TECHNOLOGY FOCUS
टैक्नोलॉजी फोकस

An In-house S&T Bulletin of DRDO

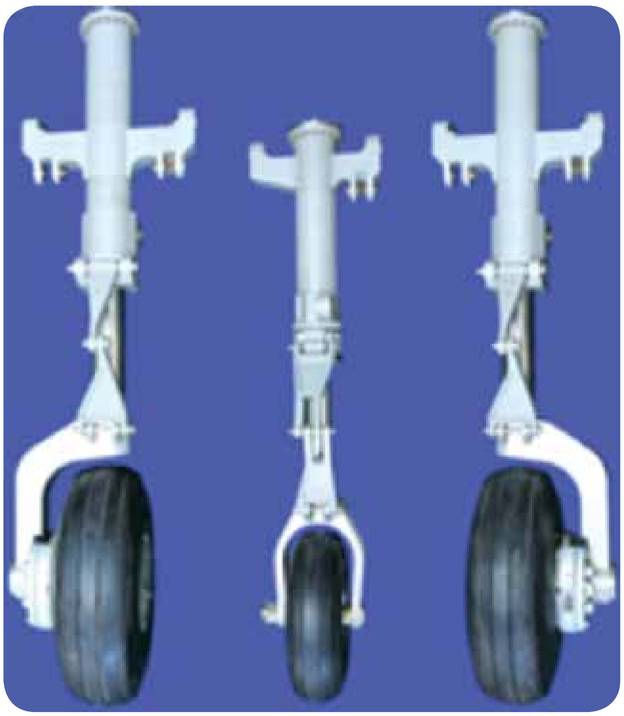
www.drdo.gov.in

Vol 28 | Issue 5 | October 2020 | ISSN No. 0971-4413

RETRACTABLE LANDING GEAR SYSTEM

Technology Focus focuses on the technological achievements in the organization covering the products, processes and technologies.

October 2020 Vol. 2| Issue 5
ISSN No. 0971-4413



Readers may send their suggestions to

The Editor, Technology Focus
DESIDOC, Metcalfe House
Delhi-110 054
Telephone: 011-23902403, 23902472
Fax: 011-23819151; 011-23813465
E-mail: director@desidoc.drdo.in; techfocus@desidoc.drdo.in; technologyfocus@desidoc.deldom
Internet: www.drdo.gov.in/technology-focus

Local Correspondents

From the Desk of Guest Editor

Dear Readers,

Unmanned warfare across land, sea, and air will soon be the new norm. Unmanned Air Vehicles (UAVs) have become quintessential inventory of modern armed forces for surveillance reconnaissance and combat. Technologies for unmanned systems would be in the "Technology denial class". Hence, it is essential to indigenously develop these technologies. One such technology of UAV is Retractable Landing Gear (RLG) System. DRDO's Combat Vehicles Research & Development Establishment (CVRDE) has indigenously developed RLG System for Beyond Horizon Long Endurance Aerial Surveillance Vehicle Tapas.

The landing gear system is the most critical multi-disciplinary engineering system of the aircraft required for smooth take-off and safe landing of the aircraft. CVRDE started the design of RLG System abinitio without having prior knowledge base.

The RLG is a complex multi-disciplinary system involving mechanical, hydraulics, electronics, software and control engineering. It comprises a tricycle retractable landing gear with a steerable nose wheel. The tricycle landing gear consists an Oleo-pneumatic shock absorber along with hydraulic actuators and retraction mechanism for deployment/retraction, landing gear controller with software, wheel and brake system and nose wheel steering. All these sub-systems, after Centre for Military Airworthiness and Certification (CEMILAC) certification need to be integrated in the aircraft finally.

For the development of RLG System, CVRDE's in-house customised test facilities are being used for testing of hydro-gas suspension of Arjun MBT. An integration test facility was established to evaluate the hydraulic system, retraction and deployment mechanism, hydraulic actuator and locking mechanisms of landing gear. Innovative project management, cross-functional teams, alternate technologies, adapting existing infrastructure test facilities for critical sub-systems, right from raw materials to finished products including testing and evaluation were used to achieve the target.

The need to design RLG with optimal weight/volume accommodating with the bay volume, high performance, adequate fatigue life and reduced life cycle cost, complying with the airworthiness and safety requirements posed many challenges to the design team. The team took up the challenge and successfully developed the system. The system, after certification by Centre for Military Airworthiness & Certification (CEMILAC) has been integrated in Tapas and has so far completed 26 flights successfully.

CVRDE is currently engaged in development of RLG systems for 1 ton class UAV and 25 ton class Advanced Medium Combat Aircraft. I am happy that this issue of *Technology Focus* would provide an insight into the design and development of Retractable Landing Gear System at CVRDE.

