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FINAL PROJECT REPORT

Fixed Wing Longitudinal Stability & Control Evaluation through Flight Tests

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INDEX

Figures

Tables

Chapter 0. ABSTRACT

This thesis investigates the longitudinal stability and control of the Skyranger Nynja, a light sport ultralight aircraft, through a series of flight tests conducted without the use of onboard instrumentation. The primary objective was to evaluate both static and dynamic longitudinal stability using practical test techniques accessible to individuals or teams without advanced flight test equipment. A variety of maneuvers—primarily adapted from the U.S. Naval Test Pilot School's Flight Test Manual No. 103—were executed to elicit the aircraft's longitudinal response.

Data was collected using limited resources, easily acquired by the public. The results show that the Skyranger Nynja demonstrates both static and dynamic stability in all tested conditions. The phugoid mode was clearly identifiable, and its period and damping ratio were successfully calculated. However, the short period mode could not be characterized due to its heavily damped nature, which made it difficult to gather quantitative data during the tests.

This study contributes to the limited body of quantitative data available on the Skyranger Nynja and showcases a simplified methodology for evaluating longitudinal stability. Beyond the technical findings, the work highlights the value of self-directed learning in flight testing and the feasibility of conducting meaningful stability analysis without full-scale instrumentation.

Chapter 1. INTRODUCTION

The objective of this thesis is to investigate the longitudinal stability and control system of an ultralight aircraft (MTOW <600Kg) through data obtained from flight tests. Both quantitative and qualitative data are recorded during testing, then analyzed and compared against relevant aviation standards and requirements.

The Skyranger Nynja is used as the test aircraft. Quantitative measurements are gathered using a chronometer, a digital accelerometer, and a portable dynamometer. Additionally, qualitative assessments are made based on the feedback of the flight test pilot, who has more than 10,000 flight hours on this platform.

Chapter 2. STATE OF THE ART AND TECHNIQUE

There are two main objectives when performing flight tests: to show compliance against applicable certification regulations and to validate other requirements outside the ones specified on the regulation (for example, performance requirements established by a client). As regulations and user requirements tend to be more demanding in order to increase safety and performance, so does the amount of data collected during flight tests. In addition, the number of digital aircraft systems is increasing; this eases data collection and storage during testing. For aircraft control systems, the use of fly-by-wire technology allows for the collection of displacements and forces applied on the flight stick/yoke.

Stability and control flight tests are usually performed during the initial type certification process. In this scenario, there is no data on the aircraft's behavior other than simulations and ground tests results. For the first test flight, the aircraft is heavily equipped with sensors and data concentrators for data collection. This equipment is referred to as Flight Test Instrumentation (FTIs) and is easily identified by orange paint. However, there are other scenarios where flight stability is tested in flight in aircraft with an approved Type Certificate; this is the case of Supplemental Type Certificates (STC) changes that involve a significant modification in aerodynamics or in the centering of the aircraft, for example when installing a heavy camera on a rotorcraft or an additional external fuel tank on a fighter.

As stated before, in a fly-by-wire system, the displacement and force applied on the flight controls are directly extracted from the control system computer (which must have been tested on the ground before). In aircraft with analog flight controls, a force gauge is usually installed on the control stick mechanism. The displacement of the flight control surfaces is also recorded and monitored with the aid of digital servos and displacement sensors.

Figure 1. Flight stick force transmitters

All the collected data is concentrated and stored in Flight Data Concentrators. These computers are highly customizable to store the data in different protocols. They usually feature additional connections to ease data extraction on the ground.

Figure 2. Flight Data Concentrator by Safran

Being able to store the data collected during flight is not enough for the complexity of today's systems. A flight test engineer usually sits on a console in the cabin where all the data is displayed for a quick analysis. Also, telemetry methods are often used to transmit the collected data in real time to a ground station. On the ground, a group of engineers analyses the data and can use it to provide feedback to the test pilots and Flight Test Engineers (FTE). This feedback can be used to maintain safety during testing, improve the validity of the collected data, and even tune the configuration of some systems. This is often used during the testing of fly-by-wire systems to adjust the gain of the control system.

Figure 3. FTE at console

Chapter 3. NOVELTIES OF THIS PROJECT

The main novelty of this project is to perform flight tests in an amateur-built aircraft in order to study the longitudinal stability and control system of this ultra-light aircraft. The main handicap is the lack of advanced flight test instrumentation. The aircraft control and indicating system is fully analogic and does not feature any data that can be extracted without installing external sensors, which is also not an option due to the weight limitations and structure of the aircraft. Therefore, tests must be designed with these restrictions in mind and the objective to obtain accurate results. Moreover, this project also aims to evaluate the amount of data that can be obtained through flight tests with a low budget.

With the said restrictions, the following instruments are used to obtain data:

- Pull dynamometer: A Commercial Off The Self (COTS) pull dynamometer with an ergonomic handle is used. It can measure in kgf and lbf. The used model is the Meilen Digital Luggage Scale, with a maximum capacity of 50 kgf (110 lbf) with an accuracy of ±0.001 Kg.
- Stopwatch / Timer: Regular chronometer. Model XSD-808 from Yuehyourt is used for these tests. The chronometer provides data with millisecond precision
- Digital Accelerometer: The internal accelerometer of a Portable Electronic Device (PED) equipped with Android or IOS software. The *Physics Toolbox* app must be installed to record data. The range and precision of the accelerometers vary depending on the hardware model used. Most devices can read values between ±10 g's with a precision of ±0.1 g's; these values are used in the data analysis.
- Cockpit camera: Used to aid evaluation of the tests on the ground. A GoPro Hero with a wide-angle lens is used for the test.

Figure 4. Flight Test Instruments Used

Chapter 4. TECHNICAL DESCRIPTION

4.1 Test Aircraft & Configuration

The following aircraft will be used for all tests covered in this project.

- **Manufacturer**: Skyranger
- **Model:** Skyranger Nynja
- **Registration:** EC-GV4

Figure 5. Test aircraft

The Skyranger Nynja is registered as an ultralight aircraft (ULM) under the Spanish aviation safety authority, AESA. These types of aircraft are not considered EASA-registered and, therefore, do not fully comply with the regulations applicable to their weight class, such as CS-23 or CS-ACNS standards.

To be classified as an ultralight by AESA, an aircraft must meet specific limitations. Some of the main restrictions for ULM aircraft include:

- The aircraft has a maximum capacity of 2 individuals (pilot+passenger or pilot+copilot).
- MTOW is limited to 600 Kg
- Stall speed in landing configuration must be below or equal to 45 kts (83,34 km/h).
- ULMs are not allowed to fly in controlled airspace or above 10 000 ft AMSL
- ULMs must always fly during daylight in VMC.
- All limitations regarding ULMs can be found here: https://www.seguridadaerea.gob.es/en/ambitos/aviacion-general/aeronaves-de-estructura-ultraligera-ulm

The structure of the Skyranger Nynja is based on aluminum tubing, with the fuselage primarily composed of durable Dacron fabric. Certain components, such as the empennage, central wing section, and engine cowling, are reinforced with fiberglass panels. This configuration results in a lightweight yet strong structure.

The Skyranger Nynja is a high-wing aircraft with a wingspan of 9.5 meters and features a conventionally shaped empennage. The standard configuration includes a tricycle landing gear conformed by chromium-molybdenum steel.

Figure 6. Skyranger Nynja structure

The aircraft is powered by a Rotax 912UL engine, which produces 80 horsepower and drives a three-blade fixed-pitch propeller. This carbureted engine does not feature an electronic or fuel injection system. It uses a dry-sump oil system for lubrication and cylinder cooling, supplemented by an additional water-cooling system.

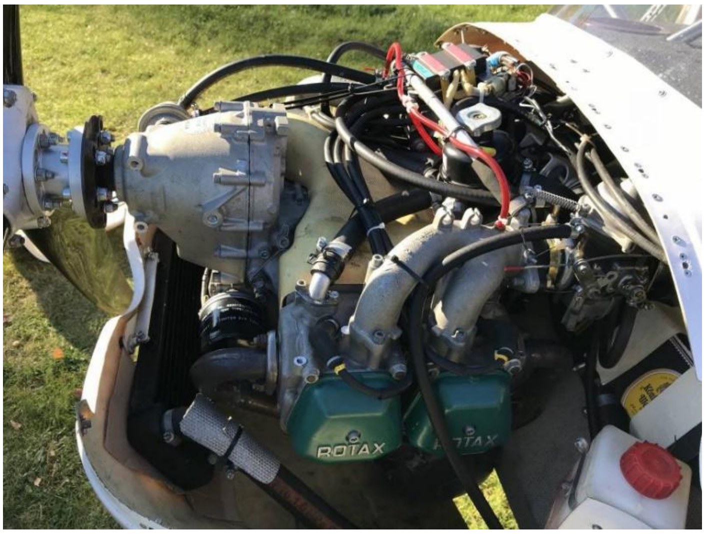

Figure 7. Rotax 912UL engine on Skyranger Nynja

In ULM aircraft, the complexity of the avionics system can vary significantly between user preferences. In the simplest configurations, only the following instruments are required:

- Flight instruments: Anemometer, altimeter, vertical speed indicator, turn & slip.
- Navigation: Compass
- Communication: One VHF AM Radio
- Engine Indications: Tachometer, Oil Press., Oil Temp. & Fuel Press.

However, other users prefer to install multiple navigation and communication systems for integrity and convenience during flight. For the scope of this project, the simplest configuration is used.

Figure 8. Skyranger Nynja Cockpit

The following table summarizes the aircraft's main characteristics and performance parameters

Table 1. Skyranger Nynja main characteristics

Parameter	**Value**
Weights	
OEW	135 Kg
MTOW	450 Kg
MLW	450 Kg
MTOW/Maximum Thrust	6.92 Kg / hp
Wing	
Wingspan	9.5 m
Wing Surface	13.75 m^2
Chord (root)	1.65m
Chord (tip)	1.35m
Maximum wing load	32.75 kg / m^2
Engine	
Type	Four-stroke piston
Cooling	Oil aided by water
Carburetors	2
Maximum power	100 hp
Torque	128 N·m
Maximum RPM	5800

4.2 Flight Stability & Control

To understand flight stability and its relationship with an aircraft's control system, it is essential to introduce the concepts of flying and handling qualities. As (Cook, 2012) states, "the flying and handling qualities of an aircraft are those qualities which describe the ease and effectiveness with which it responds to pilot commands in the execution of a flight task." While some authors use "flying qualities" and "handling qualities" interchangeably, Cook distinguishes between the two, allowing for independent study of each concept.

According to Cook, "the flying qualities may be regarded as being task-related, whereas the handling qualities may be regarded as being response-related." This distinction clarifies that flying qualities pertain to how easy it is for the pilot to perform a task, whereas handling qualities focus on how the aircraft responds to pilot inputs.

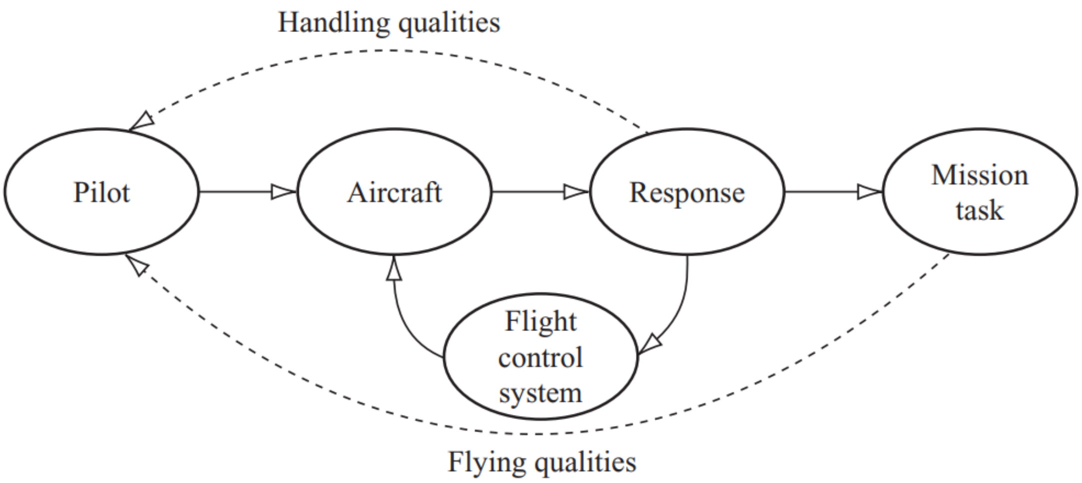

Figure 9. Conventional aircraft flight control and stability

4.2.1 Longitudinal Stability & Control

The longitudinal plane of a fixed-wing aircraft is also known as the plane of symmetry, as it is a vertical plane that divides the aircraft from nose to tail into two symmetrical halves and contains components of motion along the X and Z axes and moments on the Y axis. Movement of the aircraft along this plane is called **pitch** and is primarily controlled by the deflection of the elevators, located on the horizontal stabilizer, in conventional aircraft.

In propeller-driven aircraft with reciprocating engines, both the propeller pitch and RPM (which directly correlates with engine power) also influence longitudinal stability.

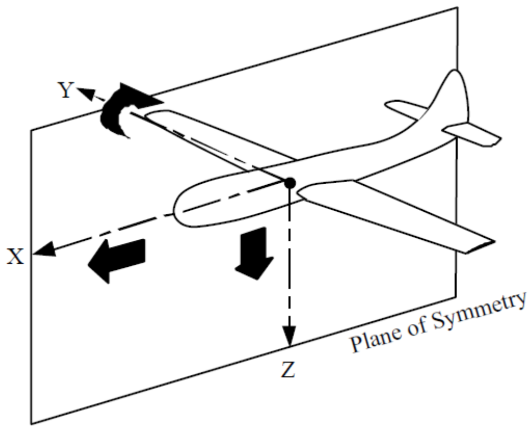

Figure 10. Longitudinal motion and plane of symmetry

It is important to note that longitudinal motion can be considered approximately independent from the motion caused on the lateral and directional planes, and therefore, it is often studied separately. Even though this is not completely true, the effects of longitudinal control on the latero-directional motions, and vice versa, are in most maneuvers insignificant.

