REPORT

INTERNSHIP TRAINING

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FAMILIARIZATION OF AIRCRAFT SYSTEMS

A Case Study of LCA Tejas

1. Introduction to LCA Tejas

The Tejas, officially named in 2003 by former Prime Minister Atal Bihari Vajpayee, originated from the Light Combat Aircraft (LCA) program initiated in the 1980s to replace India's aging MIG-21 fighters. Developed by Hindustan Aeronautics Limited (HAL), it is a multi-role aircraft designed for comprehensive air superiority and air defence. A key feature of the Tejas is its quadraplex digital fly-by-wire flight control system, which enhances pilot handling.

2. Digital Fly-by-Wire Flight Control System (DFBW FCS)

The Tejas employs a powerful digital flight control computer (DFCC). This DFCC consists of four computing channels, each with an independent power supply, all housed within a single Line Replaceable Unit (LRU). The DFCC processes signals from various sensors and pilot control stick inputs to control the elevons, rudder, and leading-edge slat actuators. The software for the DFCC channels is implemented using a subset of the ADA programming language on 32-bit microprocessors. Communication with pilot display elements, such as Multi-Function Displays (MFDs), occurs via MIL-STD-1553B multiplex avionics data buses and RS-422 serial links.

The Tejas is intentionally designed to be longitudinally unstable to improve manoeuvrability. Control laws (CLAW) are implemented to restore stability and provide excellent handling qualities to the pilot. These CLAW also ensure invariant responses despite variations in aerodynamics or fuel levels, facilitating robust performance. The "carefree" nature of the CLAW automatically limits various aircraft parameters, allowing pilots to focus on the mission without concerns about exceeding safe operational limits.

3. HAL Tejas Division Facilities

The LCA Tejas Division in Bangalore has established new structural and final assembly facilities for series production. Dedicated hangars exist for the LCA program, with fully established structural assembly facilities for Tejas aircraft production. Relevant to electronics and communication, the **Electrical Looms Shop** produces looms for the LCA Tejas, adhering to stringent quality requirements to meet EMI/EMC specifications. Automatic cable testers are used for checking and certifying these looms and panels. A **Non-Destructive Testing (NDT) Facility** is also in place for quality testing. The division utilizes state-of-the-art facilities, including a machine shop with CNC machines and environmentally controlled hangars for aircraft build.

4. Engine Health Monitoring System (EHMS)

The Engine Health Monitoring System (EHMS) provides a high level of engine fault detection and isolation, integrated directly into the engines. This system primarily functions as a flightline maintenance tool, helping mechanics identify failed Line Replaceable Units (LRUs) and guiding them in troubleshooting. Information from the EHMS is also valuable for intermediate and depot-level maintenance. The two major components of the EHMS on the aircraft are the **Full Authority Digital Electronics Control (FADEC)** and the **BHEEM-EU**.

The EHMS provides several diagnostic and engine support functions, including:

- Detection and isolation of failed control system LRUs
- Identification of invalid sensor signals
- Acquisition and storage of fault data
- Event-based troubleshooting procedures using acquired fault data
- Trend monitoring
- Measuring life usage indices for the engine parts life tracking system

Techniques employed in FADEC include memory checksums, wrap-around checks of output signals, parallel processing of input signals, timer checks, and signal range checks. The FADEC Built-In Test (BIT) identifies failures within itself or interfacing components and can isolate many failures to the system replaceable assembly level, communicating this information to the BHEEM-EU. An engine fault indicator on the central maintenance panel alerts to engine faults. Algorithms within BHEEM-EU and FADEC detect conditions such as flame out, stall, high/low oil pressure, afterburner blowout, N1/N2 overspeed, over-temperature, oil debris, and signal validity.

5. Fuel and Power Plant Systems (Electrical Aspects)

The power plant is the sole power source of an aircraft, providing not only propelling force but also power for the electrical generator, hydraulic pumps, and compressed air for various systems like environmental control and fuel tank pressurization. The **electrical generator** supplies electrical power for the operation of avionic and electrical LRUs. The F404GE-IN20 engine features an **engine accessory gearbox (AGB)** with six pads for running accessories. Key components linked to the AGB for controlling and assisting the core engine include the Jet Fuel Starter (JFS), Alternator, Variable Exhaust Nozzle (VEN) power unit, Fuel Metering Unit (FMU), Main Fuel Pump (MFP), Afterburner fuel pump, Afterburner fuel control, Lube and scavenge pump, and N2 core speed transmitter. The AGB drives these engine accessories provides torque for starting the engine. It is driven by the engine compressor rotor via a bevel gear system and supplies all engine requirements for fuel, electrical power, hydraulic power, and lubrication.

The engine oil system relies on indications for oil quantity, temperature, and pressure, which include transmitters, indicators, wiring, and warning systems. The engine drain system, while primarily mechanical in function, contributes to fire risk reduction by collecting and discharging fluid leaks, including unburned fuel.

6. Engine Starting System

The engine starting system provides a reliable means for starting the engine both on the ground and in the air. This system also fulfils additional requirements, such as dry rollover of the engine (cranking at 19-21% rpm for 60 seconds) and dry/wet cranking of the Jet Fuel Starter (JFS). It also allows for cranking and starting the engine in the air after a flameout if windmilling RPM is insufficient for re-flight.

The starting system comprises the following components:

- Jet Fuel Starter (JFS)
- Alternator
- Primary Ignition Exciter
- Secondary/Redundant Ignition Exciter
- Starter Control Unit (SECU)
- Full Authority Digital Electronics Control (FADEC)

A microcontroller-based electronic fuel control system, the

Starter Electronic Control Unit (SECU) governs JFS operations by scheduling fuel during starting, acceleration, speed governing, and shut-off. The SECU provides full authority control over fuel flow to the starter unit.

7. Armament and Avionics Systems

The Tejas aircraft is equipped with an armament control system for preparing and releasing/firing weapons from various suspension ports. The aircraft can deploy weapons day or night, in any weather condition.

Radar Warning Receiver (RWR) System: The RWR system is designed for threat acquisition, target tracking, interception, and identification of airborne and ground-based missile guidance radars. It operates in the 2-18 GHz frequency band with 360° azimuth coverage and provides audio warnings to alert the pilot of imminent threats.

Counter Measure Dispensing System (CMDS): This airborne defensive system provides self-protection against radar-guided and infrared-seeking missiles by deploying chaff and/or flare payloads to misguide them.

Smart Standby Display Unit (SSDU-GUH): The SSDU-GUH is a standalone, AMLCD-based colour display unit that acts as a standby, showing essential flight parameters to the pilot if the normal display system fails. It can perform computations, generate display pages, and drive external interfaces based on input data. Parameters displayed include Baro Altitude, Vertical Speed, Calibrated Airspeed, Mach Number, Magnetic Heading, Aircraft roll and pitch, Angle of Attack, and Flight Path Angle.

Laser Designation Pod (LDP): The LDP is used for ranging and illuminating ground targets during bomb delivery. It facilitates the selection, aiming, and release of Laser Guided Bombs, requiring the LDP for target tracking, illumination, and ranging. The LDP is directly mounted on a dedicated pylon attached to the LH air intake.

8. Electrical Systems

The LCA Tejas utilizes both AC and DC electrical systems. The 115V/400Hz AC (3-phase) system powers avionics, radar, ECS, and mission computers. The 28V DC system supports fly-by-wire controls, lighting, and backup systems. AC power is generated by brushless AC generators, and DC power is obtained through Transformer Rectifier Units (TRUs) and an onboard battery.