V. Balamurugan
Outstanding Scientist & Director, CVRDE

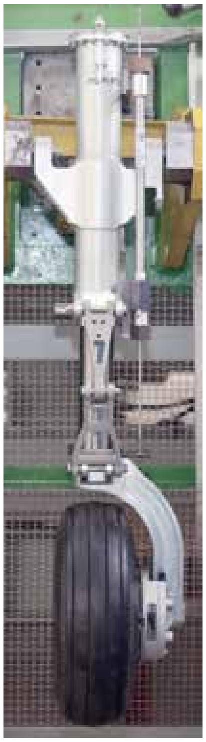
Retractable Landing Gear System

Combat Vehicles Research and Development Establishment (CVRDE) successfully developed the Hydrogas Suspension System, Transmission System and Gun Control System of Arjun MBT and number of important Line Replaceable Units (LRUs) of LCA Tejas like Aircraft Mounted Accessory Gear Box (AMAGB), Power Take-Off (PTO) Shaft, Hydraulic Filters, and 5 kW DC Generator. CVRDE is the nodal establishment for the development of retractable Landing Gear System (LGS) for Tapas UAV. The establishment executed this project and established the technologies required for the retractable LGS. Limited Qualification Tests (LQTs) on Main Landing Gear (MLG), Nose Landig Gear (NLG), hydraulic retraction actuator, landing gear controller hardware and software, landing gear relay module and nose wheel steering actuator.

Since the weight of the Tapas UAV airframe with diesel engine configuration is higher. Design of LGS existing needed upgradation to higher all-up weight and establishment of its production source as per the requirement. CVRDE has upgraded the MLG and NLG shock struts and fork and axles design. Two MLGs after the qualification tests have been integrated with Tapas. Flight trials of which are in progress.

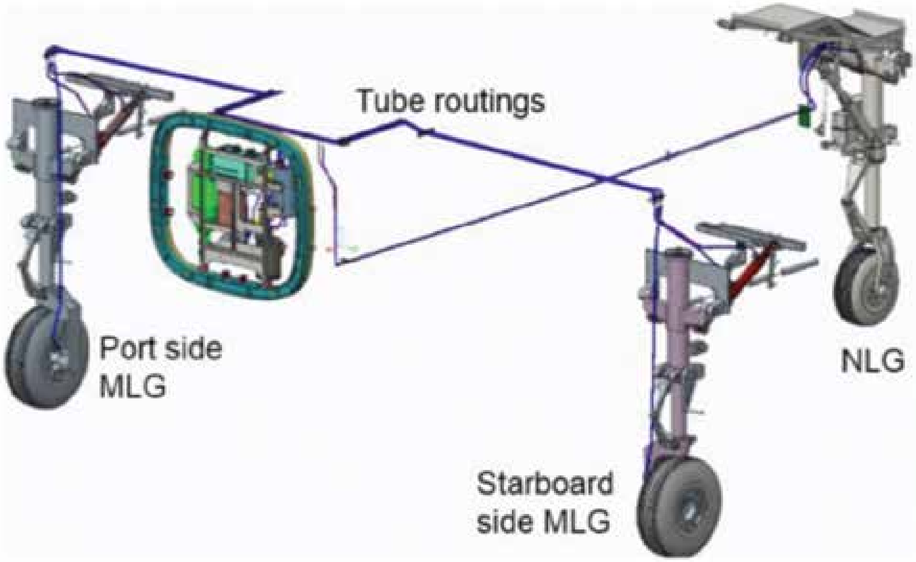
Landing Gear System

The main function of the landing gear is safe take-off and landing of UAV in various environmental and operational scenarios with the support of external pilot. A tricycle type Retractable LGS (two main landing gears and one nose landing gear) with a steerable nose wheel consists of major sub-systems, like hydrogas shock absorber



MLG

NLG



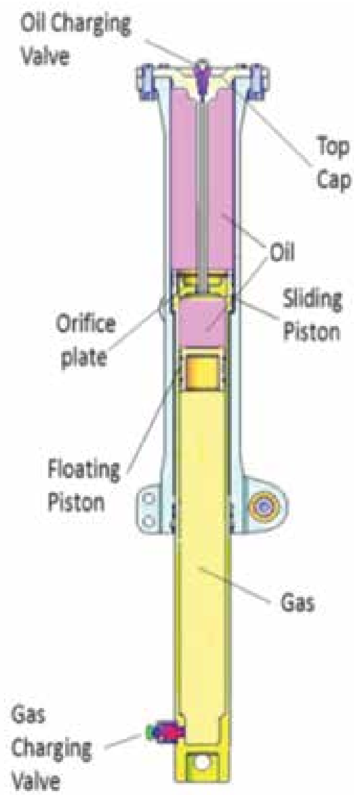
Landing gear system for Tapas UAV

strut, hydraulic actuation system with sensors, wheel and brake and nose wheel steering system, mechanism for retraction and deployment and landing gear controller for the landing gear retraction and deployment operations and its health monitoring.

Retractable Landing Gear Sub-systems

The purpose of MLG/NLG which consists of hydrogas shock strut integrated with wheel and brake system is to absorb and dissipate the landing impact load to safeguard aircraft and its onboard system and also to support the aircraft during ground maneuvering. The shock strut uses nitrogen combined with hydraulic fluid to absorb and dissipate impact loads. A tapered metering pin with orifice plate arrangement control rate of fluid flow from the upper cylinder to lower cylinder to achieve non-linear damping.

