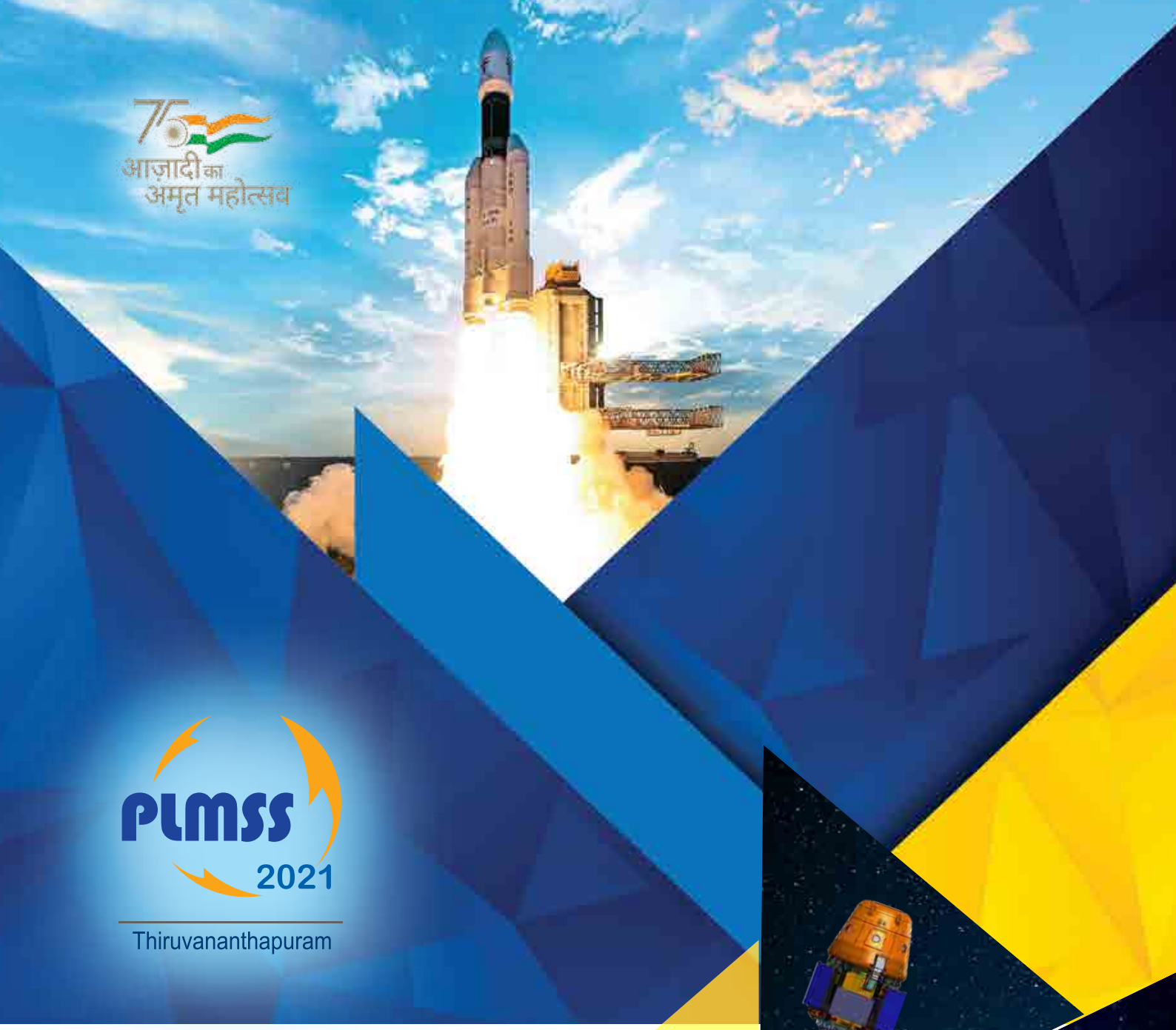

PLMSS 2021

Thiruvananthapuram

8th International Conference on Product Lifecycle Modeling, Simulation & Synthesis

17-18 December 2021

SOUVENIR & BOOK OF ABSTRACTS

Product Lifecycle - Space System Perspective

PLMSS 2021

Thiruvananthapuram

8TH INTERNATIONAL CONFERENCE ON PRODUCT LIFECYCLE MODELLING, SIMULATION & SYNTHESIS

17-18 DECEMBER 2021

PRODUCT LIFECYCLE - SPACE SYSTEM PERSPECTIVE

SOUVENIR & BOOK OF ABSTRACTS

ORGANISED BY

VIKRAM SARABHAI SPACE CENTRE, THIRUVANANTHAPURAM

INDIAN INSTITUTE OF SPACE SCIENCE & TECHNOLOGY, THIRUVANANTHAPURAM

Thiruvananthapuram

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Thiruvananthapuram

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डॉ.के. शिवन / Dr K. SIVAN
अध्यक्ष / Chairman

MESSAGE

I am glad to note that Vikram Sarabhai Space Centre, in association with Indian Institute of Space Science and Technology is organizing an International Conference on Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021) in collaboration with PLMSS trust during 17-18 December 2021 in online mode.

Product Life Cycle Management is essential for Indian programmes of strategic sectors namely Space and Defense. Modelling and simulation of life cycle of a product especially for aerospace systems using various PLM tools will help to realise the product with improved quality and reliability.

As the nation embarks upon ***"AATMANIRBHAR BHARAT"*** and ***"DIGITAL INDIA"*** programme, it is the need of the hour to reap the benefits of PLM by bringing the associated development teams, user agencies and industries on a common platform.

The workshop and conference has a very important objective and I am sure that the pre-conference workshop and the conference endeavors to provide a common platform to the national and international experts dwelling on PLM for formulating a collaborative framework to achieve self-reliance in this niche area.

I wish the organizers and delegates a very fruitful and enriching conference.

12/11/2021

Dated: November 12, 2021

(के. शिवन / K. Sivan)

Thiruvananthapuram

M E S S A G E

डॉ जी. सतीश रेड्डी
FNAE, HFCSI, FRIN (London), FMACANUD (Russia), FAeSI, FRAeS (UK), HFPMAI, FSSWR, FIET (UK), FIE, FAPAS, FIETE, AFAIAA (USA)

Dr G. Satheesh Reddy
FNAE, HFCSI, FRIN (London), FMACANUD (Russia), FAeSI, FRAeS (UK), HFPMAI, FSSWR, FIET (UK), FIE, FAPAS, FIETE, AFAIAA (USA)

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

1. I am pleased to offer my warmest congratulations to the organizers of the International Conference: "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" scheduled during December 17-18, 2021 through online mode.

2. I believe that the pre-conference workshop and the conference will be a key step in opening up a seamless platform for a free exchange of information related to the current developments in the field of product life cycle management, amongst the scientific and engineering communities. The conference seeks to cover many important areas related to Product Life Cycle Modelling, simulation and synthesis in the Indian programme of strategic sectors namely Space and Defence.

3. It is heartening to note that the indigenous initiatives and efforts in this area over the past few decades have started bearing fruits. I am sure that this workshop and conference will highlight various innovations along with the identification of new potential applications in this area of national interest.

4. I wish the workshop and conference "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" a grand success.

(Dr G. Satheesh Reddy)

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Thiruvananthapuram

M E S S A G E

Dr. Pawan Kumar Goenka
Chairperson Designate, IN-SPACe

With the opening of the Indian Space sector to private industry participation, the sector is now working towards devising a comprehensive strategy to increase India's contribution in global space economy and make Space industry an important pillar of our economy. Antrix Corporation expects the industry to grow up to $35- $50 billion by 2024.

To achieve that kind of growth, Indian space sector needs to move at a very fast pace to increase the number of launches from India, from current 4-5 per year to at least 15 per year; and increase the number of *Make in India* satellites that are launched within the country and outside India. Importantly, all this must be done maintaining the advantage of being most cost effective and ensuring safe, secure and reliable solutions.

