2023 ARMS

SOUVENIR

13th National Conference and Exhibition on

Innovations & Developments in High Altitude Technologies & Related Mechanisms

14th to 15th Dec 2023

ADRDE - DRDO

AS 9100D Certified

INSARM

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Organised at

Aerial Delivery Research & Development Establishment

Agra - 282001

SOUVENIR

ARMS – 2023

13th National Conference and Exhibition
on
“Innovations & Developments in High Altitude Technologies & Related Mechanisms”

14 - 15th December 2023

AS 9100D Certified

Organised at

Aerial Delivery Research & Development Establishment
Station Road, Agra – 282001

डॉ. समिर वी. कामत
Dr. Samir V. Kamat

सत्यमेव जयते
भारत सरकार
Government of India

सचिव, रक्षा अनुसंधान तथा विकास विभाग
एवं
अध्यक्ष, डीआरडीओ
Secretary, Department of Defence R&D
&
Chairman, DRDO

MESSAGE

I am pleased to note that Indian National Society for Aerospace and Related Mechanisms **(INSARM)**, Agra Chapter at Aerial Delivery Research & Development Establishment **(ADRDE),** Defence Research & Development Organisation **(DRDO),** Agra is organising 'ARMS-2023', 13th National Conference and Exhibition on **Innovations & Development in High Altitude Technologies & Related Mechanisms on 14th-15th Dec 2023**.

This also earmarks the recent triumph of Indian Aerospace Community by making its mark with the successful Chandrayaan-3 mission followed by launch of Mission ADITYA-L1 which is well on its way to the Sun-Earth Lagrange Point (L1). At the same time, it is heartening that ADRDE Agra is also contributing in the prestigious project **GAGANYAAN**.

These missions call for amalgamation of various expertise in these critical technology areas to strive together and create a self-sustained environment for realization of such systems & technologies. INSARM is definitely imparting its role in nurturing talent and invoking interest in the Aerospace & Defence related mechanisms amongst the scientific community. Exhibition would be an excellent platform for harnessing the synergy between the scientific community, academia and associated industry partners.

I am sure that ARMS-2023 would be able to promote scientific collaboration and research amongst the participants. I congratulate the organisers and wish a successful conduct of the event.

Samir

(Dr. Samir V. Kamat)

रक्षा मंत्रालय, रक्षा अनुसंधान तथा विकास विभाग, डीआरडीओ भवन, नई दिल्ली-110011
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एस. सोमनाथ / S. SOMANATH
अध्यक्ष / Chairman

MESSAGE

I am delighted to note that the Indian National Society for Aerospace and Related Mechanisms (INSARM), Agra Chapter is organizing the 13th National Conference & Exhibition on Aerospace & Related Mechanisms - 2023" (ARMS-2023) in association with Aerial Delivery Research & Development Establishment (ADRDE) during 14th to 15th of December 2023 at Agra.

As the nation progresses towards more challenging space missions including human spaceflight, Lunar and Interplanetary missions, the development of high reliability aerospace mechanisms will continue to play a critical role in ensuring the success of these missions. High altitude technologies and decelerator systems have a major role in ensuring the stringent safety & reliability required for human space missions. These technologies, spearheaded by research institutions like ADRDE, are an integral part of complex re-entry and stage recovery missions. We are looking forward to further innovations in this area to expand the scope of space missions towards higher complexity and robotic exploration.

I am also happy to note that the conference is specifically focusing on innovations and recent developments in the field, and sincerely hope that this event will witness a productive confluence of professionals, academia and entrepreneurs.

I wish a grand success for the Conference.

Date: November 03rd, 2023

(सोमनाथ एस / Somanath S)

एम जेड सिद्दिक़
M Z SIDDIQUE
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Director General - Aeronautical Systems

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एक कदम स्वच्छता की ओर

MESSAGE

I am happy to note that 'ARMS-2023' is being organized by Indian National Society for Aerospace and Related Mechanisms (**INSARM**), Agra Chapter during **14-15th Dec 2023** at Aerial Delivery Research & Development Establishment, Agra.

Regular conduct of ARMS conference by INSARM is an excellent initiative by all concerned to invoke interest in the Scientific, Academia and Industrial community about Aerospace and Related Mechanisms.

ARMS provides an opportunity to identify the emerging technology areas in Aerospace & Aeronautics fields.

The 13th National Conference and Exhibition on Innovations & Development in High Altitude Technologies & Related Mechanisms would enable all concerned stake holders to brainstorm and address challenges related to systems and technologies for high altitude applications.

I am certain that this conference would be the right forum for Scientists, Academicians and Industry partners to present their innovative ideas and to gain knowledge.

I take this opportunity to extend my good wishes to the participants, organizers and wish ARMS-2023 conference a grand success.

(M Z Siddique)
DS & DG (AERO)

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डॉ उण्णिकृष्णन नायर एस
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विशिष्ट वैज्ञानिक व
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MESSAGE

November 2, 2023

I am delighted to note that the Indian National Society for Aerospace and Related Mechanisms (INSARM) is organizing the 13th National Conference and Exhibition on "Innovations and Developments in High Altitude Technologies and Related Mechanisms" (ARMS-2023), at ADRDE, Agra from 14 to 15 December 2023.

This conference holds immense significance, especially in the context of India's ambitious endeavors in space exploration, including the Human Spaceflight Programme. The advancements in high altitude technologies and mechanisms are at the core of this remarkable journey. I am particularly appreciative of the contributions made by ADRDE in parachute development, a critical aspect of space missions, which has significantly bolstered India's space capabilities and exemplifies the importance of indigenous innovation in the aerospace sector. Mechanisms play a pivotal role in our exploration of various celestial bodies, including Earth, Mars, and the Moon. These mechanisms, ranging from rover wheels to robotic arms, are among the central elements of space missions, enabling scientific exploration, data collection and safe function of spacecrafts and habitats. The theme of the conference aligns with India's ambitious long term plans for establishing a sustainable presence on the Moon and developing a space station.

I am confident that ARMS-2023 will serve as a platform for knowledge exchange and collaboration among experts, researchers, and students, propelling India's space endeavors to new heights. I extend my best wishes for the success of ARMS-2023, all set in the enchanting city of Agra, home to the timeless beauty of the Taj Mahal.

(Unnikrishnan Nair S)

Indian National Society for Aerospace and Related Mechanisms, Thiruvananthapuram Chapter

G1 Flat, Future Point, Edappazhanji, Sasthmangalam PO,
Thiruvananthapuram 695010 (Regn No. T 786/98)

Subramanian UA
President, INSARM,
Thiruvananthapuram Chapter

It gives me immense pleasure to note that, ARMS 2023, National symposium and exhibition on Aerospace and Related Mechanisms, is organized by INSARM, Agra chapter in December 2023. In the current scenario, technological advances are taking place in every field and it is essential to keep abreast of the new development. Expertise created in individual groups or in an organization to meet its goals are to be shared. Joint action and coordinated efforts by national agencies, academia and industries are highly imperative to synthesize the knowledge, skills and experiences in related fields. This is more relevant in the case of highly complex and multifaceted areas like aerospace. In recent times, ISRO and DRDO, along with other defence departments are closely collaborating in many of the advanced missions like Gaganyaan and Mars landing.

Highly reliable aerospace mechanisms have been one of the strength in ISRO's march towards self-reliance in space technology. Mission critical events of satellite launching including Stage separations, Deployments, Parachute based systems etc., can be achieved only through flawless performance of complex and multi-disciplinary mechanisms. The kind of challenges of future missions like space rendezvous, interplanetary missions etc. will be much more complex.

I hope this seminar will inspire mechanism engineers of the country and open up new vistas for developing state of the art mechanisms.

(Subramanian UA)

INDIAN NATIONAL SOCIETY FOR AEROSPACE AND RELATED MECHANISMS
BANGALORE CHAPTER

President, INSARM, Bangalore Chapter

Message for ARMS-2023

It is heartening to know that 13th National Conference & Exhibition on Aerospace Related Mechanisms & Systems (ARMS-2023) is being organised by ADRDE, DRDO in association with INSARM, Agra Chapter.

Aerospace & related mechanisms play a key role in the performance of spacecraft, launch vehicles, aircraft, missiles and other defense equipment. The requirement of spacecraft mechanisms are increasing multi-fold in space by way of large deployable antenna, large deployable space structures for solar arrays, docking experiments and space robotics. Each system has its own challenges in its design, realisation and testing phase. To name a few, spacecraft mechanisms are exposed to high acceleration loads during launch, extreme temperature gradients and vacuum environment during their travel and in the final operational configuration in-orbit. Lack of gravity in-orbit causes mechanism to behave differently in ground while testing its performance. On many a times, the effect of zero gravity to be simulated in ground through a separate test system, to check the performance of these mechanisms. In addition, reliability and weight optimisation are the key factors to be considered in the design. Electromechanical systems are also gaining popularity as actuating devices. For these systems, redundancies in the electrical system play a prominent role in its successful performance. All these factors have to be accounted by suitable design, modelling, simulation and end to end testing. Hence, flawless and precise performance of these mechanisms is a culmination of rigorous design, extensive simulation and meticulous testing at each stage.

I am sure that this occasion will provide an excellent platform for researches, professionals and academicians working in the field to share their views and bring out innovative mechanisms in future.

I convey my warm greetings and felicitations to organising committee & all participants. I also extend my best wishes for the grand success of the conference.

B. P. Nagaraj

Dr. B.P. Nagaraj

Contact Address - *C/O Spacecraft Mechanisms Group, 3rd Floor, MSA/ISITE, UR Rao Satellite Centre (ISRO campus), Marathahalli Outer ring road, Karthik Nagar, Bengaluru - 560 037.* **Website:** *www.insarm-bangalore.org*
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Distinguished Scientist
DIRECTOR

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Government of India, Ministry of Defence, DRDO
Advanced Systems Laboratory
Dr. A.P.J. Abdul Kalam Missile Complex,
P.O. Kanchanbagh, Hyderabad-500 058,T.S. India.
Dated: 14/11/2023

I am delighted to know that 13th National Conference & Exhibition: ARMS-2023 on "Innovations & Developments in High Altitude Technologies & Related Mechanisms" is being organized by INSARM Agra Chapter during 14th to 15th December, 2023 at ADRDE Agra.

Major advances have been made in the development of aerospace technologies related to launch vehicles, missiles, combat aircrafts and UAVs in the recent past. I am happy to note that, INSARM is taking the initiative to bring aerospace related mechanism & systems experts together at national level for interaction on continuous basis. I hope this seminar would provide a platform to deliberate upon the pertinent issues, requirements and Innovations & Developments being envisaged in High Altitude Technologies & Related Mechanisms.

I am certainly hopeful that this National Conference will add another laurel to the legacy established by INSARM via significant contributions in the field of mechanism related to high altitude technologies by researchers, engineers and students. I urge that more emphasis be made towards innovative ideas and advanced research methodologies in this field.

I extend best wishes to ARMS-2023 Organizers and Participants.

B.V. Papa Rao

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I am Delighted to know that 13th National Conference & Exhibition: ARMS- 2023 Focusing on "Innovation and Development in High Altitude Technologies and Related Mechanism" is being organized by INSARM Agra Chapter during 14-15th December 2023.

Since its inception, ARMS conference has constantly upheld at legacy of providing a vital platform for the exchange and dissemination of cutting-edge research across a broad spectrum of mechanism and their applications in defense and space science. Moving ahead with the same inheritance I am hopeful that this conference will further enhance its reputation by facilitating significant contributions in the realm of mechanisms associated with high altitude technologies. Researchers, engineers and students are expected to present their work, emphasizing innovative ideas and advanced research methodologies.

I extend my best wishes to ARMS-2023 for a successful and impactful event.

Date: 17th Nov. 2023

Prof. V. Venkateswara Rao
President INSARM
Pune Chapter

डॉ. मनोज कुमार
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Govt of India, Ministry of Defence
Defence Research & Development Organisation
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MESSAGE

It gives me great pleasure to host 13th National Conference & Exhibition: ARMS-2023 on "Innovations & Developments in High Altitude Technologies & Related Mechanisms" organized by INSARM Agra Chapter during 14th to 15th December 2023 at ADRDE Agra.

Innovations in High altitude technologies is the need of the hour for robust defence of the nation via advanced surveillance, communications & early warning systems. It also has wide spread impact on development of smart cities leading to fast pace progress of the country. The visionary missions of national importance like Chandrayaan, Gaganyaan, Strastropheric Airship, High altitude surveillance along with delivery systems demands development of highly complex state-of-the-art systems and mechanism involving innovations, reliability, optimizations in multi-disciplinary areas of research.

I am sure that this conference and exhibition would provide a great opportunity for researchers, engineers, industries as well as students to share innovative ideas, current trends in research and developments in multi-disciplinary fields and their targeted application areas.

I extend my greetings to the organizers, delegates, participants and sponsoring agencies and wish great success for ARMS-2023.

Dr Manoj Kumar

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Program Schedule

13th National Conference ARMS-2023 on

'Innovations & Developments in High Altitude Technologies & Related Mechanisms'

DAY 1: 14th Dec 2023

0930 – 1100 hrs	**Inaugural Session** Venue: Auditorium	▪ Conference Inauguration/ Lamp lighting ▪ Welcome by Director ADRDE ▪ Address by DG Aero ▪ Address by Chairman ISRO/ DRDO ▪ Address by Chief Guest ▪ Address by AVM Rajiv Ranjan
1100 – 1130 hrs	**Inauguration of Exhibition, Release of Souvenir, Award Distribution**	
1130 – 1200 hrs	**High Tea**	
1200 – 1300 hrs	**Keynote Session** Venue: Auditorium	▪ Keynote address by Prof Sanjay Mittal, IIT (K) ▪ Keynote address by Director VSSC
1300 – 1400 hrs	**Invited Talk Session** Venue: Auditorium	▪ Invited Talk by Director NAL ▪ Invited Talk by CE CEMILAC ▪ Invited Talk by Dy Dir, URSC, B'lore
1400 – 1500 hrs	**Lunch**	
1500 – 1630 hrs	**Technical Session 1** (3 Parallel sessions)	**Session 1A:** Lecture Hall-1 **Session 1B:** Lecture Hall-2 **Session 1C:** Conference Hall
1630 – 1645 hrs	**Refreshment Break**	
1645 – 1800 hrs	**Technical Session 2** (3 Parallel sessions)	**Session 2A:** Lecture Hall-1 **Session 2B:** Lecture Hall-2 **Session 2C:** Conference Hall
1800-1830 hrs	**Talk by Industry Partners**	
1830-2030 hrs	**Cultural Event (Venue Auditorium)**	
2030-2230 hrs	**Networking Dinner**	

DAY 2: 15th Dec 2023

0930 – 1100 hrs	**Keynote Session/ Invited talk** Venue: Auditorium	▪ Welcome by Director ADRDE ▪ Invited Talk by URSC, B'lore ▪ Invited Talk by URSC, B'lore ▪ Invited Talk by URSC, B'lore
1100 – 1130 hrs	**High Tea**	
1130 – 1330 hrs	**Technical Session 3** (3 Parallel sessions)	**Session 3A:** Lecture Hall-1 **Session 3B:** Lecture Hall-2 **Session 3C:** Conference Hall
1330 – 1430 hrs	**Lunch**	
1430 – 1500 hrs	**Talk by Industry Partners**	
1500 – 1545 hrs	**Panel Discussion**	
1545 – 1615 hrs	**Best paper award**	
1615 – 1700 hrs	**Governing Council meeting**	
1700 – 1730 hrs	**Tea Break**	
1730 hrs	**Conference Closure**	

ABSTRACTS

Lighter Than Air Systems (LTA)

Paper no.	ARMS23-LTA-01
Title	**Propeller Performance Prediction for Stratospheric Airships: A Comprehensive Analysis**
Authors	Ankit Kumar & Md. Arif *ADRDE, DRDO*

This research paper delves into the critical aspect of propeller performance prediction for stratospheric airships, a pivotal element in their design and operation. The study begins by estimating the required thrust for a range of hull volumes and speeds, considering the unique aerodynamic conditions of stratospheric flight. To predict propeller performance, a modified blade element theory is applied and analysis is done by varying the blade diameter. This analysis aids in assessing how different propeller configurations influence the performance parameters such as efficiency and thrust under stratospheric conditions. Furthermore, the paper investigates the determination of the number of propellers required to meet the calculated thrust demand for each configuration, thus providing insights into the efficient distribution of propulsion systems on stratospheric airships. The results and data generated through this research will serve as a valuable resource for the preliminary design of propellers tailored to the unique demands of stratospheric airships. These insights contribute to the advancement of airship technology for stratospheric exploration and surveillance missions, where efficiency and performance are of paramount importance.

Paper no.	ARMS23-LTA-02
Title	**Solar Power output modelling for an axis symmetric airship flying at the stratospheric altitudes**
Authors	Mahesh Kumar, Vinit Kumar Ranjan & Dr. Ajit Kumar *ADRDE, DRDO*

Long endurance stratospheric airships rely on the solar power to cater for their electrical power needs. Generated solar power is used to cater for the power requirements of the propulsion system, pressure control system and on-board avionics. Output power from the solar array mounted onto the airship depends on the solar incidence angle of the solar cells, solar irradiance and cell efficiency. These factors are affected by the airship geometry, geographical location of operation, time of the day & year, altitude of operation, cell temperature etc. Considering these effects, this paper attempts to develop mathematical relations for power output modelling of a solar array mounted on an axis-symmetric airship having its hull made up of a body of revolution about the longitudinal axis of the airship.