The Electrical Power Generating System (EPGS) includes:

Main Power Sources:

- 30/40 KVA, 115/200 V, 400 Hz, 3 phase AC Integrated Drive Generator (IDG)
- Two 250 Amps TRUs providing 28V DC outputs
- Two 0.350 KVA Hydraulic Motor Driven Generator (HMDG) systems providing 28V DC outputs via voltage regulator units (Rectifier Converter Units)

Standby Sources:

- 5 KVA, 115/200 V, 400Hz, 3 phase HMDG system
- 5 KW, 28V DC generator

Emergency Sources:

- Two 44 Ah, 24 V (Nickel-Cadmium) batteries (Battery 1 & 2)

AC Generation System: Basic power is generated by one 30/40 KVA (main power source) with standby sources of KVA hydraulic driven generator and a 5kW DC generator mounted on the engine gear box. Generator control units (GCUs) provide control, regulation, and protection for the generators. GCUs also manage generator line contactors, which control all generators to their respective bus bars. Power transfer and load shedding are managed by connecting or disconnecting bus tie contactors. Emergency AC power is provided by a 250 VA static inverter.

DC Generation System: DC power is derived from two 250A TRUs operating in parallel for normal conditions, and a standby 5kW DC generator for failure conditions, with a battery connected across a buffer. A GCU controls, regulates, and protects the 5kW DC generator. Emergency DC power is provided by two 45Ah batteries connected in parallel and maintained on float charge.

DC Distribution System: Consists of:

- DC main bus bar
- DC essential bus bar
- DC alert bus bar

Working of the EPGS: The F404-GE-IN20 aero engine is the primary power source. A Power Take-Off (PTO) shaft drives an Aircraft Mounted Accessory Gearbox (AMAGB), which in turn drives two independents hydraulic pumps. One drive on the AMAGB powers the 30/40 kVA IDG, serving as the main power source. The AMAGB is also connected to two pads directly on the engine gearbox. One of the drives on the Engine Gear Box (EGB) powers the 5 kW DC generator. The 5 KVA HMDG provides standby AC power in case Alternator 1 fails.

The AC master box receives AC power from these sources and supplies it to AC distribution boxes and TRUs via circuit breakers (CBs). ACDBs then distribute AC power to various loads through CBs. Similarly, the DC master box receives DC power from both TRUs and the 5 kW DC generator, supplying it to distribution boxes through CBs and relays. The DCDBs distribute DC power to various loads. The battery box houses the battery bus and distribution line CBs, with input power for the battery bus bar coming from main/emergency sources (TRUs/5 kW DC generator) or Battery 1 in their absence. Once the engine starts and reaches approximately 58% to 60% of maximum RPM, the onboard generator automatically takes over the buses from external power.

Emergency System: Battery 1 (44 Ah, 24 V Nickel-Cadmium) powers all emergency DC loads during an electrical emergency or engine flame-out. It is kept on float charge when any TRU or 5kW DC generator is online. Battery 2 (44 Ah, 24V Nickel-Cadmium) is exclusively for driving the Electric Motor Driven Pump (EMDP) in case of a hydraulic emergency, also kept on float charge when any TR or 5kVV DC generator is online.

HTT-40 Electrical Power Generating System (EPGS): The HTT-40 aircraft's EPGS includes:

1. Starter/generator 9KW
2. Voltage regulator from Avionic instruments
3. DC Master Box - 9KW
4. 44Ah Ni Cd battery
5. Two DC distribution Boxes

The HTT-40 uses only a 28V DC system, powered by an engine-driven starter-generator, supporting basic avionics, instruments, and lighting without an AC system. The IJT (HJT-36) also uses a 28V DC system, powered by an engine-mounted generator, designed for intermediate training without complex AC loads.

9. Flight Control System (FCS)

Flight control systems are crucial for determining an aircraft's flying and handling qualities. They manage stability (ability to return to equilibrium after disturbance without pilot input) and control (ability to manoeuvre the aircraft). Aircraft movement is classified into rolling (about longitudinal axis), yawing (about normal axis), and pitching (about lateral axis). These motions are controlled using external control surfaces: ailerons, elevators, and rudder. The FCS enables the pilot to manipulate these surfaces from the cockpit.

Fly-By-Wire (FBW) Flight Control Systems: FBW and Fly-By-Light (FBL) are advanced systems that replace traditional manual controls with high-tech interfaces, enhancing aircraft performance, safety, and responsiveness. FBW converts pilot inputs into electronic signals processed by flight control computers, which then command actuators to move control surfaces. These systems often operate in a closed feedback loop, stabilizing the aircraft, optimizing control surface response, and preventing pilots from exceeding safe operational limits.

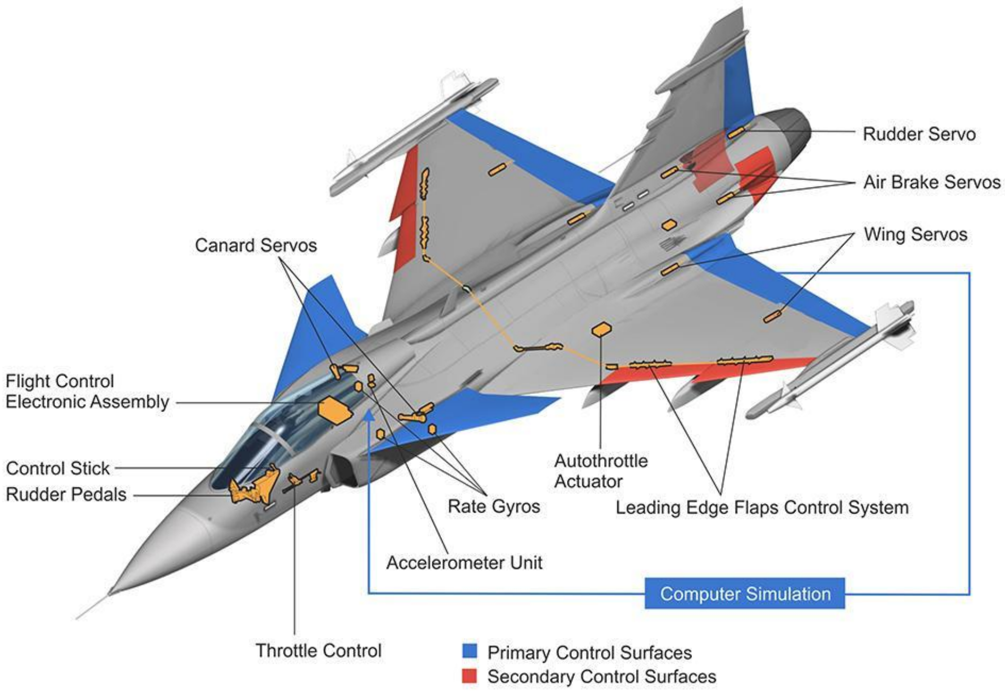
Air Data System (ADS): The ADS provides critical air data and flow angle parameters, including angle of attack, barometric altitude, Mach number, calibrated airspeed, and vertical speed. Air Data Computers (ADCs) implement these data for computation, and the output is provided to the DFCC to achieve longitudinal and lateral stability.

Components of the ADS include:

- **Nose Air Data Probe (NADP)**: Also known as the pitot static tube, it measures total pressure (Pt) for indicated airspeed, static pressure (Ps) for altitude, and pitch-up (α1) and pitch-down (α2) angles, as well as right-side (β1) and left-side (β2) banking.
- **Side Air Data Probe (SADP)**: Located on either side of the nose cone, it measures all NADP parameters except banking.
- **Angle of Attack Vane (AOAV)**: Also called the alpha sensor or vane, these probes measure pitch-up and pitch-down angles within a ±45∘ range. They are mounted with a Rotary Variable Differential Transducer (RVDT) and contain a damping fluid to reduce vibrations. The Left-Hand Angle of Attack (LHAOA) and Right-Hand Angle of Attack (RHAOA) are on the nose, ahead of the cockpit.
- **Angle of Sideslip Vane (AOSSV)**: Also known as the β vane, it provides a differential β value. A single AOSS sensor is located on the nose, below the cockpit, and is heated to prevent icing.
- **Total Air Temperature Probe (TATP)**: Senses air temperature, located on the front fuselage behind the canopy. It measures the sum of Static Air Temperature (SAT) and a kinetic component due to air compression and friction.

