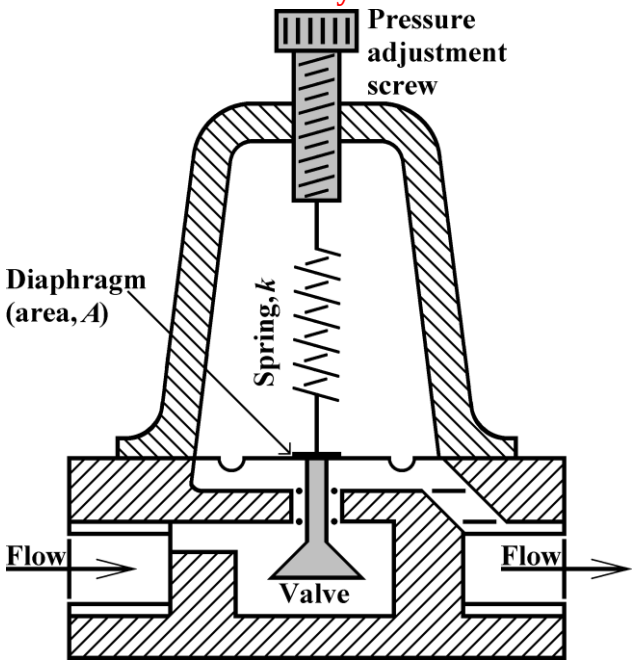


FIGURE 1.6 A pressure regulator can be viewed as a component in a fluid level-flow system as well as a subsystem itself, composing of several components (flow-regulated valve, spring, diaphragm, pressure-adjustment screw, etc.), modified from Palm [1].