The study of longitudinal handling qualities must be performed for the static response and the dynamic response of longitudinal stability.

- Static stability is interpreted as the ability of the aircraft to converge to the initial equilibrium after suffering a small disturbance. They are measured from an equilibrium condition.

- Dynamic stability describes the behavior of the aircraft on the transient motion involved in the process of recovering the equilibrium.

The following image is used to depict the difference between static and dynamic stability.

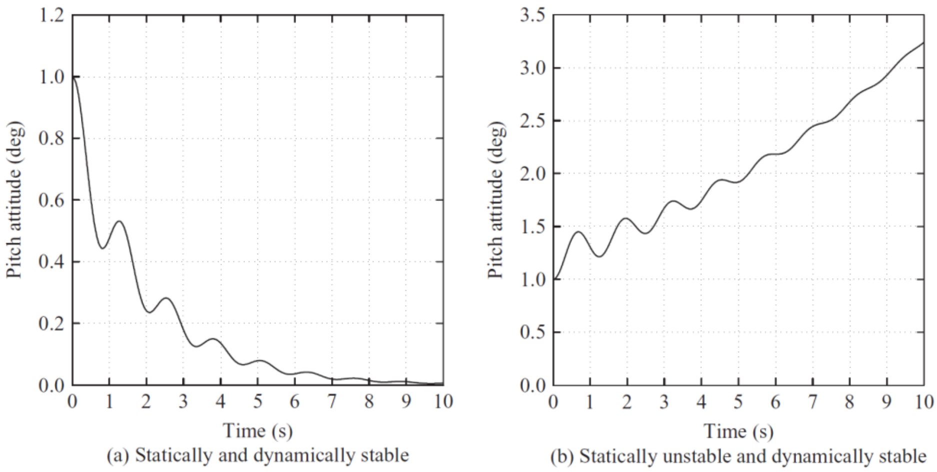

Figure 11. Reference to Figure 3.1 from (Cook, 2012)

In Figure (a), a sudden change in pitch is introduced at the beginning of the motion. Over time, the pitch variation decreases, indicating that the system is **statically stable**. Additionally, the pitch oscillations occur at regular intervals and gradually diminish until they completely fade out, demonstrating **positive dynamic stability** as the oscillations are damped over time. This behavior is desirable as it suggests the aircraft will naturally return to equilibrium following minor disturbances without requiring continuous pilot intervention.

In Figure (b), the pitch variation increases over time, indicating **static instability** in the system. However, the periodic motion still shows a damped response, which suggests **positive dynamic stability**. This behavior is undesirable and potentially dangerous, as the aircraft's attitude will diverge after minor disturbances unless the pilot applies constant corrective inputs to maintain stability.

4.2.1.1 Longitudinal Static Stability

One of the first things that must be studied is the behavior of the air pitch and the pitching momentum in relationship with the stick displacement and the amount of force required for that displacement. The variation of the pitching moments about the aircraft center of gravity with lift coefficient is the principal measure of the static longitudinal stability.

Multiple factors affect the pitching moment of an aircraft in an equilibrium condition. The wing, horizontal stabilizer, and elevator are the main components that determine the longitudinal stability of the aircraft. The design of this part is crucial as it highly affects stability.

In general, the contribution of the wings, fuselage, nacelles, and other smaller elements (for example, antennas or exterior light) negatively contribute to the static longitudinal stability, which has to be overcome by the horizontal stabilizer and elevator. The effect of the horizontal stabilizer on the pitching moment can be adjusted by modifying the aerodynamic surface to adjust the lift generated by the tail or by modifying the distance between the tail and the aircraft's center of gravity, which modifies the pitching momentum of the lift force generated by the tail.

Another important thing to consider is the effect of the wing downwash on the tail. Because of this effect, the angle of attack of the tail will not be the same as the wing. In extreme cases, the downwash of the wing can produce the aerodynamic stall of the tail; in this scenario, the pilot has no longitudinal control as there is no airflow over the elevator. This scenario must be avoided at all times in the aircraft design.

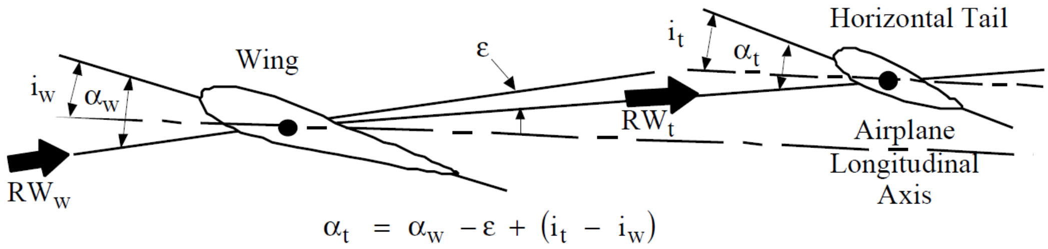

Figure 12. Relationship between airplane wing and tail angle of attack

The following figure represents the relationship between the lift coefficient and the pitching moment coefficient of each aerodynamic part of a conventional aircraft.

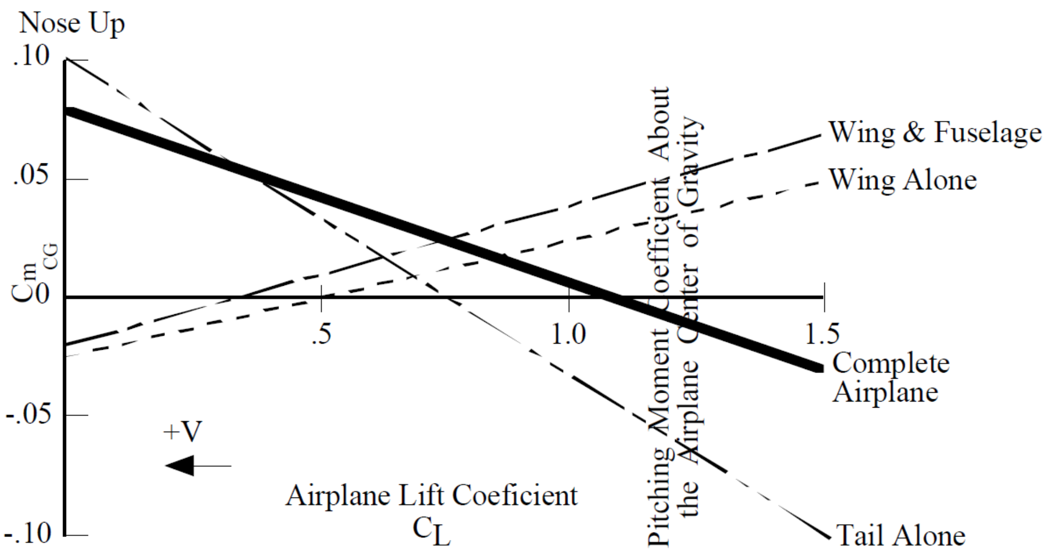

Figure 13. Relationship of aircraft parts to pitching moment vs lift coefficient

As can be overserved in the graph, the wing and fuselage have a negative effect on stability; as the aircraft increases its lift, the nose goes up, which further increases lift, making the aircraft tend to stall. On the other hand, the tail has a negative slope, which positively contributes to the longitudinal stability (As lift increases, the nose goes down to prevent a stall). The distance between the aerodynamic centers of the wing and tail and their respective aerodynamic surfaces must be designed so the final behavior of the aircraft has positive static stability, as shown in the graph.

Also, the distance between the aircraft's center of gravity and the aerodynamic centers of both the tail and wing has an impact on longitudinal stability. For this reason, the CG of the aircraft is limited in the Flight Manual. The aircraft under study does not have many configurations, and the amount of fuel loaded does not have a significant impact on the displacement of the CG. For this reason, the impact of the aircraft's CG on longitudinal stability and control is not considered.

In the previous figure, there is only one lift coefficient value corresponding to a zero-pitching moment (equilibrium). If the pilot wishes to fly at a different lift coefficient while maintaining longitudinal stability, there must be mechanisms in place to counteract variations in the pitching moment, which depend on the slope. It is important to note that the relationship between the slope of the pitching moment and the lift coefficient determines the system's stability. Therefore, the greater the stability of an aircraft, the larger the variations in pitching moments as the lift coefficient changes. To maintain longitudinal control, the pilot must have the means to compensate for or produce these variations in the pitching angle. The equilibrium equation of static longitudinal stability can be used to determine the different variables that affect the zero-pitching moment.

$$C_{m_{CG}} = C_{m_{ac}} + \frac{X_a}{\bar{c}} C_L + C_{m_{CG_{Fuselage}}} - a_t \alpha_t \eta_t \bar{V}$$

The following variables can be used to change the lift coefficient at the zero-pitching moment:

- C_{mac}: The wing pitching moment at the aerodynamic center depends the wing camber and the aerodynamic twist of the wing. This moment can be changed by modifying the wing aerodynamics using a flap at the trailing edge. Even through using a flap like system to control the longitudinal stability might help, the size of the flap required to maintain longitudinal control of conventional aircraft makes this option not feasible in most aircrafts.

- X_a / c: This term only depends on the CG position. Performing shifts of the CG mid-flight to control the pitch angle is not feasible with the current technology.

- α_t: The tail angle of attack is the most common term used to provide longitudinal control of an aircraft. This can be performed my moving the entire horizontal stabilizer (slab tail) or by providing a movable section of the stabilizer (elevator). For the aircraft under study, the elevator configuration is used.

The effects of the elevator deflection can be observed in the following graph.

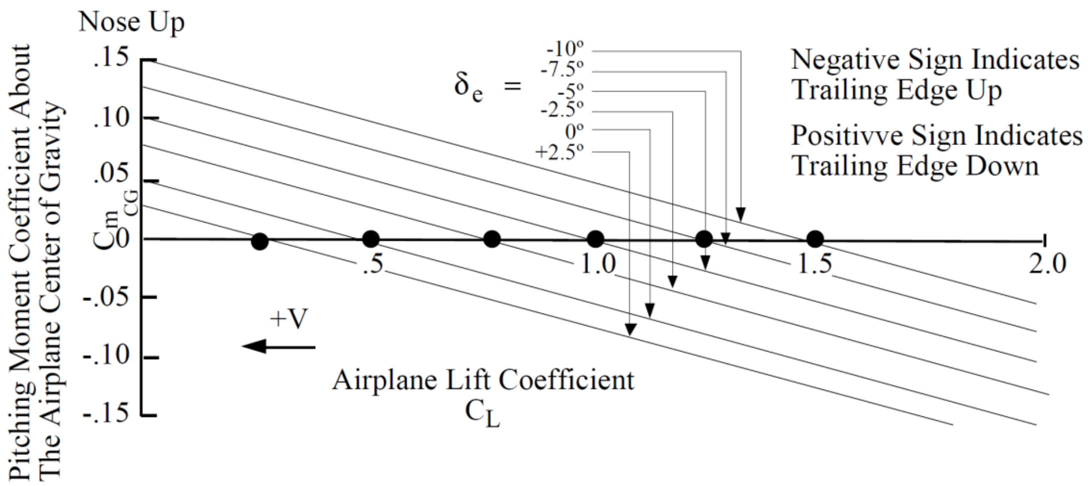

Figure 14. Influence of elevator deflection on the equilibrium of the pitching moment.

In the previous calculations, power effects of the aircraft have not been considered to simplify the calculations. However, power effects have an impact on longitudinal stability, especially in propeller-driven aircraft.

First, there is a direct effect created by the aerodynamic force generated by the propeller. This force can be divided into a thrust and a normal force. Thrust provides traction to the aircraft in the direction of flight, and the normal force is perpendicular to thrust and is generated because the air flow is never completely perpendicular to the propeller. Both the thrust and normal force provide a momentum at the aircraft's CG proportional to the distance between the propeller and the CG and the magnitude of each force itself. If the propeller is positioned ahead and below the CG, it negatively contributes to aircraft stability.

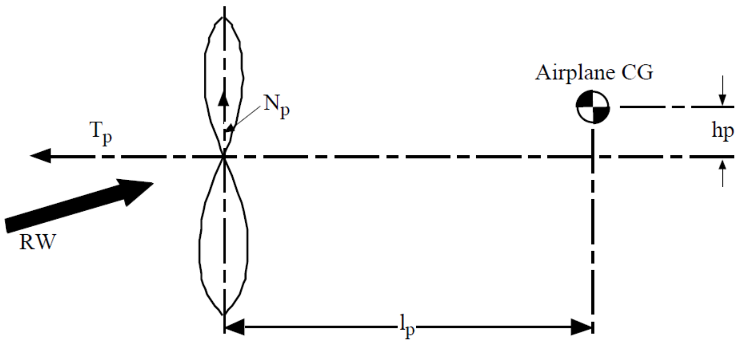

Figure 15. Momentum of propeller forces

In addition to the effects of the forces generated on the propeller, there are also indirect effects that can be generated by the propeller:

- Effect of the propeller airflow on the wing, horizontal stabilizer, and fuselage
- Effect of increased dynamic pressure on the aircraft tail.

The contribution of indirect propeller effects to longitudinal stability is hard to determine. For conventional aircraft (propeller ahead of the cockpit) the sum of direct and indirect effects is destabilizing.