Flight Control Surfaces (LCA Tejas Specific):

- **Elevons**: Since the LCA is a tailless aircraft, elevators are absent and combined with ailerons to form elevons (elevators + ailerons). There are four elevons (two on each wing), controlled by separate hydraulic actuators, allowing for rolling and pitching via differential or combined movement. Maximum deflection is ±25.
- **Rudder**: Located on the vertical stabilizer (fin), controlled by a hydraulic actuator, managing yawing motion. Maximum deflection is ±30 degree.
- **Slats**: Present on the leading edge of the wings for lift augmentation (three on each wing: inboard, midboard, outboard). Controlled by the FCS, they deploy when the aircraft is near stalling speed, essential for low-speed landings and maneuvering. Maximum deflections are 17.5 degree (inboard), 27.5degree (midboard), and 30 degree (outboard).



- **Air Brakes**: Two drag-creating surfaces on the rear fuselage below the vertical fin, deployed simultaneously for aerodynamic braking by increasing drag. They are manually controlled with separate hydraulic actuators and have a maximum deflection angle of 60 degree.

Feedback Assemblies & Autopilot:

- **Accelerometer Sensor Assembly (ASA)**: An LRU that measures lateral and vertical 'g'. The quadruplex sensor assembly provides redundancy and generates control signals for feedback.
- **Rate/Gyro Sensor Assembly (RSA)**: A gyroscope indicating the rate of change of angle with time. It measures and indicates the aircraft's bank angle with respect to the horizon across all three axes.
- **Autopilot (APP)**: Holds the aircraft on a given flight path, slope, and track. It determines the difference between actual and selected flight paths, with the DFCC performing the necessary computations and converting differences into steering commands, accounting for aircraft altitude, speed, and configuration.

10. Hydraulic Systems (Electronic Interfaces)

Hydraulic systems use pressurized fluid to drive machinery and move mechanical components. In complex aircraft like Tejas, hydraulic systems power various components, including flight control surfaces, landing gear, wheel brakes, nose wheel steering, flaps, slats, thrust reversers, spoilers, cargo doors, windshield wipers, and propeller pitch control.

A hydraulic system consists of the hydraulic fluid, a pressure generator (hydraulic pump), a hydraulically powered "motor" (actuator), and the plumbing. While the core of hydraulics is mechanical, electrical and electronic systems interface significantly. For instance, hydraulic pumps can be **electric** (AC and DC motors).

Control valves associated with hydraulic motors and actuators are positioned in response to manual or **automated system selection** (e.g., moving the flap lever), which implies electronic control signals.

The Tejas hydraulic power system consists of two independent systems (System 1 RH and System 2 LH), plus an emergency system for redundancy. The aircraft's primary flight controls remain operational after two successive failures, allowing for at least 10 minutes of flight at cruise speed.

Key hydraulic components with electronic relevance include:

- **Engine Driven Pump (EDP)**: A standby pump providing hydraulic pressure if the primary pump fails.
- **Electric Motor Driven Pump (EMDP)**: Provides emergency power when both hydraulic systems 1 & 2 fail.
- **Hydraulic Motor Driven Generator (HMDG)**: Driven by hydraulic pumps, these generators supply electrical power to the two channels of the DFCC. They run continuously and start with the engine. A 0.35 kVA generator, it produces alternating current and powers AC-run equipment and the TRU (which converts AC to DC).
- **Hydraulic Motor Driven Fuel Pump (HMDFP)**: Primary fuel pump transferring fuel and supplying the engine feed line upon main booster pump failure.

The hydraulic fluid used is MIL-H-5606E or equivalent, with a nominal system pressure of 280 bar.

11. Avionics: Detailed Systems

The avionics system encompasses communication, navigation, attitude and heading reference, and air data systems.

11.1 Communication Systems

Radio communication is provided by two V/UHF communication systems working with an intercom and Audio Management Unit (AMU). These V/UHF systems facilitate air-to-air and air-to-ground voice communication in the 118-156 MHz and 225-400 MHz frequency ranges. Two such systems are provided for redundancy.

The **Audio Management Unit (AMU)** provides communication between pilots and ground crew, offering audio signal amplification and matching for transceivers and receivers, along with up to seven audio warning signals to the pilot headset. It also provides audio output for the cockpit voice recorder (CVR).

The communication system architecture includes two V/UHF Transceivers with their Control and Display Units (CDU) for external communication. Each transceiver has two CDUs (one per cockpit) for controlling settings and displaying selected channels and frequencies. Both transceivers can be powered on for reception, but transmission is possible on only one selected set.

The **Intercom Controller & Display Unit** has two control and display units, one in each cockpit. This unit selects the mode and operating frequency of the transceiver and displays the channel frequency and number on a 12-digit alphanumeric display, enabling remote access.

Operating modes of the INCOM controller include:

- **MAIN MODE ('MN')**: Functions as V/UHF transceiver, transmitting on the selected channel.

- **GUARD MODE ('GD')**: The guard channel frequency (243.000 MHz) is available alongside the main mode, but only reception of guard frequency is possible, not transmission.
- **PROGRAM MODE ('PRG')**: Allows programming of channel numbers/adjustable frequencies into the INCOM controller and transceiver unit.
- **BITE MODE ('BT')**: Enables the built-in test facility of the INCOM transceiver unit.

The AMU Junction Box has controls for intercom volume, VOR/ILS audio volume, and a Set 1/Set 2 switches for transmission selection. A CH1/CH2 selector switch allows selection of amplifier channels in case of failure.

11.2 Navigation Systems

Global Positioning System (GPS): The GPS MAGR 2000-S provides aircraft position and track information, with handheld GPS as a standby. It is a satellite-based system utilizing 24 satellites orbiting at 20,000 km, transmitting on 1575.42 MHz. The receiver uses triangulation from four visible satellites to compute a 3D position and synchronized UTC time. The GPS receiver uses a microstrip patch antenna with a low-noise amplifier, forming an integrated active antenna with a 35 dB gain, connected via coaxial cable and installed on the nose cone. The receiver unit has an eight-channel smart PCB assembly with correlators for fast and accurate 3D fixes under dynamic conditions. It incorporates built-in signal processing for signal correlation techniques to extract navigation information with fast acquisition capabilities. The receiver is in the avionics bay in the nose cone area. Navigational management features include direct-to navigation, flight plan navigation, waypoint library loading, waypoint editing, and flight parameter calculation. It also supports database uploading using ACARS/ARINC Data Exchange (ODX) or RS232 links.

Tactical Air Navigation System (TACAN): A secondary surveillance radar system with a ground transponder and airborne interrogator. TACAN provides bearing and range information relative to a ground TACAN beacon. It also provides range to other aircraft with similar systems and beacon identification signals in Morse code. The range indicates slant range, and bearing indicates direction in degrees relative to magnetic north.

Very High Frequency Omni-Range/Instrument Landing System (VOR/ILS): VOR is a short-range radio navigation system enabling aircraft to determine position and stay on course by receiving signals from fixed ground radio beacons. ILS is a precision runway approach aid with two radio beams providing vertical and horizontal guidance for landing in bad weather.