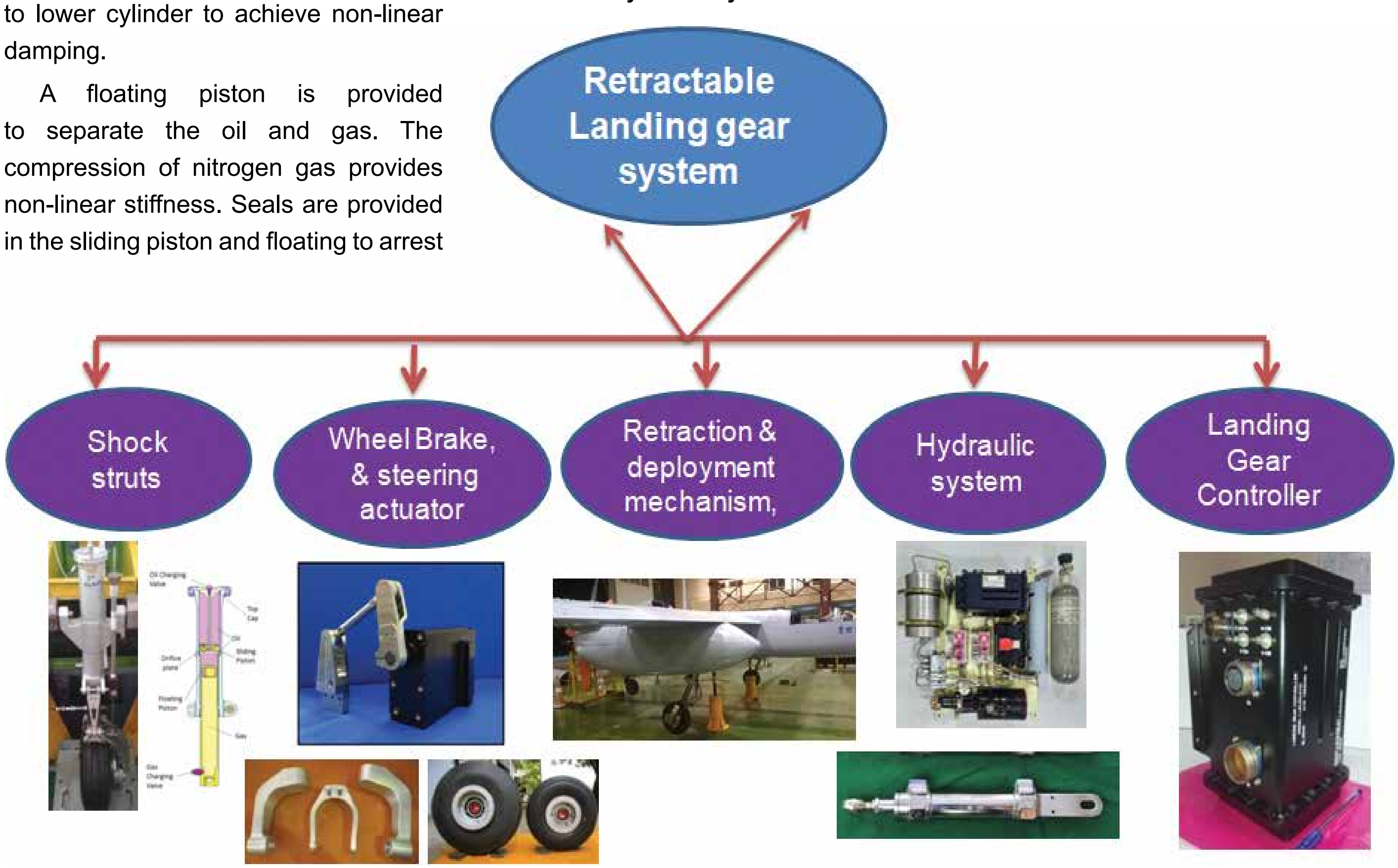
A floating piston is provided to separate the oil and gas. The compression of nitrogen gas provides non-linear stiffness. Seals are provided in the sliding piston and floating to arrest the oil and gas leakage. Oil and gas charging valve provisions are made for oil and gas charging.



Hydraulic System

Hydro-Gas Shock Strut

Retraction/deployment mechanism consists of hydraulic actuator, upper and lower drag braces, uplock, downlock and linkages connecting the door to the mechanism. The retraction/ deployment action is triggered by the landing gear controller. The retraction of the landing gear system is powered by a hydraulic system that includes hydraulic actuators, a hydraulic power pack, hydraulic valves, tubing and mechanism linkages. These units are interconnected in such a way that they operate with logic and sequence to retract and deploy the landing gear, including doors. The details about the hydraulic system as shown in the figure.