4.2.1.2 Longitudinal Dynamics

The definition of the equations of motion for an aircraft is a complex process beyond the scope of this thesis. Therefore, simplifications will be used to quantify the motion of the aircraft in the longitudinal plane using the data acquired during the flight test. The longitudinal response to the elevator deflection when there is no variation in thrust can be expressed as:

$$\begin{bmatrix} \dot{u} \\ \dot{w} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} x_u & x_w & x_q & x_\theta \\ z_u & z_w & z_q & z_\theta \\ m_u & m_w & m_q & m_\theta \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} u \\ w \\ q \\ \theta \end{bmatrix} + \begin{bmatrix} x_\eta \\ z_\eta \\ m_\eta \\ 0 \end{bmatrix} \eta$$

Where:

u	Axial velocity [m/s]
w	Normal velocity [m/s]
q	Pitch rate [rad/s]
θ	Pitch angle [rad]
x	Longitudinal force in axis system denoted by sub index
z	Normal force in axis system denoted by sub index
m	pitching moment
η	Elevator deflection [rad]

The longitudinal characteristic polynomial for a classic aircraft is fourth order, which is commonly factorized into two pairs of complex roots:

$$\left(s^2 + 2\zeta_p\omega_p s + \omega_p^2\right)\left(s^2 + 2\zeta_s\omega_s s + \omega_s^2\right) = 0$$

Where:

ζ_p	Phugoid damping ratio
ω_p	Phugoid undamped natural frequency
ζ_s	Short period longitudinal oscillation damping ratio
ω_s	Short period longitudinal oscillation natural frequency

Each of these roots can be studied as a second order system and linked to the dynamic response of the aircraft. This system can then be drawn with the following approximation:

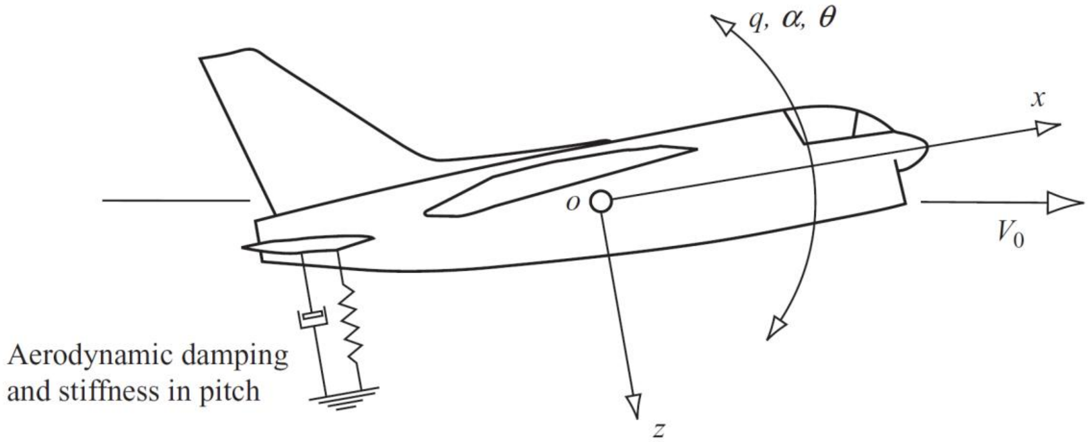

Figure 16. Diagram of the longitudinal dynamics studied as a mechanical problem

Each of these roots can be studied as a second order system and linked to the dynamic response of the aircraft. This system can then be drawn with the following approximation:

1. Short period pitching oscillation
2. Phugoid motion

<u>Short period pitching oscillation</u>

The short period pitching oscillation is the dynamic motion of the aircraft where the trajectory of the aircraft is a straight line (therefore having no loss or gain in altitude), however, the aircraft pitch still performs oscillations of small value. This dynamic is often compared to the movement of a ship.

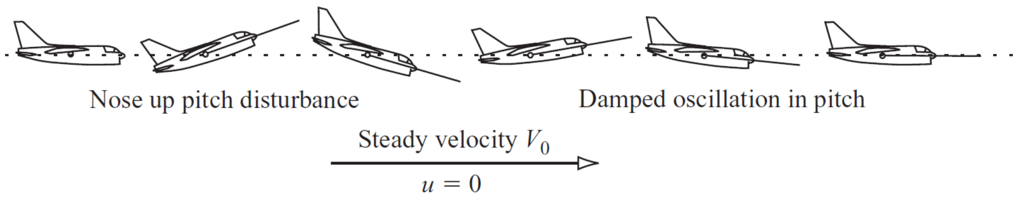

Figure 17. Stable short period pitching oscillation

In the transport category aircraft, this movement is usually very damped as it can impact on the passenger comfort. However, in smaller aircraft and aircraft that are more maneuverable, this motion shall be studied to ensure that it is still a damped oscillation.

According to (U.S. NAVAL TEST PILOT SCHOOL, 1997), the determinant of the longitudinal equation of motion for small disturbances can be written as:

$$\begin{vmatrix} s + D_u & D_\alpha - g & g \\ \dfrac{L_u}{u_0} & s + \dfrac{L_\propto}{u_0} & -s \\ -M_u & -M_{\dot{\propto}}s - M_\propto & s^2 - M_{\dot{\theta}}s \end{vmatrix} = 0$$

Where:

u	Horizontal velocity
g	acceleration due to gravity
D_u	change in drag with change in horizontal velocity divided by the mass of the airplane.
D_α	change in drag with change in angle of attack divided by the mass of the airplane.
L_u	change in lift with change in horizontal velocity divided by the mass of the airplane.
L_α	change in lift with change in angle of attack divided by the mass of the airplane.
M_u	change in pitching moment with horizontal velocity divided by the moment of inertia in pitch, a speed stability term.
M_α	change in pitching moment with angle of attack divided by the moment of inertia in pitch, an angle of attack stability term.

The previous equation can be simplified by making the following assumptions that apply to the short period pitching oscillation motion

- Airspeed is constant throughout the entire motion. Therefore, the derivates depending on parameter "u" are approximated to zero.

- Drag variation is not significant enough to influence the short period of motion
- Low Mach number; no compressibility effects are considered.

The equation can then be simplified to:

$$\begin{vmatrix} s+\frac{L_{\propto}}{u_0} & -1 \\ -M_{\dot{\propto}}s-M_{\propto} & s-M_{\dot{\theta}} \end{vmatrix} = s^2+\left(\frac{L_{\propto}}{u_0}-M_{\dot{\theta}}-M_{\dot{\propto}}\right)s-(M_{\propto}+\frac{L_{\propto}}{u_0}M_{\dot{\theta}})=0$$

The damping ratio and natural frequency of this motion can be calculated from this equation using the equations that define a second order system response to an impulse:

$$s^2+(2\zeta\omega_n)s+\ \omega_n^2=0$$

Therefore:

$$\omega_{nsp}=\sqrt{\frac{{}^{1}/{}_{2}\,P_aM^2}{I_{yy}}S\bar{c}C_{L\alpha}(\frac{x_{CG}}{\bar{c}}-N_M)}$$

$$\zeta_{sp}=\frac{\sqrt{\frac{\rho S}{2}}}{2\sqrt{-\frac{\bar{c}}{I_{yy}}C_L\left(\frac{X_{CG}}{\bar{c}}-N_M\right)}}(\frac{C_{L\alpha}}{{}^{W}/{}_{g}}-\frac{C_{m\dot{\theta}}\cdot\bar{c}^2}{2I_{yy}}-\frac{C_{m\dot{\alpha}}\cdot\bar{c}^2}{2I_{yy}})$$

The following conclusions can be extrapolated from these equations:

1. Increasing the lift curve slope, the pitch rate damping will increase the damping of the short period motion.
2. Increasing the angle of attack stability decreases the short period damping.
3. Moving the CG forward decreases the short period damping
4. Damping the short period mode of motion is not a direct function of the airspeed or Mach number.

The accuracy and amount of data that can be acquired with the instruments managed in this thesis studies and timeframe, is not sufficient in principle, to perform a quantitative evaluation of the short period motion; therefore, all evaluations of the short period pitching oscillation will be qualitative.

Phugoid motion

The phugoid is an oscillatory motion in which the aircraft's kinetic and potential energy are interchanged. As the aircraft pitch and altitude decrease, the speed increases. As the speed increases, so does the lift, reducing the variation in altitude and increasing the pitch again. Aircraft must be designed so the amplitude of the oscillation is reduced on each iteration, making the longitudinal dynamic and stable system.

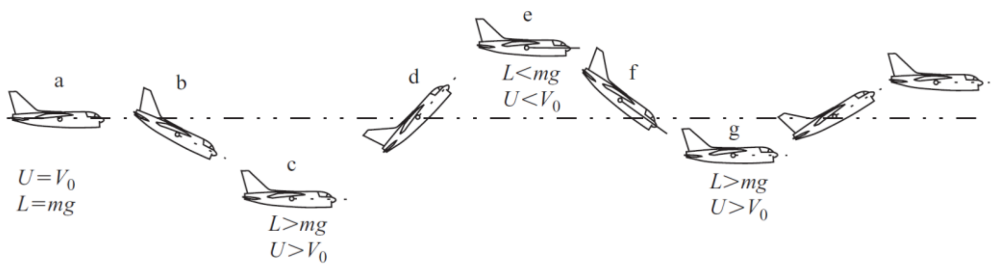

Figure 18. Development of a stable phugoid

The equation of the longitudinal dynamics can be simplified to study the phugoid motion.

$$\begin{vmatrix} s+D_u & D_\alpha - g & g \\ \dfrac{L_u}{u_0} & s+\dfrac{L_\propto}{u_0} & -s \\ -M_u & -M_{\dot{\propto}}s - M_\propto & s^2 - M_{\dot{\theta}}s \end{vmatrix} = 0$$

The previous equation can be simplified by making the following assumptions that are applicable to the phugoid motion

- The angle of attack stability (M_α) is large enough, so very small variations in the angle of attack are performed during the phugoid motion. This implies that the M_u is quite small.
- No compressibility effects are taken into account as the variation in height is not significant enough.

$$\begin{vmatrix} s+D_u & g \\ \dfrac{L_u}{u_0} & -s \end{vmatrix} = s^2 + D_u \cdot s + g \cdot \frac{L_u}{u_0} = 0$$

The damping ratio and natural frequency of this motion can be calculated from this equation using the equations that define a second order system response to an impulse:

$$s^2 + (2\zeta\omega_n)s + \omega_n^2 = 0$$

Therefore, the natural frequency and the period of oscillation are obtained:

$$\omega_{np} = \sqrt{2}\frac{g}{u_0}$$

$$\zeta_p = \frac{1}{\sqrt{2}}\frac{C_D}{C_L}$$

Thus, simplifying, the period of the oscillation can be calculated form the natural frequency.

$$T_p = 0.138 \cdot u_0$$

And as the period of the phugoid oscillation is only dependent on the aircraft horizontal velocity, the damping ratio can be approximated as:

$$\zeta_p = \frac{0.707}{L/D}$$

These approximations are used for the determination of the natural frequency and the damping ratio based on the flight test results.

4.2.2 Skyranger Nynja Longitudinal Control System

The Skyranger Nynja has a reversible longitudinal control system. The system is extremely simple as the control stick is connected to the elevator using cables. There are two additional elements in the mechanical cable of the system. A pulley system is used to orient the force direction of the cable section connected to the flight stick. Additionally, there is a spring located in the cable section between the pulley and the elevator. The spring is characterized as a constant gain element "K_x". The pulley adds slight friction to the system, but its effects are not characterized.

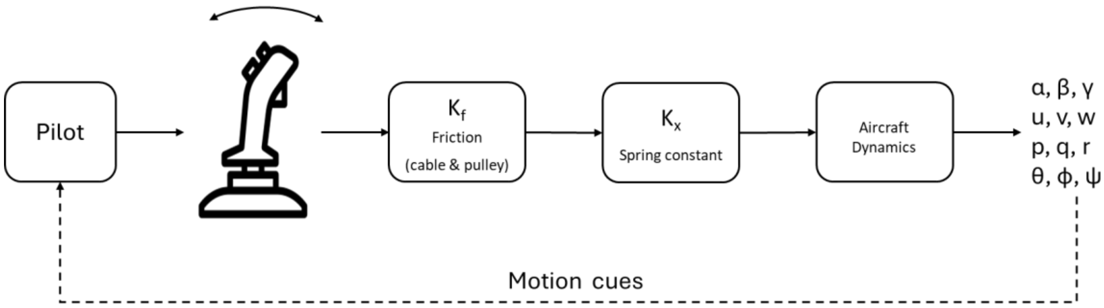

Figure 19. Longitudinal control system block diagram

Some images of the Skyranger Nynja control system are attached:

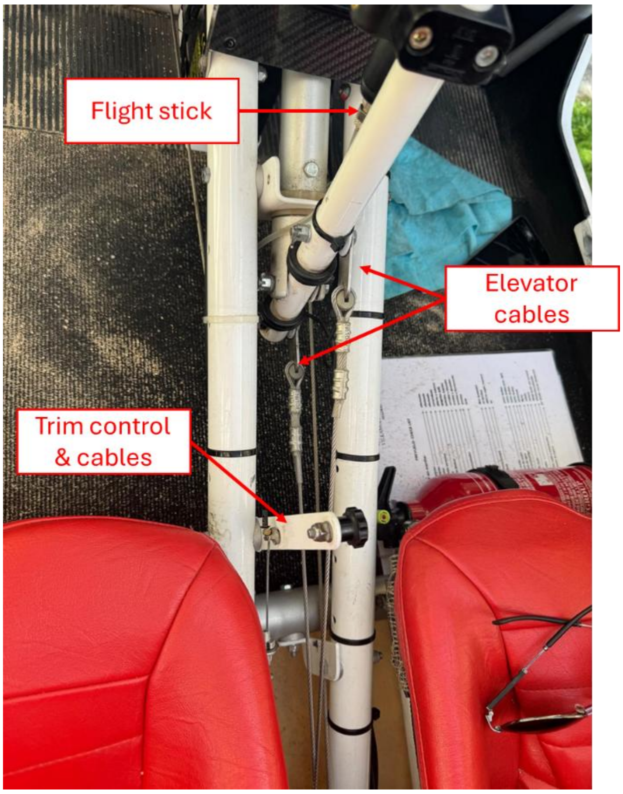

Figure 20. Skyranger Longitudinal Control Elements in the Cockpit

Figure 21. Skyranger Nynja Control System Pulleys

Figure 22. Skyranger Nynja Empenage

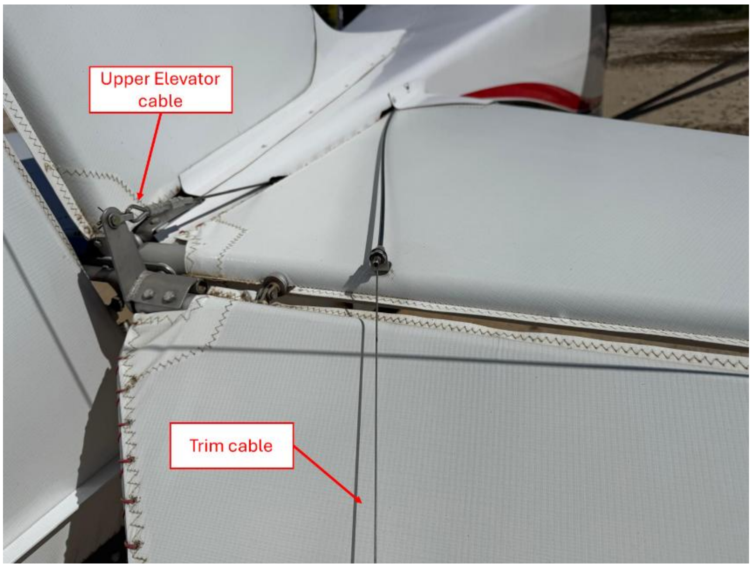

Figure 23. Elevator & Trim Cable Detail

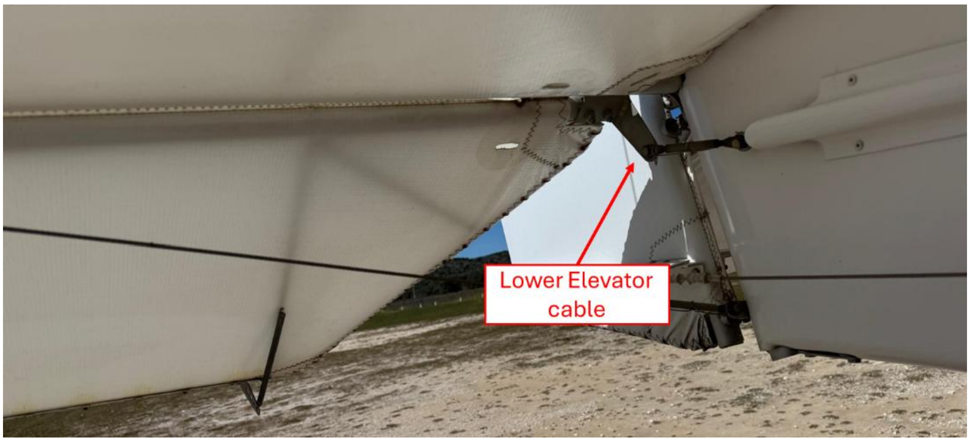

Figure 24. Lower Elevator Cable Detail

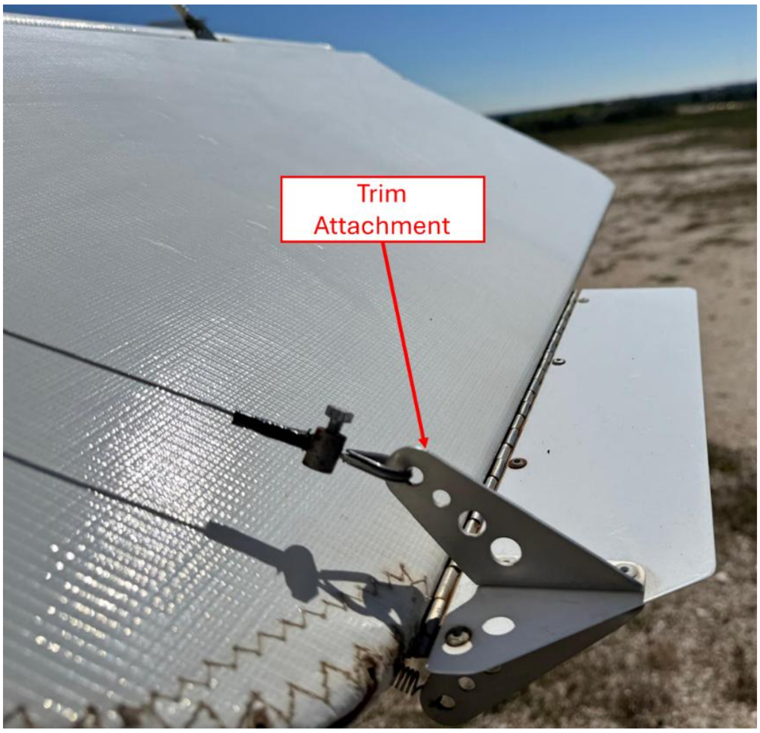

Figure 25. Trim Attachment Point

Chapter 5. FLIGHT TEST TECHNIQUES

5.1 Non-Maneuvering Tasks – Mechanical Characteristics of Longitudinal Control

The definitions of (U.S. NAVAL TEST PILOT SCHOOL, 1997) are used for the following mechanical characteristics of the control system.

5.1.1 Breakout Forces

It is defined as the force applied on the stick required to initiate movement of the longitudinal control surface.

It is measured using a portable dynamometer on the tip of the stick. One person will begin to apply force on the stick slowly while another observer on the outside communicates when the elevator begins to move.

5.1.2 Friction

It is defined as the forces in the longitudinal control system resisting the pilot's effort to change the control position. Friction on the control surface is unavoidable, but it is minimized as much as possible when designing a control system.

It is measured using a portable dynamometer on the tip of the stick. One person will begin to apply force slowly on the stick. Force is applied until the elevator reaches its maximum deflection (±25º) while another observer on the outside communicates when the elevator reaches certain angles. The movement through the whole deflection should be smooth and continuous.

5.1.3 Freeplay

It is defined as the displacement of the stick that does not initiate movement of the longitudinal control surface. Having a lot of freeplay will make precise maneuvering of the aircraft difficult, as large pilot inputs must be performed for small variations of the control surface. This parameter can be measured on the ground with a measuring tape. This parameter should be as low as possible, yet a displacement below 2mm can be considered acceptable.

It is measured using a measuring tape. One person will begin to move the stick slowly while another observer on the outside communicates when the elevator begins to move.

5.1.4 Centering

It is the ability of the stick to return to and maintain the original position when released from any other position.

It is measured by moving the stick to different positions and suddenly releasing it.

5.2 Non-maneuvering Tasks - Static Longitudinal Control Force Stability

5.2.1 Slow Acceleration Technique

This method consists of measuring the variation of vertical speed and stick force as the aircraft pitch (and, therefore, airspeed) is varied while maintaining the trim and power. This test is performed with the aircraft in its landing configuration (1-point flaps) and cruise configuration. This test allows us to evaluate if the aircraft has positive static stability. The steps are as follows:

1. Stabilize and trim the aircraft at the desired speed.
2. Record the trim position, RPM, stick position, and fuel quantity
3. Without changing the power and trim settings, vary the airspeed. Record measurements of the airspeed, vertical variation rates, and push/pull force on the stick to maintain the descend/climb rate. At least three points above and below the initial airspeed must be selected.

5.2.2 Stick Rap

This test is used to introduce a step input into the control system. It is used to determine if the air control surfaces are still responsible throughout the airspeed envelope. This test is also used to clear flutter (qualitatively, at least) in some experimental aircraft.

1. Stabilize and trim at different speeds.
2. Once the selected airspeed has been achieved, perform rapid and sudden inputs on the stick in one direction at a time (push, left, pull, and right).
3. Record the aircraft response.

5.3 Non-maneuvering Tasks – Longitudinal Long Period Evaluation

5.3.1 Measuring of Phugoid Characteristics

The objective of this technique is to determine the period and damping ratio of the phugoid motion.

1. Stabilize and trim the aircraft at cruise speed.
2. Pull the stick, without modifying the trim and power, until a speed 15 to 20 KIAS slower than the initial speed
3. Smoothly return the stick to the initial position and release the stick. The phugoid motion shall begin on its own.
4. Record the following parameters at each cycle of the phugoid:
    a. Minimum airspeed (top of the phugoid)
    b. Maximum airspeed (bottom of the phugoid)
    c. Elapsed time at:
        i. Initial airspeed
        ii. Minimum airspeed

iii. Maximum airspeed

<u>CAUTION:</u> Wings must be maintained completely level without introducing longitudinal inputs on the stick. This may be accomplished by rudder inputs and side pressure on the control stick.

Note: Airspeed changes at the top and bottom of the phugoid motion are very slow; it is recommended to monitor pitch attitude at those points to determine when the aircraft is at the peak or valley of the motion.

5.4 Maneuvering tasks – Longitudinal Stability

5.4.1 Steady Pull-Ups

In this case, steady pull-ups are used as a method to determine the stick force per g.

1. Stabilize and trim at the desired condition.
2. Pull on the stick to decelerate and reach a climbing attitude. Then, push the stick to enter a shallow dive at the initial trim altitude. As the speed reaches the initial trim speed, pull on the stick to establish a nose-up pitch rate at the desired normal acceleration.

Airspeed must remain ±5 knots from the initial trim speed during data gathering. Note that as the desired normal acceleration increases, so does the dive and the velocity applied on the stick. In some cases, it might be needed to initiate the final pull at speeds faster than the trim speed.

Altitude should remain within ±2000 ft of the initial altitude. Pitch attitudes over ±15º must be avoided, mainly during data gathering.

5.4.2 Wind-up turns

Wind-up turns are a common stability and control flight test technique, and a large amount of data can be obtained using FTI recording devices; this method is also used to study aircraft behavior during accelerated stalls. In this scenario, basic data is acquired using the digital accelerometer and force gauge. This method is used to obtain maneuvering stability data.

1. Stabilize and trim the aircraft at cruise speed.
2. Record the trim position, RPM, airspeed, and altitude.
3. Introduce the aircraft into a steady turn. Some pull force will be required to maintain airspeed. Record the normal acceleration (g's) and perform a qualitative evaluation of force in this condition.
4. Roll the aircraft back to level flight.
5. Repeat the test for various roll angles. Begin with small roll angles and increase in each iteration without varying airspeed.

5.5 Maneuvering tasks – Longitudinal Transient Dynamics & PIOs

5.5.1 Sinusoidal Stick Pumping

This method is used to qualitatively assess the dynamic response of the aircraft, it is also used to determine the frequencies at which PIOs shall be tested. First, the aircraft is trimmed at a leveled flight. Then, the pilot will continuously alternate pull and push forces on the stick. The amplitude and frequency of the pumping shall be maintained for 20 seconds or until aircraft longitudinal control is lost. Various frequencies and amplitudes are tested. The pumping motion shall be video recorded to determine the pumping frequency on analysis. The pilot should record the maximum and minimum airspeed achieved during pumping.

5.5.2 Maneuvering Task – Pilot Induced Oscillation

The pilot-induced oscillations (PIO) are defined in (U.S. NAVAL TEST PILOT SCHOOL, 1997) as sustained oscillations or instabilities resulting from the pilot being in the control loop. PIO involves a closed loop where the short period mode is driven divergent.

The sinusoidal stick pumping tests provide insight into the approximate frequencies that are likely to induce PIOs. Additional tests are performed to trigger PIOs by forcing the aircraft into a divergent movement:

1. Stabilize and trim the aircraft.
2. Alternate push and pull forces on the stick. The oscillations must be performed with an amplitude around ¼ of the maximum stick range of movement. The stick movement must be performed to counter the natural motion of the aircraft.

Note: The stick movement shall be recorded to determine the PIOs frequencies.

5.6 Maneuvering tasks – Longitudinal Short Period Evaluation

5.6.1 The Doublet

The doublet method is used to determine the short-period characteristics. The doublet consists of producing a deviation in pith in one direction and suddenly canceling it with the opposite output. By doing this, the phugoid response is suppressed, and the short period motion can be appreciated.

3. Stabilize and trim the aircraft.
4. Record the trim position, RPM, airspeed, and altitude
5. Push on the stick with a quick but continuous motion to produce a nose down attitude of a few degrees. Then, reverse the input to a pulling motion until the pitch is returned to the one at the initial trim. Return the stick to its center position and release it. (controls free short period). Airspeed and pitch should be at the trim position or with some oscillations around trim values.
6. Record the procedure. If the oscillations are not too damped, a quantitative approximation of the damping ratio can be obtained. If no oscillations are appreciated, the short period motion is qualitatively considered and essentially deadbeat.

7. Repeat steps 3 & 4, but instead of releasing the stick at the centered position, keep it immobile (controls fixed short period).

Note: The frequency at which the doublet must be applied to obtain the best response depends on the short period frequency. The maximum amplitude output is generated when the doublet input is approximately the same period as the period of the undamped short period oscillation. Use the reference feelings obtained from the sinusoidal stick pumping to determine the best frequency.

Chapter 6. Flight Test Risk Assessment

The goal of this assessment is to identify and analyze all the risks associated with the tests described in Appendix II. Depending on the risk analysis, additional measurements must be carried out during the flight test to enhance safety.

The following general precautions should be maintained during all tests:

- **Briefings:** All flights will be preceded by a pre-flight briefing including the minimum of the Aircraft Captain and the Flight Test Conductor.

- **Weather Conditions:** Visual Meteorological Conditions (VMC) are required for the flight tests. Testing in IMC is prohibited.

- **Test Area familiarization:** Since the test area may differ from those known to the crew, an extensive briefing should be made to ensure good knowledge

- **Pre-flight familiarization:** Familiarization with the test manoeuvres is performed on the aircraft during the pre-flight checks.

Only risks particular to the tests to be performed are analyzed. Other risks inherent to standard operations are not incorporated, as only the incremental risks derived from testing are to be analyzed and, where possible, mitigated during the risk analysis process.

Specific safety preventive / risk mitigation measures are listed in the risk reduction measures for each particular THA case. Applicable hazards shall be reviewed by the pilot and flight test engineer involved before the flights.

6.1 Test Hazard Analysis Definitions

The following definitions for risk analysis are used in this assessment. Definitions are extracted from AC-23.1309-1E (FAA, 2011):

- Probability: the likelihood of an event to happen. A qualitative system is used to classify the hazards based on probability.
  - Frequent: It is likely to happen.
  - Probable: It may happen.
  - Occasional: It is not frequent but sometimes happens.
  - Remote: It is not likely to happen.
  - Improbable: Very rarely happens; it can be assumed that it will not happen.
- Severity: the consequence when an event happens. The consequences are expressed as the impact to the aircraft, crew, the reduction of safety margins, or the increase in workload. A qualitative system is used to classify the hazards based on severity.
  - Catastrophic: Conditions that are expected to result in the loss of any crew member, normally with the loss of the aircraft.
  - Hazardous: Conditions with a significant reduction of safety margins. Physical distress or higher workload such that the flight crew cannot be relied upon to perform their task accurately or completely.
  - Major: Conditions that would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent

that there would be a significant reduction in safety margins or functional capabilities. It produces a significant increase in workload or impairment in flight crew efficiency. It may produce physical injuries to occupants.