11.3 Attitude and Heading Reference Systems (AHRS)

AHRS provides attitude and heading information to head-down instruments. It consists of a magnetometer slaved to AHRS for heading display on horizontal situation indicators in both cockpits. In case of AHRS/HIS failure, pilots can use a standby compass for magnetic heading to return to base.

The attitude reference system provides attitude information on the attitude direction indicator. If AHRS/ADI fails, the pilot uses a standby gyro horizon. The inertial unit comprises three orthogonal fibre optic gyros and micro-machined silicon accelerometers. The inertial unit processes magnitude sensor input and digitally converts and processes analog signals from the magnetometers.

AHRS has operational modes:

- **Initialization Mode**: For self-test initialization.
- **Alignment Mode**: Includes levelling of roll, pitch, and heading initialization, activated automatically or by pilot request, can be performed on ground or in-flight.
- **Operational Mode**: All data is available and valid. True Airspeed (TAS) from the air data system compensates for acceleration and induced altitude error. AHRS heading is normally slaved by a magnetometer for heading computation.

11.4 Air Data Systems (ADC)

The Air Data System comprises two Air Data Computers (ADCs) – ADC1 and ADC2 – and head-down instruments like Mach/Air Speed Indicator (M/ASI), Vertical Speed Indicator (VSI), and Altimeter in both cockpits. ADCs calculate air data parameters from pitot static pressure sensors and an onboard temperature probe. Computed information is sent to head-down instruments on an ARINC-429 bus. Each ADC processes static and dynamic pressure to compute Mach number, airspeed (indicated & true), and vertical speed in all axes. ADC1 normally drives airspeed information to AHRS.

A block schematic for the Air Data System on HTT-36 PT2 A/C (similar in principle to Tejas for this system) shows the interconnections:

- NADP (Nose Air Data Probe) and QAT (Questionable Air Temperature) connect to ADC1.
- SADP (Side Air Data Probe) connects to ADC2.
- ADC1 output goes to M/ASI and ALT displays for the front cockpit (F).
- ADC2 output goes to M/ASI and ALT displays for the rear cockpit (R).
- VSI (Vertical Speed Indicator) in both cockpits can swap functions with ALT or M/ASI via a VSI swap switch.
- Standby pneumatic M/ASI and Altimeter are available for use upon ADC1/ADC2 failure.

11.5 Control Display Units (CDU)

The CDU is a pilot interface with 10 illuminated membrane switches in a 2x5 array. It features a display section with two rows of 16-character LED displays for data or messages. Three LED DCDs are on communication CDUs, and an ON/OFF backlight switch controls keyboard backlight intensity. A backlit rotary switch controls LED and annunciator brightness. A volume control knob with squelch allows selection of CW/TONE test. The display unit is built on a 74951 microcontroller, which decodes display messages, prepares display formats, and scans key line commands to send suitable commands to the receiver unit.

12. LRUs and Sensors

Open Architecture Computer (OAC): The OAC is the centralized computer for the Avionics and Weapons system in Tejas, performing system and mission-related tasks. There are two identical units, OAC 1 (active by default) and OAC 2 (hot standby). Open architecture features include ease of design, build, and tooling for quick deployment, simple interfacing with other equipment, ease of modification/reconfiguration, flexibility, upgradability, technology insertion, and reusable component-based software.

Environmental Control and Fuel Monitoring Electronic Unit (ECFM-EU): An intelligent microprocessor-based dual redundant electronic control and monitoring unit. It has two independent major functions: fuel management and cockpit environmental control.

Brake, Hydraulic, Engine and Electrical Monitoring System (BHEEM-EU): A dual redundant microprocessor-based electronic unit with one active channel and one hot standby channel. It receives digital and analog information, processes data to detect exceedances and abnormal engine behaviour, and calculates and stores engine Life Usage Indices. Upon fault detection, the BHEEM-EU generates a fault code, latches the engine fault indicator at the Central Maintenance Panel, and stores event data in an aircraft computer.

Radio Altimeter (RAM): Provides accurate aircraft altitude above water or terrain. It is a Frequency Modulated Continuous Wave (FMCW) radar operating at 4.2-4.4 GHz in the C-band. It works by continuously transmitting frequency-modulated radio waves and using the differential beat frequency from the echo signal reflected from the ground. Altitude is proportional to the time for the signal's round trip.

Multimode Radar (MMR): A pulse Doppler radar operating at X-band frequency, serving as the primary Fire Control Radar. Its main role is to detect and locate targets, process information, lock on targets, and pass this input to the OAC for weapon release. It searches, detects, and tracks ground and air targets within its field of view, and creates ground and contour maps, supporting air-to-air, air-to-sea, and air-to-ground missions.

Identification Friend or Foe (IFF): A Secondary Surveillance Radar System comprising a ground interrogator, airborne transponder, processing equipment, and antenna. The Tejas uses the IFF transponder 1420AL. The ground interrogator transmits a pulse pair, triggering the airborne transponder to reply. The interrogator processes the reply to distinguish between friendly and hostile aircraft. The airborne IFF system can also inform ground control of an emergency if radio contact is lost by transmitting special codes.

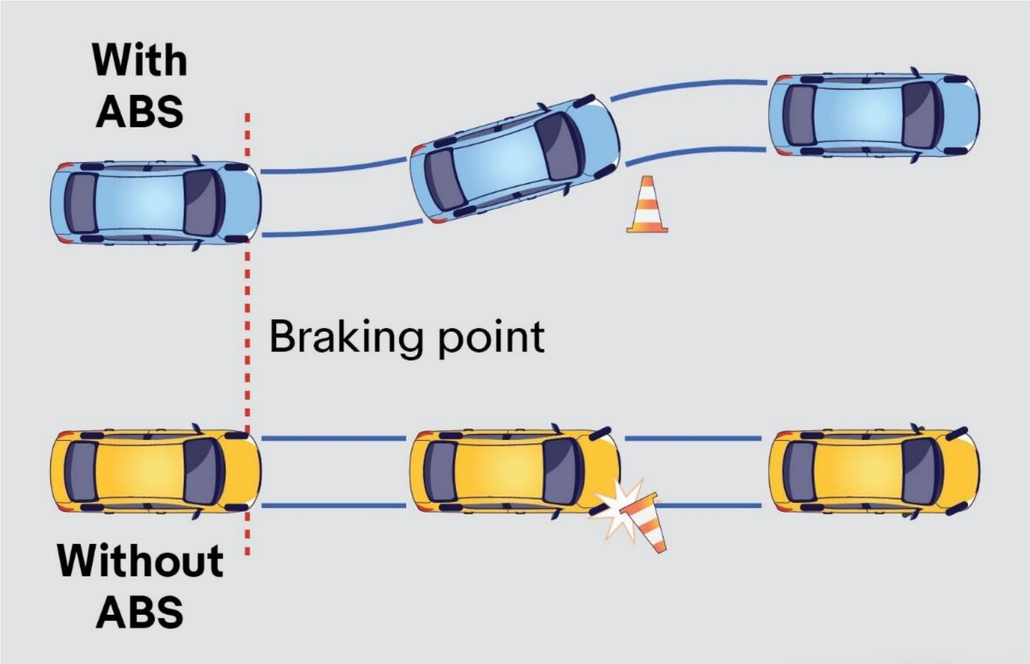
Inertial Navigation System/Global Positioning System (INS/GPS): Provides high-grade navigation functions and accuracy. This primary navigation sensor and computing unit includes an embedded GPS receiver, offering various alignment and simultaneous computation of navigation solutions.

Solid-State Crash Data Recorder Mk-II (SSCDR Mk-II): A fire and crash-resistant data recorder capable of recording and protecting aircraft data from heat and water. It records the pilot's voice for two hours and aircraft parameters for eight hours. Data and audio are recorded on a solid-state memory module with a capacity of 384 Mbs. Recorded data is retrieved via portable ground replay equipment for analysis of flight parameters and system performance.