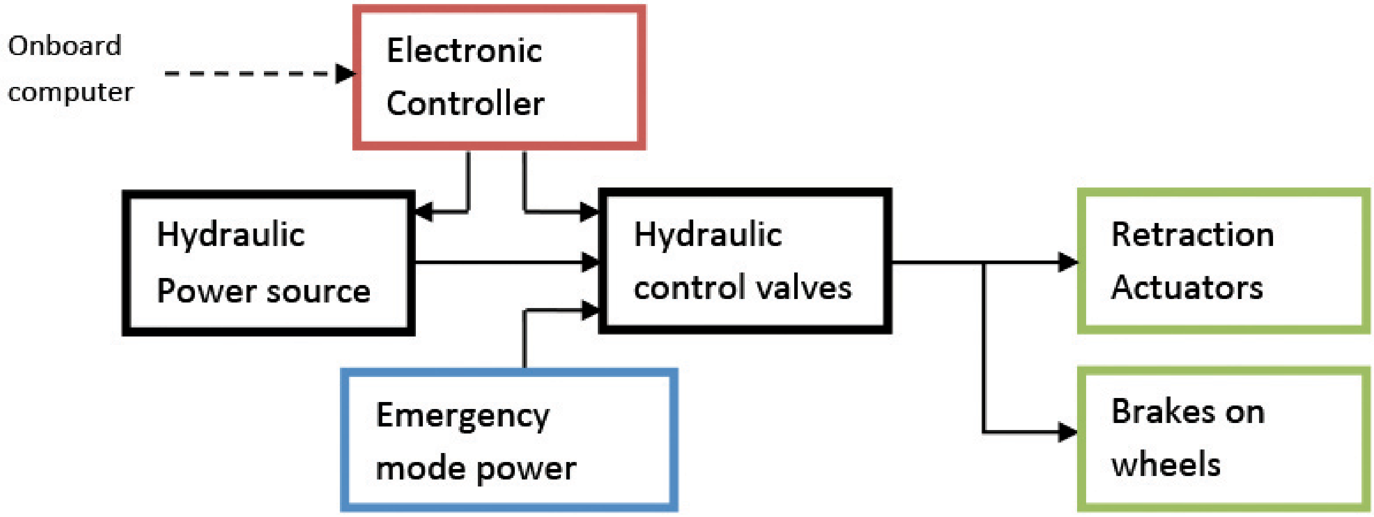
Hydraulic System

The Landing Gear Hydraulics (LGH) of Tapas employs hydraulics as the mode of power transfer. The hydraulics system is shown in the block diagram. The hydraulic power source develops hydraulic energy in terms of flow and pressure. This energy would be controlled by hydraulic flow control valves and the control flow would be given to hydraulic actuators which would convert hydraulic energy into motion and force.

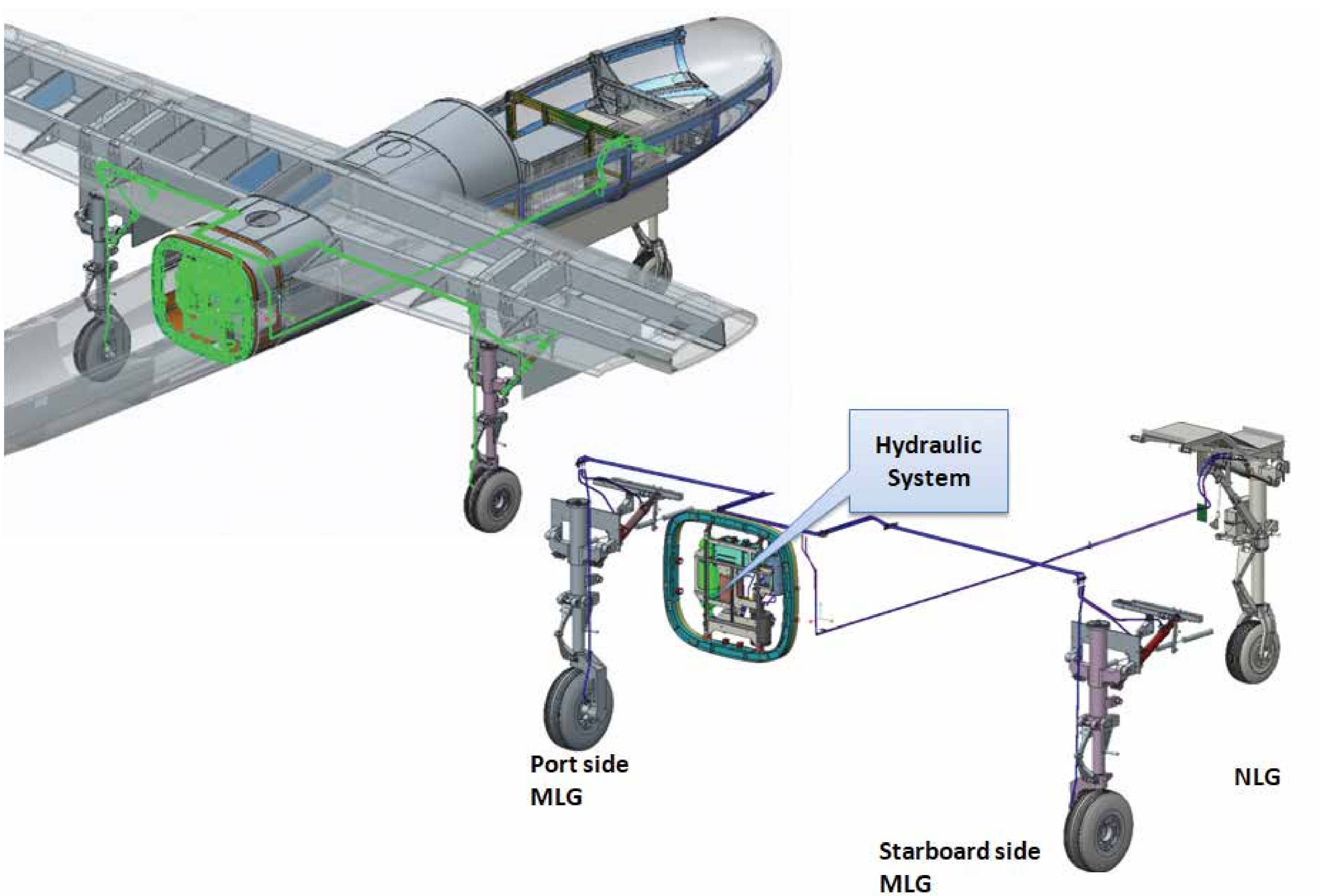
The hydraulic system also actuates the brakes which are installed on the main landing gears. The hydraulic power system consists of a power pack, manifold block installed with the control valves, hydraulic actuator and piping and fittings connecting reservoir and actuator.