D.3 A futuristic control-configured aircraft

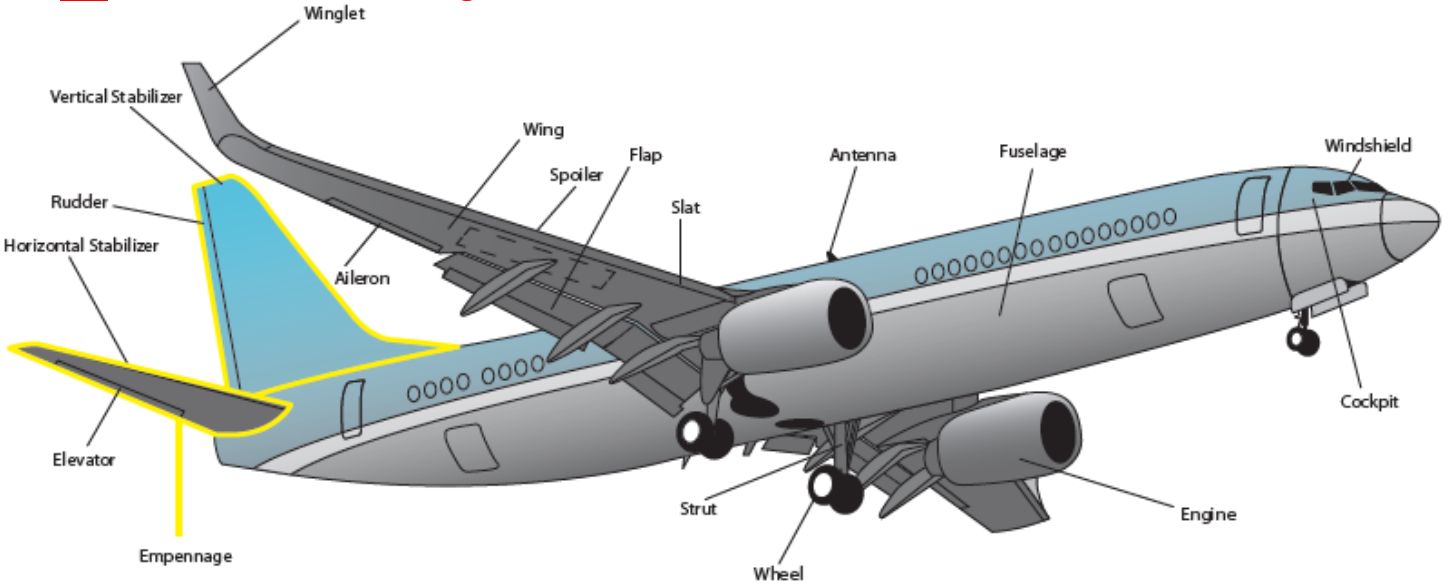