Paper no.	ARMS23-LTA-03
Title	**Design and Development of Cradle Latch Assembly for Medium Size Aerostat System**
Authors	Rishabh Singh, Kumar Dharmendra Diwakar & Sheeshram *ADRDE, DRDO*

The paper describes methodology for designing, fabrication and testing of Cradle latch assembly. The cradle latch assembly is required for hard anchoring of the Aerostat system with the Winch and Mooring System (WMS). The aerostat envelope is an aerodynamic body which has tendency to align with wind for producing minimum drag, thus the envelope when not in flight is anchored from the nose with the WMS for allowing free wind vanning to the aerostat system. The cradle lock assembly consists of a nose probe with ring structure lashed with aerostat envelope and a cradle part which is mounted on the top of the mooring tower of winch and mooring system. The nose probe has a conical profile similar to that of cradle cavity which allows it to freely slide inside the cradle cavity without any hindrance, the nose probe has a circular grove so that when nose probe slides inside the cavity, the locking pins are pushed inside the groove, the nose probe will not come out of the cradle cavity until the locking pins are released. The cradle cavity consists of spring-loaded locking pins which are free to slide in the groove of the cradle. These locking pins are continuously pushed by the spring inside the cradle cavity with the help of locking pin casing. As the nose moves inside the cradle cavity the nose slides along the locking pins and finally locking pin gets inside the grove of the nose probe once the nose probe gets completely inside the cradle cavity. The pin casing is mounted on the side of cradle base which will allow the locking pin to reciprocate inside it but it will hold the spring in such a way that one end of the spring rest inside the casing and other end is pushing the locking pin. The other end of the locking pin outside the casing is attached to the pin head which is used to pull the locking pin outside the groove when it is desired to unlock the nose probe. The releasing mechanism is used to push the pin head outward which in turn pulls the locking pins out of the locking pin groove. The paper describes the design of working principle, calculation of stress on the components of the cradle latch, material selection, fabrication methodology and testing of cradle latch assembly.

Paper no.	ARMS23-LTA-04
Title	**Design of Winch for High Altitude Aerostat System**
Authors	Bhupendra Pratap Tiwari & Rishabh Singh *ADRDE, DRDO*

The paper describes the methodology for designing fabrication and testing of winch system. The winch system is required to launch, recover and hold the aerostat system at the desired altitude for qualification testing and validation of the airborne electronic sub-systems, and other mechanical sub-systems integrated with the aerostat envelope. The winch system consists of a 3 phase 5HP brake electric motor as prime mover which is coupled with shaft of drum, the drum is used for storing nearly 5000m textile rope, it consists of a gear box between electric motor and drum shaft for maintaining required torque at the drum end, it also consist of a self-reversing screw for level winding of the rope, the self-reversing screw allows bidirectional linear movement of pawl pin under single direction of rotation of screw only at required speed ratio has to be maintained between the drum and screw, the speed ratio depend on the diameter of the winding rope and the pitch of the screw and is maintained though the series of chain drive mechanism. A roller assembly fitted on the top of the pawl pin is required for aligning the rope. The winch is designed for 2500 N winding / unwinding load and brake load capacity of 5000 N. The winch is also designed for quick and controlled manual launching, so the winch is equipped with a drum brake of 5000 N capacity and launching could be done after decoupling the drum shaft from electric motor and drum brake will be used control the launch of the aerostat system. The winch is also equipped with a worm gear assembly for manually driving the winch in case of power failure. The worm gear assembly is also equipped with a ratchet pawl mechanism at the driving end for ensuring fail safe braking during recovery of the aerostat. All these components are mounted on a structure and assembled together to form a winch system. The paper primarily focuses on the design of storage drum, calculation of stress in shaft and self-reversing screw, sizing and selection of gear box and chain drives, electric motor, motor drive, drum brake and worm gear assembly and testing plan of winch system.

Paper no.	ARMS23-LTA-05
Title	**Launch & Recovery System for Unmanned Small Airship System**
Authors	Kumar Dharmendra Diwakar, Rishabh Singh & Bhupendra Pratap Tiwari *ADRDE, DRDO*

The paper describes the design and development of Launch and Recovery system (LRS) for Airship Systems. An airship is an autonomous lighter-than-air aircraft that can be steered and propelled through the air using rudders and propellers or other thrust mechanisms. Launch and Recovery system is required to inhaul and outhaul the airship during launching and recovery of the airship. The LRS provides platform to hold the airship for the fitment of the payload to it and maintenance requirements of the Airship. The winch system of LRS is used for in-hauling the envelope from the nose end to ensure docking of airship nose with the cradle mounted on the tower. The mooring tower of LRS is of telescopic type which can be adjusted for the required height for mooring. The tower can be folded on the trailer allowing the system to be transported from one place to another. The mooring tower assembly, the nose line winch and hydraulic power pack are assembled on a platform which can rotate freely with respect to the 20 ft flatbed trailer on which the platform is mounted in order to allow free wind vanning to the airship envelope when not in flight. The trailer has four extendable outriggers for stabilizing the LRS during mooring condition. A resting pad of adjustable height for envelope is attached at a 12m distance from the trailer end which is connected to the base plate by two telescopic arms in order to secure tail fin of the envelope during mooring condition. The resting pad unit has large castor wheels at the bottom which allows free wind vanning to the complete system. The nose line winch, actuators of the mooring tower, cradle and outriggers are powered through a single hydraulic power pack with one gear pump coupled with 5 HP 3 phase electric motor. The paper focuses on the load estimation on LRS, calculation of the stresses in the mooring tower calculation of crippling load on the mooring tower, stress calculation in the cradle, selection and sizing of hydraulic power pack i.e. pump, motor, actuators valves, etc. and design of hydraulic circuit. The end the paper will also give a slight glimpse on the testing of the launch and recovery system.

Paper no.	ARMS23-LTA-06
Title	**Literature Survey on mechanical hardware for High Altitude Airship Systems**
Authors	Rishabh Singh & Mahesh Kumar *ADRDE, DRDO*

High Altitude system have generated a great interest as a means to provide communications and surveillance capabilities since last decade. The airship consists of airship envelope, propulsion system, thrust vectoring system, actuators, mechanical sub-systems and related mechanical interfaces. This paper primarily focuses on airborne mechanical hardware used in airship system. The mechanical hardware exposed to high altitudes must withstand all aspects of the related environment. This includes thermal cycling, ultraviolet radiation, and in some environment atomic oxygen. All of these may have significant effects on material properties either alone or in synergism. Thermal cycling temperatures are dependent on the component's thermo-optical properties, Thermal cycling can cause cracking, crazing, delamination, and other mechanical problems, particularly in assemblies where there is mismatch in the coefficient of thermal expansion. The exposure to UV radiation can cause hardening weakening of polymers affecting performance of lubricants adhesives, seals and paints. Atomic Oxygen (AO) oxidizes metals, especially silver and osmium. AO reacts strongly with any material containing carbon, nitrogen, Sulphur, and hydrogen bonds of 5 eV bond energy or less, meaning that most polymers react and erode away. The paper will give a detailed survey on the selection of raw materials i.e. for strength bearing members like titanium alloys, stainless steel, carbon fiber and graphite epoxy composite, type of bearings like dry lubricant and ceramic ball bearings and electromagnetic bearings, type of fasteners like Aluminium alloys, stainless steel and titanium, type of lubricants like perfluoropolyether, cyclopentane and polyalphaolefin and solid lubricants like molybdenum disulfide (MoS2) and ion-plated lead (Pb), type of paints like Chemglaze, silicon paint and ceramic paints type of seals and gaskets like silicone, fluoro-silicone, and ultra-high-performance elastomers, type of adhesives, gaskets and different metal components which can withstand high altitude harsh environment.

Paper no.	ARMS23-LTA-07
Title	**Airship Fin Structural Optimization**
Authors	Amit Kumar *ADRDE, DRDO*

An airship is a lighter-than-air craft that can navigate through the air by its airborne power. Airship balances its weight by buoyancy produced by lighter-than-air gas filled aerodynamic shaped envelope. Due to non-inflammable characteristics, Helium gases are extensively used for such applications. Airship is a system of systems. It has propulsion system mounted on thrust vector system, Gondola mounted at the belly of envelope for housing the payloads & other electronics, fins for directional control, various sensors etc. All of these are integrated to make ready an Airship system. Airship has proved excellent platform for the installation of surveillance and communication sensors used for military applications. When Airship is in mission mode and gains the significant speed, its fins becomes effective and the directional controls are primarily governed by it. The fins provide the moment required by airship to turn and pitch up/pitch down and roll when air flow takes place over control surface of fin in deflected condition. Fin is critical sub-system of Airship and it has mechanical structure having fixed surface and control surface. Fixed surfaces are responsible for stability while control surfaces are responsible for directional control of Airship during its flight. The movement of control surface on fixed surface is achieved by using actuators. The actuation mechanisms are of different configurations like push-pull, pull-pull and direct drive. Based on the size, torque transfer capability, deflection etc., one of the configurations of actuation mechanism is selected. The role of fin on Airship mission is vital and hence a rigorous optimization for its structural design is to be done for its effective performance. The optimization involves consideration for design of mechanical structure, selecting the actuation mechanism, selecting the suitable aerofoils, material removal, FEM analysis and trade-off. The optimization will result in fin mechanical structure spars and ribs dimensions, actuation mechanism linkage pin sizing, suitable shapes for material removal as the boundary conditions of both the end of each ribs are different. The optimization requires iteration so the iteration matrix for the test cases is to be defined for analysis. In this paper, systematic approach for the optimization of Fin is elaborated.

Paper no.	ARMS23-LTA-08
Title	**Quality Function Deployment (QFD): Transformation of Customer Requirements into Design Requirements & It's Application for Design & Development of Unmanned Small Airship System**
Authors	Arvind Kaushik & Vivek Mairothia *ADRDE, DRDO*

ADRDE is a pioneer DRDO laboratory, involved in the design and development of Lighter Than Air Technology (LTA) platform for monitoring & surveillance activities in military & civil application. An airship comes under the category of lighter-than-air aircraft which can navigate/steered through air under its own power source (Propulsion System). Airships are designed to carry useful payloads to a specific height. It increases the Line of Sight (LOS) of ground-based sensors. Airships have proved to be excellent platform for the sensors for surveillance and communication purpose of civil and military application. Quality is foremost important aspects for LTA platform. Quality must be designed into the product, not inspected into it. Quality can be defined as meeting customer needs and providing superior value. This focus on satisfying the customer's needs places an emphasis on techniques such as Quality Function Deployment (QFD) to help understand those needs and plan a product to provide superior value.

Mechanisms in Launch Vehicles/Missiles/Aircrafts/Satellites (MLV)

Paper no.	ARMS23-MLV-01
Title	**Significance of Sneak circuit analysis for Human Space flight**
Authors	N.Sairam *VSSC, ISRO*

Sneak circuit refers to latent circuit paths that can cause unwanted function to occur or actual function not happen even though all systems and sub-systems working properly without any fault. These circuits are characterized by their ability to escape detection during normal analysis & testing. Physical testing at system level alone cannot detect these since it is too complex to verify all combinations of relay configurations & wiring harness which might occur. Sneak circuit analysis is an important technique followed to avoid unanticipated failure of electrical systems especially in pyro electrical systems which are safety and mission critical, caused not by component failure but by inherent design flaws. In aerospace systems with many complex systems developed by different teams and with added redundancy especially for Human space flights, sneak circuits escape detection in initial design phase. To improve reliability for human space flights multiple level of redundancies will be incorporated as design progresses which ultimately introduces sneak path if design is not analyzed for sneak paths. This paper discusses about significance of sneak circuit analysis over conventional reliability analysis like FMECA, FTA, risk assessments.

Paper no.	ARMS23-MLV-02
Title	**Design and development of Motherboard Assembly Jig for an Electronic Package**
Authors	G Venkata Vasanta, Prashant DB & Sreeniwas Sahu UR Rao Satellite Centre, ISRO

A new data handling and processing package is designed to cater to satellite high data rate requirements. This electronic design called for Mother-board connectors which can handle large data rates of up to 3Gbps. Compact Peripheral Component Interconnect (cPCI) connectors are the Mother-board connectors chosen to ensure these high data rates. cPCI connectors are metric based with 2mm pin spacing. Three form factors 3U, 6U and 2 x3U of the Motherboard connectors are used in four different electronic layout designs. Special solder alignment tools are used to align and fix the connectors on to daughter card and motherboard cards during soldering. Each PCB card is mounted on a mechanical housing, forming an electronic subassembly/module. Eight such assemblies are horizontally stacked together to make the electronic package. Each electronic module is mated to the motherboard before stacking of all modules using six studs. Mating these high dense Mother-board connectors demanded a

custom jig for safe and proper mating. This required controlled movement and precise application of mating force. Undue application of force may lead to improper mating/damage to the pins. This fixture is also used during de-mating, when the need arises. Screw based pushing mechanism was developed for pushing each electronic module in guided ways. This paper discusses design and development of this mechanical assembly jig.

Paper no.	ARMS23-MLV-03
Title	**Impact of Fillers & Fins on Phase Change Material (PCM) based Heat Sink for realization of Hybrid Heat Sink**
Authors	Ankit Singla, Ajit kumar Maurya, Austin Joe A, Sunil Yadav & Rakesh Ranjan *VSSC, ISRO*

This Paper investigates the transformative potential of Phase Change Materials (PCMs) in optimizing the thermal performance of hybrid heat sinks used in the passive cooling of electronic devices in aerospace and launch vehicles. As PCM material has low thermal conductivity, Thermal Conductivity Enhancer (TCE) is essential for increasing the thermal conductivity of the system and this can be done by adding highly conductivity fillers or introducing fins inside the heat sink for distributing heat across the PCM uniformly to maximize exposure of PCM to heat flux or by using both fillers and fins. Among all the fillers under study, BN proved higher TC with Pentaglycerine (PG). In the study, the heat sink with square fins to assess its thermal performance, both with and without the use of fillers. In the case of a finned configuration, the overall performance increased by 10% BN but decreased by 20% Boron Nitride (BN), which could be due to higher inert content. In a configuration without fins, filler has a good impact on overall performance due to the improved thermal conductivity of the system and the addition of 10% BN to PG takes 77s longer time to reach 95°C. The finned configuration emerges as the overall best performer due to its ability to facilitate faster heat transfer into the bulk of the PCM. This enables a more efficient and uniform phase transition, allowing the PCM to absorb more.

Paper no.	ARMS23-MLV-04
Title	**Ground effect mechanism of Reusable Launch Vehicle**
Authors	M Prasath, Mofeez Alam, V R Ganesan & K Srinivasan *VSSC, ISRO*

Indian Space Research Organization (ISRO) is exploring a Reusable Launch Vehicle (RLV) as a first step towards developing a Two-Stage to Orbit Vehicle (TSTO). Ground effect is the phenomena that occurs when an aircraft approaches a barrier, such as the ground or water, from close proximity. At NWTF, IIT-Kanpur, wind tunnel tests are conducted at 20 m/s to replicate ground effect. When a vehicle approaches near the ground, a 10 to 15% rise in normal force, pitching moment and drag is noticed. Moreover, test findings suggest that the ground effect diminishes when H/b > 1. Also, the influence of sideslip angle on incremental ground effect coefficients are negligible

Paper no.	ARMS23-MLV-05
Title	**Design and Development of Parachute Releaser Unit for RLV Landing Experiment**
Authors	Vikas, Ciju Paul, Bishwajyoti Dutta Majumdar, Ani Daniel Kurien & Shri Sheeju Chandran *VSSC, ISRO*

Pyro devices are commonly used in launch vehicles due to their numerous merits such as high power to weight ratio, compact and simple design, less input energy requirement, quickness of action, etc. Landing experiment of Reusable launch vehicle conducted by ISRO employed functionally critical pyro devices to meet the mission objectives. One of them is the parachute releaser unit (PRU) for releasing the brake parachute from the vehicle after decelerating to required velocity on the runway. The function of the device is to anchor the brake parachute with reusable launch vehicle after its deployment until the parachute function is completed. After receiving the firing current, the device actuates and releases the parachute from the launch vehicle. Towards this, an integrated pyro device has been designed, developed and qualified which works as a structural member during the time of parachute operation and releases parachute upon actuation. In the paper, configurational, structural and ballistic design methodology of PRU is discussed. It also covers the details of the development and qualification tests conducted for the device towards verification of its structural and ballistic margins for flight use.