The system has an emergency mode of operation which employs a pre-charged pneumatic bottle to actuate retraction actuator and brakes, in case the hydraulic power source fails to operate.

RLG Hydraulics System of Tapas UAV



Block diagram of RLG Hydraulics system of TAPAS UAV

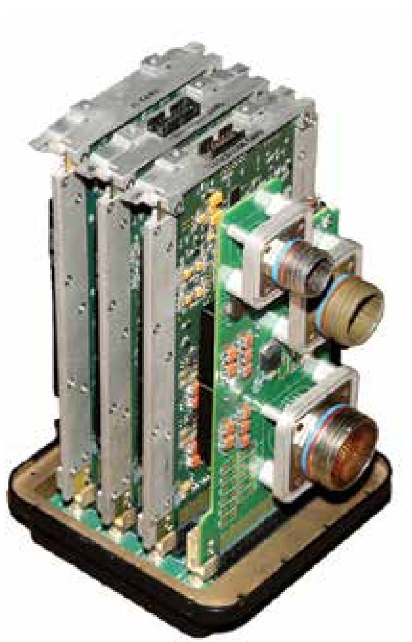


Schematic of RLG Hydraulics system of Tapas UAV

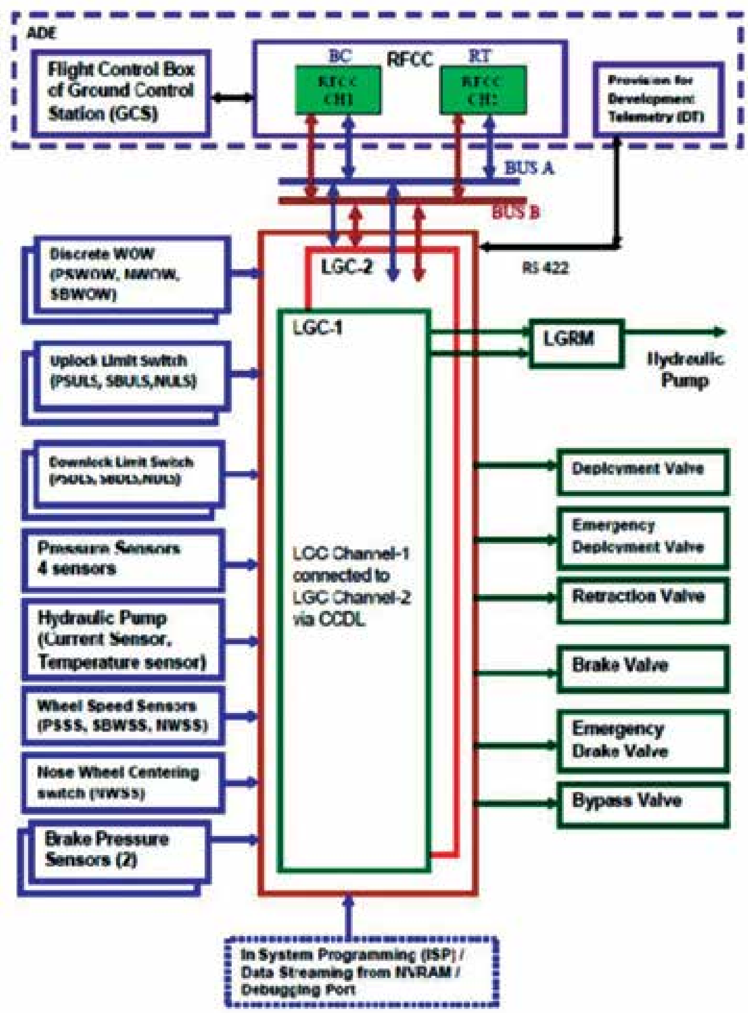
RLG Retraction actuator of Tapas UAV

Landing Gear Controller

Landing Gear Controller (LGC) is designed and developed to perform retraction and deployment of landing gear and applying brake by switching ON the hydraulic pump and the valves based on the command from Flight Control Computer (FCC). Also to monitor the status of various sensors like the weight on wheel, wheel speed, landing gear up and down locks, temperature and pressure.