A significant enabler to achieve this is the application of Product Life Cycle Management (PLM) tool. PLM helps to reduce time to market, cut costs, increase productivity, improve quality and bring in innovation. Product Life Cycle management is a powerful package of tools that dominates every industry today and has become the mainstay of all modern-day innovation driven industries.

Sustainable space solutions and products demand all lifecycle phases to be optimized and adopting PLM provides a foundation for strong disciplined systems engineering. PLM will be an important enabler to achieve 'Make in India' objectives for Space sector.

I am very happy to note that a dedicated international conference is being organized on "Product Life Cycle Modelling, Simulation and Synthesis" (PLMSS-2021)" by Vikram Sarabhai Space Centre and Indian Institute of Space Science & Technology through virtual mode.

I urge all the participating stakeholders including R&D institutes, academia and industry to make the best use of this common platform, and work together to discuss and deliver novel scalable solutions to the current challenges in PLM from the space system perspective.

I wish the Conference a grand success.

Dr. Pawan Kumar Goenka
Chairperson designate, IN-SPACe

Thiruvananthapuram

MESSAGE

Dr. B. N. Suresh
Chancellor, IIST

I am very pleased to note that that Indian Institute of Space Science and Technology (IIST) andVikram Sarabhai Space Centre (VSSC) is organizing anInternational Conference and Workshop: "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" scheduled during December 17-18, 2021 through online mode.

The strategic sectors of aerospace and defense require various complex products for different applications. In the realization of such products successfully it becomes imperative to follow the management of product life cycle involving the engineering, design, manufacture and all other elements associated with its service life. Both these sectors have adopted these practices and their efforts in this area over the last couple of decades have started giving very meaningful results.

As the nation embarks upon "Digital India", it is the need of the hour to consolidate these gains in the field by bringing the associated development teams, user agencies and industries on a common platform. This workshop and conference are indeed relevant to keep abreast with the latest developments taking place world over in this important field. Therefore, it is quite apt that this Conference is being organized now to consolidate our experiences and generate a well-structured blueprint for all our further projects.

I am sure this pre-conference workshop and the conference will give an excellent opportunity to all academicians, professionals as well as the industries engaged in the product development to interact and exchange their experiences and innovative ideas and formulate a way forward for self-reliance in this niche area.

I convey my very best wishes to all participants and wish the Workshop and Conference a grand success.

Thiruvananthapuram

MESSAGE

ಆರ್. ಮಾಧವನ್
ಅಧ್ಯಕ್ಷ ಮತ್ತು ವ್ಯವಸ್ಥಾಪಕ ನಿರ್ದೇಶಕ
आर. माधवन
अध्यक्ष एवं प्रबंध निदेशक
R. MADHAVAN
Chairman & Managing Director

ಹಿಂದೂಸ್ತಾನ್ ಏರೋನಾಟಿಕ್ಸ್ ಲಿಮಿಟೆಡ್
ಪ್ರಧಾನ ಕಛೇರಿ
हिन्दुस्तान एरोनाटिक्स लिमिटेड
मुख्यालय
HINDUSTAN AERONAUTICS LIMITED
CORPORATE OFFICE

MESSAGE

I am very happy to note that 8th Edition of "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" is planned from December 17-18, 2021 in online format.

From the first conference organized by ADA, Bangalore jointly with IISc to the eighth edition of the conference jointly organized by Vikram Sarabhai Space Centre (VSSC) and Indian Institute of Space Science and Technology (IIST); the response has grown substantially as evident from the number of registered participants and the large number of contributed papers.

With robust and fast disciplinary analysis tools, widespread availability of computation power and good expertise, Product Life Cycle Management (PLM) is soon likely to become the defecto method for managing entire life cycle of a product from its inception throughout the life of the product, be it in aerospace domain or any other systems. PLMSS concepts were widely used in Aerospace Engineering field. But, today its scope and foot prints are observed in all engineering fields due to its relevance and the benefits emerging out of using such practices.

I am sure the pre-conference workshop and the conference will be beneficial to the Engineering community in the country. I wish the Workshop and conference a great success.

Best Regards,

(R. MADHAVAN)

Bangalore
22 Nov, 2021

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Thiruvananthapuram

M E S S A G E

LARSEN & TOUBRO

S.N. Subrahmanyan
Chief Executive Officer &
Managing Director

Message

I am immensely pleased to note that the 8th edition of International Conference on "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" is being organized in digital format jointly by Vikram Sarabhai Space Centre (VSSC) in association with Indian Institute of Space Science and Technology (IIST) during December 17-18, 2021.

This Conference will create better understanding of recent advancements in the Product Lifecycle Management and provide an opportunity to domain specialists to showcase their ideas and innovations. Am sure that the International Conference and the pre-conference workshop will be beneficial to all the researchers from academic institutions, R&D labs and professional from industries.

The International Conference of this magnitude/multi-disciplinary theme would not have been possible without the support of PLMSS trust which is jointly Managed by Defense Research Development Organization (DRDO), National Aerospace Laboratory (NAL), Aeronautical Development Agency (ADA), Indian Institute of Science (IISc) and other Indian Industries.

This Conference will also enhance awareness of recent trends in Computer Aided Design, Modelling and Engineering, Product Lifecycle Management (PLM) and Enterprise Resource Planning (ERP) and contribute to better system development.

I convey my best wishes for the success of the conference and hope that the deliberations held will move the state of current understanding, forward.

S N Subrahmanyan (SNS)

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Thiruvananthapuram

M E S S A G E

LMW

LAKSHMI MACHINE WORKS LIMITED

16th Nov 2021

SANJAY JAYAVARTHANAVELU
CHAIRMAN & MANAGING DIRECTOR

I am happy to be a part of the 8th edition of the PLMSS (Product Life Cycle Modelling, Simulation and Synthesis) Conference. This year's event, held in the virtual mode, is jointly led by the Vikram Sarabhai Space Centre (VSSC) and the Indian Institute of Space Science and Technology (IIST). I am delighted to note that the organizing team has done an exceptional job choosing quality research presentation papers, excellent keynote addresses and a suitable selection for the master class session.

This year's conference sees the participation of many Research Institutes, Government R&D labs and the Indian Industry, the inherent stakeholders for the growth of Product Life Cycle Management Research & Implementation in India.

Product lifecycle management (PLM) is the process of managing a product's lifecycle from inception, through design and manufacturing, to sales, service, and eventually retirement. As a technology, PLM software helps organizations develop new products and bring them to market. PLM helps connect geographically distributed multi-disciplinary teams, shortening product introduction time, increasing productivity and quality, optimizing cost through waste elimination.

I am confident that through conferences like PLMSS, meaningful interaction between research institutes, academia, and industries can happen on a topic like PLM. As conference patron, I confidently look forward to productive participation and interaction amongst all participants.

I take this opportunity in conveying my best wishes for the success of the conference.

Sanjay Jayavarthanavelu

SANJAY JAYAVARTHANAVELU

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Thiruvananthapuram

M E S S A G E

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MESSAGE

December 6, 2021

Product Lifecycle Management (PLM), which has gained immense prominence in the recent past, has been a very important tool for many successful organisations across the globe. PLM empowers designers & engineers with the ability to estimate & model various phases from product conceptualisation, idea generation, prototyping, embodiment, launch, growth and stabilized production. It is extremely important to plan the revisions / improvements in the design, introducing variants as well as initiating new product development. Aerospace sector has been successful in imbibing this in their product development. The recent advancements in the Aerospace sector, combined with unlocking the space sector in the country, have bolstered the importance of implementing concepts like PLM in the organisations to stay current and relevant in the market.

With this primary objective, Vikram Sarabhai Space Centre is pleased to host an 'International Conference on Product Lifecycle Modeling, Simulation & Synthesis' - PLMSS 2021' during December 17 - 18, 2021 via online platform in association with Indian Institute of Space Science & Technology (IIST) and PLMSS trust and supported by various prominent industries.