PROJECT

Anti- Skid Braking System Simulink Model on Matlab

An Anti-Skid Braking System (ABS), also known as Anti-lock Braking System, is a safety system in vehicles that prevents the wheels from locking up (i.e., skidding) during emergency braking or braking on slippery surfaces. It helps maintain steering control and reduces stopping distance in certain conditions.



Working Principle of ABS:

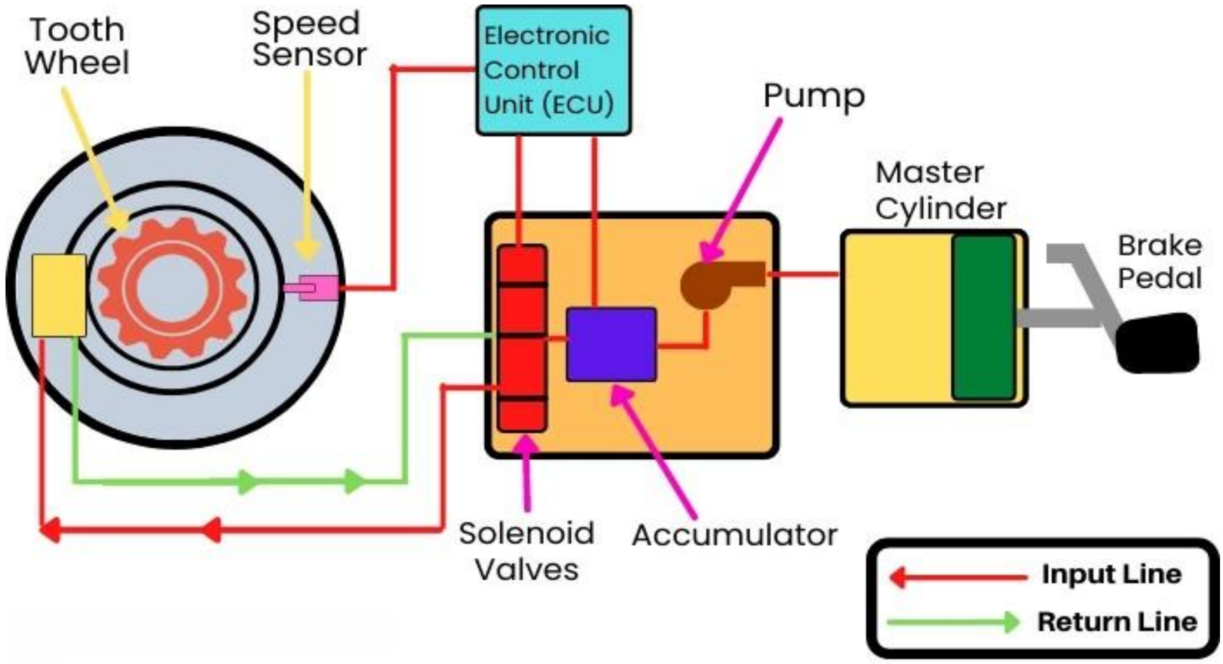
When a driver applies brakes suddenly:

- Without ABS: Wheels may lock → loss of traction → skidding → loss of steering control.
- With ABS: System detects wheel lock → modulates brake pressure → maintains traction and steering.

ABS monitors wheel speed and, if it senses that any wheel is decelerating too quickly (i.e., about to lock), it reduces braking force temporarily to that wheel, then re-applies it. This release–reapply–hold cycle can repeat up to 15 times per second.

The basic working cycle begins when the driver applies sudden or heavy brakes. If any wheel shows signs of locking (detected as rapid deceleration or zero rotation by sensors), the ECU intervenes. It signals the hydraulic modulator to reduce brake pressure to the locking wheel, allowing it to regain traction. Once rotation resumes, brake pressure is re-applied.

By continuously adjusting braking force, ABS keeps the wheels rotating just below the slip threshold (about 10–20% slip), which provides maximum friction and maintains steering control, especially on slippery or uneven surfaces.



Main components:

The Anti-lock Braking System (ABS) prevents wheel lock-up during braking, ensuring better control and stability. Its main components include:

1. **Wheel Speed Sensors** – Monitor the rotational speed of each wheel in real time.
2. **Electronic Control Unit (ECU)** – Processes data from sensors and makes decisions.
3. **Hydraulic Modulator** – Adjusts brake pressure via solenoid valves based on ECU commands.
4. **Brake Actuator** – Applies and modulates the braking force to the wheels.

Key Formulas:

1. Slip Ratio (λ):

Slip ratio is a key variable ABS monitors.

$$\lambda = \frac{V_{\text{vehicle}} - V_{\text{wheel}}}{V_{\text{vehicle}}}$$

- $V_{vehicle}$: Linear velocity of the car
- V_{wheel}: Linear velocity at the tire perimeter
- Ideal slip ratio for max traction ≈ **0.2 (20%)**

When slip ratio approaches 1, wheels are fully locked → skidding.

$V_{vehicle} > V_{wheel}$: it will skid
$V_{vehicle} = V_{wheel}$: no skidding
$V_{vehicle} < V_{wheel}$: it will accelerate

2.Braking Force (F_b):

$$F_b = \mu \cdot N$$

- μ: Coefficient of friction between tire and road (function of slip)
- N: Normal force on the wheel

ABS aims to keep μ **at maximum**, which occurs around 10–20% slip.

3. **Wheel Dynamics (Newton's Second Law):**

$$I \cdot \alpha = T_b - R \cdot F_f$$

- I: Moment of inertia of the wheel
- alpha: Angular acceleration
- T_b: Braking torque
- R: Wheel radius
- F_f: Friction force at tire-road interface

ABS regulates T_b to avoid excessive negative alpha *(i.e., wheel lock).*

4. Stopping Distance (d):

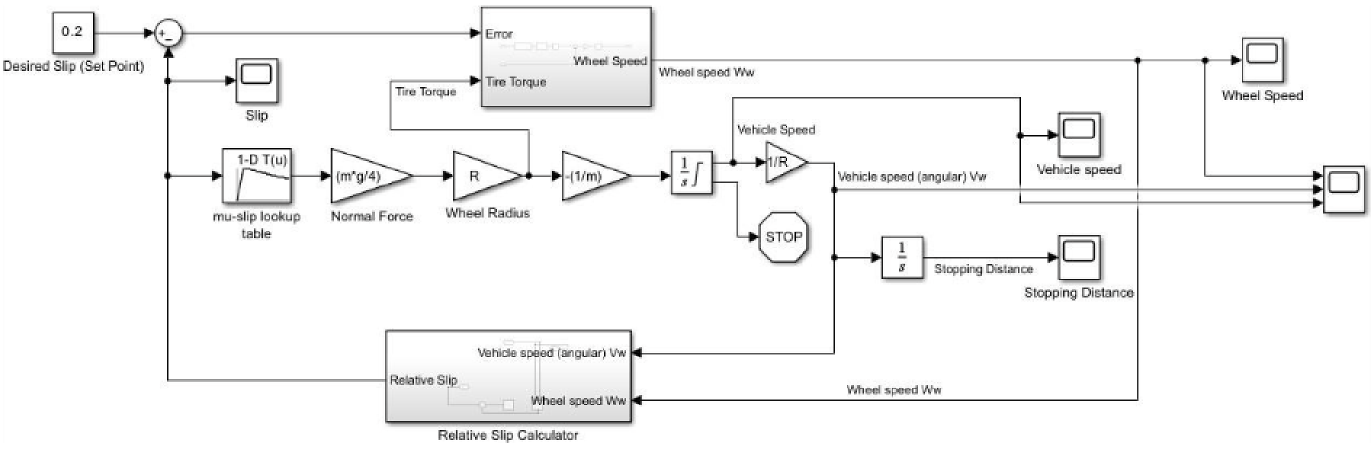
Without ABS:

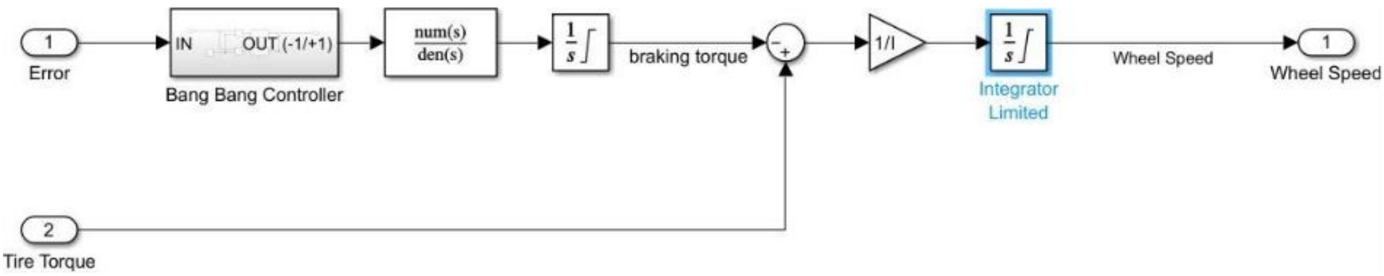
$$d = \frac{v^2}{2\mu g}$$

With ABS:

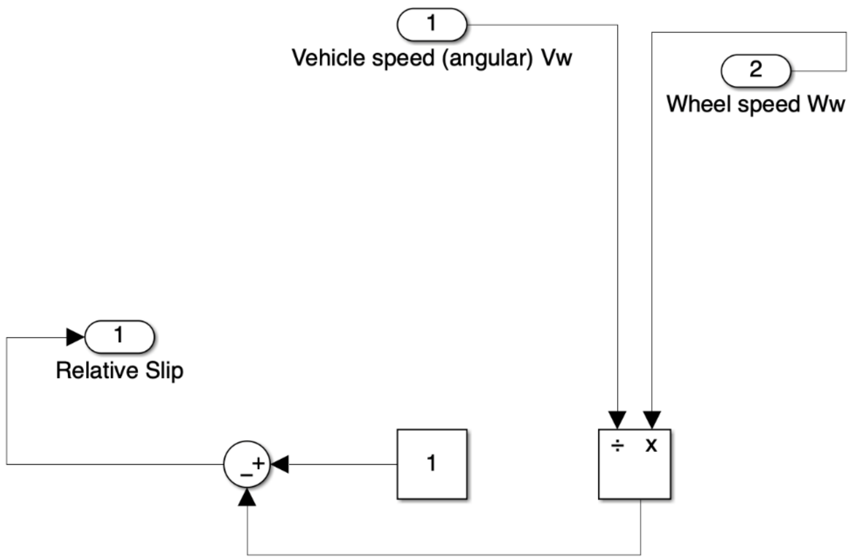
- μ is **not constant**, but optimized dynamically via ABS.
- Effective stopping distance is **reduced** especially on wet/slippery roads.

Simulink Model:

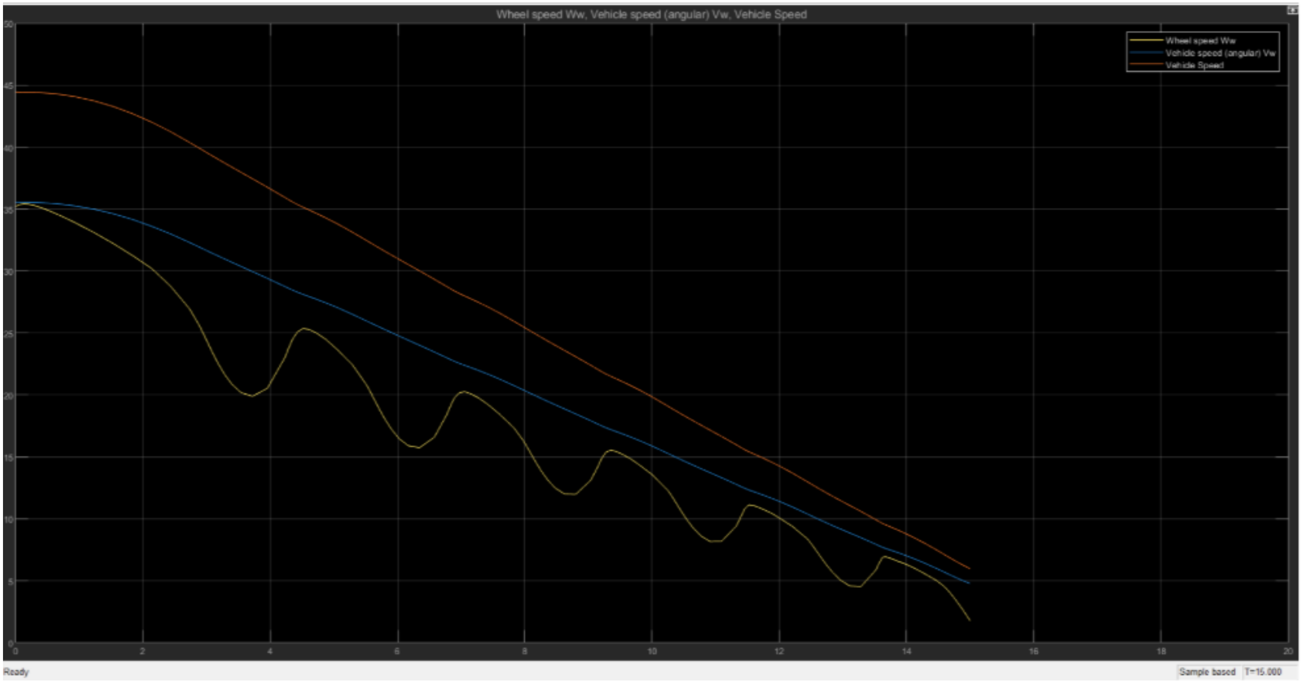




Relative Slip Calculator:



Graphs with ABS:



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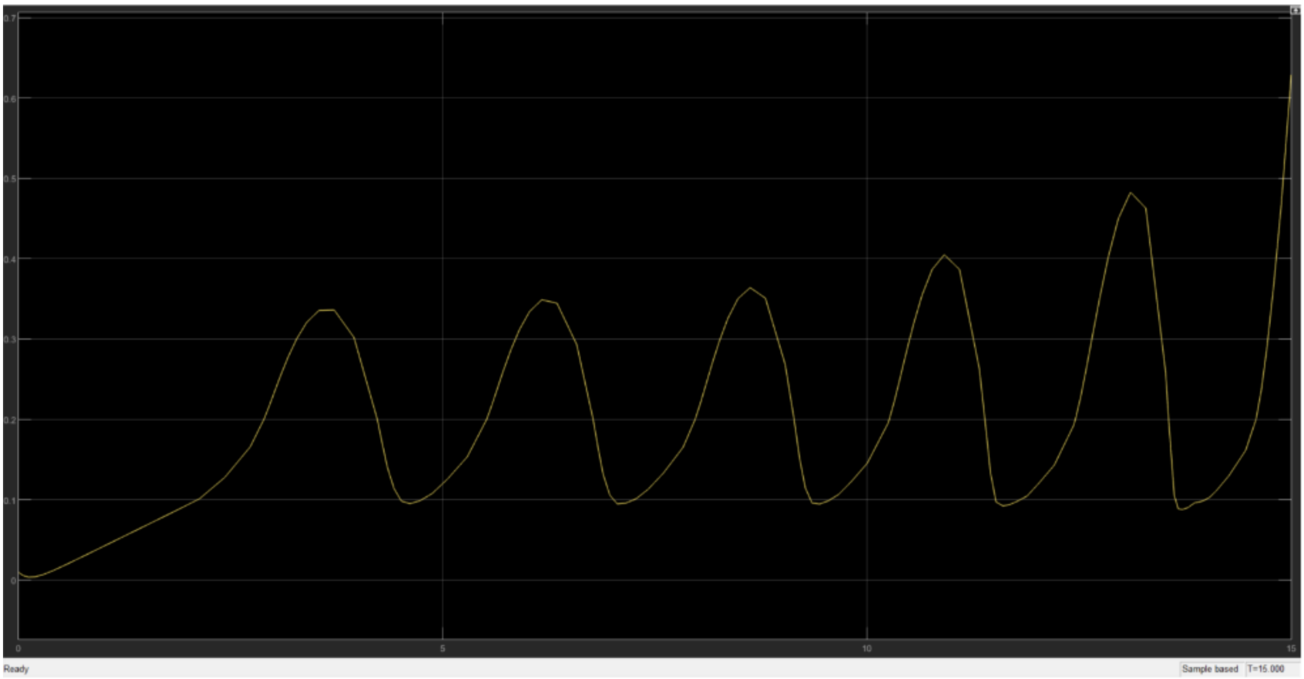
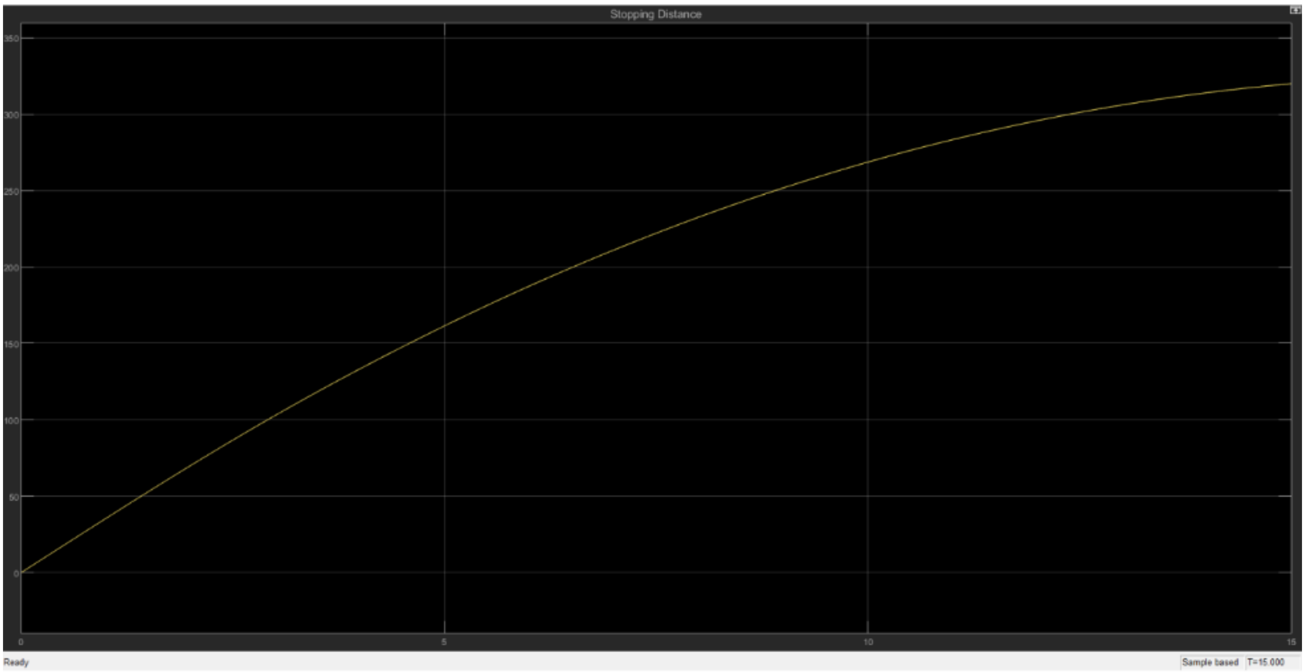


Stopping distance:



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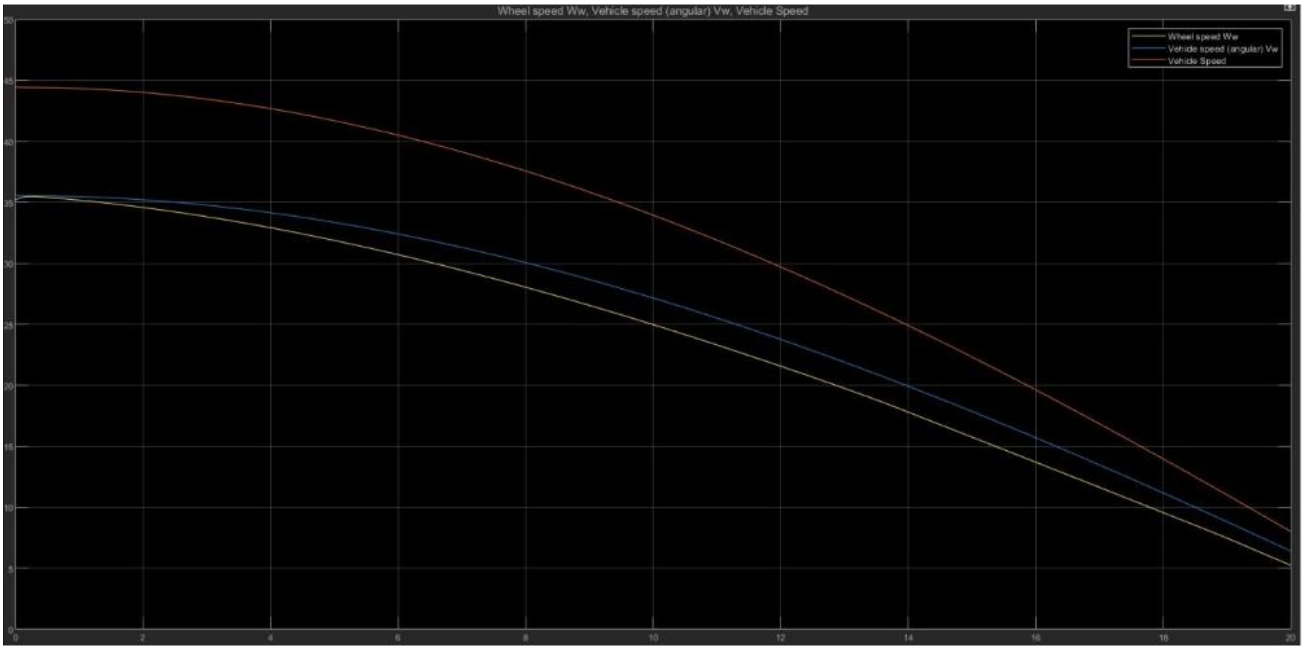
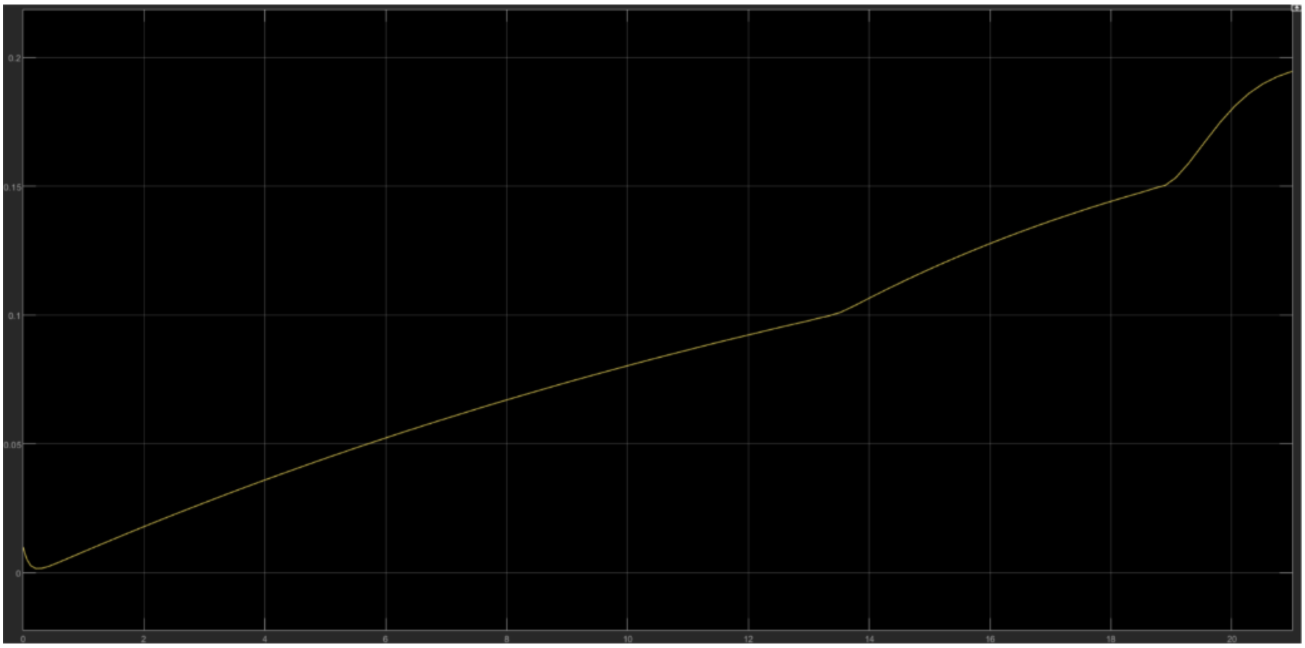