Landing Gear Controller



Block diagram of Landing Gear Controller

Landing Gear Controller

LGC Hardware

As LGC being a critical sub-system used for controlling the landing gear operation, a dual redundant microcontroller is designed and developed. In this scheme, two MPC 5554 based controllers (Main and Stand by – Controller A&B) reside on the same chassis. One is the hot standby of the other. Under normal operation, Controller-A, which is the main, will be active and issues the signals. During this state, Controller-B (standby) continuously monitors the data on the bus and acts as hot standby. In the operational state, LGC shall look for the RFCC commands and perform the various operational sequences namely,

- Hydraulic Extension
- Hydraulic Retraction
- Emergency Extension
- Hydraulic Continuous Braking
- Hydraulic Intermittent Braking
- Emergency Continuous Braking
- Emergency Intermittent Braking

In an operational state, LGC shall do redundancy management of the limit switch, pressure sensor, wheel speed and discrete output. In the background, LGC shall do Continuous Built-in Test (CBIT), Pre-flight Built-in Test (PBIT) and Operator in Loop Built-in Test (OLBIT).

LGC Software

The LGC software interacts with the FCC through MIL1553B interfaces. The LGC software receives the command from the FCC for landing gear deployment, retraction and braking and sends back the status to the FCC. The LGC software switches on/off the hydraulic power pack and monitors the health of the hydraulic power pack by reading the current sensor, pressure sensor and temperature sensor through analog interfaces.

The LGC software performs the following functionalities:

- Perform operations like retraction, deployment, brake, emergency deployment, emergency brake based on FCC command
- Activates the landing gear subsystem assemblies like hydraulic-power pack, retraction, deployment, brake, bypass and emergency valves
- Monitors the sub-system assembly like wheel speed, weight on wheel, hydraulic pressures, valves pressure and limit switches and post the status to FCC
- Redundancy Management (RM) of all the sensors and the system
- The autonomous decision of hydraulic and pneumatic during braking and actuation through PWM outputs
- Performs Power on Self Test (POST), Initiated Pre-flight Built-in Test (PBIT) and Continuous Built-in Test (CBIT) functionalities
- Communicate the parameters to telemetry

LGC software interacts with the RFCC through MIL1553B interfaces. LGC software reads the pressure sensors, temperature sensor and current sensor values through ADC interface, processes the data and performs data sanity checks.

The software will be implemented using C and assembly language and compiled using Green Hills Multi Compiler, Software for the landing gear controller to meet the requirements of DO 178B level A safety level standard, which deals with software considerations in airborne systems and equipment certification. The developed software will undergo verification and validation and independent verification and validation process with SW.

Landing Gear Relay Module

Landing gear Relay Module (LGRM) is designed to Power on hydraulic powerpack pump motor based on the discrete commands from LGC, monitor the motor current and hydraulic oil temperature continuously. Relays within LGRM shall be independently powered by Alternator Bus A and Alternator Bus B.

The LGRM shall take the dual discrete output command from Processor A and Processor B of LGC. The LGRM shall power on the hydraulic pump motor using Main Relay A or Main Relay B.

Challenges Faced During the Design and Development of Landing Gear System

The development team prepared different configuration layouts and analyzed their implication and with due consideration of space constraints in the undercarriage bay volume and various aircraft parameters.

The retractable LGS layout was finalized, after the number of iterations considering overall aircraft dimensions and clearance requirement at static and failure modes. Based on the design requirement specifications and overall aircraft dimensions, load on the MLG and NLG under various landing conditions have been estimated using the FAR 23 Standard.

The shock strut stroke was estimated based on the aircraft sink velocity. Design of metering pin and damper orifice to absorb the loads within the allowable rate is a challenge and the design has been innovated through mathematical system modeling and simulation. These detailed simulations in the initial stage of design have helped in achieving the first time right design. Instead of having a fixed orifice, a variable orifice design is implemented in an innovative way that provides variable nonlinear damping enabling uniform absorption of landing impact energy and to realize the variable orifice, an innovative self-centering mechanism is deployed.

The upper and lower cylinders of the shock strut being a long one posed a challenge for machining confirming to geometric dimensioning and tolerance (GD&T) requirements and the same has been achieved with proper tooling. The seals which are critical element in the shock strut have been indigenously developed and validated. The MLG/ NLG shock struts designs have been analyzed and optimized through detailed finite element simulations, for various types of landing loads estimated as per FAR 23 Standards to ensure adequate factors of safety and fatigue life.

Aircraft wheel and brake assembly is another critical module of a landing gear system. The design team has analyzed the kind of loads experienced on the system during taxing and landing. The total kinetic energy level is calculated for normal landing and take-off and rejected take-off conditions. The tyre has been chosen based on the wheel size. The fork and axle have been designed and developed for aircraft landing loads. A nose wheel steering system is designed to provide aircraft control during ground operations with a four-bar linkage mechanism to transfer the power from an electromechanical actuator to wheel through torsion links.