I firmly believe that the conference will be a beneficial platform for practicing professionals, researchers & student community for valuable exchange of information related to current developments in the field of PLM. This will also provide an impetus to adopt the product lifecycle management techniques in strategically important sectors. I wish the organisers and organising committee of PLMSS-2021 a grand success.

(S Somanath)

Thiruvananthapuram

M E S S A G E

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एम. शंकरन/ M. SANKARAN

विशिष्ठ वैज्ञानिक/DISTINGUISHED SCIENTIEST/

निदेशक/DIRECTOR

MESSAGE

I am glad to note that Vikram Sarabhai Space Centre in association with Indian Institute of Space Science and Technology(IIST) is organizing a two-day International conference with one-day pre-conference workshop on "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" during December 17-18, 2021 on virtual mode.

Product Lifecycle Management (PLM) is one of the most important arena for planning and accelerating product deliverables, optimizing cost and maximizing revenue of major manufacturing industries. With its success in the manufacturing domain, it is only logical that aerospace and other high value, technology product organisations will embrace it to make their complex processes cohesive, simplified and streamlined.

PLM system is a natural requirement for space technology. Satellites in particular, are complex and challenging because of their multidisciplinary nature, encompassing various domains of Engineering & Science, hardware and software. Space technology organisations are considering the available alternatives for system engineering of space systems to move from the well-known document based system to IT enabled model based systems. In a world disrupted by the Covid-19 pandemic, the IT enabled, model based approach for system engineering of space systems deserves a serious look: to enable closed loop collaboration of the design, management and supplier teams. The expected outcomes of reduced cost, better documentation and assured end to end traceability makes PLM systems worthy of serious consideration.

PLMSS-2021, International conference at this juncture, is an ideal platform for the participants, especially from the Space technology community, to understand the future trends & challenges in the Product Lifecycle Management (PLM) and to enhance the participant's knowledge base. Thus paving way for tomorrow's competitive world.

Conceived by the PLMSS trust, the PLMSS series of conferences and workshops have been focusing on not only the Product Lifecycle Management, but also on other related fields including CAD, CAM, CAE and ERP. I am happy to note that, this year the PLMSS-2021 organisers have included the emerging topics of Block Chain, Digital Twin & Digital Thread, Augmented and Virtual Reality (AR and VR), Cloud Deployment etc.

I am confident that, this conference will benefit with valuable takeaway for all the participants and I wish PLMSS-2021 a great success.

एम . शंकरन
M. SANKARAN

Thiruvananthapuram

M E S S A G E

सत्यमेव जयते

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एन एम देसाई / N M Desai
विशिष्ट वैज्ञानिक/Distinguished Scientist
निदेशक / Director

MESSAGE

Indian Space Research Organisation (ISRO) is one of those scientific and technical organizations in India, which have the privilege and responsibility of developing complex engineering systems with activities spanning from concept to delivery. Over last few decades, activities of ISRO in general and Space Applications Centre (SAC) as well have increased manifold with the development of array of sophisticated technological payloads. While technological advancement is of utmost significance, its timely and efficient implementation is also equally important, especially in the present context of newly announced reform policies for space sector under New Space.

In my considerate view, Product Lifecycle management can help ease the pressure of managing project elements. It can establish the context in the inception phase of a project by identification of various activities, resources in the form of manpower, infrastructure, budget funds etc. and an underlying, well defined reference framework for execution of various activities. All these being done digitally, it eliminates an exclusive need of manual intervention for project management. This has become very relevant in this Pandemic era, where contactless management transactions are of essence and have become the new normal.

Human Spaceflight is the new endeavour by ISRO. This area leaves no room for any errors as human life is involved. Special needs of this new program include development of human centric technologies with human rating and certifications instead of only technology centric approach being followed till now in SAC and ISRO. Thus, ***Product Life Cycle Management (PLM) becomes an inevitable tool in Human Spaceflight Programme to support these activities leading to certification*** and I believe PLM will now have even greater relevance.

I wish ***all the success to the pre-Conference Workshop and the two-day International Conference on "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)".*** It will also give good exposure of the state-of-the-art approaches in PLM to all the participants and an opportunity to listen to various experiences in diversified fields.

07/12/2021

(एन एम देसाई) / (N M Desai)
निदेशक / Director

Place: Ahmedabad
Date: 7 December 2021

Thiruvananthapuram

M E S S A G E

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MESSAGE

It gives me immense pleasure to note that VSSC along with IIST is organizing a two-day International Conference along with a one-day Pre-conference Workshop on Product Life Cycle Modeling, Simulation and Synthesis–PLMSS-2021. This seems to be the first time our space community is organizing a Conference on this topic which is highly relevant in the current scenario of Space reforms and the need to cater to multiple launches and hardware deliveries at very short intervals.

Novel concepts like Product Life Cycle Management [PLM] have to be seriously persuaded as we are presently facing the pinch of multiple launches, multiple developmental initiatives, testing hardwares for varied missions, large scale fabrication through external industries and amongst all these maintaining high quality output. PLM has very high relevance in our scheme of things as at present we need to roll out hundreds of components/modules/electronic packages for qualification/testing/flight in a concurrent manner. This scenario calls for the management support and novel techniques to streamline products, production, time and cost. PLM is one effective way to achieve this as it is the foundation of Digital thread delivering supply chain agility and product flow continuity. Data Governance and traceability provided by PLM shall definitely enable us to accelerate our product delivery, and drive down costs without compromising on quality and compliance.

It is so very pertinent that our technologists are well-versed with such techniques like PLM and I am sure this Conference shall provide ample insight to such tools. The Conference shall also throw light into newer management concepts like Knowledge modeling, Virtual factory, Kanban/Agile methodologies etc.

I am sure, this International Conference shall bring together professionals working in these fields from various sectors and shall provide a very good platform for knowledge, experience sharing and fruitful technical interaction between Researchers, Academia and Industries. At this juncture, let me extend my Best Wishes for the International Conference, PLMSS–2021.

November 9, 2021.

[V. Narayanan]

Thiruvananthapuram

M E S S A G E

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ए. राजराजन **A. Rajarajan**
प्रतिष्ठित वैज्ञानिक **Distinguished Scientist**
निदेशक **Director**

MESSAGE

I am glad to know that Vikram Sarabhai Space Centre (VSSC) in association with Indian Institute of Space Science & Technology (IIST) is organizing the 8th edition of two-day International Conference and Pre-conference workshop on Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021) on 17-18 Dec 2021. The topics chosen for this conference are apt to the theme and keeping pace with endeavours of ISRO in near future.

Continuous improvements with positive feedback is very much essential to keep any Product or System contemporary. It is necessary to include a perennial feedback loop of improvements in the processes or applications that the product/system addresses as part of its Life Cycle management.

The higher the agility that is built into the Product/System design, the greater is the industrial and societal benefits it will deliver. The need of the hour is to implement the human potential in making the processes increasingly autonomous throughout its life cycle, so that repeatability, reliability and amenability for quick change are ensured.

Workshops such as these, go a long way in acquainting the delegates about the advances trends in Product Life Cycle Management. The very fact that it is being held in virtual mode will enable all the delegates to enrich their knowledge following all safety protocols against the ongoing pandemic.

I heartily compliment the organisers and wish them all the best for this Conference.

राजराजन 30

(A Rajarajan)
Director, SDSC SHAR

Thiruvananthapuram

M E S S A G E

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डॉ. उन्निकृष्णननायर. एस
Dr.UnnikrishnanNair.S
विशिष्टवैज्ञानिकएवंनिदेशक
Distinguished Scientist & Director

Message

Arnold Toynbee, the renowned British historian, used the concept of "Challenge and Response" to explain how civilisations like the Indus, Maya, Mesopotamian, Roman, Persian, etc. were built, thrived and declined with time. Rise and fall are built into every system. The period of sustenance depends upon the ingenuity of the response to the challengesand how the intermediate stages are managed through innovations and mid-course corrections.