Slip:



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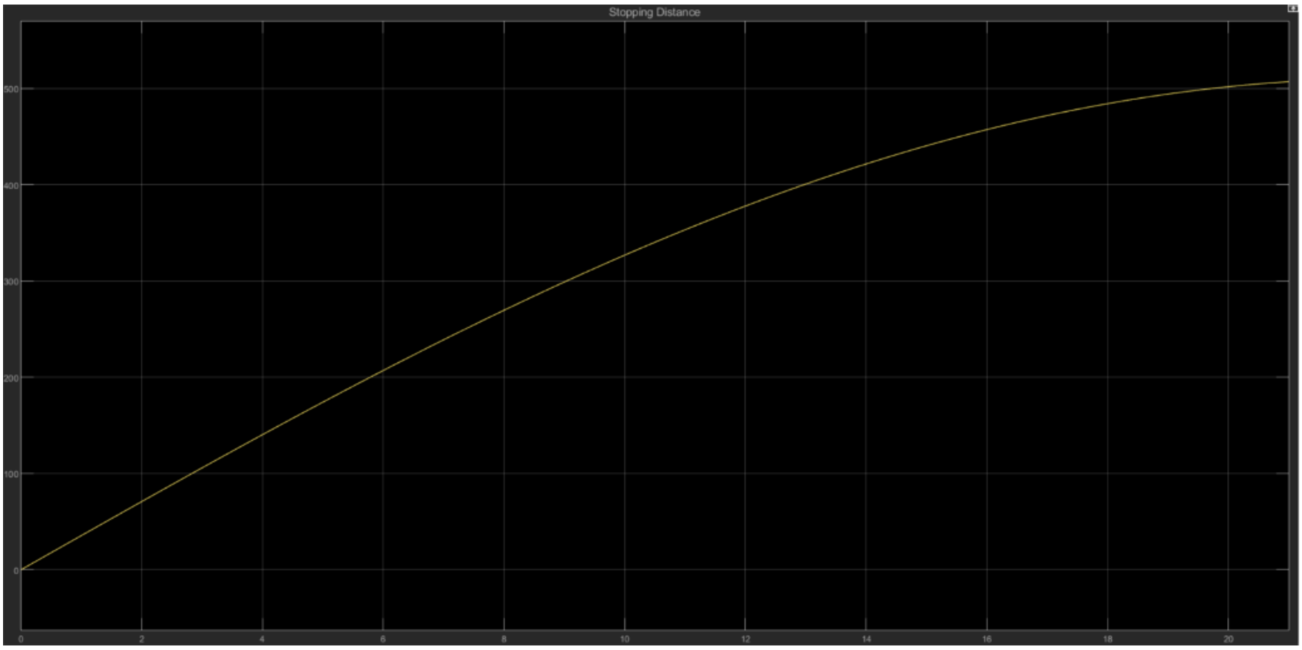

CONCLUSION:

This project successfully demonstrated the design, implementation, and simulation of an **A**nti-lock Braking System (ABS) using MATLAB/Simulink. The model effectively replicated the core function of an ABS by preventing wheel lock during heavy braking, which significantly enhances vehicle safety and control.

The simulation results clearly showed that the ABS-equipped vehicle achieved a shorter stopping distance and maintained directional stability when compared to a vehicle with a conventional braking system where wheels would lock. By modulating brake pressure to maintain the wheel slip ratio within an optimal range, the controller maximized the available tire-road friction, confirming the system's effectiveness.

The development process highlights the power of Simulink as a platform for modelling and analysing complex dynamic systems. It provided a flexible and efficient environment for testing the control logic under various conditions without the need for physical prototypes.

Future work could involve expanding the model's complexity by incorporating different road surfaces (e.g., icy or wet conditions), integrating it with a full vehicle dynamics model, or exploring more advanced control strategies like fuzzy logic or Model Predictive Control (MPC) to further optimize braking performance.

REFERENCES:

[1] Z. Wang, F. Gu, Y. Tao, Z. Wang and X. Wang, "Multi-Mode PID Aircraft Anti-Skid Braking Control System Based on Particle Swarm Optimization," 2024 IEEE International Conference on Mechatronics and Automation (ICMA), Tianjin, China, 2024, pp. 1789-1794, doi: 10.1109/ICMA61710.2024.10633040.

[2] S. Jing et al., "Simulation analysis on the performance of hydraulic fuse for aircraft brake," CSAA/IET International Conference on Aircraft Utility Systems (AUS 2018), Guiyang, 2018, pp. 1-4, doi: 10.1049/cp.2018.0229.

[3] G. Chen, J. Liu, Q. Gang, X. Ma, Z. Jiao and K. Luo, "Analysis & simulation modeling for brake control system of civil aircraft," CSAA/IET International Conference on Aircraft Utility Systems (AUS 2018), Guiyang, 2018, pp. 599-603, doi: 10.1049/cp.2018.0233.

[4] S. Jing et al., "Simulation analysis on the performance of hydraulic fuse for aircraft brake," CSAA/IET International Conference on Aircraft Utility Systems (AUS 2018), Guiyang, 2018, pp. 1-4, doi: 10.1049/cp.2018.0229.

[5] I. Tunay, E. Y. Rodin and A. A. Beck, "Modeling and robust control design for aircraft brake hydraulics," in IEEE Transactions on Control Systems Technology, vol. 9, no. 2, pp. 319-329, March 2001, doi: 10.1109/87.911383.