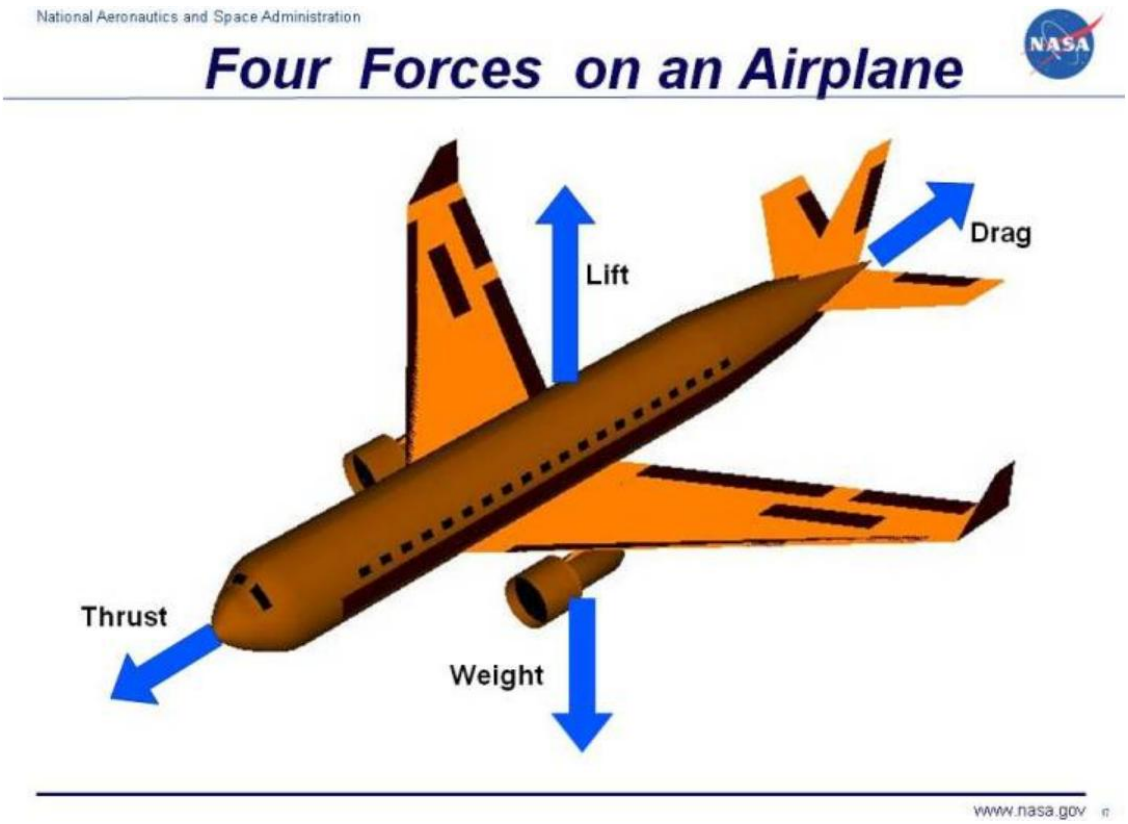
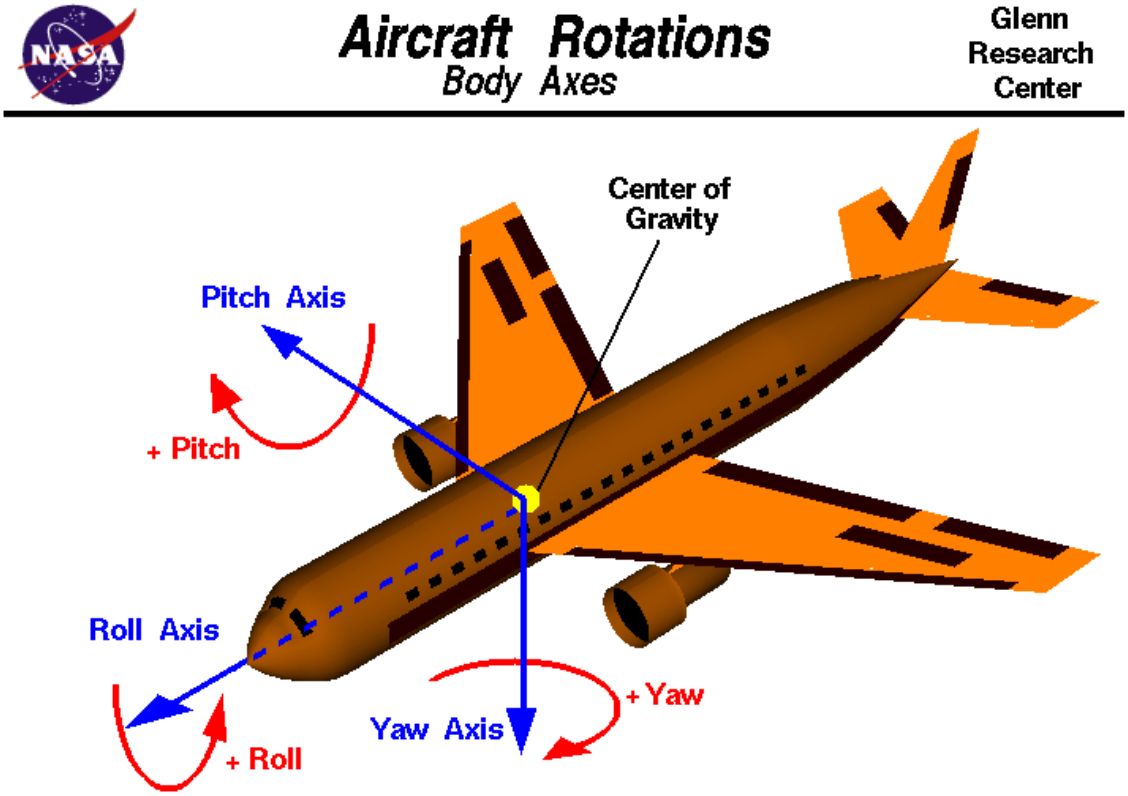