The concept of product life cycle management (PLM) too deals with the beginning and inevitable decline of products, interlaced with the intermediate stages of growth and maturity. Any product developer will strive to go fast through the stages of *introduction* and *growth* and delay the inevitable decline as much as possible. PLM had its origin in the mid-1980s as a manufacturing business tool for maximizing the advantage of bringing new products to the market first. However, within very short time it evolved into a powerful tool to shape everything from engineering trade studies and testing to integrated vehicle operations.

With the advent of the digital revolution, the idea of a digital-twin -where a fully functioning digital model of a physical system is created- to take the product virtually through the four different phases of product life, has become commonplace. Such a digital model helps in understanding how to accelerate faster through the initial phases of *introduction* and *growth* and to stay longer at the *maturity* phase well before the product hits the market.

Globally, the Space sector is no longer in State domain with many commercial entities and startups becoming active partners in Space programmes including in human Space flights. In order to stay competitive and to bring out products and services faster, tools like PLMS are of great use. In that context, it is highly appropriate that VSSC with IIST is taking the lead in organizing PLMSS-201, an international conference on this topic.

I wish the conference every success.

Thiruvananthapuram

M E S S A G E

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उमामहेश्वरन आर./Umamaheswaran. R
विशिष्ट वैज्ञानिक एवं वैज्ञानिक सचिव, इसरो
Distinguished Scientist &
Scientific Secretary, ISRO

MESSAGE

It is heartening to know that Vikram Sarabhai Space Centre and Indian Institute of Space Science & Technology are organizing a two day International Conference with one day pre-conference workshop on "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" during December 17-18, 2021 through virtual mode.

The theme is more appropriate for a better understanding on the systematic and function oriented approach to improve the value of new and advanced technologies from the design stage onwards. I hope the conference will provide valuable insights for value improving techniques while addressing the different aspects of technology development including materials, design and realisation of each and every system without decreasing its quality, function or reliability.

I am sure the Conference and the workshop would be greatly utilised by all scientists, academic experts, and R&D professionals so that innovative ideas can be extracted.

I extend my hearty wishes for the grand success of PLMSS-2021.

उमामहेश्वरन आर

Dated: November 17, 2021

(Umamaheswaran R)

Thiruvananthapuram

M E S S A G E

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डॉ. डी. साम दयाल देव / Dr. D Sam Dayala Dev
विशिष्ट वैज्ञानिक / Distinguished Scientist
निदेशक / Director

MESSAGE

I am extremely glad to note that Vikram Sarabhai Space Centre (VSSC) in association with Indian Institute of Space Science and Technology (IIST) is organizing an International Conference PLMSS- 2021 on "Product Lifecycle Modelling, Simulation and Synthesis" during December 17-18, 2021 through virtual mode.

The Aerospace sector especially the space has always been way ahead of the other industries in terms of adoption of the latest technologies, classical examples being CAD & CAX. As ISRO gears up for the next decade with several technologically complex missions including Gaganyaan and RLVs, a highly focussed approach is mandatory with regard to product definition & design, engineering processes, realisation and last, but not the least, the maintenance of the integrity of the information throughout the life of the product. This in our case is a sustained period as our Spacecrafts have to work for several years in orbit.

I am sure that the conference will provide a unique platform to highlight the recent and emerging technological developments in the area of modelling, simulation and synthesis. With the Absolute Quality implementation for all systems/subsystems in the lime light for ISRO programmes, the modelling and simulation are going to be the two pillars providing strength and confidence to the designers. This should be coupled with reliability enhancement techniques and hence to realise a zero defect system for the prestigious future missions of National importance. A glimpse of the emerging ideas and the possibilities they hold in the area of simulation/ synthesis techniques will definitely lead to innovative solutions for system design.

At this juncture, I congratulate VSSC and IIST for providing the right leadership and platform to inspire the technologists working in this vital arena. The core recommendations emanating from the deliberations of the conference are going to enhance the efforts in overcoming the technological challenges and ultimately for utilisation of the systems with no rejection.

I wish the conference a grand success.

November 12, 2021

डी. साम दयाल देव/
D SAM DAYALA DEV

Thiruvananthapuram

M E S S A G E

भारत सरकार
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K. ALAGUVELU
Director

The prime endeavour of space technology managers is to ensure the availability of right product/technology at appropriate time at economical cost. It is easier said than done. The challenge posed by this demand is intense due to the fact that design and development of high end technologies like space system technologies is fraught with large scale of uncertainties and at the same time have only limited users/markets. Also the cost involved in the design, development and production of space systems is prohibitively very high.

Amidst such complexities, Product Life Cycle Modelling, Simulation and Synthesis gives hope in providing reasonable solution to these problems. Technology managers as well as entrepreneurs worldwide are successfully employing this Product Life Cycle Management strategy nowadays and reaping the benefits. In such circumstances, I am very glad to note that Vikram Sarabhai Space Centre (VSSC), in association with Indian Institute of Space Science and Technology (IIST) is organizing a two-day International conference with one day pre-conference workshop on "Product Life Cycle Modelling, Simulation and Synthesis (PLMSS-2021)" during December 17- 18, 2021. I am hopeful that this conference and workshop will facilitate exchanging of new modelling approaches, sharing best practices and establishing newer standards and benchmarks in this field.

I wholeheartedly wish grand success of this event and hopeful of this event being very much fruitful to all the participants and in particular to the organizing institutions namely Vikram Sarabhai Space Centre (VSSC) & Indian Institute of Space Science and Technology (IIST).

With warm greetings and wishes,

(K Alaguvelu)

Thiruvananthapuram

M E S S A G E

PRODUCT LIFE CYCLE MODELING, SIMULATION AND SYNTHESIS (PLMSS) TRUST , Established in 2014
CSIR – National Aerospace Laboratories, P.B. No. 1779
HAL Airport Road, Kodihalli, Bengaluru, 560017, India
Mobile: 9880017049

MESSAGE

We are happy that Vikram Sarabhai Space Centre (VSSC) is organising the 8th International Conference on Product Life Cycle, Modelling, Simulation and Synthesis (PLMSS-2021) and the Pre-Conference with the Theme "Product Life Cycle – Space System Perspective", jointly with Indian Institute of Space Science and Technology (IIST) in Thiruvananthapuram from Dec. 16th to 18th , 2021. VSSC is a pioneer in Rocket Research and Launch Vehicle Projects and pursues research in multifarious development activities associated with areas like Propellants, aero dynamics, aero Structural, composites, vehicle integration and testing just to name a few. Hence it is very appropriate that such a Conference should be organised by VSSC to share and disseminate knowledge among Engineering Community in these areas. We understand that large diverse organizations have sent in contributed papers for the Conference and that the Pre-Conference Workshop has speakers who are experts from India and Abroad.

The Product Lifecycle, Modelling, Simulation and Synthesis Trust (PLMSS) was setup in December, 2014 by Eminent persons from Organizations of DRDO, ADA, NAL, IISc and other Industries. It was formed in order to take up research, aid, promote, guide, manage, coordinate, execute and disseminate activities during the complete lifecycle of a Product or a Project. Till date Seven International Conferences and Three Workshops have been conducted successfully.

The Chairman and Managing Trustee, Vice-Chairman, and all the Trustees have expressed great pleasure to be associated with organisers of the Conference. We look forward to the successful completion of the Workshop and Conference.

On behalf of the Trust, I extend warm greetings and good wishes to the organisers, VSSC and IIST and Participants. We are sure that the participants will get technically enriched by attending the Workshop and Conference.