A mechanism has been designed and developed for retraction of the landing gear after take-off, and deployment of the landing gear before landing within the stipulated time. The retraction/ deployment mechanism was simulated through detailed multi-body dynamics simulations and is designed innovatively so that the same hydraulic actuator used for retraction/deployment is used for releasing the uplock and operating the landing gear bay door. A detailed hydraulic circuit has been designed and all the hydraulic elements like pump and motor, valves, filters, distribution block, reservoirs and hoses and fittings have been finalized based on the design requirements. The design and development of the hydraulic actuators have been done with due consideration of endurance requirements.

Landing gear controller was developed with completely customized MIL grade PCBs using dual redundant, hot standby configuration. As LG C being a critical subsystem, control the landing gear operation, dual redundant digital computer-based avionics architecture is adopted. Standby switch over based on watchdog timer, built-in test features, fault detection and isolation of individual channel, redundancy management of sensors and discrete outputs, MIL-1553B communication and redundant cross channel communication are the other features included considering highest safety requirements. The customized configuration has helped in bringing the complete controller within an optimized weight of 3.5 kg. The LGC software has been developed in-house as per the requirements of ADE, following stringent DO178B Level-A safety standards.

Development of Airworthy Prototypes and Qualification Testing

Detailed manufacturing drawings were made and coordinated with the CEMILAC, airworthy raw materials have been identified, sourced and the prototypes manufactured. The components were kit cleared, assembled in coordination with the Regional Directorate of Aeronautical Quality Assurance (RDAQA).

Ingeniously modified MBT suspension test facilities already available to test landing gear assembly with suitable adaptations for mounting MLG and NLG. Suitable adaptations were also done innovatively for three directional loading of the landing gear.

Some unique facilities like hydraulic actuator endurance test facility, Snub-test facility, harness endurance test facility, were developed in-house for qualification testing of landing gear systems. For performance testing of landing gear controller an innovative test jig has been developed and used.

CVRDE established an integration test facility to evaluate the hydraulic system retraction and deployment mechanism, hydraulic actuator and locking mechanisms of the landing gear.

The landing gear sub-systems such as MLG/NLG shock struts, retraction/deployment mechanisms, hydraulic retraction actuators, landing gear controller and harnesses were subjected to about 70 numbers of qualification tests, including drop testing and strength testing in coordination with RDAQA and the reports are coordinated with CEMILAC and RDAQA. Based on the test reports and analysis reports CEMILAC has certified the landing gears for integration into Tapas UAV. Two sets of airworthy landing gears have been handed over to ADE for aircraft integration.