Paper no.	ARMS23-MLV-06
Title	**A compact Gravity Compensation System for Thruster Pointing Mechanism**
Authors	Rahul Ghatak, Milind Undale, K Prakasha, Abhishek Kumar, B. Lakshminarayana *URSC, ISRO*

This paper describes the detailed configuration, design, and an overall development of the Gravity Compensation System used for the deployment of Thruster Pointing Mechanism (TPM). Thruster Pointing Mechanism (TPM) is a 2-axis gimbal mechanism which is used for orientation of spacecraft thrusters in two mutually perpendicular axes by a specific range so that the thrust vector passes through centre of gravity of the satellite. These thrusters are also used for orbit raising and station keeping of the satellites in geostationary orbits. Gravity compensation is the process of offloading the weight of the entire moving mass during ground deployments and testing phase so that mechanism components and actuators doesn't get stressed during ground deployments and the system performance gets checked under simulated zero-g condition. This further allows us to design a compact and optimized mechanism which needs to take care of on orbit dynamic conditions only. For achieving gravity compensation, every mechanism needs a suitable fixture that needs to be designed and tested before implementation in actual flight hardware. This paper describes the configurational details of the entire gravity compensation system for TPM and also describes how the same system is used for giving compensation about two mutually perpendicular axes about which TPM moves on orbit. It also describes about the compactness of the gravity compensation system which enables it to swiftly relocate with TPM hardware as per needs of testing. As TPM consists of significant number of components including the thruster at the location of compensation with asymmetrical centre of gravity, it is not configurationally possible to offload the weight at the exact centre of gravity of the moving mass. This paper describes how this prime challenge has been taken care along with the other challenges which have been faced during the design and realization of the gravity compensation system.

Paper no.	ARMS23-MLV-07
Title	**Design and development of orifice type air bearing pads for Spacecraft micro-gravity simulation**
Authors	Harshit Kumar, Dipanshu Mittal, Raghavendra Prasad HM, Nagendra VS & Vivek NK *URSC, ISRO*

The paper emphasizes on the design, analysis, and testing of a thrust air bearing pad developed for spacecraft microgravity simulation. This addresses inherent limitations within conventional roller-bearing zero-gravity setups, particularly concerning resistance and friction during deployment. The existing microgravity simulation test system encounters challenges in deployment dynamics due to the contact type nature of roller bearings. This becomes especially pronounced as the size and mass of appendages increase. Consequently, the imperative arises to establish a non-contact microgravity simulation test setup. The introduction of an air bearing into the microgravity test system is proposed to substantially reduce friction and enhance the accuracy of simulating on-orbit deployment dynamics. The chosen air bearing design features a circular shape with four equally distributed orifices arranged concentrically exhibiting a load-carrying capacity of 40 Kgf. The initial segment of the paper revolves around a comprehensive discussion of governing parameters drawn from existing literature. Design parameters are then derived through appropriate assumptions. The design's flow path is modelled in 3D using UGNX software, subsequently subjected to thorough analysis in the computational fluid dynamics (CFD) software package ANSYS. CFD analysis offers valuable insights into the pressure distribution profile along the flow path, guiding iterative corrections to design parameters to maximize the air bearing pad load-bearing capacity. A laboratory-level test setup is developed to empirically evaluate the performance of the air bearing under a supplied pressure of 3 bar. The maximum load-carrying capacity of the air bearing pad, achieved under the specified pressure, is correlated with CFD analysis results, demonstrating a close alignment with experimental data. This comprehensive exploration establishes the viability and efficacy of the proposed thrust air bearing pad for enhancing microgravity simulation in spacecraft testing environments.

Paper no.	ARMS23-MLV-08
Title	**Design and development of a light-weight and low shock Hold Down and Release Mechanism for dual gimbal reflector**
Authors	Mariya Ratlami, Anshumaan Sharma, Shalini, Subash Yadav, Abhishek Kumar & Lakshmi Narayana B *URSC, ISRO*

Dual gimbal antennas are essential in space applications, particularly for satellite communication and earth observation. They serve a crucial role in ensuring precise pointing and tracking of objects with improved coverage and flexibility. This paper introduces an innovative Hold-Down and Release Mechanism (HDRM) designed to meet the demanding requirements of space borne Two-axis Antenna Steering Mechanism (TASM). The HDRM discussed in this paper exhibits remarkable adaptability, catering for reflectors with smaller or larger apertures, without any interference. The current design is for a 0.6m aperture gimballed reflector. Typically, appendages are initially stowed and the HDRM secures them in this position during launch. Upon release, these appendages are then allowed to move into their deployed/nominal state. The distinctive feature of this HDRM is that it holds the antenna in its nominal position during launch. Once released, the hold-down (HD) lever opens, providing the necessary space for antenna to move freely about two axes. A two-lever configuration is used to clamp the outboard bracket at two spigot locations. Each lever is connected to the hinge bracket at one end and to the hold-down loop at other with spigot interface in between. One of the standout feature of this HDRM is its lightweight construction. The release hinge is based on a spring loaded plunger design making it lightweight and compact. The design also includes locking provision and telemetry switch at the release location as to monitor the HDRM's status. Unlike traditional hold-down systems using multiple actuator and interfaces on the satellite deck, this HDRM is designed with interface on the inboard bracket and a single actuator with hard redundancy to offer high reliability. This also offers ease of integration activities at spacecraft level. The HDRM system presented in this paper offers significant improvements over traditional HDRMs making it a versatile component for a wide range of space missions. This paper covers the concept and detailed design for the hold- down and release mechanism for TASM.

Paper no.	ARMS23-MLV-09
Title	**Realization of the High Gain Antenna Steering Mechanism and challenges encountered**
Authors	Saurabhkumar H Patel, Anoop Kumar Srivastava, K Prakasha, S Narendra & Abhishek Kumar *URSC, ISRO*

High Gain Antenna (HGA), aperture parabolic dish, is required for payload data transmission from the deep space mission spacecraft as the distance is large, angular rotations required for pointing the Antenna would be small. However, the pointing accuracy requirement shall be stringent. Quantum of payload data being very high, X band high power RF rotary joint was required be accommodated. In order to cater to the need of accommodating maximum mass for payload, the mechanism required for steering of the Antenna should be mass, power and volume optimized. Taking all the required inputs, a dual axes steering mechanism is realized to accomplish pointing requirement of HGA during various phase of the mission. High Gain Antenna Steering Mechanism (HGASM) was realized and integrated with the spacecraft. The mechanism was configured with three hold-downs to withstand the launch loads. The two drive modules were mounted in cross axis fashion, the axis of the drives was made intersecting primarily to reduce the volume of the mechanism and ensure required rotation angles. The mechanism was configured as a complete zero backlash drive to ensure high pointing accuracy. mechanism being developed was new in terms of accommodating large antenna dish with plural number of hold-downs and intersecting axis mounting of the orthogonal drive modules, various challenges were encountered d realization. The challenges were classified majorly as design challenges and testing challenges. This paper not only defines the configuration of the system for steering a large antenna on board a spacecraft, but also provides detailed insight in various challenges encountered during design and testing. Various test setups have also been highlighted. Each challenge is dealt as lessons learnt and mitigation techniques have been illustrated. Further, towards the end, couple of recommendations shall be made for future mechanisms similar kind. The paper provides chronological illustrations of events which will provide the readers with an insight for the methodology to be adopted for mitigating similar challenges.

Paper no.	ARMS23-MLV-10
Title	**Miniature Control Moment Gyro: A torque dense, energy efficient actuator for spacecraft**
Authors	Shivam Sharma, Abhilash Mony & Gireesh Sharma N *IISU, ISRO*

Ranging from imaging missions demanding high agility, to satellite on-orbit servicing tasks which require integrated control of multiple spacecraft, missions have become very diverse and demanding. One of the common requirements in these missions is the need for a power efficient attitude control actuator with high torque and momentum capability. Reaction Wheels (RWs) are the actuator of choice due to the inherent simplicity. However, beyond torque capability of 1 Nm, they become highly inefficient in terms of both mass and power. On the other hand, Control Moment Gyros (CMGs) are momentum exchange actuators which produce output torque by means of gyroscopic effect. Due to the effect of torque amplification, they can generate 5-10 Nm output torque at a fraction of the RW power consumption. In this paper, the development of a compact, high torque, high angular momentum, power efficient CMG is discussed. The miniature CMG generates 5 times the RW torque consuming only 25% of the RW peak power, weighing only 20% more than a high torque RW. The major sub-systems in CMG are fully indigenous. The system is having a cantilevered gimbal configured using the new generative design technique, to obtain the required stiffness. The design is configured with integrated control electronics to achieve a low foot-print. The mechanical elements are planned to be realized using a combination of additive manufacturing and final finish machining. The development of this new actuator is a highly essential addition to the family of satellite attitude control actuators.

Paper no.	ARMS23-MLV-11
Title	**Aero-elastic structural analysis of Low-Caliber High Slenderness ratio Rocket system**
Authors	B Dineshwar, B R Rao & Prashant Kumar *ARDE, DRDO*

Low-caliber rockets are extensively used since they are versatile and play a crucial role in contemporary aerospace endeavours. These rockets are low caliber (up to 2.75 inch) in nature and provide high slenderness ratio (≈20). To address operational challenges, the structural thickness is minimized. This research paper presents an exhaustive static aero-elastic analysis of a low-caliber rocket, aimed at enhancing our understanding and advancing the development of this pivotal technology. This study encompasses the formulation of a conceptual rocket design, followed by a rigorous system analysis under various aerodynamic and inertial loads and estimated meticulously using analytical method. The static aero-elastic analysis involves the use of Euler equations and elastic linear structural equations to assess normal reaction forces at the nose cone and fin. Inertia forces are determined by accounting for drag force and dynamic pressure on the rocket body, considering a specific angle of attack. A static structural analysis of the low-caliber rocket body is conducted incorporating the rocket's material properties, geometric parameters, and mechanical attributes to ascertain the stresses and deformations developed within the structure to study how aerodynamic forces influence the structural integrity and behavior of the rocket system at various joint locations. In conclusion, the analysis results closely align with theoretical calculations, reinforcing the validity of our findings. Ultimately, the study affirms that the rocket body design can endure the anticipated loads without surpassing material limits.

Paper no.	ARMS23-MLV-12
Title	**Motorized SADA-Yoke Hinge for Controlling, Deploying and Steering Large Solar Array**
Authors	Shalini, Amit Kamboj, Abhinandan Kapoor, Subash Yadav, Abhishek Kumar & S Narendra *URSC, ISRO*

The paper describes the process of developing a feasible, optimal, and simple configuration for the motorized solar array deployment mechanism, taking into consideration its impact on other elements of the mechanism. The solution proposed is to incorporate a motor at the Solar Array Drive Assembly (SADA)-Yoke hinge to drive as well as control the deployment process. Motorized SADA-Yoke hinge mechanism is an alternative approach for the controlled deployment of large solar arrays which will help in reducing the latch up moment and allowing the implementation of lighter solar panel substrates.

The most suitable design of motorized SADA-Yoke hinge mechanism was selected for hardware realization. The selection was done based on the configuration and option studies. Three different configurations were analyzed for connecting the motor to the SADA interface bracket based on different design parameters. Motorized SADA-Yoke hinge mechanism was characterized to evaluate its performance. Simulator level deployment tests were conducted after assembling motorized SADA-Yoke hinge in the existing solar array. The test aimed at studying the impact of time offset for powering 'ON' of motor, motor speed, etc., on the movement of array. The proposed design simplifies the overall mechanical configuration of the solar array deployment mechanism by combining the functions of a damper and an actuator into a single device. To validate this approach, extensive hardware testing was conducted to determine the suitable motor configuration and torque requirements. The results of the tests were compared to the predicted values from the analysis, and a good match was established, demonstrating the feasibility of the proposed solution.

Paper no.	ARMS23-MLV-13
Title	**Design optimization of hold down release mechanism for deployable Reflectors**
Authors	Raghavendra Prasad H M, Sidharth Tiwary, Suresha Kumar H N *URSC, ISRO*

Spacecraft appendages are generally stowed during launch due to space constraints and will be deployed after launch or once it reaches intended orbit. Such appendages require deployment mechanism, which should be highly reliable with respect to extreme space environments and launch conditions.

In general spacecraft appendages are solar panel and antenna reflectors. In this paper, design optimization of hold downs for Reflector Deployment Mechanism (RDM) is discussed; FE analysis results shows fair stress margin exists for hold down and the also dynamic test results of the system qualifies the design as flight worthy.

The deployable reflector for a communication satellite, is configured on the side deck of the spacecraft. The antenna reflector is a dual gridded type. Dual gridded reflector (DGR) has two reflecting surfaces, assembled one over the other. Two reflecting surfaces are connected with a peripheral ring and intercostal ribs. Top reflector is made out of RF transparent material, so that communication with bottom reflector also can be established.

To improve the electrical performance, intercostal ribs are removed in reflector design, which resulted into, the requirement of stiffer deployment mechanism. The existing design of deployment mechanism has spring driven hinge pair (connects reflector with spacecraft deck at bottom side of reflector) with two hold down and release mechanism (connects top side of reflector to spacecraft). Due to modification in reflector design, existing two hold downs are not adequate to meet mission requirement. The stiffness of reflector without intercostal ribs is enhanced by providing two additional hold-downs at the bottom side of reflector (closer to hinges) which is a new configuration for the reflector sub-system. The locations of the four hold downs are configured in a such way to meet stowed natural frequency of the system.

The details of new four hold-down configuration design, analysis and ground testing details are discussed in this paper. Comparative results between FE and ground testing are highlighted.

Paper no.	ARMS23-MLV-14
Title	**A Compact Reaction Wheel Assembly for Mini Satellites**
Authors	Marimagesh S, Dipak Sagar, Pradeep R, Sajeev Kumar A, Smitha Krishan, Sreejith S & M H Ravichandran *IISU, ISRO*

Advanced capabilities such as earth observation, high data rate transfers, propulsive manoeuvres and docking of spacecraft need three-axis stabilization. Reaction wheels are the solution for precise attitude control of spacecraft which requires accurate speed control and low disturbance torque levels. Power and volume requirements, however, drive a simple and compact design. Therefore, a reaction wheel is developed for the Indian Space Research Organization (ISRO) with the Wheel Drive Electronics (WDE) integrated inside the Reaction Wheel (RW) housing. This paper presents the design features of a compact 3Nms (at 6000rpm) RW capable of delivering up to 0.02 Nm torque, with a mass of about 2.7 kg, average power consumption of 6 W and size of 180 x 180 x 92 mm. The reaction wheel is proposed for the SPADEX (Space Docking Experiment) project by ISRO, where two independent miniature satellites dock, undock and perform compound operation of the docked satellites.

Paper no.	ARMS23-MLV-15
Title	**Dynamic analysis of guided stage separation with objective to estimate maximum guide load**
Authors	Mohammad Arif, Dinesh Amresh, Koushik Jalali, Manu V Unnithan, UA Subramanian, TR Binny, Sunil Bhaskar, PR Mani, U Syam Kumar & S Unnikrishnan Nair *VSSC, ISRO*

The separation of typical stage takes place at an altitude of approximately 150 km in the flight trajectory, by means of a multi-point separation system consisting of eight separation mechanisms activated independently. Four flexible guide pin systems are provided in close proximity to the separation system to ensure collision-free separation. The separation starts with the shut off of expended stage engine followed by simultaneous ignition of 4 retro rockets and actuation of the separation mechanism. The separation takes about 10ms, after which the stages are only restrained by means of 4 guide pins. The retro rocket thrust keeps on increasing after retro ignition command, and then attains steady state condition. This thrust pushes down the expended stage relative to ongoing stage. The guide pins laterally restrain the relative motion between the stages at the separating plane since the separation command, after which the expended stage is further pushed down till it is completely clear ongoing stage. Design of the guide system components is done for maximum guide force encountered during the stage pullout. And it is estimated from the separation dynamics analysis. The guide system stiffness plays an important role in governing the dynamics of the stage separation process. The data on

the variation of stiffness (with respect to the stage pullout) generated by FE analysis has been carried out for the estimation of the worst case guide load. The effect of the varying guide stiffness on guide force with respect to the stage pullout is assessed by means of a mathematical model of the separating stages. This report presents the dynamic analysis of the separation process of typical stage separation with the objective of finding the maximum force magnitude encountered by the guide system. The input parameters are appropriately selected for maximizing the guide forces. The estimated worst case guide load is utilized for the design and analysis of guide system.

Paper no.	ARMS23-MLV-16
Title	**Configuration of Solar Array Deployment Mechanism with Integrated Drive Module for Solar observatory spacecraft**
Authors	Somashekar V N, Narendra S, Arun Kumar Gupta & K Prakasha *URSC, ISRO*

Solar observatory satellite will be stationed at Sun Earth Lagrangian L1. The L1 orbit provides for continuous observation of the sun from the space. The spacecraft has a power requirement of 1500 Watts. Two solar arrays had to be provided on either side of the spacecraft to meet this requirement. Since for this spacecraft sun visibility is always defined at L1 and rotation is required only during the cruise phase we have provided an Integrated Solar Panel Drive Mechanism (SPDM) with limited rotations which has significant mass and volume advantage. In this paper the configuration studies to accommodate the heritage type solar array with minor modification has been brought out. Also, the interface design to integrate onto low mass SPDM has been highlighted. A stepper motor, harmonic gear based compact, low mass SPDM is used to rotate the solar array. Since there is no 3600-rotation requirement, the array rotation has been limited to ± 1750. It is designed to have a rotation range of 3500 with a position sensor to measure the angle of rotation. SPDM is designed to have suitable interface with solar array and capability to have harness routing and to not make any specific changes in solar array configuration. Contact switches are provided to indicate the extreme end of solar array rotations. Further to this, hard stoppers are provided for the array to physically not rotate beyond these angles. Solar array harness needs to pass through each panel and go inside the spacecraft. Further, the harness routing through SPDM has been configured and characterized for providing least resistance to rotation. Changes are made in harness looping to meet the space constraint for harness routing compared to earlier spacecraft's and provide safe deployment of array and characterization of the same at extreme temperature and vacuum.