R.K. Ramanathan

Dr. R K Ramanathan
Hon. Secretary, PLMSS Trust

Thiruvananthapuram

PREFACE

M. Mohan
Deputy Director, VSSC (MME) /
Chairman, Organising Committee
PLMSS 2021

It is our pleasure to welcome you to the 8th International Conference on Product Life Cycle Modelling, Simulation and Synthesis (PLMSS) - 2021 being conducted in Digital Platform by Vikram Sarabhai Space Centre (VSSC) and Indian Institute of Space Science & Technology (IIST) in collaboration with PLMSS trust.

A major objective and feature of the conference is to facilitate exchange of ideas and share experiences and research results about many aspects of Product Lifecycle, engineering and synthesis. It is gratifying that there was a huge response to the call for technical papers and briefs from the various scientific organizations, institutes and industries in various disciplines of engineering, technology and simulations.

We hope the participants will have a very rewarding experience, enhance their knowledge in PLM and engage in a spirit of innovation. PLMSS 2021 would be both stimulating and informative with a wonderful array of keynote and invited speakers from across different domains of science and technology. The topics for the conference were carefully chosen to attract papers from emerging fields like Digital manufacturing, AM, AI & ML, in addition to the classical fields of aeronautics, aerospace, simulation, CAD/CAM, propulsion etc.

I am sure that, with your support and participation, the conference will continue its success for a long time. We would like to thank the organization staff, the members of the program committees and reviewers, who had given valuable suggestion for the authors to improve the quality of the papers/presentations. We also would like to express our gratitude to the authors for contributing their research result to the conference.

Finally, special thanks to Indian National Academy of Engineering (INAE) and Springer Press for agreeing to publish in an exclusive Transactions of INAE.

ABOUT THE CONFERENCE

Vikram Sarabhai Space Centre (VSSC) and Indian Institute of Space Science and Technology (IIST) is jointly hosting the 8th International Conference on Product Lifecycle Modelling, Simulation and Synthesis (PLMSS - 2021) in collaboration with PLMSS Trust during 17-18 December 2021 along with pre-conference workshop on "Digital Aerospace Manufacturing" on 16 December 2021. The theme of PLMSS 2021 is "Product Lifecycle-Space System Perspective". The conference and pre -conference workshop will be conducted in online mode.

ABOUT VSSC

Vikram Sarabhai Space Centre (VSSC) is the lead Centre of Indian Space Research Organisation (ISRO) under the Department of Space (DOS), Government of India. The Centre is named in the fond memory of Dr Vikram A Sarabhai, the great visionary leader and the father of Indian Space Programme. VSSC pioneers in rocket research and launch vehicle projects of ISRO. The Centre also pursues research and development activities in associated areas like propellants, solid propulsion technology, aerodynamics, aero structural and aero thermal fields, avionics, polymers and composites, guidance, control & simulation, computer and information, mechanical engineering, aerospace mechanisms, vehicle integration and testing, space ordnance, chemicals and materials. Systems reliability and quality assurance of all aspects of engineering and operations are assessed and evaluated to the levels of conformance to specifcation.

ABOUT IIST

Indian Institute of Space Science and Technology (IIST) functions as an autonomous body under the Department of Space, Government of India. The institute is the first of its kind in the country to offer high quality education with special focus to space sciences, space technology and space applications. IIST offers various undergraduate and post graduate programmes in areas relevant to space science and technology. The institute also recognizes the importance of research in developing future technologies and applications of space research. IIST encourages close collaboration with DOS/ISRO centres through joint research projects. With Dr. A P J Abdul Kalam as the first chancellor, the institute has an enviable reputation among the educational institutions in the country.

ABOUT PLMSS TRUST

PLMSS TRUST was registered on 03 December 2014 as a nonprofit organisation. The trust is headed by eminent persons from the organisatons of DRDO, ADA, NAL, IISc and other industries. It was formed in order to take up research, aid, promote, guide, manage, coordinate, execute and disseminate activities in the following areas:

1. Computer Aided Design (CAD)
2. Computer Aided Manufacturing(CAM)
3. Computer Aided Engineering (CAE)
4. Product Lifecycle Management (PLM)
5. Enterprise Resource Planning (ERP)
   and other related topics.

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Jawaharji K	VSSC	
Aby Isaac	LPSC	
Vimal Thomas	VSSC, Member Secretary	

INAUGURATION

17TH DECEMBER 2021

9.30 – 9.35	**Invocation**	
9.35 – 9.40	**Welcome Address**	**Shri Mohan. M** Deputy Director, MME, VSSC, Chairman Organising Committee, PLMSS-2021
9.40 – 9.50	**Presidential Address**	**Shri. S. Somanath** Director, VSSC
9.50 – 10.10	**Inauguration & Address**	**Dr. K. Sivan** Chairman, ISRO/Secretary DDS
10.10 – 10.15	**Release of Souvenir**	**Dr. V. Narayanan** Director, LPSC
10.15 – 10.30	**Felicitations**	**Dr. V. Narayanan** Director, LPSC **Prof. Gurumoorthy. B** Co-Chair, PLMSS Trust **Dr. D. Sam Dayala Dev** Director, IISU
10.30 – 11.00	**Keynote Address**	**Dr. Tessy Thomas** Director General, Aeronautical Systems, DRDO
11.00 – 11.05	**Vote of Thanks**	**Shri. Victor Joseph. T** Group Director, PPEG Organising Secretary, PLMSS-2021

DAY 1

17TH DECEMBER 2021, FRIDAY

TIME	EVENT		
09:30-11:05	**Inaugural function**		
11.15-12:00	Invited Talk: **Dr. Unnikrishnan Nair**, Director HSFC		
12:00-12:45	Invited Talk: **Shri. B.H.Laxmesh**, Head Aerospace & Defense, L&T		
	Audi - 1	**Audi - 2**	**Audi - 3**
14:00-17:15	**Session CP-1** Materials & Manufacturing Process Development & Simulation	**Session CP-2** Space System Design	**Session TB-1**
	SESSION CHAIR: **Shri. Saratchandran S,** Former Dy. Director, VSSC	SESSION CHAIR: **Prof. Kurien Issac K** Sr. Professor & Dean, IIST	SESSION CHAIR: **Prof. Sivashanmugam** NIT, Trichy
	RAPPORTEUR: **Smt. Nagapriya S,** VSSC	RAPPORTEUR: **Shri. Viswanath V**, LPSC	RAPPORTEUR: **Dr. R.K.Gupta**, VSSC

DAY 2

18TH DECEMBER 2021, SATURDAY

TIME	EVENT		
09.00 - 09.45	Invited Talk : **Shri. Sameer Prabhu,** Worldwide Industry Marketing Diector, Mathworks		
09:45-10:30	Invited Talk: **Shri. Yannick Wittner,** A&D Industry Global Market Development Leader, Dassault Systèmes		
	Audi - 1	**Audi - 2**	**Audi - 3**
10:30-13:20	**Session CP-3** Additive Manufacturing	**Session CP-4** PLM Aerospace & Aircraftapplication	**Session TB-2**
	SESSION CHAIR: **Shri. Roy M Cherian,** Former Associate Director, VSSC	SESSION CHAIR: **Dr. Reena Sharma** Former Proj. Director, CABS, DRDO	SESSION CHAIR: **Shri. Suresh MS** Associate Director, LPSC
	RAPPORTEUR: **Shri. Sandeep Verma,** VSSC	RAPPORTEUR: **Shri. A.E.Perumal,** VSSC	RAPPORTEUR: **Smt. Pooja Dutt**, VSSC
13:30-15:15		**Session CP-5** Aerodynamic Mission design, modeling & simulation	**Session CP-6** AI, ML, Industry 4.0, CAD/ CAM/CAE
		SESSION CHAIR: **Shri. Sowmianarayanan** Associate Project Director, Space Transportation System, VSSC	SESSION CHAIR: **Shri. Alex A** Dy. Director, LPSC
		RAPPORTEUR: **Dr. Desikan SLN,** VSSC	RAPPORTEUR: **Shri. Mankatiya Vittal Naik,** LPSC
16:00-17:10	**Concluding Function**		