- Minor: Conditions that would not significantly reduce airplane safety and involve crew actions that are within their capabilities. Minor failure conditions may include a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, or some physical discomfort to occupants.
- No Safety Effect (NSE): Conditions that would not affect safety.

- Risk: It is the combination of the probability and the severity of a hazard. A quantitative system based on colors is used to determine the risk.

Extreme	Unacceptable risk to the personnel, aircraft, or environment. Tests cannot be performed with severe mitigations to this risk.
Very High	The test with these risks is not recommended. Tests can only be performed under various mitigations and conditions.
High	Significant risk to the personnel and aircraft. A high level of safety margins must be performed during these tests.
Medium	Major risk to the personnel and aircraft compared to normal flight operation. Requires further monitoring during the tests.
Low	There are no additional risks compared to a normal flight operation

- Risk Matrix: This matrix is used to define the relationship between the severity and probability of a hazard to determine the risk level.

Probability	**Severity**				
	Catastrophic	Hazardous	Major	Minor	Non-Safety Effect
Frequent	25	23	19	14	8
Probable	24	22	18	12	7
Occasional	21	20	15	11	5
Remote	17	16	13	6	3
Improbable	10	9	4	2	1

Figure 26. Risk Assessment Matrix

6.2 Test Hazard Analysis

The following hazards related to the tests have been identified and analyzed.

Table 2. Test Hazard No.1

Hazard No.	1	Mid-air collision
Cause		Lack of situational awareness of traffic due to additional workload because of the testing maneuvers.
Effect		Impact against other aircraft. Damage that may cause death and aircraft loss.
Risk (Probability / Severity)		17 (Remote / Catastrophic): High / Medium
Mitigations		a) Tests are performed in VMC conditions b) A visual inspection of surrounding traffic must be performed before commencing a maneuver. c) At the beginning of the tests, a communication announcement of the ongoing tests is performed to alert nearby traffic. d) Tests are performed during non-busy hours of the local airfield to minimize surrounding traffic.
Residual Risk		10 (Improbable / Catastrophic): Medium

Table 3. Test Hazard No.2

Hazard No.	2	Bird impact during flight
Cause		ULM aircraft operate below 10000ft, where bird impact is possible. Sighting of vulture and eagle species is common in the airfield used during tests.
Effect		Significant damage to the aircraft and major injuries to the crew.
Risk (Probability / Severity)		16 (Remote / Hazardous): High / Medium
Mitigations		a) Tests are performed in VMC conditions b) A visual inspection of surrounding birds must be performed before commencing a maneuver. In case a bird is spotted nearby, tests must be concluded immediately. Transitioning to a different test zone may be required. c) Communications before take off will be performed asking for any bird sightings nearby.
Residual Risk		9 (Improbable / Hazardous): Medium / Low

Table 4. Test Hazard No.3

Hazard No.	3	Reduction of altitude below acceptable levels
Cause		Loss of situational awareness of the altitude by the pilot during test, the aircraft does not have safety systems to prevent collisions against terrain.
Effect		Significant reduction of safety margins, increase workload to prevent CFIT
Risk (Probability / Severity)		16 (Remote / Hazardous): High / Medium
Mitigations		a) Tests are performed in VMC conditions. b) A minimum altitude level is defined in the applicable tests. The pilot must monitor this limit so that it is not surpassed at any time. c) The FTE engineer can also stop a test in case a safety margin is reduced below acceptable levels.
Residual Risk		9 (Improbable / Hazardous): Medium / Low

Table 5. Test Hazard No.4

Hazard No.	4	Unexpected stall & spins
Cause		Unexpected divergent behavior in aircraft stability during tests. Loss of aircraft control in one or more axes.
Effect		Significant reduction of safety margins, increase workload to recover aircraft control.
Risk (Probability / Severity)		20 (Occasional / Hazardous): VERY HIGH / High
Mitigations		a) A qualitative evaluation of all maneuvers is performed prior to each test. This qualitative assessment is performed to evaluate aircraft response prior to measurements in less critical conditions. b) A minimum altitude level is defined in the applicable tests. This level is decided during the preflight briefing for each test. This altitude must be high enough so the aircraft can be recovered after a spin or dynamic stall. c) Airspeed limitations are established in applicable tests to avoid stall conditions. A safety margin is used for these limits (Usually 1,1 V_s). d) Recovery maneuvers are reviewed during preflight.
Residual Risk		16 (Remote / Hazardous): High / Medium

Chapter 7. FLIGHT TEST RESULTS SUMMARY

The following table summarizes the test results for Flight Test Card 001 Non-maneuvering longitudinal control measurements:

Table 6. Non-maneuvering longitudinal control test results

Test	Results		
Friction	1.28 Lbf of constant friction through the entire sweep (on the ground)		
Free-play	± 3mm of free-play		
Full Sweep	No noticeable variations in force through the sweep		
Qualitative Evaluation	Positive stability is appreciated in all maneuvers		
Breakout Force with Friction	Pull Breakout	0.12 lbf	
	Push Breakout	0.40 lbf	
Stick Rap	Positive recovery at all speeds. The speed and amplitude of the response vary with airspeed.		
Slow Acceleration (Flaps)	Airspeed [Km/h]	Force [lbf]	Vertical Var. [ft/min]
	80	0.98	300
	90	0.64	200
	100 (Trim)	N/A	0
	110	-0.74	-300
	120	-1.20	-400
Slow Acceleration (Clean)	Airspeed [Km/h]	Force [lbf]	Vertical Var. [ft/min]
	120	1.26	200
	125	0.58	100
	130	0.38	50
	140	N/A	0
	150	-1.36	-250
	160	-1.46	-500
Phugoid	Time [s]	Airspeed [Km/h]	Altitude [ft]
	0	140	3980
	6.98	100	4060
	14.23	140	3980
	19.07	150	3900
	23.64	140	3940
	30.31	125	3980
	36.84	140	3940
	42.08	145	3900
	46.72	140	3920
	54.26	135	3900
	62.02	140	3890

The following table summarizes the test results for Flight Test Card 002 Maneuvering longitudinal control measurements:

Table 7. Maneuvering longitudinal test results

<table>
<tr><th>Test</th><th colspan="6">Results</th></tr>
<tr><td>Qualitative Evaluation</td><td colspan="6">Positive stability is appreciated in all maneuvers</td></tr>
<tr><td rowspan="4">Steady Pull-Ups</td><td colspan="3">Peak Normal Acc.</td><td colspan="3">Force [lbf]</td></tr>
<tr><td colspan="3">1.5</td><td colspan="3">1.48</td></tr>
<tr><td colspan="3">2</td><td colspan="3">2.34</td></tr>
<tr><td colspan="3">2.5</td><td colspan="3">3.81</td></tr>
<tr><td rowspan="5">Wind Up Turns</td><td colspan="2">Bank Angle [º]</td><td colspan="2">Normal Acc.</td><td colspan="2">Force [lbf]</td></tr>
<tr><td colspan="2">≈30</td><td colspan="2">1.24</td><td colspan="2">0.92</td></tr>
<tr><td colspan="2">≈40</td><td colspan="2">1.35</td><td colspan="2">1.26</td></tr>
<tr><td colspan="2">≈50</td><td colspan="2">1.43</td><td colspan="2">2.80</td></tr>
<tr><td colspan="2">≈60</td><td colspan="2">1.51</td><td colspan="2">3.02</td></tr>
<tr><td>Sinusoidal Stick Pumping</td><td colspan="6">No aircraft control loss at any of the frequencies and amplitudes. As expected, as amplitude increases and period shortens, the variation in acceleration is more significant, which affects flight comfort.</td></tr>
<tr><td rowspan="2">Doublet</td><td colspan="3">Controls-free</td><td colspan="3">A slight short-period response could be appreciated. The response was too dampened to be measured</td></tr>
<tr><td colspan="3">Controls-fixed</td><td colspan="3">No short-period response appreciated</td></tr>
<tr><td>Pilot Induced Oscillations</td><td colspan="6">No pilot-induced oscillations could be achieved</td></tr>
</table>

Chapter 8. FLIGHT TEST DATA ANALYSIS

8.1 Mechanical Characteristics of the Control System

A full sweep of the longitudinal control is performed to evaluate the stick position in relation to the elevator deflection.

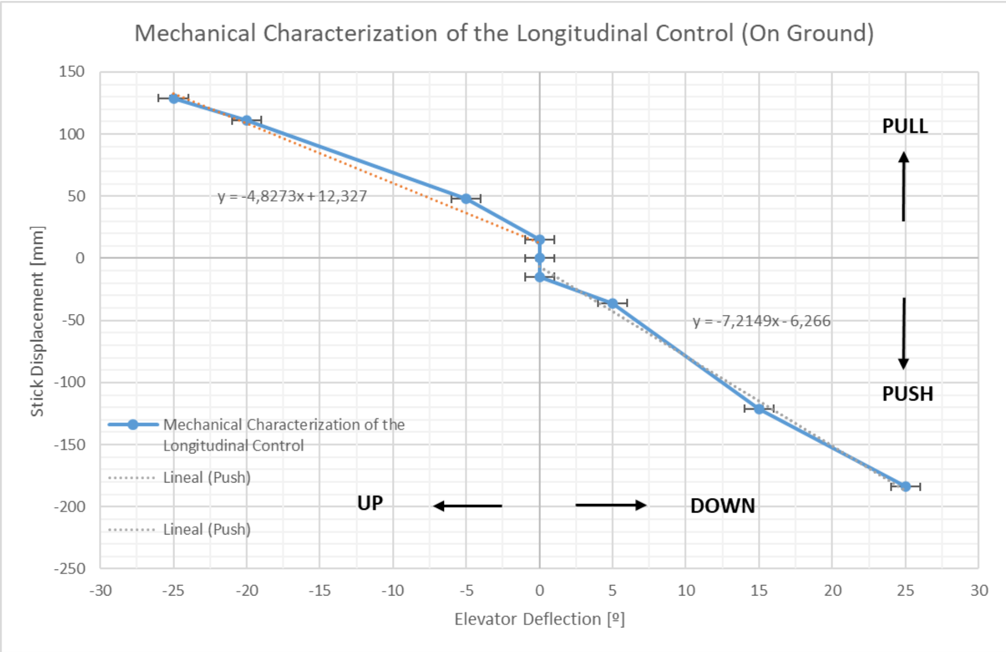

Figure 27. Mechanical characterization of the longitudinal control

There is a linear relationship between the stick position and the elevator deflection. However, it can be appreciated that the slope of the graph is more significant in the pushing motion than in the pulling motion, meaning that the linear relationship is not symmetrical. This slight asymmetric is likely to compensate for the weight of the elevator during flight.

Overall, the asymmetry is considered within the normal range, and the linear relationship is expected in a reversible control system. The relationship between the elevator deflection and the control displacement is considered ACCEPTABLE.

8.1.1 Friction (On Ground)

The recorded friction value is 1.28 lbf. This value is inside expected values according to USNTPS-FTM No.103 (U.S. NAVAL TEST PILOT SCHOOL, 1997), which establishes a maximum value for friction of ±1.5 lbf. This friction value is measured on the ground, which includes the elevator weight; for that reason, the recorded friction value is larger than the breakout force, including friction measured during flight. For this reason, the recorded friction is deemed INCONCLUSIVE.

8.1.2 Freeplay (On Ground)

As shown in Figure 27, the measured freeplay of the longitudinal control is 3 mm. This amount of freeplay is considered ACCEPTABLE. It is large enough to prevent undesired inputs while holding the control due to aircraft vibrations and small enough to allow for minor corrections without the need to perform ample hand movements.

8.1.3 Breakout (with friction)

The breakout, including friction, is 0.12 lbf for pulling forces and 0.40 lbf for pushing forces. These values are inside the expected values (±3 lbf) according to USNTPS-FTM No.103 (U.S. NAVAL TEST PILOT SCHOOL, 1997) and, therefore, considered ACCEPTABLE.

The breakout force in the aircraft is asymmetrical. The pulling breakout force with friction is too low, making it impossible for the pilot to rest its hand while holding the control stick without introducing inadvertent control inputs. For this reason, during normal operation, the aircraft is usually trimmed with a slight nose-down attitude.

8.1.4 Centering

ACCEPTABLE centering is observed throughout various tests. The control returns to the neutral position.

8.2 Static Longitudinal Control Stability in Unaccelerated Flight

Two tests are performed to study the static longitudinal stability in unaccelerated flight. The slow acceleration technique is used to provide quantitative measurements of the stability. In addition, the stick raps are used to evaluate the aircraft response to a step input by a qualitative analysis. The results of both tests lead to the conclusion that the aircraft presents **positive static stability** in the longitudinal axis in unaccelerated flight maneuvers.

8.2.1 Slow Acceleration

The static longitudinal stability is mainly measured with the slow acceleration technique. The relationship between the airspeed and the control force on the stick must be linear, and the force shall increase proportionally to the deviation of the airspeed from the trim speed. Tests have been performed in the landing configuration (1 point flap) and in the cruise configuration.