Paper no.	ARMS23-MLV-17
Title	**In-Orbit Temperature-Induced Distortion Analysis on Large Unfurable Antenna**
Authors	Vijay Shankar Rai, Subash Yadav, Milind Undale, Murali NS, K Balaji, Nagaraj BP *URSC, ISRO*

This paper presents a comprehensive analysis of thermal distortion of Deployed Unfurable Antenna (UFA) on the satellite during its in-orbit operation. The Unfurable Antenna in-orbit deployed configuration with spacecraft is exposed to the extreme thermal environment. The study utilizes temperature data evaluated under various seasonal conditions, including equinox, summer and winter solstice. The UFA comprises essential components, including a root hinge mechanism, an arm, and a deployable structure that supports a pre-tensioned cable network. Notably, the reflector surface takes the form of a parabola with a known focal point, focal length and vertex, which is an integral part of the cable net. Throughout the in-orbit phase, the temperature gradients affecting the root hinge mechanism, primary arm, deployable structure and reflector surface induce thermal distortion. This phenomenon has significant implications for the Root Mean Square (RMS) deviations of the parabolic surface. To address these challenges, this study employs Finite Element Analysis (FEA) in the MSC NASTRAN package, using Non-linear static analysis techniques. The parabolic surface is then evaluated to account for the thermally induced distortions using AXYZ software. The critical geometric properties are meticulously examined. The study calculates the peak RMS deviations of the distorted reflecting surface. Furthermore, it investigates the variations in load within the cable net and evaluates the loads imposed on the deployable structure. This research contributes valuable insights into the behavior of large deployable antennas in response to thermal challenges, with direct implications for optimizing RF performance of large, lightweight deployable antennas (UFA), particularly in communication satellites.

Paper no.	ARMS23-MLV-18
Title	**Realization of 3-Panel Solar Array Deployment Mechanism for Small Spacecrafts**
Authors	Phani Dinakar BS, Manoj Reddy D, Ganesha K, S Narendra & Lakshmi Narayana B *URSC, ISRO*

Small satellites of mass less than 500kg is generally used for remote sensing applications. These satellites are configured on IMS-2(Indian Mini Satellite) bus. The scientific payloads on these satellites are powered with solar panels. Present IMS-2 bus configuration, equipped with two solar arrays, each consisting of two panels, can meet power requirements upto 850 Watts. For some spacecrafts built for astronomical observations, the power requirement may be higher which is driven by the functionality and operability of the scientific payloads. So, to increase power generation capacity for IMS-2 bus, an additional solar panel of same size for each array is added. This addition of an extra solar panel necessitated modifications in the solar array deployment mechanism, posing significant design challenges. The paper details the challenges faced in augmenting with an extra solar panel to the existing configuration and the changes incorporated and tests done on the mechanism. This paper details the design modifications, detailed analysis and tests conducted on the mechanism.

Paper no.	ARMS23-MLV-19
Title	**Design of Footpad Plate for Lunar Lander Leg Mechanism**
Authors	Phani Dinakar BS, Sakthivel M, Gaurav Sharma, Dipanshu Mittal & Arun Kumar Gupta *URSC, ISRO*

The lunar lander incorporates a landing leg mechanism designed to absorb impact forces upon touchdown, ensuring a soft landing on the lunar surface. This mechanism typically comprises several telescopic struts that extend and contract during landing, mitigating the impact. Additionally, the landing leg mechanism is engineered to stabilize the lander post-landing. A crucial element of this system is the footpad, which plays a vital role in providing a stable and secure landing on the lunar terrain. The footpad is specifically crafted to distribute the lander's weight across an area, preventing it from sinking into the lunar surface. Furthermore, the footpad assembly includes features aimed at absorbing impact loads during landing, such as a honeycomb structure, mechanism to adapt lunar terrain etc. This paper delves into the intricate design of the footpad plate utilized in lunar landers, shedding light on its specific characteristics and functionality.

Paper no.	ARMS23-MLV-20
Title	**Optimization of Spacecraft Jettisoning System for Multi-Satellite Missions**
Authors	Sandeep Prasad Shaw, Surve Partha Ajit, Thara Nair & Raveendra Babu KK *VSSC, ISRO*

Separation of multiple satellites from the upper stage of a launch vehicle poses the challenge of ensuring collision free separation as well as keeping the rate imparted to the satellites within limit even in the worst case. The location and energies of springs in the separation system can be tuned to ensure the same. Optimization of the same for such a mission is carried out using Differential Evolution and a strategy is laid out. The analysis is also carried out in MSC ADAMS software to study the gap available for the satellite during separation.

Paper no.	ARMS23-MLV-21
Title	**Design and Realization of Overhead Structure for Conducting Lander Drop Testing for Lander Mission**
Authors	Narasimha Murthy N, Phani Dinakar BS, Arun Kumar Gupta, Lakshmi Narayana B, Abhishek Kumar & Narendra S *URSC, ISRO*

Landing on an unknown terrain of a celestial body is a challenging task. To accomplish this task, specialized spacecrafts are built that carry interplanetary landers. The success of a landing mission depends on the ability of the lander to absorb the impact forces on touchdown and provide a stable platform for other scientific equipment mounted on lander to carry out their functions efficiently. These missions will be designed to impact the terrain with a known vertical and horizontal velocity but due to various other unknown factors, the tolerance band for the impact velocity will be on higher side. So, these landers are required to be tested for impact under higher velocities on various terrain conditions and their energy absorption capacity, stability after landing should be established. A mechanism is developed which imparts different vertical and horizontal velocities to the lander simulator during the test at touch-down. This mechanism is required to be suspended from an overhead structure that provides a stable platform for the mechanism to carry out its intended task. This paper outlines the design and realization of this overhead structure.

Paper no.	ARMS23-MLV-22
Title	**A study to understand the distinct behavior of the linear bellow system in the payload fairing of a launch vehicle mission**
Authors	B.Venkat Shivaram Jadav, Aaron Baptista, Ananthu.M.Aji & G.Vidyad *VSSC, ISRO*

Payload fairing (PLF) for a launch vehicle is used to ensure safe and controlled environment for payloads accommodated within it, protecting the payload against aerodynamic, acoustic and thermal loads till the instant of its separation. The Linear bellow System (LBS) is a pyro-based separation system used for the longitudinal separation and jettisoning of the payload fairings. The functioning of each arm of the LBS is monitored in flight using independent bellow pressure sensors. In a particular mission, one of the measured bellow pressure levels was observed to drop monotonously and wasn't matching with previous flights trend. It was following the trend of PLF compartment pressure. Reason for different flight behaviour, drop in the measured bellow pressure, possible leakage paths and depressurization process of the LBS into the PLF were studied using in-house software MPVENT (multipath vent software). The possible leakage area and their discharge coefficient are brought out in this paper.

Paper no.	ARMS23-MLV-23
Title	**Design and Development of a Contamination Free Explosive Transfer Line Coupling with Additional Means of Initiation**
Authors	Bishwajyoti Dutta Majumdar, Shete Mayuresh Kailas, Vineeth GM, Ciju Paul, Sheeju Chandran & Ani Daniel Kurien *VSSC, ISRO*

Towards development of Payload Faring Separation mechanism with enhanced reliability, there was a need for an alternate means for initiation of detonation in the pyro chain. This additional means of initiation was designed as a fallback option, providing fault tolerance, enhancing the overall reliability of the system. Thus, a novel design of explosive transfer line (ETL) coupling with additional means of initiation was conceived to meet the stringent design challenges like containment of detonation pressure within acceptable limits due to additional transfer charges, totally leak-proof contamination free system due to proximity of satellites and other payloads, mass and envelope minimization considering stringent mounting requirements etc. The design solution for pressure containment as well as reliable detonation transfer margin at various interfaces was arrived at through various deign iterations through hydrocode modelling. The need for complete leak tightness was met through elastomeric seals and potting of epoxy resins in reverse taper interface along with the lead wires configured with connector with elastomeric gasket interfaces. This paper describes the necessity of the system, various design drivers involved, its key features and development methodology adopted.

Paper no.	ARMS23-MLV-24
Title	**Motorised Driveline for Ramp Deployment in Interplanetary Missions: Design, Realisation and Testing**
Authors	Ramprasad Regulavalasa, Raghavendra Prasad H M, Harshit Kumar, Akash A Shetty, Shankara A & Arun Kumar Gupta *URSC, ISRO*

In interplanetary surface explorations, a deployable ramp serves the purpose of facilitating the smooth rollout of a rover from the lander. The ramp will be stowed by folding and deployed by unfolding. A Ramp Deployment Mechanism (RDM) is required to assist folding and deployment of the ramp. A stepper motor-based drive was chosen as prime mover for RDM to have low latch-up velocity at the end of the deployment. This paper focuses design, realisation and testing of a motorized driveline for RDM in planetary environmental conditions.

Paper no.	ARMS23-MLV-25
Title	**Measurement and analysis for Lander Drop Test Fixture**
Authors	Prakher Singhal, Avenash A, Mariya Ratlami, Arun Kumar Gupta, Milind Undale & B Lakshminarayana *URSC, ISRO*

A special Lander drop test setup was designed to give horizontal velocity to the Lander when dropping from a certain height. A four-bar mechanism was used for this purpose. An encoder system was connected with it. Measurements were conducted to measure rotational motion of the bottom plate connected to four bar mechanisms in the Lander drop test setup, when moved manually and were validated corresponding optical encoder reading.

Measurement technique 'Photogrammetry system' was chosen over other non-contact measurement techniques like Laser Tracker or Theodolite due to its own advantages. Photogrammetry, as its name implies, is a 3-dimensional coordinate measuring technique that uses photographs as the fundamental medium for metrology (or measurement).

The work details the measurement methodology correlating analytical calculations in order to determine the rotation angle ensuring accurate measurement. As there was no physical measuring point available to establish axis of rotation, a derived method was used to get actual point about which rotation was taking place. Coordinates were found out for three different positions (for three different rotational angle of the moving link) for same point. These three points will be in a arc and centre of this arc/circle will be the point about which rotation is taking place. Rotation angles readings of oscillating links were measured. Relationship between the encoder reading i.e. on Link-1 and Photogrammetry reading i.e. on Link-2 was established with respect to rotation angle. It was found that encoder's rotation angles readings are within specification. Analysis also establishes relation between the parallelism of top and bottom plates of the fixture with rotation angle. Top plane and Bottom plane are parallel with angle 0.09 degree. This angle increases with increase in rotation. Detailed calculations and observations based on the studies carried out has been presented in the full length paper. This work can serve as guidance when carrying out similar measurements in future.

Paper no.	ARMS23-MLV-26
Title	**High strength Hold Down Bolt for Solar Array Deployment Mechanism**
Authors	Nithin Menon P, Narashimhamurthy N, Sakthivel M & Abhishek Kumar *URSC, ISRO*

The power requirement of spacecraft is met by deployable solar array wings. In launch configuration, solar panels are kept in stowed configuration to meet stiffness requirement & launch vehicle envelope constraints and deployed in orbit. Hold-down bolts are used to keep the solar panel rigidly in launch configuration with required pretension to resist the vibration loads on the panel stack during the launch phase.

Hold down bolt is made of two metallic terminals made of cold worked SS304 with a stainless-steel wire rope swaged into them. The stowed stack height of the solar array demands flexible hold-down bolt for smooth deployment as the bolts come out of the hole in the solar panels. The hold-down bolt terminal dimensions near the swaging location are selected based on the wire rope diameter (5.6 mm), which is higher than the existing hold down bolt wire rope diameter. As the joining process for wire rope and metallic terminal is by swaging process, a new swaging terminal and swaging die have been designed. Qualification tests were conducted to ensure the load capacity of the new bolt.

This paper covers the design, development and test results of high strength hold-down bolt for solar array deployment mechanism and also the corrective measurements carried out to qualify the bolt.

Robotics, Space Docking, Berthing and Rover Mechanism (ROB)

Paper no.	ARMS23-ROB-01
Title	**Development of Robot using Artificial Intelligence Control Learning Techniques for Defense Applications**
Authors	Amit Yadav*, S M Jain†, Ajeet Gaur†, Sumati Sidharth*, Kavita Lalwani*, Jyoti Vimal* & D K Chaturvedi* **Dayalbagh Educational Institute, Agra, †ADRDE, DRDO*

In recent days the technology shift can be well observed towards artificial intelligence if we talk of intelligent robots. Robot and intelligent robot's which is based on control algorithm developed by using artificial intelligence. Robot main function to identifying obstacles and avoid in its path during operation. The approach assumes external sensors and control algorithm for complete the task. A real-time application for obstacle detection is developed, and verified experimentally on a robot. The research has implemented in three phases first we have done mathematical modelling of the system in kinematics, dynamics and electrical drives. The second part of the research based on development of artificial intelligence control algorithm. The third part consider as the test and validation of the robot in real time circumstances.

Paper no.	ARMS23-ROB-02
Title	**Pulse width Modulation-based Thermal Stimuli for the SMA Spring Actuators**
Authors	ANP Panandikar, P Bhargava, Komal Agarwal, Amit Kumar Gupta & Pardha S Gurugubelli *Birla Institute of Technology & Science Pilani, Hyderabad Campus*

Shape Memory Alloys (SMA) are a class of smart materials characterized by their thermomechanical responses based on two different microstructure phases – a low temperature phase as martensite and a high temperature phase as austenite. SMA exhibits an ability to recover to a pre-trained shape on heating above the transition temperature from the martensite phase to the austenite phase and this ability is referred to as the shape memory effect (SME). This effect of SMA materials is widely used in aerospace and defense applications for actuator mechanisms. The rate of actuation depends on the rate of heating SMA springs which is directly proportional to the square of the voltage applied and inversely proportional to the resistance of the spring. One of the most commonly used techniques to achieve a

controlled actuation process is by providing the thermal stimuli that is controlled by variable voltage supply.

In this work, we implement a method wherein the thermal stimuli to the SMA spring is provided by varying the pulse width (PW) of a constant voltage supply. The process of varying pulse width of a constant voltage source is also commonly known as Pulse Width Modulation (PWM). PWM is known to be efficient compared to their variable voltage generators from the energy consumption point of view. The work involves studying the temperatures of the NiTiNOL spring at various voltages and duty cycles. In summary, the work proposes development and demonstration of thermal stimuli mechanism that controls the SMA based actuators

Paper no.	ARMS23-ROB-03
Title	**Fabrication and Thermomechanical Characterization of Shape Memory Alloy-based Helical Springs**
Authors	J A Stefen Paul, Vishnu Gopalakrishnan, Chaitanya S Nayak, R Santhanam, Pardha S Gurugubelli, Abhishek Sarkar & Amit Kumar Gupta, *Birla Institute of Technology & Science, Pilani, Hyderabad Campus*

Shape memory alloys (SMA) due to their exceptional capacity to experience a reversible phase shift when exposed to temperature variations, have attracted a great deal of interest in the field of actuators for a variety of applications, including robotics, aircraft, and medical equipment. The objective of this study is to fabricate SMA helical springs with varying spring parameters such as wire diameter, coil diameter, and number of active coils and to obtain its characteristic curves through experimental processes for a range of operating stresses, strains, and temperatures. Firstly, a code has been developed to calculate the spring parameters (wire diameter, coil diameter, number of active coils, and the initial spring angle) based on force and stroke length. Before the fabrication of helical springs, the as received NiTi wires (having transition temperature at around 60°C) are tested at room temperature for cyclic loading and until fracture, and at a temperature above 60°C. These material properties are used in the design and fabrication of the helical springs. Finally, helical tension springs have been fabricated with appropriate fixtures and shape-setting procedures. The springs are then tested for various thermomechanical behaviors such as stress-strain curves at constant temperatures, strain-temperature curves at constant stresses, and the phase diagrams for the NiTi helical springs. This research work helps in understanding and harnessing the properties of SMA for actuator applications in aerospace and defense mechanisms.

Paper no.	ARMS23-ROB-04
Title	**Seven Degree of Freedom Actuator Design for Mirror Telescope Segment**
Authors	Shreyash Ravindra Pawar *Indian Institute of Space Science and Technology, Kerala*

This report presents the comprehensive design and analysis of actuator system made for precise control and alignment of mirror telescope. For space exploration telescopes are crucial components. For deep space we need large and more sophisticated telescopes. To achieve the desired optical performance actuator are important like maintaining the shape and alignment of individual mirror segments. This report provides insights into the structural analysis and potential advancements of a 6-DOF actuator system tailored for mirror telescopes. Various designs for mirror alignments are discussed, their pros, cons and design evolution through various steps. Structural analysis under different conditions is performed to observe design capability.