FIGURE 1.7 Typical parts of a commercial airplane, adopted from NASA [2].



(a) **4** forces on an airplane: upward lift *vs* downward weight and forward thrust *vs* backward drag



(b) **3** rotations of an airplane: pitch, yaw and roll

FIGURE 1.8 Forces on an airplane and aircraft rotations, adopted from NASA GRC [3].

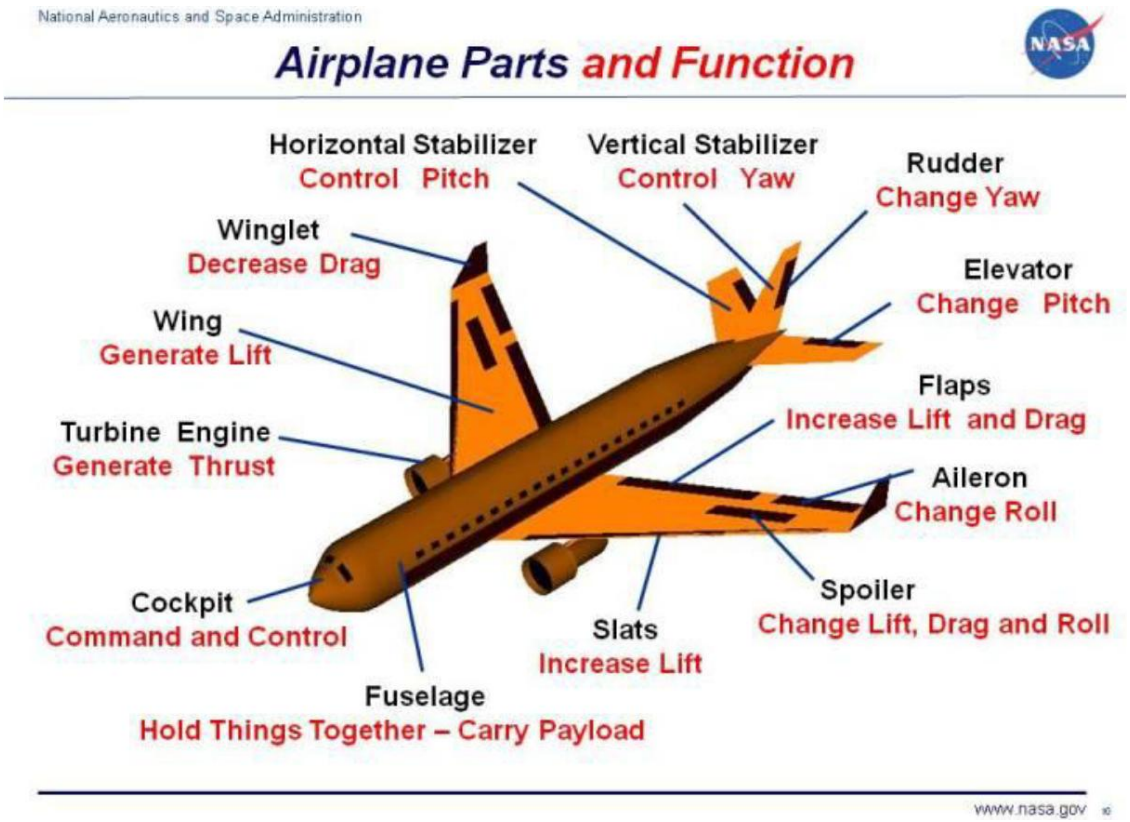


FIGURE 1.9 Conventional airplane parts and their control functions, adopted from NASA GRC [3].

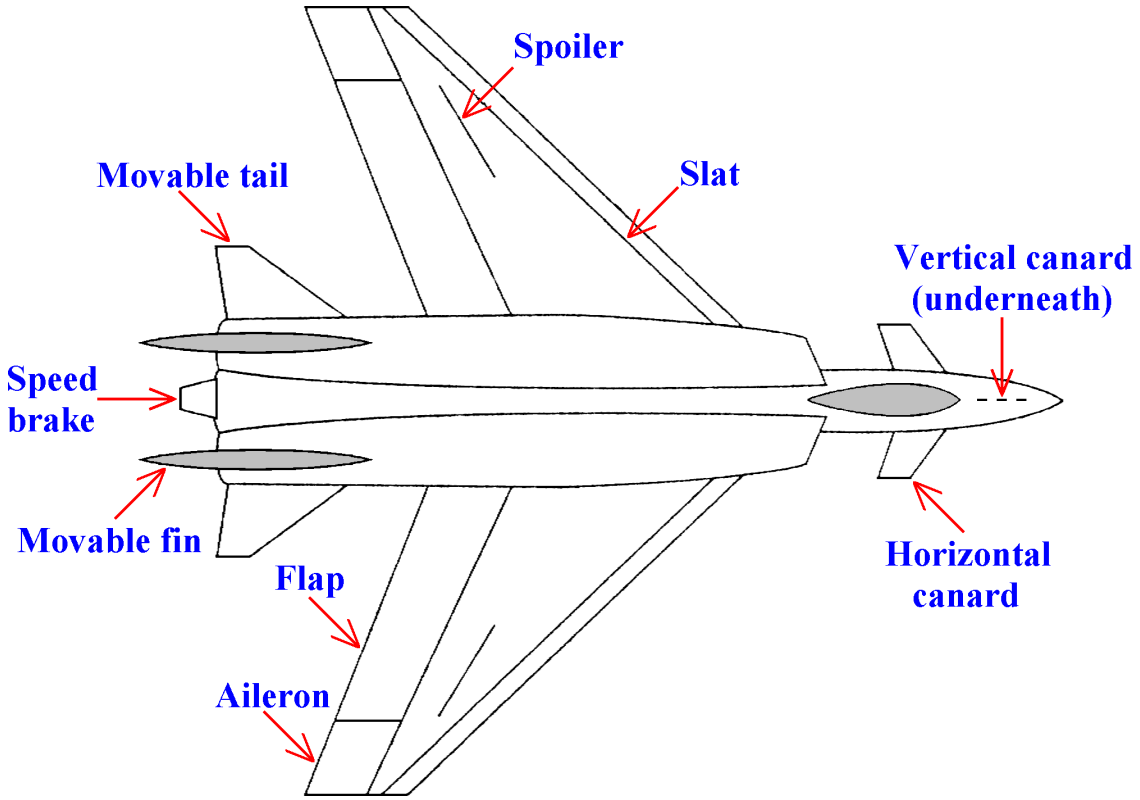


FIGURE 1.10 A proposed futuristic control-configured aircraft, which utilizes more control surfaces than the usual elevators-ailerons-rudder system, modified from Palm [1].

REFERENCES

[**1**] W.J. Palm, III, ***Modeling, Analysis, and Control of Dynamic Systems***, 2nd ed., Wiley, 2000.

[**2**] *Parts of an Airplane*, National Aeronautics and Space Administration (NASA), https://www.hq.nasa.gov/office/aero/pdf/parts_of_an_airplane_9-12.pdf.

[**3**] *Guided Tours of the BGA* (*Beginner's Guide to Aeronautics*), National Aeronautics and Space Administration - Glenn Research Center (NASA-GRC), https://www.grc.nasa.gov/www/k-12/airplane/guided.htm.