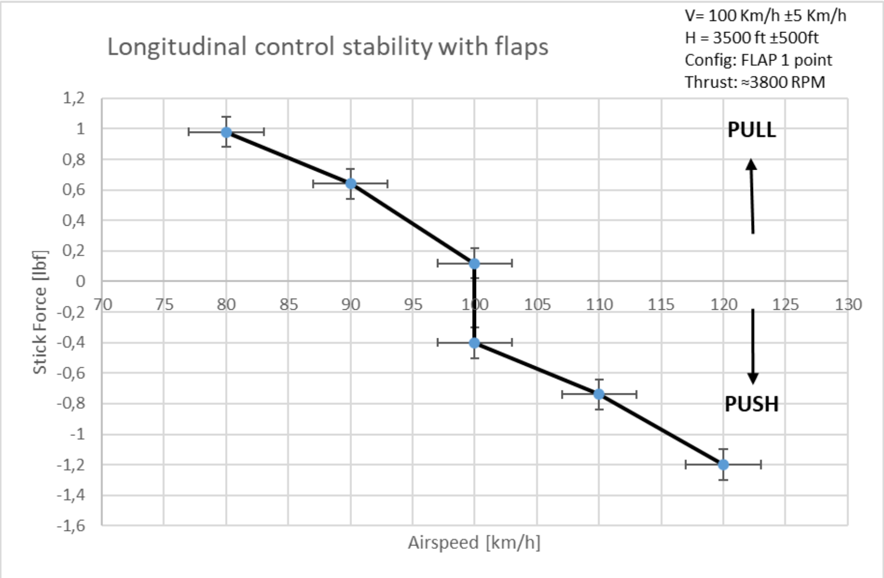

Figure 28. Longitudinal control stability, landing configuration

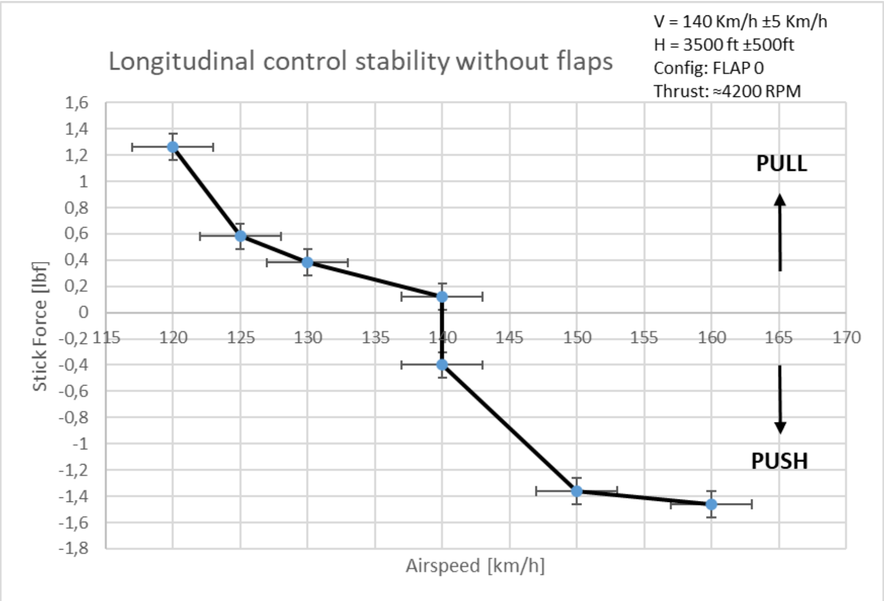

Figure 29. Longitudinal control stability, cruise configuration

The results showcased are ACCEPTABLE, as positive stability is presented. As airspeed values differ from the trim speed, the required force on the control stick increases. However, the overall recorded forces are small, making it easy to introduce inadvertent inputs.

These results can also be compared with FAA requirements FAR §25.173 Amdt. 25-7 & FAR §23.173 Amdt. 23-34:

- *FAR §25.173 (a) & FAR §23.173 (a) A pull must be required to obtain and maintain speeds below the specified trim speed and a push required to obtain and maintain speeds above the specified trim speed.* The results are compliant with this requirement.

- *FAR §23.173 (c) The stick force must vary with speed so that any substantial speed change results in a stick force clearly perceptible to the pilot.* To determine compliance with this requirement, the material guidance is used to gain further insight in compliance demonstration, according to AC23-8C (FAA, 2011): *Stable Slope. Section 23.173(c) is extremely general. It requires the test pilot's best judgment as to whether the stable slope of the stick force curve versus speed is sufficiently steep so that perceptibility is satisfactory for the safe operation of the airplane.* Even though the forces applied on the stick are small (below 2lbs), the control stick friction and breakout help the feeling provided by the control system in order to show compliance with this requirement at small speed changes.

- *FAR §25.173 (c) The average gradient of the stable slope of the stick force versus speed curve may not be less than 1 pound for each 6 knots.* The results comply with this requirement as the maximum force recorded is -1.46 pounds for a variation of 20 Km/h (10.79 kts), which represents a force of 0.81 pounds for each six knots.

Note: FAR 23 & FAR 25 requirements do not apply to ULM aircraft. FAR 25 requirements are not even applicable due to weight classification. The requirements are used to obtain reference metrics for an acceptable control system.

8.2.2 Stick Raps

Stick raps are used to simulate a step input into the control system. Stick raps are performed in all directions of the stick (push, left, pull, right) for various airspeeds. The aircraft positively responds to the input by dampening the input and returning to the stable trim position in a timely manner; therefore, the behavior is acceptable, showcasing positive stability.

For low speeds, the aircraft response is abrupt, but the recovery is smooth. As speed increases, the response to the input becomes more damped and the recovery is faster.

8.3 Dynamic Longitudinal Control Stability in Unaccelerated Flight – Long Period Oscillations

The analysis of the test performed showcases that the aircraft's control system presents **positive dynamic stability** for long-period oscillations in both the transient and stationary values. The system is underdamped with a full recovery to static equilibrium in around one minute.

8.3.1 Phugoid

The long-period dynamic response is evaluated by performing a phugoid. The phugoid presents a period of 25 seconds and a damping ratio of 0.095. The aircraft presents a stable long-period response with a total recovery from a 40 Km/h deviation from trim in around one minute without the introduction of pilot corrections.

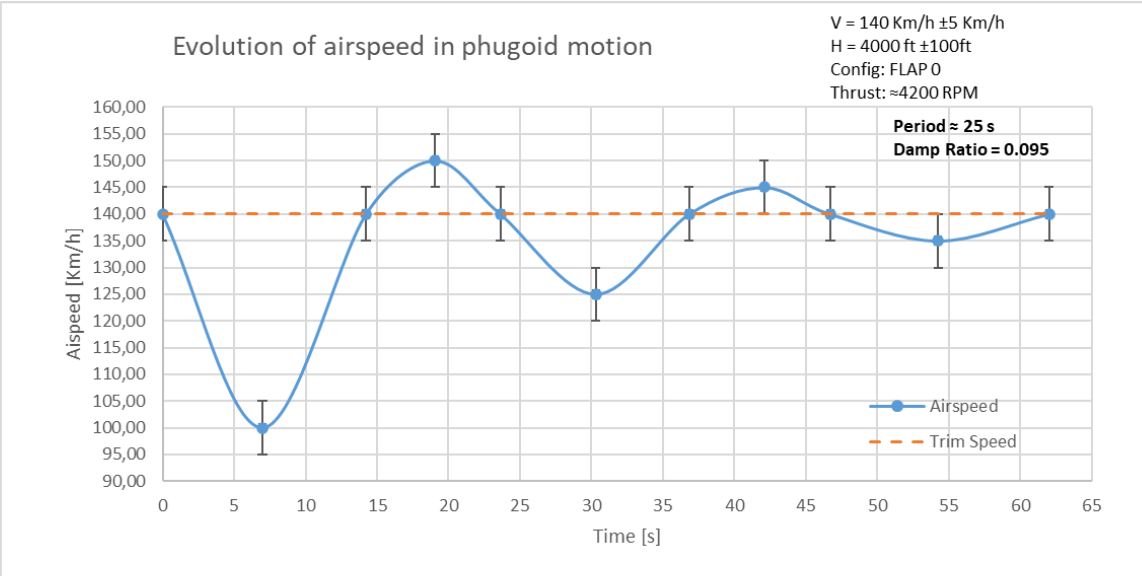

Figure 30. Phugoid response data

The long-period dynamic response is evaluated by performing a phugoid. The phugoid presents a period of 25 seconds and a damping ratio of 0.095. The aircraft presents a stable long-period response with a total recovery from a 40 Km/h deviation from trim in around one minute without the introduction of pilot corrections.

According to MIL-STD-1797A (MOD, 2004), a damping ratio above 0.04 is an acceptable value for Level 1 flying qualities, which include maneuvers inside the operational flight envelope. For Level 1, pilot comments must indicate satisfaction with aircraft flying qualities, with no worse than "mildly unpleasant" deficiencies.

These results can also be compared with FAA requirements FAR §23.173 Amdt.23-34 & §23.181 Amdt.23-62:

- *FAR §23.173 (b) The airspeed must return to within the tolerances specified for applicable categories of airplanes when the control force is slowly released at any speed within the speed range specified in paragraph (a) of this section. The applicable tolerances are: The airspeed must return to within plus or minus 10 percent of the* *original trim airspeed.* The results are compliant with this requirement as the final airspeed is equal to the trim speed ±10 Km/h.

- *FAR §23.181 (d) During the conditions as specified in Sec. 23.175, when the longitudinal control force required to maintain speeds differing from the trim speed by at least ±15 percent is suddenly released, the response of the airplane must not exhibit any dangerous characteristics nor be excessive in relation to the magnitude of the control force released. Any long-period oscillation of flight path, phugoid oscillation, that results must not be so unstable at to increase the pilot's workload or otherwise endanger the airplane.* The control was released at an airspeed of 100 Km/h, which differs from the trim speed by 28.6%. The long-period oscillations were damped and the aircraft presented dynamic and static stability in this condition, showing compliance with this requirement.

8.4 Static Longitudinal Control Stability in Accelerated Flight

The analysis of the test performed showcases that the aircraft's control system presents **positive static stability** in accelerated flight.

8.4.1 Steady Pull-ups & Wind-up Turns

The static longitudinal stability in accelerated flight is mainly analyzed through two maneuvers, wind-up turns and steady pull-ups. Since no instrumentation is used, the captured data from steady pull-ups can be challenging to measure. The data captured during wind-up turns is usually more reliable, but normal acceleration values above 2 g's cannot be achieved due to bank angle limitations.

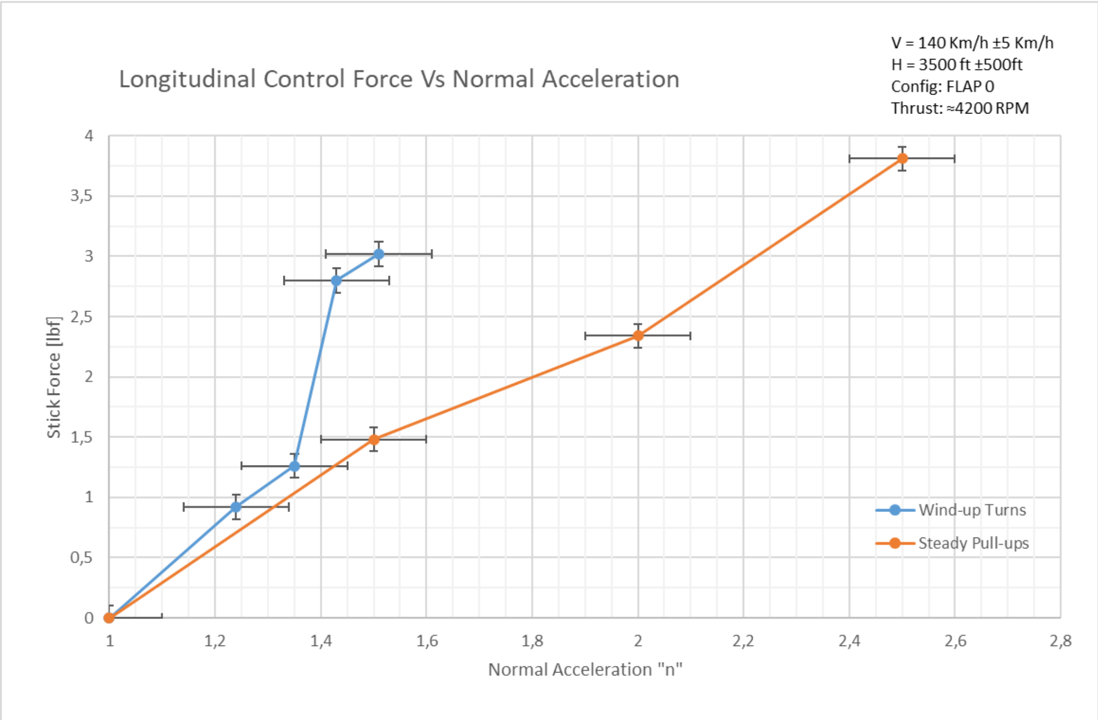

Figure 31. Static longitudinal stability in accelerated flight

The results of the steady pull-ups show a linear relationship between normal acceleration and force on the control stick. Force values are within an acceptable range and in accordance with expected values. The aircraft can be considered stable for this maneuver, and the behavior is ACCEPTABLE.

The results of the wind-up turn also showcase that as the normal acceleration increases, so does the force on the control stick. However, the relationship does not seem to be fully linear. The first two measurements were taken for a right turn, and the third and fourth for a left turn. Most probably, the difference in the expected linearity is due to the gyroscopic effects of the propeller; for this reason, the results of the wind-up turn are deemed INCONCLUSIVE due to a bad monitorization of the test procedure by the flight test engineer. It is recommended to edit the flight test card to prevent future mistakes in the execution of the technique.

These results can also be compared with FAA requirements §23.155 Amdt.23-50:

- *FAR §23.155 (c) There must be no excessive decrease in the gradient of the curve of stick force versus maneuvering load factor with increasing load factor.* The results of the sudden pull-up tests showcase that there is no decrease in the gradient of the curve of stick force versus load factor. Further maneuvers should be performed and measured in order to determine full compliance with this requirement, but the amount of data collected presents a positive output so far.

8.5 Dynamic Longitudinal Control Stability in Accelerated Flight

The dynamic longitudinal stability is hardly measured with quantitative data without flight test instruments. Therefore, all of the procedures used to evaluate it include the observation of aircraft behavior by the flight test engineer and the feeling of the test pilot while performing various maneuvers. For the test performed, no abnormal behaviors have been obtained, and the aircraft behavior is considered **dynamically stable** in accelerated flight for the maneuvers performed.

8.5.1 Sinusoidal Stick Pumping

Sinusoidal stick pumping is performed at various amplitudes and frequencies. No aircraft control loss is observed after 20 seconds of performing the control pumping. It is demonstrated that the aircraft structure can withstand the sudden variation in normal acceleration performed by the maneuver. The aircraft's behavior is considered ACCEPTABLE.