Paper no.	ARMS23-ROB-05
Title	**Rover Control Co-Simulation using ADAMS and MATLAB/Simulink**
Authors	Hardhik Gembali*, Amit Kamboj†, K Balaji† **National Institute of Technology, Bhopal, †URSC, ISRO*

Rovers on planetary surface are operated in semi-autonomous mode where the actual path traversed by the rover can differ from the commanded path due to uncertainties. This paper aims to develop a simulation framework capable of commanding the rover to reach the actual destination irrespective of terrain conditions.

The simulation framework seamlessly integrates ADAMS and MATLAB/Simulink for the purpose of controlling rover motion. The primary objectives of this research are twofold: first, to create a robust simulation environment that facilitates co-simulation between ADAMS and MATLAB/Simulink; and second, to apply this framework to control the motion of a rover. This approach allows for more advanced control strategies, resulting in improved rover motion accuracy. Error comparisons between simulations with and without MATLAB/Simulink co-simulation indicate a significant reduction in error when using ADAMS-MATLAB/Simulink co-simulations.

In summary, this activity demonstrates the successful integration of ADAMS and MATLAB/Simulink for rover control. The findings suggest that co-simulation enhances control precision and adaptability, making it a promising approach for the development of autonomous rover systems.

Paper no.	ARMS23-ROB-06
Title	**Five Degree of Freedom Robotic Manipulator for future Inter Planetary Missions**
Authors	Anirudh R, Damodaran P, Gopakumar M, Subramanian UA *VSSC, ISRO*

Space exploration depends on the development of robotic manipulators with higher load and motion capabilities with minimum weight for carrying out multiple operations and for minimizing the payload mass. This paper presents a newly designed and developed five Degree of Freedom (DOF) robotic manipulator capable of achieving interplanetary mission objectives. The developed robotic arm manipulator is made of five rotary actuators and has a total payload capability of 5 kg in earth's gravity. Manipulator is configured for handling multiple end effectors by having a two DOF at wrist. The major milestone was to design a size optimized actuator capable of handling torque ratio as high as 100000:1. Actuator was designed with built in harmonic drive, planetary gear system, encoder and an integrated bearing system.

Mathematical model for forward kinematics and inverse kinematics was completed by deriving the DH parameters. Quintic polynomial-based trajectory and obstacle avoidance of a known target has been amended to the path planning algorithm. A Simulink model was developed for the manipulator. Electrical routing of the manipulator was completed in such a way that it will not hinder with the free movement of the actuator. A Graphical User Interface (GUI) based control system was developed to test the system capability. Two electrically actuated grippers were fixed at the end effector to demonstrate the manipulator capability. A test setup was completed to measure the validity of the algorithm. Detailed summary on the design, development and execution of an inter-planetary manipulator is presented in this paper.

Paper no.	ARMS23-ROB-07
Title	**Optimal Smooth Trajectory Planning of Robotic Manipulator for Additive Manufacturing in Space**
Authors	Dasu Deva Karthik Lakshman, Anirudh R & Manu V Unnithan *VSSC, ISRO*

Trajectory planning plays a crucial role in the performance of the robotic manipulator for any task. In this paper, an optimal smooth trajectory is generated for the additive manufacturing in space using a three degree of freedom series-parallel hybrid robotic manipulator. The total time and jerk in trajectory planning for additive manufacturing are two conflicting objectives and have serious effects on the power consumption and product quality. In this study, the optimal trajectory planning of the robotic manipulator is formulated as a multi-objective optimization problem with total time and jerk measure as the objective functions. Cubic spline which is most widely used technique for planning robotic trajectories is employed for the current study and two most commonly used infill strategies in additive manufacturing, *zig-zag* and *contour* infill paths are considered as the test cases for the optimal trajectory planning problem. Furthermore, an accurate indirect approach for inverse kinematics of this type of robotic manipulator has been proposed in this paper by formulating it as a Non-linear Programming Problem (NLP). Non-dominated Sorting Genetic Algorithm-II (NSGA-II) is employed for solving the optimal trajectory problem.

Paper no.	ARMS23-ROB-08
Title	**Design Parameters of Robotic Arm for Space Application**
Authors	Aayush Kejriwal, Sidharth Tiwary, Subash Yadav, Arun Kumar Gupta & Abhishek Kumar, S Narendra *URSC, ISRO*

With the advancement of space exploration, the need for advanced mechanisms to perform activities which are risky and/or complex for humans have emerged. Among the many technologies, the robotic arm stands out as the crucial mechanism capable of performing various tasks such as, satellite/appendage deployment, maintenance & repair, sample retrieval, debris collection etc. In addition, it has supported several on-orbit operations to astronauts on-board thus cementing its importance.

Apart from the harsh and unforgiving environment of space such as extreme temperatures, radiation and vacuum condition, there are several other parameters which contribute to the design of a robotic arm for space application. Precise, reliable and in some cases autonomous operation is of prime importance for robotic arm in space, given the critical nature of tasks and the unavailability of human intervention in case of any failures. Furthermore, the weight and size constraint of space missions necessitate lightweight yet robust design. One more aspect of space application is the need of redundancy in system which

is critical to ensure reliability of the system. The robotic arm performance is defined by the actuator at each joint. An actuator is a combination of multiple parts such as motor, bearing, gearbox etc. and each part are selected based on the robotic arm requirement. In this paper we will discuss the various parameters to be considered to finalize the design of a robotic arm for space application and the method to select the appropriate value for those parameters.

Paper no.	ARMS23-ROB-09
Title	**Improved robotic spacecraft attitude control using coordinated twin manipulator actuations**
Authors	Lima Agnel Tony*, G. Krishna Kumar Teja†, Amritha A*, Manali Sharma*, Shaheen M P*, Harikumar Ganesan*, Sangeetha G R*, Dhanesh S*, Durairaj R* **IISU, ISRO, †VSSC, ISRO*

The absence of a fixed base makes controlling space robotic manipulators different and challenging compared to terrestrial robotic arms, as any motion of the joints can induce reaction forces on the base. In this paper, the idea is to use these reaction forces to control the spacecraft attitude. Previous studies have established that, to achieve one degree of freedom (DOF) in base attitude, a manipulator with at-least two degrees of freedom is necessary; and a suitably configured 3 DOF arm is sufficient to achieve 3 DOF base motion. However, the base attitude profile thereby has large oscillations compared to the effective change. In this work, this phenomenon is studied, and a solution for reducing oscillations by coordinated motion of two arms is proposed and validated on a 1 DOF test bed. Accordingly, a configuration is conceived with a base and two 2 DOF robotic arms placed symmetrically on the either side of the base. The manipulators follow a closed loop path in their joint space to produce an attitude change in the base about one axis. Variation in the base attitude for different paths in the joint angle space are computed and simulated in MATLAB for the given model. The developed results were implemented on hardware.

Paper no.	ARMS23-ROB-10
Title	**Electromagnet Assisted Docking for Space Applications**
Authors	Sreejith M R, Smitha Krishnan, Ravichandran M H, Harikrishnan A & Sajeev Kumar A *IISU, ISRO*

The electromagnetic force generated by single or combination of electromagnets can help to control the relative separation between them and are found useful in the docking systems for small satellites. This paper discusses the merits and demerits of electromagnet assisted docking followed by the major configurations of electromagnets that are useful in docking. Results of FE simulation carried out to bring out the effectiveness of electromagnet are also presented. The details of a low cost experimental test bed to study the functionality of electromagnets for different lateral and axial separations are also presented.

Paper no.	ARMS23-ROB-11
Title	**Reactionless actuation of Robotic Manipulators for on-orbit operations**
Authors	Deepak Jogi*, Vivek R S*, Kevin John*, Sangeetha G R†, Shaheen M P†, Harikumar Ganesan†, Dhanesh S† & Durairaj R† **VSSC, ISRO, †IISU, ISRO*

This paper presents a method for achieving reactionless actuation of a free-floating robot. The robot has a floating base with six passive degrees of freedom (DOF) and two manipulator arms each with three active DOF. The lack of a fixed base and presence of reaction forces caused due to manipulator motion are challenges in space robotics control. In this paper a method of manipulator control is presented that minimizes the reaction forces on the base. A stabilization method which accounts for modelling errors and external disturbances is also presented in this paper.

Paper no.	ARMS23-ROB-12
Title	**Design, Development and Testing of Retarder Mechanism for VELC Payload of Aditya-L1 Mission**
Authors	Harikrishnan A, Rohit Katiyar, Dhanya G, Anand P, M H Ravichandran IISU, ISRO

This paper presents the design, development and ground performance evaluation of Retarder mechanism, designed for holding the retarder optics of Visible Emission Line Coronagraph (VELC) payload of India's maiden solar observatory mission, Aditya-L1 project. VELC payload will image the solar corona and perform the spectroscopic and spectropolarimetric observations. For the Spectro-polarimetric observations, the retarder optics needs to rotate at 5.95rpm, for a session of proposed observation. The Retarder is a polarizer which has 16 slots of different polarization. For each slot of the polarizer optics (22.5 o slot), an exposure will be taken, related to each polarization angle. To get enough SNR, the exposure time at each slot is selected as 504ms, whereas traversing a 22.5 o slot will take 630.15 ms (for a speed of 5.95rpm). Here angle information is very critical to stop the current observation and start the new exposure at the correct angle so that the scientific exposure will not lose its uniqueness. The aim of the mechanism is to hold the retarder optics without obstructing the optical path and rotate at the designed speed with speed stability within 1%.

Paper no.	ARMS23-ROB-13
Title	**Reconfigurable Truss Mechanism for need based shielding of a Quadruped robot during space exploration**
Authors	V Sri Pavan RaviChand*, Shishir Kolathaya†, K Balaji* & B Lakshmi Narayana* *URSC, ISRO †Indian Institute of Science, Bengaluru

Space exploration missions for longer durations need to withstand extreme environmental conditions that are not only harsh in terms of range of parameters like temperature but also severe in terms of cycles of change like sun presence. In such scenarios, the life and operation capability of the robot sent to space can be significantly enhanced by having a safe shielding zone for the robot when it is subjected to difficult environmental conditions. A safe shielding zone consists of two prime constituents, which are structure made of rigid elements (which will provide shape and volume to the zone) and covering on the structure made of membrane (which will serve as shield to the zone for extremes of environment like temperature). The present paper discusses one such concept of structure for the safe shielding zone with regard to a quadruped space robot using Reconfigurable Truss Mechanism (RTM). This RTM is a network of closed bays formed by rigid links connected using revolute joints to form a single degree of freedom system. The RTM is attached using a motor, for actuation, at backend of the torso on the top face of the quadruped. The details of the linkage along with kinematics corresponding to two configurations (spatial and planar) using same set of links and joints of the linkage have been presented in the paper. This includes the details of the truss mechanism as well as the closed linkage forming a single bay.

The paper is organized into four sections. First section presents the introduction including the motivation and literature survey. Second section presents the description of the quadruped including its physical dimension details that form the input for synthesis of the RTM along with description of the truss mechanism. Third section presents the kinematics of the mechanism. This includes the mobility estimation of unit bay as well as the network of bays, i.e., the truss for both the spatial and planar configurations. Finally, the fourth section presents the concluding remarks along with the future scope of applications for this work.

Paper no.	ARMS23-ROB-14
Title	**Deployment Mechanism of RAMBHA-LP Payload onboard Chandrayaan-3 Lander**
Authors	Md Sabir Alam, Johns Paul, Santhosh J Nalluveettil, Subramanian U A VSSC, ISRO

RAMBHA-LP is one of the key scientific payloads onboard the Indian Space Research Organization's (ISRO) Chandrayaan-3 lander. Its objectives were to carry out first in-situ measurements of the surface-bound Lunar plasma environment over the south pole. The probe is mounted on the lander's upper deck and initially kept in a stowed condition. A mechanism was designed and realized to meet the functional requirement of deploying the probe at a distance of 1 meter, equivalent to the Debye length of the probe in the moon's plasma environment. This paper presents the design and development process of the probe and its deployment mechanism and the details of the various tests conducted to qualify it for use in a lunar landing mission

Futuristic Aerospace Mechanism, Aerospace Tribology, GNC, Positioning, Ejection System (AMECH)

Paper no.	ARMS23-AMECH-01
Title	**Scope of aircraft noise for clean energy harvesting**
Authors	Arunesh Kumar Singh*, Shahida Khatoon*, Kriti Tripathi* & Dr. D.K. Chaturvedi† **Jamia Millia Islamia, New Delhi, †Dayalbagh Educational Institute, Agra*

This paper presents the scope of aircraft noise pollution energy harvesting. The noise pollution is highest at the landing and take-off of the aircraft. The airport site and runway experience the high decibel of noise pollution generated from the aircraft. The source of the aircraft noise is the wheel-runway friction, braking system at the time of landing of the plane and high-speed turbulence etc. This low frequency vibration energy has a scope to get harvesting and provide clean energy generation. For this purpose, an energy harvester can be developed to harvest the waste energy and provide electrical energy signal that can be used to glow the LEDs on the sideline of the runways at night and other applications.

Paper no.	ARMS23-AMECH-02
Title	**Development of Parafoil based Autonomous Payload Delivery System**
Authors	Manish Bhatnagar, Ajeet Gaur, Mahboob Ahmad & Ajitabh Tiwari *ADRDE, DRDO*

Controlled Aerial Delivery System (CADS), designed and developed by ADRDE(DRDO) is capable of precise delivery (via airdropping) of payload upto 1000 kg at a pre-designated landing location within the CEP of 100 m utilising the steering capabilities of the RAM Air Parachute and onboard actuator with related electronics systems. This system has many advantages over the conventional paradropping of supply and cargo drops. The limitations of CADS could be attributed to its limited endurance leading to strict compliance to mission planning enabling it to touch down near target landing point. Being a non-powered system, CADS is never able to ascend and thus its glide ratio remains affected by prevailing wind conditions, its drop offset and drop altitude. These limitations can be overcome by utilisation of a power source with CADS to enhance its endurance. Since unlike CADS, it is capable of take-off from ground and land back on ground after the flight, which makes it an attractive alternative for strategic activities in civil and military fields. Addition of autonomous feature to the Powered CADS would further enhance its overall utility. This paper presents the design approach of Parafoil based Autonomous Payload Delivery System, development of a scaled down prototype and flight data generated from its flight trials.

Paper no.	ARMS23-AMECH-03
Title	**Design Development of active Sea Marker Dye dispensing system**
Authors	Surbhi Baghotia, Anoop P P, Manu V Unnithan, Damodaran P & Subramanian UA *VSSC, ISRO*

Sea marker dye is used widely as a locating aid for recovery operations in sea. Upon contact with water, it gives a fluorescent green colour streak that can be easily detected during aerial survey. An active dye dispensing system is developed for crew module re-entry mission as an alternate locating aid for crew module.

The system is located in the crew module parachute compartment and is actuated when the crew module splashes down in sea. The system comprises of a dye container with float, a retention system with pyro thruster & helical compression spring and an entanglement free tether dispenser. Upon splashdown, the pyro thruster is commanded to release the lock on dye container which is then jettisoned by helical compression spring. The dye packaging is custom designed for the sustained release of dye into sea water for duration of about 2 hours from the time of impact.

The development and qualification tests have been completed and the system has been successfully demonstrated in Human Space Flight Test Missions of ISRO. This paper brings out design features, development and qualification details of the system.

Paper no.	ARMS23-AMECH-04
Title	**Performance parameter evaluation, Design Qualification and Pilot Scale manufacturing of Electrically initiated Impulse cartridge for operating ejection mechanism of Deployable flight Data recorder System of Transport Aircraft**
Authors	AK Sahu, PG Karande, YB Salkar, H Singh, RK Srivastava & BA Parate *ARDE, DRDO*

Impulse cartridges are utilised for large number of applications to operate system & subsystem of Aircraft like ejection of externally carried store, jettisoning of Canopy, deployment of parachute, operating mechanism of deployable flight data recorder system and many more. The energy in the form of gaseous pressure generated from the energetic propellant composition of the impulse cartridge operates the mechanism. In this paper the method adopted for Performance parameter evaluation, Design Qualification and Pilot Scale manufacturing of Electrically initiated Impulse cartridge were discussed.

The cartridge was developed for operating the mechanism to eject the flight data recorder from the aircraft which encounter accident. It is manufactured from the hardware

components and energetic materials as per pre-defined methods. 100 Nos of cartridges were manufactured and subsequently test fired in constant volume test vessel to specify the test parameter. For operating the ejection mechanism instantaneous pressure, namely Pmax is required, which is measured by using pressure sensor mounted on test vessel. The range of Pmax parameter is decided based on mean and standard deviation of the Pamx data from the population. After finalization of the performance parameter the cartridges were subjected to design qualification trials namely vibration, shock, salt mist, Drop test, Hot, cold conditioning, hygroscopic and subsequently test firing in closed vessel. The cartridge passes all tests required for design qualification and found within the specified range. It fulfils the technical requirements of the system. One pilot batch of 40 cartridges were manufactured and qualified, samples were drawn as per IS 2500 Part I and successfully cleared in closed vessel trials. This paper explains about the development of the cartridge, performance evaluation trials, design qualification trials and subsequently pilot scale manufacturing.