PROGRAMME SCHEDULE

CONCLUDING FUNCTION

TIME	EVENT	
16:00-16:05	Welcome	
16:05-16:15	Gist of conference/ Proceedings	**Dr. V Ashok,** Deputy Director, VSSC (AERO) / Chairman, Technical commitee
16:15 -17:00	Panel discussion	**Topic : Product Life Cycle - Space System Perspective** PANELISTS : **Dr. Sam Dayala Dev,** Director, IISU **Dr. Rajalakshmi Menon,** DRDO **Dr. Ramanathan RK,** PLMSS Trust **Dr. V Ashok,** VSSC **Shri. BH Laxmesh,** L&T **Dr. Sunil Kumar S,** LPSC **Shri. M K Mishra,** HAL MODERATOR: **Dr. SVS Narayana Murty,** LPSC
17:00-17:05	Announcement of Prizes	**Mr. P S Subramanyam,** Former Director and PGD (CA), ADA
17:05-17:10	Vote of thanks	

KEYNOTE ADDRESS

Dr. Tessy Thomas
Director General
Aeronautical Systems, DRDO

INVITED TALKS

Dr. S Unnikrishnan Nair
Director, HSFC

Mr. B H Laxmesh
Head Aerospace & Defence, L&T

Dr. Sameer Prabhu
Worldwide Industry
Marketing Director, Mathworks

Mr. Yannick Wittner
A & D Industry Global Market Leader
Dassault Systems

ABSTRACTS

SESSION: CP-1
MATERIALS & MANUFACTURING PROCESS DEVELOPMENT & SIMULATIONS

PAPER NO	TOPIC	AUTHORS
CP1-1	Fatigue Tests under Simulated Autofrettage and Proof Pressure Cycles for Commercially Pure Titanium (CP-70) in Forged and Annealed Dome	Manikandan P, Sudrashana Rao G,Muthuraju N, Pravin Muneshwar, A Venugopal, VMJ Sharma, D Sivakumar, Ramesh Narayanan P, Mohan M
CP1-2	Analysis of surface strain distribution over the biaxial stretch-formed and deep-drawn cups of Cu-Cr-Zr-Ti alloy thin sheet	Dibya Ranjan, Sushanta Kumar, Sujoy Kumar & K thomasTharian, SVS Narayana Murthy
CP1-3	Serrated plastic deformation and multi-necking behaviour of 16Cr-6Ni Austenitic-Martensitic stainless steel at 20K	Antony Prabhu, Murugesan, Sudhakar
CP1-4	Sector Weld Repair Study on Ti6Al4V alloy in EBW for COPV	Anil Jain, Biju S, Girish V, Mohan M
CP1-5	Development of an Automated Crawler Device for Composite Sandwich Panel Inspection using an Instrumented Coin Tap equipment	Haridas K Kh
CP1-6	Experimental and Numerical Analysis of Resistance Spot Welded Joint Strength On 15CDV6 steel	JoshwinEmmanuel Johnson, Joyal Varghese Jacob, Nihal Paul, Muhammed Shiyas&Vinayan E G,Rajesh V
CP1-7	Design & Simulation of Manufacturing Processes & Tools for Productionising Double Walled Nozzle Extension of Cryogenic Engine (CE-20)	Hanuman Manoj Kuderu, Prabhakant Prasad, Ajith Kumar D
CP1-8	Design and Fabrication of Low Noise Pressure Regulating Valve for the Trisonic Wind Tunnel	David Van Every, Srinivasan Renganathan, Deependran B, Segar D G
CP1-9	Simulation of transient thermal profile of cryogenic engine on Cu-Cr-Zr-Ti alloy and evaluation of mechanical properties	Santhoshkumar R, Ajit Kumar, Ravi Ranjan Kumar, Anoop CR, Amruth M, Dr. SVS N Murthy, Alex A
CP1-10	Design and manufacturing of a spherical AA6061-T6 pressure vessel liner for aerospace applications	R Pramod,A Rajesh Kannan, N Pravin Kumar,KSanjeevi Prakash, N Siva Shanmugam &Krishnadasan C K
CP1-11	Structural integrity assessments of Ni-Cr-Mo-V Steel	Satyaprakash Mishra, Anish Ranjan, Sushil Mishra
CP1-12	Design and fabrication of cylindrical shell for flow conditioning in wind tunnels	David Van Every, Srinivasan Renganathan, Deependran B, Valmik Shukla

SESSION: CP-2
SPACE SYSTEM DESIGN

PAPER NO	TOPIC	AUTHORS
CP2-1	Design and Development of thrust transfer structure-NCA of LVM3-X/CARE Mission of ISRO	PhaniCharanNidamarthi, Rachel Selva Kumari D, Sirajudeen Ahamed
CP2-2	Space Systems Mechinical Testing	Shivashankaraiah Kumaraswamy, Dayanand Kumar Yadabettu, Mostapha Choukri
CP2-3	Development of Composites Overwrapped Pressure Vessels (COPVs) for Aerospace applications: PLM perspectives	Satheesh Kumar N
CP2-4	Enhanced Smart Quality Management System to implement Agile based In-built Quality Produc Life Cycel Management of Space Systems	Vipin V, Ashitha S Babu, Satyanarayanan R
CP2-5	Design and Development of Turbine Exhaust Gas Expansion Nozzle for a Cryogenic Engine Gas Generator	Siju K Mathew, Dr. Bijukumar K S, Baiju A P
CP2-6	Thermal Design aspects of Electronics Packaging for Airbrone applications	Annapurna Sogunuru, Niranjanappa Ac & Hemachandra Reddy K
CP2-7	Load Estimation Cycle of a Launch Vehicle from Initial Design Phase to Launch	Biju G, Sundararajan T, Narendra Nath, Venkateswaran K P, Geetha S
CP2-8	A tapered common bulkhead dome for the cryogenic stage of an Indian launch Vehicle	Yogesh Pratap Singh,LaxmikantSarjerao Mane, Jyotirmoy Ghosh, Pratik Tolambiya, Harjit Singh, Mr. Bhat
CP2-9	Design and Assessment of Composite probe for soil surface temperature measurement	Kiran John Anotony
CP2-10	Design options for a mettallic tori-sperical nozzle closure for Semi-Cryo engine	Yogesh Jamthe, Umer HM, Suresh Mathew Thomas, Asraff AK
CP2-11	Design and prototyping of a variable diameter wheel for exploration vehicles	Vijay Kumar Guvvada& Sam Noble
CP2-12	A Pragmatic approach in an indirect health prediction of critical launch vehicle components through dynamic response analysis	Narendra Nath, Venkateswaran K P, Biju G, Sundararajan T, Geetha S

SESSION: CP-3 ADDITIVE MANUFACTURING		
PAPER NO	**TOPIC**	**AUTHORS**
CP3-1	Integrated Numerical Modeling and Machine Learning Approaches to Predict Melt Pool Dimensions during Deposition of SS316L Single Tracks using Laser Powder Bed Fusion Process	Raja Thanumoorthy, Jitender Chaurasia, Srikanth Bontha, Balan S S, Anil Kumar V
CP3-2	Repair of Aerospace Component using Additive Manufacturing	Durga Prasad, Gurumoorthy B
CP3-3	Optimization of Post-Processing Heat Treatment Cycle for L-PBF Processed Al-4.8Mg-0.3Sc Alloy	Apurba Roy, Anil Kumar V, Pradeep P I, S K Singh, Govind, Ankit Sahu
CP3-4	Effect of post processing and comparative study of Indigenous and Imported IN 718 alloy powders for additive manufacturing	Dineshraj S, SamuelMG, Rohit Kumar Gupta, D Sivakumar, Govind, Ramesh Narayanan P
CP3-5	Parametric Investigation of LPBF of IN625 at Poor Overlap Index (30%) and at Higher Layer Thickness (100µm)	Saurav Nayak, Jinoop A N, Christ P Paul, Kushvinder S Bindra
CP3-6	Characterisation of Laser Powder Bed Fusion AM Processed AlSi10Mg Components for Liquid Engines	Pradeep P I, Vivek R, Anilkumar V
CP3-7	Understanding the Effect of Interlayer Delay on Hastelloy-X Wall Structures built using Laser Directed Energy Deposition based Additive Manufacturing	Jinoop A N, S K Nayak, C P Paul
CP3-8	Prediction of IN617 deposit track features in Directed Energy Deposition using Machine Learning	Dileep Kumar, Christ P Paul & Manoj K Saxena, Kushvinder S Bindra
CP3-9	Study on Geometrical Features of FDM Components Based on Inegrated Material-Process Design Using Multi Criteria Decision Making Method	Anoop M S, Sooraj V S, Senthil P
CP3-10	Characterisation of L-PBF 3D Printed High Strength Aluminium Alloy Al4.8Mg0.3Sc Bracket for Aerospace Application	Pradeep P I, Vivek R, Anilkumar V