Low amplitude stick pumping does not cause significant oscillations in pitch or uncomfortable sensations to the pilot independent of the frequency of the input.

Medium amplitude and short period stick pumping does not cause significant oscillations in pitch, but a slight short period response can be appreciated. The short period only lasts as long as the pumping is being performed and is damped in less than 5 seconds once the input into the control stick stops. This dynamic can produce a slight sickness in inexperienced fliers. The test pilot did not find any discomfort during the maneuver.

Medium amplitude and long period stick pumping causes significant oscillations in pitch; no short period response is appreciated in this case, probably because it is masked by the phugoid-like motion produced. The variation in pitch does not increase with time and oscillates within stable values as long as the pumping movement is maintained. Once the input stops, the motion is damped in less than 10 seconds (stick fixed to neutral position). This motion produces negative accelerations that can produce sickness feeling to some fliers. However, the motion is not enough to affect flying qualities and can be considered mildly unpleasant.

8.5.2 Doublet

Two doublet inputs are performed. The movements performed on the stick are identical, but in a control-free doublet, the control is released at the end of the movement. In a control-fixed doublet, the control is restrained at the neutral position at the end of the movement. The observed aircraft behavior observed in both cases is considered ACCEPTABLE.

In the control-free doublet, a short-period motion is observed. The motion is very subtle and damped out in less than 2 seconds, to the point where no quantitative data can be measured without flight test instrumentation.

In the control-fixed doublet, no short period is observed. The aircraft smoothly cancels out the opposite inputs and returns to level flight without oscillations.

These results can also be compared with FAA requirements §23.181 Amdt.23-62:

- *FAR §23.181 (a) Any short period oscillation not including combined lateral-directional oscillations occurring between the stalling speed and the maximum allowable speed appropriate to the configuration of the airplane must be heavily damped with primary* *controls: (1) Free; and (2) In a Fixed position.* The results are compliant with this requirement the doublet was performed with both fixed and stick free. Only a slight short period was observed in the stick-free maneuver is heavily damped.

8.5.3 Pilot-Induced Oscillations

Pilot-induced oscillations (PIOs) are tried to be forced by alternating pulling and pushing motions on the control stick at amplitudes around ¼ of the maximum stick movement range. After several oscillations, no PIOS are observed. All the observed motion is derived from the stick pumping, which produces rapid variations in normal acceleration, which provides a mildly unpleasant feeling. The aircraft structure can withstand the maneuver without damage or permanent deformation. Since no PIOS are observed and the aircraft dynamics are within envelope limits, the aircraft behavior is considered ACCEPTABLE

Chapter 9. CONCLUSIONS AND IMPROVEMENTS

9.1 Aircraft Longitudinal Stability & Control

Various tests have been performed to study the Skyranger Nynja longitudinal stability and control system. The conclusions are presented in the following table:

Table 8. Aircraft Longitudinal Stability & Control Conclusions

Parameter	Results	Notes & improvements
Longitudinal control characteristics and feel	Positive with minor deficiencies	The flight control presents forces and displacements in all parametric within expected ranges according to guidance material. Even within acceptable metrics, the overall feeling of the control is soft (the amount of force required to perform maneuvers in flight is very low); this causes small perturbations to be noticeable during flight, even if they are damped due to aircraft stability. This condition may be improved in future designs by the addition of a counterweight on the control system.
Static stability	Positive stability	The aircraft presents positive static stability in both unaccelerated and accelerated maneuvers. No control reversal is experienced at any airspeed or accelerations. Compliance with the following FAR requirements has been demonstrated: FAR §23.173 Static longitudinal stability (a)(c) FAR §23.155 Elevator control force in maneuvers (c) FAR §25.173 Static longitudinal stability (c) Although the results are positive, the amount of data gathered is not sufficient to fully assess the aircraft stability in all flight conditions. Further tests with an instrumented aircraft may be required for a full evaluation.

Parameter	Results	Notes & improvements
Dynamics stability	Positive stability	The aircraft presents positive dynamic stability in both unaccelerated and accelerated maneuvers. The short-period motion is rarely presented. In the few presented cases, it is heavily and rapidly damped. The long-period motion is stable and damped out in periods in the order of the minute. Compliance with the following requirements has been demonstrated. FAR §23.173 Static longitudinal stability (b) FAR §23.181 Dynamic stability (a)(d) MIL-STD-1797A §4.2.1.1 Long-term pitch response. Although the results are positive, the amount of data gathered is not sufficient to fully assess the aircraft stability in all flight conditions, especially for the short period as it is heavily damped. Further tests with an instrumented aircraft may be required for a full evaluation.

Overall, **the aircraft is statically and dynamically stable** in all of the performed maneuvers. To **fully evaluate the aircraft's control system and stability** in all flight conditions, **an instrumented aircraft is required**.

9.2 Flight Test Results and Techniques

One of the main challenges of this thesis is the selection of flight test techniques taken into account the available measuring tools. The validity of the test results and adequacy of the test techniques are evaluated in the following table:

Table 9. Flight Test Results and Techniques Conclusions

Test	Results	Notes & improvements
Mechanical characteristics of the control system		
Mechanical Characterization of the Control System (On ground)	Acceptable Figure 27	The technique used and the results are considered acceptable. Better results can be achieved by further instrumenting the aircraft and performing the test in flight
Friction (On Ground)	Inconclusive ±1.28 lbf	The proposed technique is not adequate as the control system is reversible, and the weight of the elevator is included in the friction measurements on the ground. Friction measurements require the instrumentation of the aircraft in order for large data collection to interpolate the friction throughout the control sweep range.
Freeplay (On ground)	Acceptable 3mm	The technique used and the results are considered acceptable.
Breakout with friction	Acceptable 0.12 lbf pull 0.40 lbf push	The technique used and the results are considered acceptable.
Centering	Acceptable	The technique used and the results are considered acceptable. A quantitative deviation in centering can be determined using an instrumented aircraft.
Static longitudinal stability in unaccelerated flight		
Slow acceleration	Acceptable Figure 28 Figure 29	The technique used and the results are considered acceptable. Taking further points would have been desired as specified in the flight test cards, but the precision and lag of the airspeed indicator make it impossible to take measurements with further precision.
Stick Raps	Acceptable	The technique used and the results are considered acceptable. In order to obtain quantitative data from this maneuver, an instrumented aircraft is required.
Dynamic longitudinal stability in unaccelerated flight		
Phugoid	Acceptable Figure 30	The technique used and the results are considered acceptable.

Test	Results	Notes & improvements
Static longitudinal stability in accelerated flight		
Steady Pull-ups	Acceptable Figure 31	The technique used and the results are considered acceptable. Taking accurate measurements with the used measuring tools is extremely difficult, and the precision of the accelerometer used leads to poor precision in results, yet acceptable.
Wind-up turn	Inconclusive Figure 31	The proposed technique was adequate, but the execution and the explanation on the flight test card were inadequate and led to inconclusive results. Measurements should be taken both for right and left turns independently due to the propeller effects. It is recommended to edit the flight test card for future tests.
Dynamic longitudinal stability in accelerated flight		
Doublet	Acceptable	The technique used and the results are considered acceptable. In order to obtain quantitative data from this maneuver, an instrumented aircraft is required.
Sinusoidal Stick Pumping	Acceptable	The technique used and the results are considered acceptable. In order to obtain quantitative data from this maneuver, an instrumented aircraft is required.
Pilot Induced Oscillations	Acceptable	The technique used and the results are considered acceptable. In order to obtain quantitative data from this maneuver, an instrumented aircraft is required.

The flight test technique used to measure friction was not adequate as the system is reversible, and friction is not to be measured on the ground. **This deficiency could have been prevented by** a **further study of the control system** and a **better understanding of the flight test techniques** before the execution of the tests.

The wind-up turn flight test technique was poorly executed by the flight test pilot due to the bad coordination of the flight test engineer and a misleading redaction in the flight test card. **Editing of the flight test card shall be performed to avoid further issues.**

The main conclusion is that the selected flight test techniques are adequate, and the results are acceptable. Multiple conclusions regarding longitudinal stability and control data have been achieved with the limitations on the available instrumentation.

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APPENDIX

Appendix I – Flight Test Briefings

BRIEFING Nº:	1	
FLIGHT TEST CARDS:	001 & 002	
DATE:	08/04/2025	

#	BRIEFING POINTS	COMMENTS
1.	WEATHER ASSESSMENT	Adequate weather conditions
2.	REVIEW OF FLIGHT TEST PROCEDURE ORDER & TEST ALTITUDE	N/A
3.	REVIEW OF FLIGHT TEST RISKS 1) Mid-air collision 2) Bird impact during flight 3) Reduction of altitude below safety level 4) Unexpected stalls & spins	All reviewed. No nearby traffic No bird sightings near aerodrome
4.	INSTALLATION OF FLIGHT TEST INSTRUMENTS • Camera mount • Tablet/phone with accelerometer • Force gauge	Installed

Nº	Flight Test Card #	Procedure	Altitude [ft]
1.	001	Ground Measurements	-
2.	001	Qualitative evaluation	3 500
3.	002	Qualitative evaluation	3 500
4.	001	Breakout	3 500
5.	001	Stick Raps	3 500
6.	001	Slow Acceleration (landing config)	3 500
7.	001	Slowe Acceleration (cruise config)	3 500
8.	001	Phugoid	3 500
9.	002	Steady-pull up	3 500
10.	002	Wind-up turn	3 500
11.	002	Sinusoidal Stick Pumping	3 500
12.	002	Doublet	3 500
13.	002	Pilot-induced Oscillations	3 500

OBSERVATIONS

DEBRIEFING Nº:	1
FLIGHT TEST CARDS:	001 & 002
DATE:	08/04/2025

#	DEBRIEFING POINTS	COMMENTS
1.	REVIEW OF FLIGHT TEST RESULTS	See Observations
2.	INSPECTION OF AIRCRAFT AFTER TESTS	No damage

Nº	Flight Test Card #	Procedure	Deviations
1.	001	Ground Measurements	Friction measurements inconclusive
2.	001	Qualitative evaluation	N/A
3.	002	Qualitative evaluation	N/A
4.	001	Breakout	N/A
5.	001	Stick Raps	N/A
6.	001	Slow Acceleration (landing config)	N/A
7.	001	Slowe Acceleration (cruise config)	N/A
8.	001	Phugoid	N/A
9.	002	Steady-pull up	N/A
10.	002	Wind-up turn	Inconclusive
11.	002	Sinusoidal Stick Pumping	N/A
12.	002	Doublet	N/A
13.	002	Pilot-induced Oscillations	N/A

OBSERVATIONS

- On the ground, the flight stick goes forward due to the weight of the elevator. It is not possible to perform friction measurements on the ground
- After reviewing the wind-up turn results, odd values are detected. Measurements were taken for left and right turns; since the propeller has noticeable effects during turns, the results are inconclusive.

Appendix II – Flight Test Card(s)

TEST CARD Nº:	001	
TEST PROCEDURE:	Non-maneuvering longitudinal control measurements	
DATE:	08/04/2025	
T. O. TIME	10:27	WEATHER: OAT: 21ºC No wind on the ground. Slight windshear due to hot airflow in the air. Clear sky, no clouds. Suitable for VFR.
T. O. AIRPORT	Villanueva del Pardillo	
LAND TIME	11:15	
LAND AIRPORT	Villanueva del Pardillo	

AIRCRAFT

MODEL	S/N	REG	INITIAL FUEL	FINAL FUEL	PILOT
Nynja 80	SYK 1504961	EC-GC4	50L	45L	JGR License: 30617

OBSERVATIONS	N/A
TEST CONFIGURATION	Clean aircraft.

POSITION	PILOT	COPILOT	FUEL	BAGGAGE
WEIGHT	74	78	36	2
BALANCE	+0.15 m	+0.15 m	-0.29 m	-0.29 m
TOTAL WEIGHT AND CG	446 Kg @26.41mm			
TEST ALTITUDE	3 500 ft			

#	TEST POINT TASK DESCRIPTION	DONE	FAILED
1.	GROUND MEASUREMENTS – MECHANICAL CHARACTERISTICS	X*	
2.	PRE-FLIGHT	X	
3.	TAKE OFF	X	
4.	CLIMB TO TEST ALTITUDE	X	
5.	INITIAL QUALITATIVE EVALUATION	X	
6.	BREAK-OUT FORCE MEASUREMENTS	X	
7.	STICK RAP	X	
8.	STEADY POINT MEASUREMENTS (LANDING CONFIG)	X	
9.	STEADY POINT MEASUREMENTS (CRUISE CONFIG)	X	
10.	PHUGOID MEASUREMENT	X	
11.	END OF TESTS	X	

OBSERVATIONS

- (*)The friction test is inconclusive. On the ground, the control stick goes completely forward due to the weight of the elevator.
- (**): On the stick raps the aircraft response vaies depending on airspeed. At slow airspeed, response amplitude is low, but the time until recovery is slower. As speed increases, so does the amplitude of the movement, but the time to recover trim state is also faster.
- (***): Due to the nature of the aircraft (ULM) and the lag of the airspeed indicator, it is very challenging to perform 5 Km/h increments during measurements, making it unable to collect some data.

TEST CARD Nº:	001
TEST PROCEDURE:	Non-maneuvering longitudinal control measurements
DATE:	08/04/2025

TEST PROCEDURES

1. Ground measurements – mechanical characteristics

These tests must be performed inside the hangar. No wind must effect force on air control surfaces.

a) **Mechanical Characterization**: Measure the relationship between the stick movement and the elevator deflection at various points.

Elevator deflection	Measurement [mm]
+25º	-184
+15º	-121
+5º	-36
-5º	48
-15º	111
-25º	129

b) **Friction:** Center the stick. Perform a pull movement on the stick to the end of its movement range. Record the force required at different deflections of the elevator. Repeat the measurement for pushing forces.