Paper no.	ARMS23-AMECH-05
Title	**Shelf Life Revision Study of Percussion Primer utilised for testing of mechanical firing mechanism of Aircraft ejection seat during maintenance and servicing**
Authors	AK Sahu, H Singh PG Karande, YB Salkar, RK Srivastava, BA Parate & RM Kumar *ARDE, DRDO*

Mechanical initiator devices are employed in ammunition and gas generating cartridges as first fire element. The initiatory composition filled inside the metallic casing. These initiator Cap are also employed for testing the mechanical percussion mechanism of seat ejection system installed onboard fighter aircraft. In the present study life revision study of Test Cap KVM-3 were carried out.

The experimental methods are accelerated environmental testing followed by performance evaluation in velocity test rig. The test set up was fabricated to assess the functioning of the device. For operating the mechanism instantaneous pressure is required to be generated, which is measured.

The performance of the device after conduct of accelerated ageing test found comparable with the standard test data. It fulfils the technical requirements for the system. The trials results obtained in two phases. The performance of environmentally simulated device fulfil functional requirement and it is comparable with the standard test data confirms the serviceability.

This paper explains about the experimental method adopted during revision of storage life study. The Test Cap assigned storage life 8 years for ground application. This life assigned on the store will empower the User Agency to optimally utilize the Cap through the assigned shelf life period.

Paper no.	ARMS23-AMECH-06
Title	**Concept of Indigenous Development of Aircrew Smart Ejection Seat (ASES)**
Authors	Mahendra Pratap *ADRDE, DRDO*

Ejection seat is a safety equipment fitted in the fighter aircraft cabin for the bailout of the aircrew during emergency to save the pilot's life. Ejection seat need to operate in synchronous manner for minimal aircrew injuries, within define physiological limits of aircrew. Indigenisation of the ejection seat is initiated at ADRDE for the selected aircraft(s). The aim is to enhance the capability of Indian aircrafts using indigenous seat which would be comparable to 5^{th} generation aircraft and develop repair/maintenance calibre within the country. Indigenous seat would be capable to accommodate percentile range 3 – 97 % of IAF population. This paper is a part of indigenisation process and discusses the basic concept of development, requirements and comparative study with available modern ejection seats.

Paper no.	ARMS23-AMECH-07
Title	**Effect of Dielectric Barrier Discharge on the Single Expansion Ramp Nozzle Flow**
Authors	Suresh K *ADRDE, DRDO*

Single expansion Ramp Nozzle (SERN) is used in SCRAMJET engines in hypersonic aircrafts. Dielectric Barrier Discharge (DBD) has gained importance in recent years as a subsonic flow control technique. The objective of present work is to analyze the effectiveness of a simple DBD actuator in supersonic flow issued from SERN, to identify its impact on boundary layer separation. Computational simulations are performed to identify flow separation location with respect to ramp angle. These results from CFD are used for the placement of DBD actuator. The DBD actuator was built using a fly-back transformer and a driving circuit. Schlieren flow visualization study was conducted to visualize the shock structures, flow separation and vortical structures from ramp region. The effect of DBD for various ramp angles and nozzle pressure ratios (NPR) was studied and found to be significant in delaying flow separation along the ramp of the nozzle. Also, the vortices formed at the end of shock cells were stronger in the DBD actuated mode.

Paper no.	ARMS23-DST-01
Title	**Technological Challenges in Adaptation of P-7 Heavy Drop Platform System for Main Parachute Aerial Drop Tests and Integrated Main Parachute Aerial Drop Test of Gaganyaan Programme**
Authors	Anurag Yadav & B K Singh *ADRDE, DRDO*

ADRDE is a pioneer DRDO laboratory, involved in the design, development and production of Heavy Drop Platform Systems (HDPS). Different versions of HDPS for paradrop of military stores upto 16000 kg weight class using transport aircraft have been realized by ADRDE. P-7 HDPS is used by Indian Armed Forces for quick delivery of heavy combat payloads of 7000 kg weight class for their operations at target areas such as battlefields, training zones, border areas etc. Paradrop of such heavy payloads by means of P-7 HDPS is facilitated using IL-76 transport aircraft. Quantity 146 sets of these systems have been produced and supplied to Indian Army for their combat operations. Indigenous realization of these systems has assisted the Users in achieving self-reliance in this domain and boosted the "Atmanirbhar Bharat" program of Nation. Platform is required for arranging and lashing of payload and for the purpose of mounting of Parachutes in packed condition. Configuration requirements for these Heavy Drop Platforms include a Pallet along with associated mechanical devices and accessories, required, for palletization and lashing of payload, guidance of loaded platforms inside aircraft & their locking in aircraft monorail, actuation of parachutes, separation of parachutes from Platform and attenuation of impact at ground touchdown, etc. Gaganyaan program is an ambitious human space flight Programme of ISRO proposed with the objective to send three crew members to Low Earth Orbit using launch vehicle and to bring them back safely to a pre-determined location on the earth using parachute based deceleration system.

Responsibility of developing this parachute based deceleration system for 5000 kg has been assigned to ADRDE. Main parachutes of this system are to be qualified prior to actual usage. As a part of qualification, Aerial Drop Tests and Integrated Aerial Drop Test have been conducted. Integrated test was conducted with cluster of main parachutes deployed by mortar fired pilot parachutes. Since, configuration of deceleration system being developed is quite different from that of conventional heavy drop parachutes, required modifications were to be carried out in P-7 HDPS. The task was not easy and several technological challenges were faced in adaptation of existing P-7 HDPS for these aerial drop tests due to additional specific requirements. These include finalization of integration scheme, mounting of mortars & Parachute Release Units, strength validation & modification of few accessories etc. The present paper throws light on these technological challenges.

Paper no.	ARMS23-DST-02
Title	**Design of New configuration of Energy Absorber Assembly for Aircraft Arrestor Barrier System**
Authors	Rishabh Singh & Surendra Mahavir Jain *ADRDE, DRDO*

The paper describes design of new configuration of energy absorber assembly for Aircraft Arrestor Barrier system. The Aircraft Arrestor Barrier system (AABS) are installed at the end of the runways for the purpose of arresting combat aircraft overshooting runway length during aborted takeoff and emergency landings. The AABS consist of a multielement net assembly, top end of which is attached with the stanchion system and the lower end is connected with the purchase tape. The purchase tape is winded on tape drum and tape drum is attached with the energy absorber assembly. The energy absorber assembly is the heart of AABS consisting of rotor vanes submerged inside glycol fluid. These rotor vanes produce drag force when start rotating and ultimately bring the aircraft to rest within the safe run out distance. Presently there are two different types of energy absorbers (40-ton class and 20-ton class) for engagement of different types of aircraft. There is no universal aircraft arrestor barrier system based on water twisting technology which can be used for arresting all types of combat aircraft. The new configuration of energy absorber assembly consists of 40 Ton class absorber, 20 Ton class absorber and a tape drum stacked one over another. The 20 Ton class energy absorber is fixed at the bottom, the 40 Ton class energy absorber is mounted above the 20 Ton class energy absorber with the help of metal structure and the tape drum is held above the 40 Ton class energy absorber with the help of metal structure. The system shaft is held with the tape drum with the help of splines, the system shaft is made in two parts in order to make the system modular and easy to assemble, one part of the shaft goes from tape drum to 40 Ton absorber and second shaft goes through 20 Ton absorber. The system shaft is used for engaging the desired absorber with the tape drum. The rotor bush of both the absorbers have free rotation with respect to the system shaft. However, a dog clutch is added for desired engagement. The rotor bush is connected with female dog clutch with the help of flange. The male dog clutch is held with system shaft with help of splines, these splines allow upward and downward motion of the male dog clutch. The male dog clutch is attached with the slider fork and actuator assembly which produces the linear movement. Both absorbers have their independent female and male dog clutches with their independent actuators. So, this configuration allows that any of the energy absorber could be coupled with the tape drum as per aircraft requirement. The paper primarily focuses on the working principle of the new configuration of energy absorber assembly.

Paper no.	ARMS23-DST-03
Title	**Development of Baro Altimeter System for real time decisions on Gaganyaan Crew Module Deceleration Systems**
Authors	Harshit Kumar Gupta*, Vinu Rajakumar C*, Sandeepkumar Epuri†, Jayanta Dhaoya‡ & Bijoy Jacob K* **IISU, ISRO, †VSSC, ISRO, ‡HFSC, ISRO*

During descent phase, the Gaganyaan-Crew Module (CM) vehicle will trigger several Real Time Decisions (RTDs) related to deacceleration systems like drogue chute release (main chute deployment) based on CM altitude. The primary source of altitude information is the filtered aided navigation solution in CM Navigation Guidance and Control. Additionally, CM houses Baro-altimeter (BALT) system providing CM altitude information autonomously using barometric pressure measurements. In case of unavailability of aided navigation solution, altitude information from baro altimeter will be used for triggering real time decisions on parachute deployment. BALT system utilizes local atmospheric model relating the atmospheric pressure with altitude to derive the altitude information based on the barometric pressure measurement. Ideal location of baro sensors is the location with zero Coefficient of Pressure (Cp). But in the descent phase of Gaganyaan mission, Angle of Attack (AOA) is expected to vary in the range of ±60o for contingency scenarios of mission, which poses difficulty in locating a point with near zero Cp for all the possible AOA conditions. Hence, an alternative technique utilizing skin pressure measurements, Computational Fluid Dynamics (CFD) predicted, wind tunnel validated Cp value is presented to derive altitude information of CM. In this article various aspects of baro altimeter system design covering details on sensor selection, sensor location, pros and cons of various algorithms is presented. Error simulation shows that expected maximum altitude error is well within mission requirements.

Paper no.	ARMS23-DST-04
Title	**Payload advantage of using an inflatable aerodynamic decelerator for first-stage recovery**
Authors	Harris V John, Sandeep Prasad Shaw, Divyansh Prakash, Kriti Raj, Vinod Kumar, Amit Sachdeva & Dr. Pankaj Priyadarshi *VSSC, ISRO*

Reusable launch vehicles without lifting surfaces rely on retro propulsion to achieve the deceleration required for vertical landing. This retro firing is typically split into an entry burn to limit the peak dynamic pressure and the terminal phase landing burn. In this work we explore the feasibility of using aerodynamic drag to passively reduce the peak dynamic pressure in the descent trajectory and eliminate the entry burn. The drag coefficient of an Inflatable Aerodynamic Decelerator was studied at hypersonic, supersonic and subsonic speeds. This data was used to estimate the propellant required for the terminal phase landing burn. Through trajectory optimization, the payload penalty of reserving this amount of fuel during ascent was estimated as 93.5-98% of the payload capability without reserving fuel for recovery. This is in contrast to the 88.7% payload capability when recovering the first stage of the vehicle through retro propulsion alone.

Paper no.	ARMS23-DST-05
Title	**Kit GAURA: Life Saving Equipment**
Authors	Lt Col Anuj Chandra Shrivastava *ADRDE, DRDO*

Indian has a fragile eco system. It ranks among the top three countries in world that bears maximum brunt of natural disasters every year, resulting into an average of 11 deaths and another 1.5 lakh getting effected every day. While various agencies work towards HADR missions, spear headed by NDMA, however that is hardly sufficient. Kit GAURA will add to the technological prowess of the rescue agencies owing to its multi facet advantages. This low cost solution is best suited for high disaster prone developing countries. Modifications can be made as per the user requirement.

Paper no.	ARMS23-DST-06
Title	**Kit VARTIKA: Equipment Carrier for Covert Operations**
Authors	Lt Col Anuj Chandra Shrivastava & Vipin Kumar Verma *ADRDE, DRDO*
Special Forces operations require equipment specially designed for their varied need. A covert operation suited equipment carrier is a must for any airborne operation. Kit VARTIKA will act as a force multiplier for all such tactical manoeuvres.	

Paper no.	ARMS23-DST-07
Title	**Reliability Analysis on Parachute Configurations For Deceleration System Of Gaganyaan**
Authors	Mathew Tom, Maruthi SS, Sunoj M & PK Sreekumar *VSSC, ISRO*
Deceleration system plays a crucial role in safe recovery of crew in human space missions. It is employed to bring down the Crew Module velocity in steps using parachute systems during descent phase. For India's human space mission programme 'Gaganyaan', two deceleration system configurations were initially considered. Both configurations are complex in nature with interdependent functions. They were compared and analysed w.r.t. various aspects of reliability. This paper describes how detailed reliability assessment/analysis can be carried out on such complex configurations in an effective manner, so that the superior one can be selected for induction	

Paper no.	ARMS23-DST-08
Title	**Terminal velocity measurement of Gaganyaan Main Parachute during Airdrop trials**
Authors	Vamsi Karumuri, A Jothi Ramalingam, Santhosh J Nalluveettil & U A Subramanian *VSSC, ISRO*

This paper introduces an innovative method using a laser sensor for measuring the terminal velocity of the Gaganyaan Main Parachute during airdrop trials. The Parachute system in the Gaganyaan programme plays a pivotal role in reducing the velocity of the Crew Module, thereby ensuring the safe recovery of the crew in manned missions. Traditional methods for measuring terminal velocity using Baro-sensors face challenges as they are prone to errors due to pressure disturbances and mounting location constraints, especially in cases of oscillations during descent. In this study, a solution is proposed by introducing a laser-based distance measurement sensor in combination with accelerometer and signal conditioning circuits to capture the terminal velocity data accurately. Additionally, parachute load measured during descent is utilized for analysis. The output of the sensor, based on the distance between the platform and ground is measured and stored in an onboard acquisition system. Analyzing the slope of the distance data, coupled with the compensation of payload oscillations using accelerometer data, yields an accurate method for measuring terminal velocity. This scheme has already been successfully implemented and qualified in airdrop trials at Agra and during the Integrated Main Parachute Airdrop Test (IMAT). This paper presents the methodology, implementation, and results of this innovative approach, highlighting its potential contributions to enhance space mission safety and efficiency.

Paper no.	ARMS23-DST-09
Title	**Experimental Investigation of Parachute System with and without Cylindrical Fore body**
Authors	Vipin Kr Verma, Anil Kr Nigam and Dr Gaurav Singh *ADRDE, DRDO*

Parachute is always used with Forebody and Forebody generate its own wake that affects the parachute performance. Many parachute jumpers have experienced failure of a pilot chute that was ejected and then collapsed and fell back on the jumper due to wake. The lot of work done in the field of various types of parachutes design but very few useful information available on Forebody-parachute effects. Hence a need to generate useful database using Experimental Investigation to understand the effect of fore-body on the aerodynamics of parachute. To meet the objective, experimental investigation of aerodynamic interference of fore body on Parachute was conducted at National Wind Tunnel Facility (NWTF), IIT Kanpur. This paper discusses the details of the test set-up and parametric studies carried out for different configurations of parachute with and without cylindrical forebody.

Paper no.	ARMS23-DST-10
Title	**Design and Development of Paratrooper Trainer Assistance Software (PTAS)**
Authors	Ajitabh Tiwari, Gautam Paliwal, Puneet Kumar & Anurag Kumar Singh *ADRDE, DRDO*

Combat Paratroopers are specialized combat units airdropped into battle zones by steerable parachute. One of the primary advantages of Combat Paratroopers is their ability to rapidly deploy to distant or remote areas, often behind enemy lines. Their capability to access the battlefield through an aerial route is a major tactical advantage, particularly where other forms of transportation are unavailable. Extensive training is needed by the paratroopers for achieving efficiency and confidence for carrying out combat missions. However, trainee paratrooper finds hard to achieve it. The lack of experience, terrain knowledge and weather conditions make it extremely difficult for paratroopers to reach to Drop Zone or DZ. Particularly during Night training, it's quite impossible for them to navigate towards the DZ leading to accidents and sometime even causalities. To enhance the performance and safety of both the paratrooper and training exercise, a Paratrooper Trainer Assistance Software (PTAS) has been designed and developed.

The PTAS is used to assist paratroopers in guiding them to a specific target or landing zone. The system employs a GNSS & Heading sensor allowing it to determine the location, altitude and heading of the paratrooper during the flight. The system incorporates an on-board computer that processes sensor data and provide real-time guidance to the paratrooper toward the desired target. With the help of a Mesh Radio, the Chief trainer at the ground could also locate the paratrooper in real-time, ensuring safety and objective of the training.

In this paper, the Paratrooper Trainer Assistance System is detailed for its significant potential to enhance performance and improve efficiency in paratrooper training exercise.

Paper no.	ARMS23-DST-11
Title	**Drag chute Deployment Chamber Door Actuation Mechanism Concept and analysis**
Authors	Gayasuddin Quraishi, Vinod Yadav, Anurag Yadav & K D Diwakar *ADRDE, DRDO*

Combat aircrafts use the drag chute to decelerate the aircraft and reduce its landing roll. The drag chute is also helpful in case of landing on shorter runway length, obstruction on the runway, during snowy or rainy weather and other emergency conditions. Drag chute provide aerodynamic braking to the aircraft. These drag chute are fitted at rear fuselage of the combat aircraft and deployed once the nose landing gear has made contact with the runway. Drag chute will be packed in the pack cover made of fabric and is kept isolated in the drag chute chamber. Objective of this paper is to bring out the concept of different type of drag chute chamber configuration and bring out the pro and cons of different configuration. In this paper dynamic analysis of single configuration is also shown which is carried out on SIEMENS owned Simcentre Software.