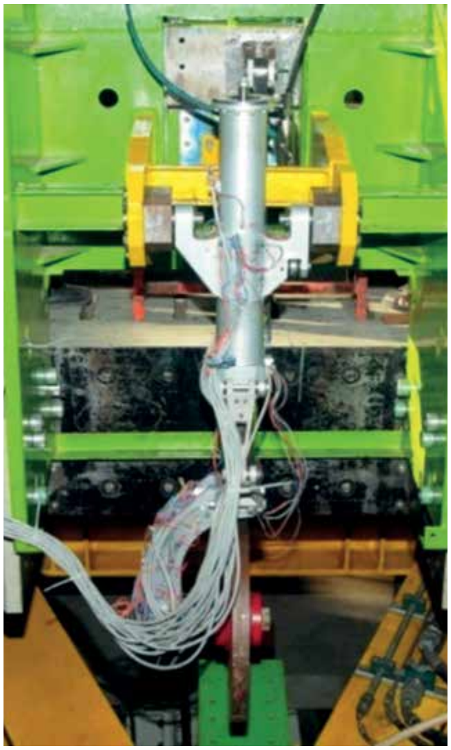
Landing gear spring curve test

Snub test – MLG

Testing of LGS in Integration Test Rig

Drop testing of MLG

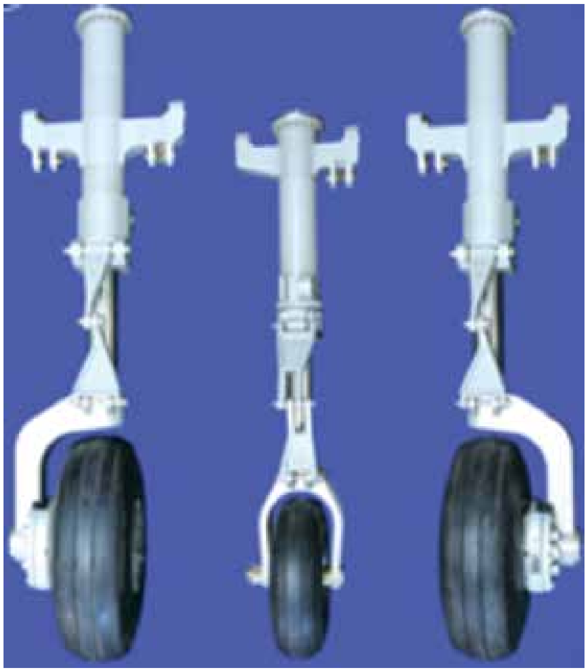
Drop testing of NLG



Strength testing of MLG

Landing gear controller testing

Harness bend test



First set of Landing Gear

Second set of Landing Gear

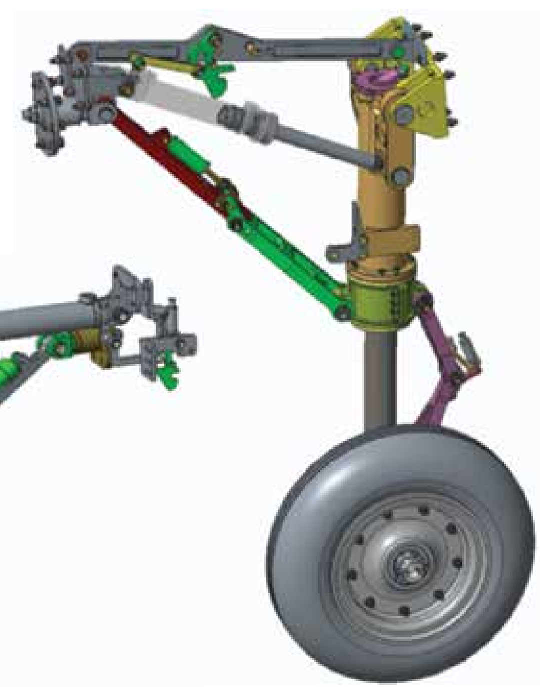
Flight Clearance from CEMILAC and Flight Trials

After obtaining the integration clearance from CEMILAC, the MLG and NLG landing gear have been integrated into the Airframe-5 and 6. The retractable LGS after integration into the aircraft, Low-speed Taxi Trial (LSTT) and High-speed Taxi Trials (HSTT) have carried out before the first flight. During the taxi trials, the brake performance, aircraft stopping distance, hydraulic system functional performance, landing gear controller hardware and software performance, all the limit switches performance and retraction and deployment mechanism components performance in the deployment mode have been evaluated and completed the LSTT and HSTT successfully. Based on the LSTT and HSTT performance, flight clearance certificate obtained from CEMILAC and successfully completed sixteen flights with 11 in fixed mode and 5 in retracted mode.

Landing Gear integrated

First Flight

Retractable mode flight



MLG for 1 ton class UAV

NLG for 1 ton class UAV

TECHNOLOGY FOCUS

READERS' FEEDBACK

Your feedback is important to us in our efforts to further improve the content and presentation of information. The editorial team requests you to kindly fill in the feedback form and give your level of satisfaction and newer aspects you would want to incorporate in the *Technology Focus*.

Rate the ***Technology Focus*** as a medium to present DRDO's technology and product developments?

Excellent ☐ Good ☐ Satisfactory ☐ Needs improvement ☐

How do you rate the quality of photographs in the ***Technology Focus***?

Excellent ☐ Good ☐ Satisfactory ☐ Needs improvement ☐

Optimal number of pages you would like for the ***Technology Focus***?

16 Pages ☐ 20 Pages ☐ 24 Pages ☐ 28 Pages ☐

Preferred medium of ***Technology Focus***?

Print ☐ Online (PDF) ☐ E-pub ☐ Video Magazine ☐

Whether magazine is delivered on time?

Yes ☐ No ☐

What should be the frequency of ***Technology Focus***?

Bimonthly ☐ Quarterly ☐ Half-yearly ☐

For updates on ***Technology Focus***, Kindly provide your e-mail id.

Suggestions, to further improve the ***Technology Focus*** ?

Name: Signature

Address:

Design Upgradation and Productionisation of LGS

Based on the ADE's requirement, CVRDE has taken up design upgradation and productionisation of landing gear system for Tapas UAV with an increased all-up weight of 2.85 tons. The MLG and NLG design has been upgraded and optimized for the weight and airworthy MLG and NLG are manufactured. Limited qualification tests have been completed for MLG and NLG and delivered to ADE.

The delivered landing gear system integrated into the AF6-A aircraft after the CEMILAC clearance and completed 10 flights successfully.

Way Ahead

Design and Development of 1 ton and 25 ton LGS

ADE projected a requirement to develop a retractable landing gear system for 1 ton class Stealth Wing Flying Testbed (SWiFT) UAV, which is under development. SWiFT UAV is a Technology Demonstrator and is a scaled-down version of Ghatak UCAV (Unmanned Combat Air Vehicle). The main intent of SWiFT UAV is to demonstrate and prove the stealth technology and high-speed landing technology in autonomous mode. The landing gear design has been completed and the manufacturing of the airworthy components are under progress.

Based on the experience and domain expertise gained and milestones achieved in the design and development of LGS for 2 ton class UAV, landing gears for 25 ton class twin-engine Fighter Aircraft AMCA, has been takenup based on ADA's requirements and design phase has started.

Published by DESIDOC, Metcalfe House, Delhi-110 054
www.drdo.gov.in