SESSION: CP-4
PLM - AEROSPACE & AIRCRAFT APPLICATIONS

PAPER NO	TOPIC	AUTHORS
CP4-1	Role of SLM in Modern Military Aircraft Development Program	Murali Krishna Teki, Satish Kumar, Vani V
CP4-2	A Life Cycle Perspective on the Development of a Test Rig for ISRO Smart Limb	Rahul R, Sandeep P, Victor Joseph T, Somanath S
CP4-3	Possibilities and Challenges to migrate PLM on Cloud in R&D	Amrita Kashyap, Suresh Srivastav, Mk Jayanthi Kannan
CP4-4	Product Life Cycle Modelling in Launch Vehicle Avionics Components	Nisha G R, Krishnakumar T K
CP4-5	PLM and Process Automation Tools for Critical Systems of Launch Vehicles	Bhushan Pal Singh, Ashok Bandyopadhyay, Chadrasekaran C
CP4-6	Reliability Centered Product and Process Development in PLM by Real Time Integration of Various Business Tools using RPA	Elangovan A, Nachiyappan R, Rajasimhan M A
CP4-7	Requirements Capture and Schedule Management for a Transport Aircraft Using a PLM Tool	Pankaj A C, Ganesh Madhunath,Archana P Hebbar, Vijaykrishnan K, Devendra Singh, Kodanda B, Jayasankar S, Raghavendra Badrinath, Abhay A Pashilkar, Loganathan P R
CP4-8	Product Life Cycle of an Ordnance Device-A Case study	Mohammad Munis, Akhil Srivas, Pramod R Nair

SESSION: CP-5
AERODYNAMIC, MISSION DESIGN, MODELLING & SIMULATIONS

PAPER NO	TOPIC	AUTHORS
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CP5-2	Soft computing Approach for Dynamic Calibration of a Stress-wave Force Balance	SimaNayak, Niranjan Sahoo
CP5-3	VR flight simulator with cognitive load estimation feature	P Archana Hebbar, G S Rajshekar Reddy, Somnath Arjun, Sanjana Vinod, Abhay A Pashilkar, Pradipta Biswas
CP5-4	Effectiveness of ADS-B integration in Airborne Surveillance Mission	Rajesh Gandhi, Nanditha U, Ramkumar R, Rajesh R
CP5-5	Ultrathin Wideband Metamaterial based Microwave Absorber	Bhavya E V, Balamati Choudhury, Raveendranath U Nair
CP5-6	Study of Controlled Fragmentation of Cylindrical Warhead Casing	Jai Prakash Kamal, Abinash Kumar Swain
CP5-7	Hot Shut Off Valves for Hypersonic Wind Tunnel	Patil K S, Suriyanarayanan, Rajaraman M S

SESSION: CP-6
AI / ML/ INDUSTRY 4.0 /CAD /CAM/CAE

PAPER NO	TOPIC	AUTHORS
CP6-1	Novel Equipping Fixture Design for Composite Aircraft Parts Bonded Assembly to Enhance Productivity using 3D CAD	Senthilnathan K, Rajesh Kumar S, Neelakanta Gowda M N, Naik B N
CP6-2	Practice of Agile Scrum in Product Development	Chandra Sekhar Kappagantu, Mahesh Nair, Basavaraja Patil
CP6-3	Artificial Intelligence as a Force Multiplier in Airborne EO/ IR System	DhipuTM, Rishabh Verma, Rajesh R
CP6-4	Systems and Methods for automation of layout generation for automative transmission graphs	Henri Karhula,Mike Nicolai & Akshobhya, Vinay Ramanath, Abhay Kumar
CP6-5	Generation of Parametric Modeler for CAD automation using Knowledge Based Engineering (KBE) Tools available in 3D Experience (CATIA) software	Satyabrta Satyajit Sahoo, Ankur Deb, Krishna Pratap Singh, Anil Kumar Garg
CP6-6	Implementation of Digital Manufacturing for Aircraft Development-A Case Study	Durga Prasad, Tarun Kumar, Vegesna Vani
CP6-7	Finite Element Analysis of Stiffness of Bio-inspired Two-hierarchial (2H) Stairwise Staggered Composite with Regular Staggered Composite (SR) as Platelets	Abhirami A J, Anup S

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TB1-2	Challenges and Lessons Learnt in Additive Manufacturing Technology for Realization of Wind Tunnel Models for Combat Aircraft	Balaji Haridasu,Srinivasa Rao L, SaikatBhowmik, Vellaisamu Dinu
TB1-3	Wire arc Additive Manufacturing of Near-net-shape Ti6Al4V Parts for Aerospace Applications using GTAW	Natarajan S, AntonyPaul, Midhun Babu
TB1-4	Development of Hardware for Biology in Spaceflight: Exploring the Prospects of Design for Additive Manufacturing (DfAM)	Akhil Madhavan, Kumaran G, Sreejalekshmi
TB1-5	Did we "build" it correctly? - Exploring automation possibilities of on-orbit inspection for in-space additive manufacturing	Ajay Agarwal
TB1-6	Topology Optimization of Additively Fabricated VTM brackets using SS316L	Bhrigu Ahuja, Ankit Sahu
TB1-7	A Study on Methodology of Topology Optimization for Air Brone Structures Using Finite Element Analysis Simulation	Udhay Chandra Patel
TB1-8	Performance optimization and production of U-Fitting Bracket using LMD Technology	Brian Matthews, Manju Pravin, Maria Garcia- Cosio
TB1-9	Prediction of Fastener Nut Factor Value using Machine Learning Technique	Srinath J,Amaljith T H, Mariappan S, Dr.S. Christopher Solomon
TB1-10	A new approach to Electrical System Design for Aero and Space platforms	Prashant Gandhi
TB1-11	Role of Digital Risk Twin in Space Systems	Dinesh Tallur, SyamKumar, Monisha Mohandas, Daniel Chan
TB1-12	Effect of Roller Burnishing on Fatigue Life of Alloy Steel Fasteners for Landing Gear Applications	Sivaraman Arjunan

Technical Briefs

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TB1-14	Design, fabrication, Installation and testing of slender air storage vessels	Prasant Bachhav, Srinivasan Renganathan, Deependran B
TB1-15	Design of Forging process for Manufacturing Inconel 718 Hemispherical Forgings for Oxygen Storage by Modelling and Simulation	Chenna Krishna, Karthick N K, Pravin Muneshwar, Nitesh N, Ramesh Narayanan P, Mohan M
TB1-16	Transforming manufacturing work instruction in Digital way-Efficiently	Srinivasan K S
TB1-17	Optimization of process parameters for Thermal Protection System (TPS) application on structures of launch vehicles to increase quality with productivity using CNC manipulator	Suresh Kumar S, Prabhkant Parasad
TB1-18	Development of Processing Technique to Eliminate Reheat Cracking of XH67MBTIO alloy	Yuvraj Jagtap, SaurabhSingh, AlokSingh, Pramod Yadav, Sanjay Ingale, Kumar K, Alex A
TB1-19	Eco-friendly anodization process for the corrosion protection of aircraft Al alloys: Pilot plant establishment and demonstration of process technology	Prakash Badi,Manikandanath N T, Balaraju J N, Ganesh Murugesan, Sai Pramod Pemmasani, Meenu Srivastava, Nagacharan K V, Manjunatha C M
TB1-20	Thermal and Structural Modelling of Maraging Steel Welding	Deepak Soman, Parvej Raut, Indradev Samajdar, Sushil Mishra, SVS Narayana Murthy