Paper no.	ARMS23-DST-12
Title	**Analysis of High-Performance Ram-Air Parachutes**
Authors	Uday Karale & Vipin Kumar Verma *ADRDE, DRDO*

This paper talks about parametric design methodology and development of ram-air parachutes. The purpose of this paper is to summarize the results following the successful test of a guided Ram-Air Parachute system and generate results using Para-Z software. The total system weight was 150 kg. which flew using a 34 m^2 parachute. The primary objectives of the test are to both investigate the flight envelope and mature the technology related to the deployment and flight of parachutes. The program had 3 primary technical challenges: (1) successful deployment and inflation of the parachute system, (2) achieving a stable steady state flight condition, and (3) Finding predictable analysis using CFD.

During the test, all three challenges were completed successfully. The system successfully released, inflated, and was then controlled with scripted flight followed by autonomous flight. The script portion of flight was a sequence of left and right turns which repeated until transition into autonomous flight.

Data collected during the flight included GPS, load, and control data logged onboard the Ground Control System (GCS), high-definition video, these data have enabled a number of findings related to high altitude parachute flight concerning flight performance and turn responsiveness, which will be discussed.

Paper no.	ARMS23-DST-13
Title	**Adaptive Polar Fuzzy System for Parachute Trajectory Control**
Authors	D.K. Chaturvedi & Shiva Mishra *Dayalbagh Educational Institute, Agra*

This paper describes an adaptable Polar fuzzy logic system (APFLS) based on a neural method. A rule base and a database represent the FLC's inference process. The APFLS is tuned using two parameters determined by the ANN and the parachute state at that moment. The fuzzy logic-based parachute control is adaptive to variations in operating conditions due to this tuning process. As a result, the system response varies less under various operating conditions than it does when using traditional fixed-parameter controllers. Experiments and simulations have been used to evaluate the APFLS's performance.

Paper no.	ARMS23-DST-14
Title	**Trajectory Analysis for Combat Parachute System**
Authors	Krishan Kumar Katiyar, Rajeev Jain & Kuldeep Yadav *ADRDE, DRDO*

Drift of paratrooper changes due to wind at various altitude during the decent in High Altitude High Opening (HAHO) condition. Purpose of this study is to analyse the trajectory of Parachute System so that paratrooper can reach the Desired Landing Point (DLP) in the presence of winds at various altitude during decent. Drift of the canopy is calculated from empirical formula based on average wind velocity during free fall and canopy action phase. A drop circle has been generated at aircraft release point considering the wind effect during decent of paratrooper. This will ensure the paratrooper to reach the DLP if jumped inside the drop circle. A series of circle has also been generated at various altitude to enable the paratrooper to remain inside the circle so that DLP can be achieved positively.

Modeling, Simulation, MEMS, Armaments, Fuzes, AI (MSM)

Paper no.	ARMS23-MSM-1
Title	**Revolutionizing Sustainable Agriculture using AI-based Drone Technology**
Authors	D.K. Chaturvedi & Shiva Mishra *Dayalbagh Educational Institute, Agra*

The organic farming is very important and crucial aspect in terms of yields. When the farmers wish to shift from inorganic to organic farming, the main issues are – yield, diseases prevention and protection, weed control, maintain the crop performance. To cope up with some of these issues drone technology is used to early detection of diseases so that better prevention and protection can be done. Drone technology will also help in deciding that how only affected area can be well focused and find the ways to overcome chemical based pesticides and use bio/organic based pesticides. It reduces the amount of bio/organic pesticides requirement and cure the plants. Effort requirement will also drastically reduce. Artificial Intelligence (AI) and machine learning will further help in this matter.

Paper no.	ARMS23-MSM-02
Title	**Determining Inflation Pressure for Inflatable Wing for UAV Application Using Finite Element Analysis**
Authors	Shubham, Raman Verma, Chandra Shekher Yerramalli *Indian Institute and Technology, Bombay*

In the last few decades, Unmanned Aerial Vehicles (UAVs), sometimes known as drones, have become crucial in not only scientific research but also applications such as agriculture, surveillance, and rescue. Furthermore, inflatable wings are considered to be an innovative design feature in UAVs to enhance their adaptability and versatility. These inflatable wings offer numerous benefits, including easy deployment in addition to compact storage and compliance to different mission profiles. It can be a boon for strategic missions of armed forces. However, it is vital to determine the peak pressure at which these inflatable wings can be inflated without undesirable deformation while maintaining integrity of structure to ensure their reliability in real-world UAV applications. These inflatable wings are constructed from high-strength fabrics that are lightweight and can be rapidly inflated for deployment. When inflated, these wings provide lift and stability during flight, and when deflated, they facilitate easy storage and transport. The ability to inflate and deflate the wings makes UAVs highly portable and versatile. Researchers, therefore, are trying to explore this design even further.

The primary objective of this study is to perform finite element analysis (FEA) simulations on the inflatable wing structure to determine the pressure at which the wings can be inflated without deformation while maintaining structural integrity.

Paper no.	ARMS23-MSM-03
Title	**Mathematical modeling for estimation of scramjet air intake opening mechanism linkages load**
Authors	Mohammad Arif, Dinesh Amresh, Tanmay Singhal, Manu V Unnithan, UA Subramanian, Binny TR, Sunil Bhaskar, Mani PR, U Syam Kumar, Unnikrishnan S Nair *VSSC, ISRO*

The scramjet air intake mechanism is designed to keep the air inlet closed till the carrier vehicle attain the required Mach number, after the carrier vehicle attains the required Mach number the mechanism opens the air intake to scramjet engine on single command and lock it in the final opened position. A flap hinged at one end (called cowl) is used for closing the air intake to scram jet engine initially, this cowl is rotated on command using actuator and linkages for establishing supersonic flow in the combustion chamber. The mechanism linkages are designed not obstruct air the flow stream to combustion chamber and to the air flow stream external to cowl. The actuator is made using a proven pyro puller coupled with damper to ensure cowl opening time within specification. This paper describes the configuration of air intake mechanism, its kinematic and kinetic analysis to estimate the linkages load for the purpose of structural design and analysis of the linkage and other components. A centrally mounted pyro actuator coupled with hydraulic damper is used as actuator for opening the cowl through torque tube and linkage mechanism. The load on the cowl (aerodynamic, centrifugal and inertial) pyro pressure (at the start of piston motion), polytrophic coefficient pyro gasses (generated from the tests), the geometry of the air intake mechanism (from the system configuration), damper geometry and the damper oil properties are considered as primary input for the estimation of the linkages load. This model is also used for firming up the orifice size based on cowl opening time specification. The loads on the mechanism linkages are estimated with respect to the cowl rotation angle and maximum load on the mechanism linkages are estimated for structural designs and analysis.

Paper no.	ARMS23-MSM-04
Title	**Representative Volume Element (RVE) Finite Element Model Development and Validation for Honeycomb Structure**
Authors	Pradeep Kumar Pal* & P M Majumdar† **ADRDE, DRDO, †Indian Institute of Technology Bombay*

The engineering honeycomb structure is inspired by the natural honeycomb structure. These structures have a high strength-to-weight ratio. These have number of applications where these are used as energy absorbers. The honeycomb structure exhibits a complex deformation pattern. It absorbs the energy by crushing in turn reducing the damage effects reaching to the payload. The typical characteristics parameters are edge length, depth or node length, and cell wall thickness. To investigate the behavior of the honeycomb under quasi-static and dynamic impact cases, it is required to develop a robust FEM model which not only correlates with the experimental findings but shall also be capable of capturing the crushing behavior. As these structure are made of number of cells and modelling them in finite element requires huge computational cost and time. Over the years researchers tried to obtain the mathematical expression for both in-plane and out-of-plane loading. Theoretical methods like energy conservation, work done, and plasticity were used to formulate the expression for the impact parameters. Researchers developed a Representative Volume Element (RVE) model so that later equivalent honeycomb model can be developed. Which will reduce the computation cost and time both. In this work for the paper honeycomb panel a RVE finite element model is developed for out of plane loading and is validated against the peer reviewed analytical work. This model can capture the physics behind the honeycomb structure buckling and cell folding under compressive load. The uniform compression finite element analysis is carried out using LS Dyna software. From this work, it is understood that the techniques deployed here, selection of elements capture the correct physics of the problem. The Non-linear collapse and folding are also captured properly using the finite element method.

Paper no.	ARMS23-MSM-05
Title	**Challenges in structural analysis of flexible structures**
Authors	Imtiaj Khan *ADRDE, DRDO*

Air Inflatable structures are made up of textile fabrics. Characterisation of these structures is important from design point of view. Material properties used in the analysis should be estimated accurately. Bending, shear, torsional, wrinkling behaviour are required to be obtained thorough analysis and experimental techniques. Advanced simulation tools will be used for the analysis work. Material properties are obtained through image processing techniques.

Conventional stain gauges are not used for experimental stress measurement. This paper highlights a new measurement technique developed to measure the strain. Accuracy of measurement is comparable with Finite element analysis results.

This paper highlights challenges in structural analysis of flexible structures.

Paper no.	ARMS23-MSM-06
Title	**Characterization of MEMS Sensor for a Spinning Projectile**
Authors	Dr. Anchal Yadav, CP Singh & Dr. BB Padhy *ARDE, DRDO*

This paper describes the characterization of MEMS sensor for a spinning projectile. Characterization of MEMS sensors at higher RPM has provided accurate estimate of misalignment of Gyros & Accelerometers at the dynamic balancing. Effect of Cross coupling has been minimized after compensation of misalignments during post processing of data in Matlab. Real time parameter display has provided quick way to analysis flight performance. The simulation results show the identification accuracy of estimated aerodynamic parameters using proposed strategy. Here, the main focus is on calibration, which enables calculation of the scale factor and measurement of misalignment in x, y & z axis.

Paper no.	ARMS23-MSM-07
Title	**Thermo-Elastic Damping Analysis of a Fluid Carrying MEMS Resonator under Flexural Vibration**
Authors	S. Narendar *DRDL, DRDO*

Several different damping mechanisms can cause dissipation in fluid carrying micro-electro-mechanical systems (MEMS) resonators. The most important of these is an intrinsic material damping due to thermo-elastic effects. Such effects are studied on a fluid carrying nano/micro-scale tube type resonator where the primary element is modelled as a flexural hollow beam with consideration of small-scale effects based on nonlocal elasticity model. The thermal effects are captured by solving a Guyer-Krumhansl heat condition model. Knudsen number is employed to create the nanoflow as a fluid passing through the tube. Coupled thermo-elastic equations of the system are solved in frequency domain based on spectral assumption. Analytical solutions are obtained for the thermo-elastic damping (Q-factor) of the microfluidic resonator. The effects of the fluid velocity, friction, small-scale, time relaxation in temperature, material, critical velocity and mode number are studied in detail. The results presented in this work are very useful for the design and development of futuristic MEMS/NEMS radio-frequency device.

Paper no.	ARMS23-MSM-08
Title	**A Load Assisted Arming Mechanism for Land Based Applications**
Authors	Anit Kumar Srivastava & Harikrishnan S *ARDE, DRDO*

Most of the Land based munitions which are used against the Soft Targets are of blast type and get actuated under application of pressure. This pressure actuated munitions consist of a fuze which gets actuated on application of a predetermined pressure/load. These fuzes should have a safety arming mechanism which ensures safety during handling, transportation and storage of the system. The assurance of safety is utmost important for an armament designer who ensures the safeties of end Users during deployment as well as recovery of the munitions. Mostly the Mechanical Fuzes employ a Striker-ball lock arrangement to initiate the first and the most sensitive explosive element through the kinetic energy of the striker which can further detonate the main charge. For considering a safety aspects, a designer always design the munitions having explosive train in mis-aligned condition till it is intentionally armed for the deployment. Mostly, the explosive train gets aligned after the arming of the munitions. Also, the explosive train in the systems where mechanical fuzes are used, should be aligned before the striker releases and thereby ensures the initiation of the primary explosive element. The kinetic energy of the striker is usually provided through a pre-compressed spring. This paper depicts an effective mechanism which provides load assisted alignment of explosive

train. The function of the mechanism is to keep the explosive train in misaligned condition even after removal of all safeties and arming of the system. The mechanism starts aligning the explosive train only when the specified pressure/load is applied on the system for its actuation. This mechanism is operated by using a gear-rack arrangement. Also, it ensures the safety of munitions against blast pressure of breaching systems deployed in near vicinity. This mechanism ensures the alignment of the explosive train before release of striker. One such innovative mechanism developed and has been successfully utilized for application to one of land based Soft target munition developed by ARDE. This mechanism provides consistency, repeatability and already exploited in the developed system. The ingenuity involved in the design of the mechanism has been explained and various components associated with the design along with the functioning of the mechanism have been discussed. At the end, the easy convertibility of the mechanism, its versatility and various advantages are also elaborated.

Paper no.	ARMS23-MSM-09
Title	**Design and Development of Linear Solenoid based Safe Arm Mechanism**
Authors	Shete Mayuresh Kailas, Sijimon TP, Muraleedharan K, Abraham K Kurian, Ani Daniel Kurien, Vinod Kumar N *VSSC, ISRO*

Safe Arm devices plays very important role in pyrosystems of the launch vehicle by preventing the energy transfer while in SAFE position and allowing the same in ARM position. The linear solenoid based safe arm device is developed for the high explosive systems complying to international standards. All the mandatory functional tests in safe and arm positions are completed successfully.

This paper gives details of design, development and functional testing of the solenoid based safe arm device.

Paper no.	ARMS23-MSM-10
Title	**Defect Investigation of Re-cocking Cartridge for Aircraft gun Re-coking Mechanism**
Authors	Bhupesh Ambadas Parate & P W Sonawane *ARDE, DRDO*

The manuscript discusses a comprehensive investigation into defects associated with metallic brass cartridge cases utilized in the re-cocking mechanism for fighter aircraft applications. These cartridge cases play a crucial role in the operation of the aircraft gun's re-cocking system. The primary objective of this study was to uncover the underlying factors behind two types of failures: the shearing or cracking of the cartridge case body from the neck,

and the failures observed during the hygroscopic testing of the cartridge case after extraction from the test vessel during proof trials. This investigation was initiated in response to reports from the Aeronautical Quality Assurance Wing (AQAW) in Khamaria, who detected these issues and called for a thorough defect investigation. The methodology employed for this investigation included subjecting the cartridge cases to a Mercurous Nitrate (MN) test, a hardness assessment, microstructure examination and a Critical Examination (CE) to gain a deeper insight into the root causes. The hardness test conducted at the mouth of the cartridge case was intended to verify compliance with specified hardness levels. Notably, the results revealed that Lot No. 1 and 2 exhibited hardness levels exceeding the specified limits, although the cartridge performance observed within the specified proof limits. The findings of this investigation suggest that the issues may be attributed to various factors, including non-compliance with the specified annealing process, higher zinc content, or excessive hardness. Furthermore, the presence of residual stresses resulting from cold working was identified, underscoring the need for stress relief measures to prevent aging-related cracks. The recommendations proposed by the committee have been incorporated into the drawings and specifications. As a result, it is determined that the root causes of the failures have been successfully identified and addressed.

Paper no.	ARMS23-MSM-11
Title	**Numerical Modelling for Estimation & Optimisation of Frontage in Dispersed Mine(s) System**
Authors	Jayesh Argade, B. R. Rao & Prashant Kumar *ARDE, DRDO*

The paper focuses on the mathematical model which is developed for estimation and optimisation of frontage obtained by dispersion of land mines which are dispersed using one of the methods called the Vehicle Based Mine Scattering System (VBMSS) in which the land mines are ejected from pods mounted on the vehicle. Thus, the program helps in identifying the parameters to be changed such as ejection angle of mine, azimuth angle, ejection velocity, vehicle velocity etc. so as to obtain the best possible frontage.

Paper no.	ARMS23-MSM-12
Title	**Multi body dynamics simulation of parachute-payload system using MSC ADAMS**
Authors	Abdul Salam PM, Aromal Loujan, Johns Paul, Santhosh J Nalluveettil & UA Subramanian *VSSC, ISRO*

A parachute based deceleration system is designed and developed for safe descent and recovery of Crew Module (CM), as part of Gaganyaan project of ISRO. A clustered parachute system comprising of different types of parachutes is conceived for bringing down the velocity of descending CM to safe levels prior to splash down in sea. The system consists of four types of parachutes namely ACS (Apex Cover Separation), Pilot, Drogue and Main parachutes. Dynamic interactions between parachutes and module are one among the major parameters in the design of recovery systems. A simulation program is developed in MSC ADAMS software for studying the dynamics characteristic of parachute payload system during the parachute inflation and steady state descent phase. This multi body simulation can accurately display the relationship between acceleration, velocity, altitude and attitude of module and parachutes. Also it is capable to estimate various loads acting on the parachutes and payload. In this paper the simulation is validated with data from one of the drop tests being done for the qualification of sub system, IMAT-01 from IL 76 aircraft.