Force Direction	Elevator deflection	Measurement [Lb]
Pull (+)	+5º	1.28
	+15º	1.28
	+25º	1.28
Push (-)	-5º	1.28
	-15º	1.28
	-25º	1.28

c) **Freeplay:** Center the stick, record the center position relative to a fixed point on the cabin. Perform a pull movement until the elevator begins to move. Measure the displacement between the centered position and the current position. Repeat the measurement for a pushing movement. Note: It is recommended to use tape or a string to annotate displacement and precisely measure them on a bench on the ground.

Force Direction	Measurement [mm]
Pull (+)	+1.5
Push (-)	-1.5

c) **Full sweep:** Perform a full sweep of the flight stick. Characterize any noticeable variation in force in the observations section.

TEST CARD Nº:	001
TEST PROCEDURE:	Non-maneuvering longitudinal control measurements
DATE:	08/04/2025

2. Initial qualitative evaluation

Perform the following techniques and record the aircraft's response.

Maneuver	Description	Response
Break out and friction	Lightly move the stick in a push-pull motion. Describe the amount of force required to produce a change in airspeed.	Slight freeplay is appreciated. No unexpected aircraft behavior
Steady Pull (flaps down)	At low speeds, perform pulling motions to reach different airspeeds. Describe the evolution of pulling force as airspeed decreases. Warning: Do not decelerate below 70 Km/h	Pulling force progressively increases
Steady Pull (flaps up)	At cruise speed, perform pulling motions to reach different airspeeds. Describe the evolution of pulling force as airspeed decreases. Warning: Do not decelerate below 70 Km/h	Pulling force progressively increases
Phugoid Response	Pull on the stick to decrease 15 Km/h from trim, then push on the stick to return to the trim airspeed, then release the stick. Describe the aircraft response.	Positive response, recovery to trim position. No divergence in oscillations is appreciated
Wind up turn to 10º	Roll the aircraft to a 10º bank while maintaining RPMs and airspeed. Describe the amount of force required to maintain speed without losing altitude.	No excessive force is required to maintain the roll. Force is higher than in the steady pull.

3. Breakout force with friction measurement

a) Stabilize and trim at cruise speed.
b) Record the trim position, RPM, stick position, fuel quantity and altitude at the trim position.
c) Very slowly pull on the stick and record the pull force right before an airspeed variation or pitch movement is detected.
d) Return to the trim position. Repeat the previous step by pushing on the stick.

Note: After trimming, do not modify the trim and thrust for the duration of the test.

INITIAL PARAMETERS				
Trim Speed (≈120 Km/h)	Trim position	Stick position	RPM	Fuel QTY
140 Km/h	Neutral	Neutral	4200	~50

Force Direction	Measurement [lb]
Pull (+)	0.12
Push (-)	0.40

4. **Stick rap**
    a) Stabilize and trim at different speeds.
    b) Once the selected airspeed has been achieved, perform rapid and sudden inputs on the stick in one direction at a time (push, left, pull and right).
    c) Record the aircraft response.

Note: The input must be sudden and fast, and the stick must always be returned to the centered position.

Airspeed [Km/h]	Response
95	Positive**
100	Positive**
105	Positive**
110	Positive**
120	Positive**
125	Positive**
130	Positive**
140	Positive**

5. **Slow acceleration measurements (1-point flaps)**
    a) Stabilize and trim at landing config speed.
    b) Record the trim position, RPM, stick position, fuel quantity and altitude at the trim position.
    c) Pull on the stick until the speed is decreased to the points on the table. Maintain that pitch configuration and record the airspeed, vertical variation rates and force applied on the stick.
    d) Return to the trim position. Repeat the previous step by pushing on the stick.

Note: After trimming, do not modify the trim and thrust for the duration of the test.

WARNING

Speed must be maintained between 70 and 110 Km/h at all times.

INITIAL PARAMETERS				
Trim Speed (≈100 Km/h)	Trim position	Stick position	RPM	Fuel QTY
100 Km/h	Neutral	Neutral	3900	~50

Airspeed	Long. Control Force [lb]	Vertical Variation [ft/min]
Trim Speed -10 Km/h: 90	0.64	200
Trim Speed -15 Km/h: 95	-***	-***
Trim Speed -20 Km/h: 80	0.98	300
Trim Speed +10 Km/h: 110	-0.74	-300
Trim Speed +15 Km/h: 115	-***	-***
Trim Speed +20 Km/h: 120	-1.2	-400

TEST CARD Nº:	001
TEST PROCEDURE:	Non-maneuvering longitudinal control measurements
DATE:	08/04/2025

6. **Slow Acceleration measurements (cruise)**
    a) Stabilize and trim at cruise speed.
    b) Record the trim position, RPM, stick position, fuel quantity and altitude at the trim position.
    c) Pull on the stick until the speed is decreased to the points on the table. Maintain that pitch configuration and record the airspeed, vertical variation rates and force applied on the stick.
    d) Return to the trim position. Repeat the previous step by pushing on the stick.

Note: After trimming, do not modify the trim and thrust for the duration of the test.

WARNING

Speed must be maintained between 70 and 165 Km/h at all times.

INITIAL PARAMETERS				
Trim Speed (≈120 Km/h)	Trim position	Stick position	RPM	Fuel QTY
140 Km/h	Neutral	Neutral	4200	~50

Airspeed	Long. Control Force [lb]	Vertical Variation [ft/min]
Trim Speed -10 Km/h: 130	0.38	50
Trim Speed -15 Km/h: 125	0.58	100
Trim Speed -20 Km/h: 120	1.26	200
Trim Speed +10 Km/h: 150	-1.36	-250
Trim Speed +15 Km/h: 155	-***	-***
Trim Speed +20 Km/h: 160	-1.46	-500

TEST CARD Nº:	001
TEST PROCEDURE:	Non-maneuvering longitudinal control measurements
DATE:	08/04/2025

7. **Phugoid Characteristics Measurement**
   a) Stabilize and trim at cruise speed. Record the initial parameters.
   b) Pull on the stick until the speed is decreased between 30 to 40 Km/h.
   c) Smoothly return the stick to the initial position and release the stick.
   d) Monitor the airspeed and elapsed time at the top, middle and bottom of the phugoid movement.

It is recommended to perform a video during the phugoid motion where the pitch, airspeed, and elapsed time are appreciated.

WARNING

Speed must be maintained between 70 and 165 Km/h at all times.

If airspeed reaches 140 Km/h in the initial oscillations, abort the procedure.

Wings must be maintained completely levelled, without introducing longitudinal inputs on the stick.

INITIAL PARAMETERS				
Trim Speed (≈120 Km/h)	**Trim position**	**Stick position**	**RPM**	**Fuel QTY**
140 Km/h	Neutral	Neutral	4200	~50

Airspeed	Elapsed time [s]
Minimum Speed: 100	6.98
Trim Speed: 140	14.23
Maximum Speed: 150	19.07
Trim Speed: 140	23.64
Minimum Speed: 125	30.31
Trim Speed: 140	36.84
Maximum Speed: 145	42.08
Trim Speed: 140	46.72
Minimum Speed: 135	54.26
Trim Speed: 140	62.02
Maximum Speed:	-
Trim Speed:	-
Minimum Speed:	-
Trim Speed:	-
Maximum Speed:	-

Note: Airspeed changes at the top and bottom of the phugoid motion are very slow. It is recommended to monitor pitch attitude at those points to determine the peaks and valleys of the motion.

TEST CARD Nº:	002	
TEST PROCEDURE:	Maneuvering longitudinal control measurements	
DATE:	08/04/2025	
T. O. TIME	10:27	WEATHER:
T. O. AIRPORT	Villanueva del Pardillo	OAT: 21ºC
LAND TIME	11:15	No wind on the ground. Slight windshear due to hot airflow in the air. Clear sky, no clouds. Suitable for VFR.
LAND AIRPORT	Villanueva del Pardillo	

AIRCRAFT

MODEL	S/N	REG	INITIAL FUEL	FINAL FUEL	PILOT
Nynja 80	SYK 1504961	EC-GC4	50L	45L	JGR License: 30617
OBSERVATIONS	N/A				
TEST CONFIGURATION	Clean aircraft.				

POSITION	PILOT	COPILOT	FUEL	BAGAGE
WEIGHT	74	78	36	2
BALANCE	+0.15 m	+0.15 m	-0.29 m	-0.29 m
TOTAL WEIGHT AND CG	446 Kg @26.41mm			
TEST ALTITUDE	3 500 ft			

#	TEST POINT TASK DESCRIPTION	DONE	FAILED
1.	PRE-FLIGHT	X	
2.	TAKE OFF	X	
3.	CLIMB TO TEST ALTITUDE	X	
4.	INITIAL QUALITATIVE EVALUATION	X	
5.	STEADY PULL-UPS	X	
6.	WIND-UP TURNS	X*	
7.	SINUSOIDAL STICK PUMPING	X	
8.	DOUBLET	X	
9.	PILOT-INDUCED OSCILLATIONS	X	
10.	APPROACH AND LANDING	X	

OBSERVATIONS

- (*): Test results for the wind-up turns are inconclusive. See debriefing.
- (**): As the aircraft is not equipped with an attitude indicator, maintaining roll rates with a precision of 5º is quite difficult, making it unable to collect data at some points. Rolls are performed at 10º intervals using an inclinometer in a cell phone.

TEST CARD Nº:	002	
TEST PROCEDURE:	Maneuvering longitudinal control measurements	
DATE:	08/04/2025	

TEST PROCEDURES

1. Initial qualitative evaluation

Perform the following techniques and record the pilot's description of the aircraft's response.

Maneuver	Description	Response
Steady pull-up	At cruise speed, perform a pushing motion to enter a shallow dive. Then, pull on the stick to acquire a nose-up configuration. Warning: Do not decelerate below 70 Km/h.	Positive Response
Wind up turn to 20º	Roll the aircraft to a 20º bank while maintaining RPMs and airspeed. Describe the amount of force required.	No excessive force is required to maintain the roll.

2. Steady pull-up measurements

a) Stabilize and trim at cruise speed.
b) Record the trim position, RPM, stick position and altitude at the trim position.
c) Pull on the stick to decelerate and reach a climbing attitude. Then, push on the stick to enter a shallow dive at the initial trim altitude. As the speed reaches the initial trim speed, pull on the stick to a certain deflection.
d) The FTE will monitor the normal acceleration and notify the pilot when the peak normal acceleration is reached.
e) Repeat the test for various desired normal accelerations.

WARNING

Speed must be maintained between 70 and 165 Km/h at all times.

Altitude must remain within ±2000ft of the initial altitude.

Pitch values over ±15º must be avoided.

INITIAL PARAMETERS				
Trim Speed (≈120 Km/h)	**Trim position**	**Stick position**	**RPM**	**Fuel QTY**
140 Km/h	Neutral	Neutral	4200	~50

Stick position	Peak normal acceleration [g's]	Long. Control Force [lb]
¼ full pull	~1.5	1.48
½ full pull	~2.0	2.34
¾ full pull	~2.5	3.81

TEST CARD Nº:	002
TEST PROCEDURE:	Maneuvering longitudinal control measurements
DATE:	08/04/2025

3. **Wind-up turns measurements**
   a) Stabilize and trim at cruise speed. Record the initial parameters
   b) Smoothly and slowly roll into a wind-up turn. Increase normal acceleration by increasing bank angle and aft stick position while maintaining constant airspeed.
   c) Record the turn normal acceleration. Perform a qualitative evaluation of the pull force.
   d) Roll the aircraft back to level flight.
   e) Repeat the test for various roll angle forces.

Notes: Caution should be exercised. Start with low g points and build up to higher values of normal acceleration.

INITIAL PARAMETERS			
Trim Speed	**Trim position**	**Altitude**	**RPM**
140 Km/h	Neutral	3500	4200

Bank Angle	Normal Acc. (expected)	Force on stick
≈30º	1.24 (1,26 g)	0.92
≈35º	-** (1,30 g)	-**
≈40º	1.35 (1,36 g)	1.26
≈45º	-** (1,41 g)	-**
≈50º	1.43 (1,48 g)	2.80
≈60º	1.51	3.02

Note: Qualitative evaluation should assess if the force required during the turns is excessive (so it can not be maintained for long periods) and compared with the force of the previous angle.

4. **Sinusoidal stick pumping measurements**
   a) Stabilize and trim at cruise speed.
   b) Alternate pulling and pushing motions on the stick for 20 seconds or until aircraft longitudinal control is lost.
   c) Return to the initial trim position.
   d) Repeat the test for various pumping frequencies and amplitudes.

Perform a video of each stick movement to determine the frequency of the oscillation.

Control stick movement	Time until loss of A/C control
Low amplitude & long period	No control loss
Low amplitude & short period	No control loss
Medium amplitude & long period	No control loss
Medium amplitude & short period	No control loss
High amplitude & long period	Not performed due to recommendation of test pilot

- Amplitude:
  - Low: small movements, similar to those performed for small corrections during touchdown
  - Medium: Normal movements performed during ascends and descends in normal flight conditions
  - High: Movement almost to the full range of the stick.
- Period:
  - Long: Around one push-and-pull motion per second
  - Short: Between 1 to 3 push and pull motions per second

TEST CARD Nº:	002
TEST PROCEDURE:	Maneuvering longitudinal control measurements
DATE:	08/04/2025

5. **Doublet measurements**
   a) Stabilize and trim at cruise speed. Record the initial parameters
   b) With a smooth but rapid motion, set a nose down attitude for a few degrees (≈5º), then pull to reverse the input back to trim. As the pitch reaches trim, release the stick.
   c) Return to the initial trim position.
   d) Repeat the test but restrain the stick at the center position after the doublet input.

Perform a video of each test.

Doublet type	Aircraft Response
Controls-free	A short period response is appreciated. Motion is damped motion with a duration between 1 to 3 seconds.
Controls-fixed	No short period motions is appreciated.

6. **Pilot-induced Oscillations**
   a) Stabilize and trim at cruise speed. Record the initial parameters
   b) Alternate pulling and pushing motions on the stick. The amplitude of the motion shall be performed around ¼ of the maximum stick range of motion. The stick movement must be performed to counter the natural motion of the aircraft.

Aircraft Response
No PIOS are observed.

WARNING

In case aircraft control is lost, immediately stop the test and recover the aircraft.