Paper no.	ARMS23-MSM-13
Title	**Study of Effect of Rotating Cylinder on Flow Separation over NACA 0012**
Authors	Ku Pa Suresh *ADRDE, DRDO*

The design and analysis of rotating cylinder on upper surface of NACA 0015 at various angles of attack and also analysis of aerodynamic characteristics for different operating conditions. The revolving cylinder on aerodynamic surfaces, which postpone the flow separation and maintain the local flow attached for as long as possible, has been the subject of extensive research since flow separation can frequently result in increased drag. may cause lift loss and stall, both of which are undesirable. By delay the boundary layer transition, increase lift coefficient the flow remains attached by the rotating cylinder which involves in upper portion of an airfoil. By implementing this rotating cylinder delay the flow separation efficiency can be increased with the wide range of angle of attack and aerodynamic properties conducted and assessed.

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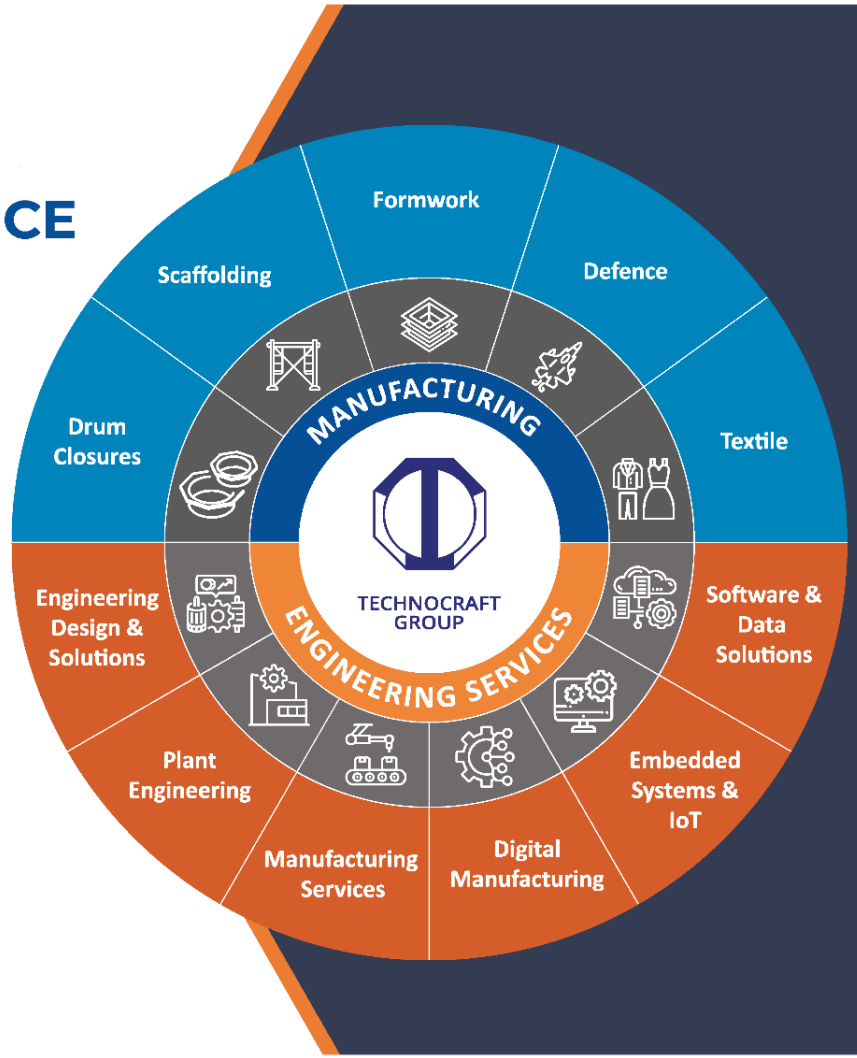

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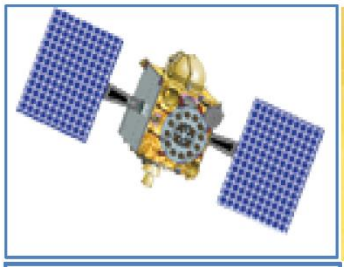

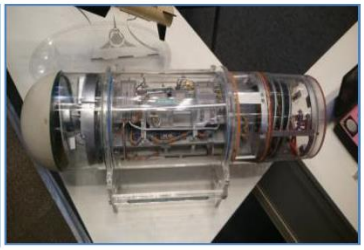

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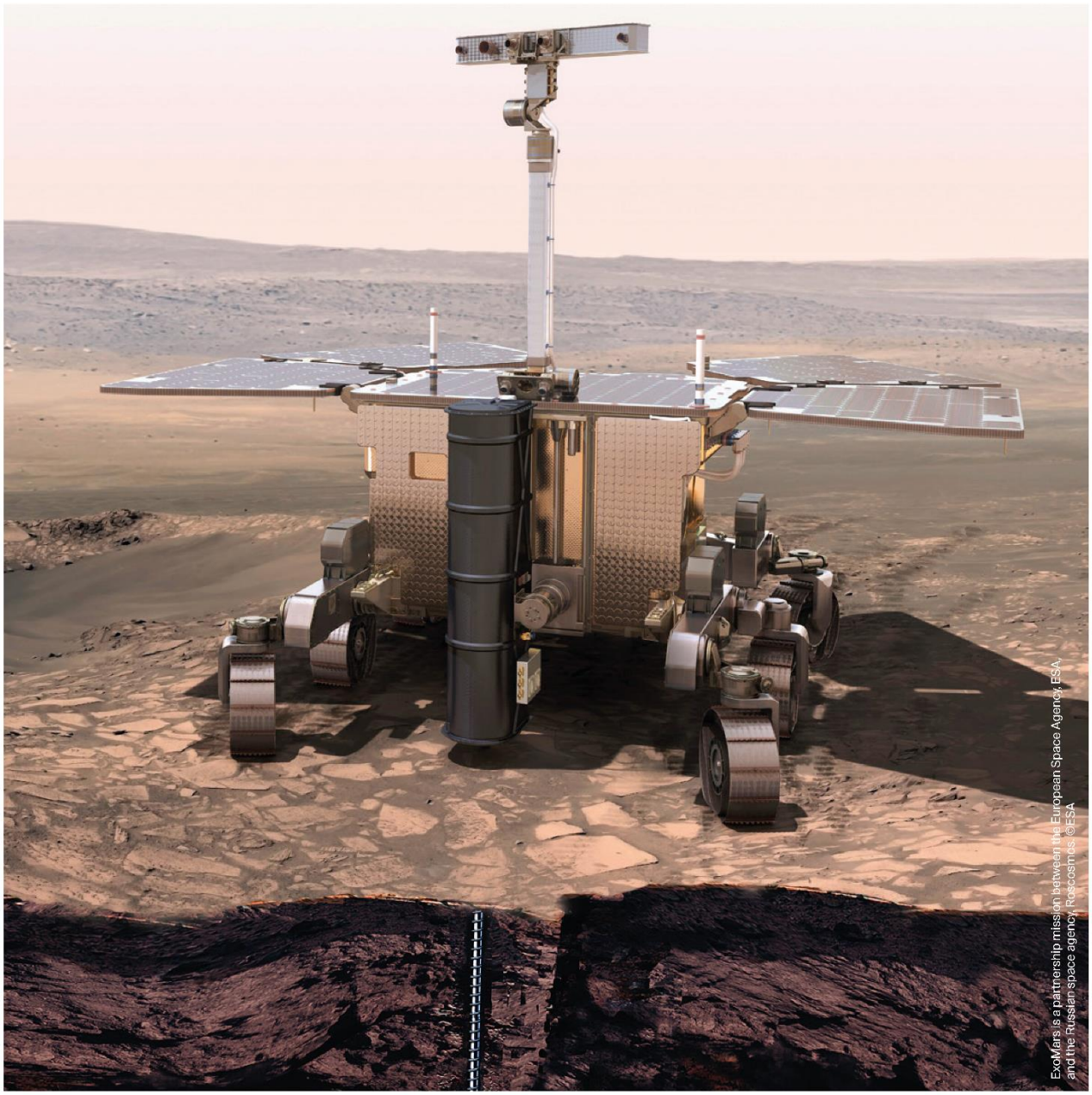

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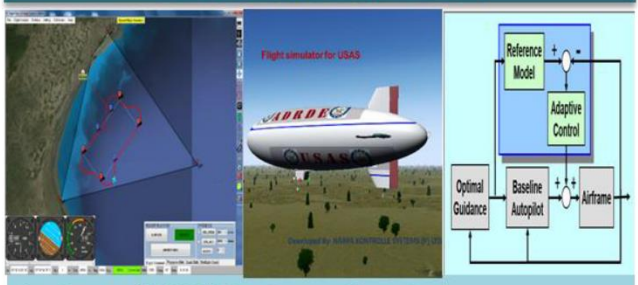

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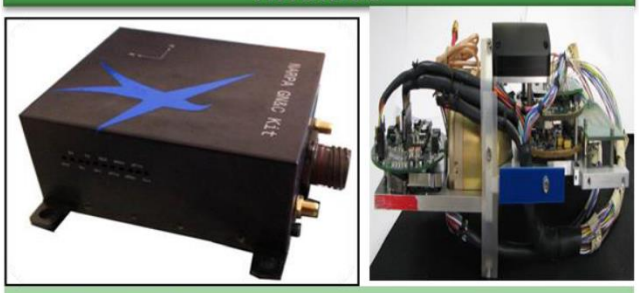

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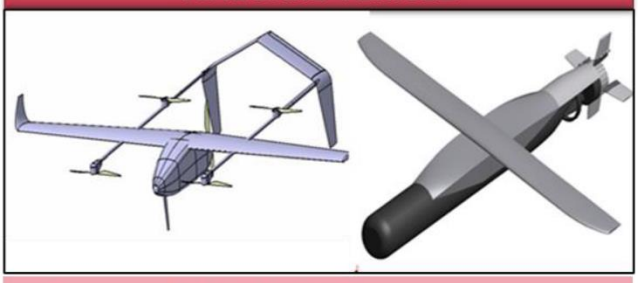

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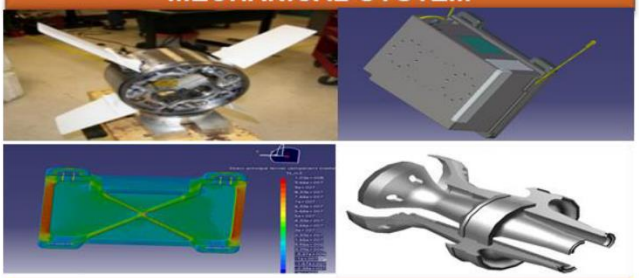

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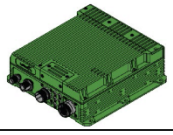
1		2		3	
	LTE eNodeB / NIB		**5G OPEN RAN RU**		**ADS-B-Receiver**
4		5		6	
	Software Defined Radio		**Telemetry & Command Link**		**AIS Transponder**
7		8		9	
	Mobile Mesh Radio		**Fixed PtP IP Radio**		**Telemetry Radio**

For any query, please ping us.

at

business@lekhawireless.com

Lekha Wireless Solutions Private Limited

Roshini Chambers #947, 24th Main Rd, J P Nagar, 2nd Phase,

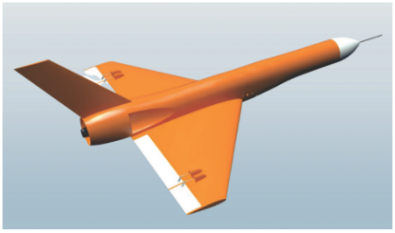
Bangalore- 560078, Karnataka, India

Phone: +91-80-26590100 / 26593100, & **Website:** www.lekhawireless.com

NFOTEC

NFOTEC Digital Engineering Pvt. Ltd. specializes in Advanced Software distribution and Digital Engineering, with a dedicated team experienced in Aerospace and Defence projects.

NFOTEC is a MSME Engineering company with active participation in DRDO, ISRO, HAL and DPSU Projects with ISO Certification and compliance to Aerospace Standards. NFOTEC is a CEMILAC certified for Design House.



NFOTEC's ***Drone Technology Group*** has also Designed, Developed and Qualified ***JET MX***—a High Speed Jet Aircraft Platform for Defence Targets.

NFOTEC's ***Design & Simulation Group*** has core experience in distribution and offering services of major CAE Products such as *SIEMENS, HAMMERS, TAITUS, ALPHASTAR, PERMAS, MEDINA, SAMCEF, NUMECA, J2 Aircraft Dynamics, ADF, GALILEO EMT and GALILEO EME.*

NFOTEC CAE Core Competence:

- Domain Expertise in Digital Design, Engineering and Simulation of MIL Systems
- Familiarity with DRDO, Army, Navy, Air Force, DOS specifications & SOP
- Deep understating of Aerospace Specification and Certification Standards
- Finite Element Modelling and Quality check, Execution of Finite Element Analysis
- Pre and Post Techno Sales and Marketing for CAE Products
- Experience in executing work packages / providing services using various CAE products
- Design and Simulation of Composite Airframe Structures
- Providing consultancy, professional training and training for specialized CAE products

NFOTEC is a Channel Partner of SIEMENS, focused on Siemen's portfolio for digital product development, simulation and manufacturing and data management solutions.

- **SOLID EDGE** for Product Development
- **NX** for Manufacturing
- **SIMCENTER** for Simulation and Test Solutions
- **INSIGHTS HUB** for industrial IoT for Manufacturing
- **TEAMCENTER** for Product Life Cycle Management (PLM)
- **TEST LAB** for Test Solutions
- **AMESIM** for simulation platform to virtually assess & optimize system performance
- **HEEDS** design space exploration and optimization to drive product innovation
- **CAPITAL** for Electronics and Electrical systems development
- **POLARION** for application lifecycle management (ALM)

GLIDERS INDIA LIMITED

Ordnance Parachute Factory (OPF) was established in the year 1941 at Kanpur, Uttar Pradesh under the aegis of erstwhile Ordnance Factory Board (OFB) as a parachute repair unit. In the last eight decades OPF has diversified into all types of parachute manufacturing and has grown leaps and bounds to establish itself as the most premier parachute manufacturing unit, not only in India but also globally. OPF has always thrived to meet the supreme quality standards and meet the customers requirement. Presently OPF meets the requirement of all the three services, MHA, other defence departments, civil trade and exporting to various countries. Gliders India Limited, a Govt. of India undertaking was incorporated on 14th August 2021 as a 100% Government owned Defense Public sector undertaking (DPSU) and OPF was made the only manufacturing unit under it. Today the company excels in producing indigenously a wide variety of Parachutes, Floats, Inflatable Boats and Accessories under the ambitious "Atmanirbhar Bharat" scheme of Government of India. GIL is presently venturing into parachutes for adventure and recreational sports like Para-gliders & Para-sails, Drone rescue parachutes, various support and life saving equipments.

QUALITY CERTIFICATIONS:

- ISO 14001:2015 (Environment Management system)
- ISO 9001:2015 (Quality Management System)
- ISO 45001:2018 (Occupational Health and Safety Management System)
- ISO 17025:2017 (NABL)
- AFQMS (Approval of a firm and its Quality Management System by DGAQA)
- AS 91000D (QMS for Aviation, Space and Defence Organizations)

MAJOR PRODUCTS:

- Man Carrying Parachutes
- Brake Parachutes
- Pilot Parachutes
- Supply Drop/Cargo Parachutes
- Rubber Inflatables; Boats, Float Assembly for KM Bridge
- Combat Clothing items

RECENT PRODUCT DEVELOPMENTS:

- Recovery Parachute System for Gaganyaan
- Drone Rescue Parachute
- Speed Resistance Parachute
- Inflatable Boat Gemini Craft

EXPORTS:

Gliders India Limited is successfully moving towards establishing India in the Global map of Parachute Industry. In the last two years exports have increased manifold. GIL is becoming the preferred supplier of parachutes to various countries across the Globe.

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- High Quality High Modulus Carbon Fibre & Hybrid composite manufacturing Facility
- Development of Electrical Propulsion System as per customer requirement
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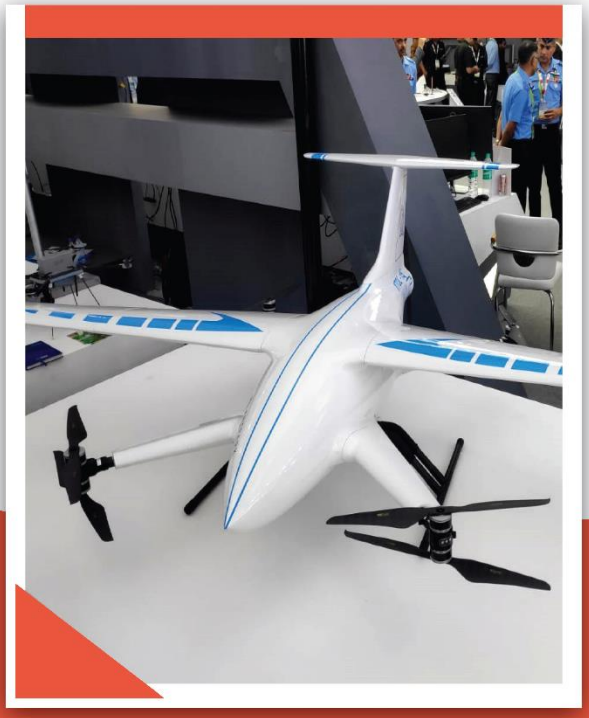

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