SESSION: TB-2

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TB2-2	Detection of lightning-prone zones of fighter aircraft utilizing CAD data by Rolling Sphere Method	Anjan Murmu, Srinivasa Rao L, Shyni Thomas, Vegesna Vani
TB2-3	Preliminary Studies on Design and Modeling of Advanced Ceramic Heaters for Space Applications	Senthil Kumar S, Aruna St
TB2-4	A Review Paper on Rocket Engine Nozzle Cooling	Ashutosh Kumar
TB2-5	Enhancing Space System Design and Modelling	Avinash Gangaiah
TB2-6	Development of Sealing configuration between Crew Escape Motor and Shroud of Crew Escape System(CES)	Promit Chakraborti, ManirajanM, Sadeeshkumar A, Sunil P
TB2-7	A Comprehensive PLM approach for Aerospace Fasteners used in Launch Vehicles of ISRO	Srinath J, Dr. Christopher Solomon S, Dr. Govind, Mohan M
TB2-8	Concept of a Specialised Project Manager Module- "Project HandBook"	S Saigunaranjan
TB2-9	Content Management using PLM Active Workspace in Aero engine Applications at GTRE	Malini Malleswarappa, Nalini T Varadaiah, Ajith Valappil
TB2-10	i3PLM-A futuristic Product Life cycle Management framework with interprteability, interoperability, and interactive capabilities	Vinay Ramanath, Krishna Chaitanya, Ramanathan Muthuganapathy, Palaniappan Ramu, Ganapathy Krishnamurthi, Saravanakumar Gurunathan
TB2-11	Implementation of a Simple Production Management Tool for Avionics Systems.	Smitha Jose, Sheena Abraham, Jeyapaul K
TB2-12	Simulation studies on the interaction of cutting edges and machining induced defects in CFRP composites	Sooraj V S, Danish Handa
TB2-13	Functional Hazard and Fault Tree analysis for a Transport Aircraft	Ganesh Madhunath, Achuthan Pankaj
TB2-14	Role of Non-Destructive Testing in the Product Life Cycle of Space Composite Structures-Current and Future Perspectives	Hari Krishna S, Mathew Sebastian, PremdasM, Usha K M, Bijudas C R, Priyadarshan H
TB2-15	Wire Arc Additive Manufacturing of SS 321 for Aerospace Applications to Bear Static and Cyclic Loads	K Sanjeevi Prakash, A Rajesh Kannan, R Pramod, N Pravin Kumar, N Siva Shanmugam
TB2-16	Tailoring the microstructural characteristics and mechanical properties of Austenitic Stainless Steel 308L overlays deposited using Gas Metal Arc Welding Process	N Pravin Kumar, A Rajesh Kannan, R Pramod, K Sanjeevi Prakash, N Siva Shanmugam
TB2-17	3D Printing / Additive Manufacturing (AM) Digital Transformation with the EOS's Digital Tools(Software) & Training	Prakasam Anand, Daniel Amos

Fatigue Tests under Simulated Autofrettage and Proof Pressure Strains for Commercially Pure Titanium (CP-70) in Forged and Annealed Condition

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Abstract—Fatigue specimens were cut from indigenously developed CP-70 dome in forged and annealed condition from top and bottom locations in longitudinal (L) and transverse (T) directions. Fatigue tests were carried out by applying 2.5 % plastic strain in tension to simulate the strain of autofrettage cycle and immediately followed by cycling between 0 to 1.5 % plastic strain, which are expected during proof pressure test (PPT). One specimen from each location the test was stopped after 300 cycles to verify initiation of any surface cracks. Based on the results, it can be concluded that stress response and total strain response are decreasing gradually till failure. Material exhibited cyclic softening behaviour during fatigue test. Number of cycle to failure (Nf) varied from 213 to 414. Microcracks were observed in fatigue-tested specimens in which the test stopped at 300 cycles, from the bottom location in longitudinal and transverse directions.

Keywords— *CP-70 dome, Autofrettage, commercially pure titanium, low cycle fatigue, plastic strain, metallic liner*

Analysis of surface strain distribution over the biaxial stretch-formed and deep-drawn cups of Cu-Cr-Zr-Ti alloy thin sheet

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***Abstract*—** In the present study, the strain distribution profiles were determined by deforming the Cu-Cr-Zr-Ti alloy sheets through stretch forming and deep drawing experiments, and the limiting dome height (LDH) and cup depth of the deformed components were evaluated. The finite element (FE) models of both the processes were developed by incorporating the Hill48 anisotropy yield criterion and Hollomon power hardening law to predict the strain distribution profiles. The LDH of the stretch-formed component was 20 mm, whereas the cup depth obtained from the deep drawing process was 33.5 mm. In stretch forming experiment, the strain localization was observed at a distance of 17.14 mm from the pole with major and minor strain values of 0.43 and 0.19, respectively. The top edge of the deep-drawn cup wall region was found to deform under radial tension-circumferential compression mode, whereas the deformation at the cup corner region followed close to plane strain mode with major and minor strain values of 0.12 and 0.04, respectively. Also, the grain size, precipitates and texture were characterized through optical microscopy, SEM-EDS and EBSD techniques. This material showed excellent formability without orange peel and earing defects in the deformed samples due to its higher n-value of 0.46, lower grain size of 25-30 μm and negligible planar anisotropy parameter of -0.04.

Keywords*—Cu-Cr-Zr-Ti alloy, Microstructure, Stretch forming, Deep drawing, FE modeling, Strain distribution*

Serrated plastic deformation and multi-necking behaviour of 16Cr-6Ni Austenitic-Martensitic stainless steel at 20K

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***Abstract*—**Tensile tests have been conducted on 16Cr-6Ni (AISI 301) Austenitic-Martensitic transition class stainless steel at 20K to obtain mechanical properties. This steel is widely used as a structural material in cryogenic engineering because of its outstanding mechanical behaviour especially at low temperatures. AISI 301 exhibits low temperature serrated deformation (LTSD) behaviour at 20K. In addition to the serrated deformation, multi-necking phenomenon has been detected along with serrated deformation, which generally never happens on the materials at other conditions. However the fracture occurred on the most deformed neck after significant elongation. Adiabatic deformation is the important drive to occurrence of this phenomenon. Scanning electron microscopy (SEM) and Optical microscopy (OM) results are presented to discuss the possible reason of multi-necking. In additional, an optical method is used to gauge the geometry of multi-necking specimens.

Keywords*—component, formatting, style, styling, insert*

Sector Weld Repair Study on Ti6Al4V alloy in EBW for COPV

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***Abstract*—** Composite overwrapped pressure vessels (COPV) with a composite shell encapsulating a metallic liner are used in the aerospace applications for storing high pressure helium gas. Metallic liners are made up of titanium alloy Ti6Al4V. These liners are manufactured by machining two hemispherical forged domes having lip configuration in female dome and electron beam welded and subsequently weld bead is shaped to form liner. Weld defects in any welding process is likely to occur. Therefore, repair welding is carried out to accept the hardware. Normal practice of weld repair in EBW is repeat cir-seam welding. It was observed experimentally that full cir-seam welding is not appealing in most of the cases and number of repairs is increasing. In order to limit the repair at location of defect, sector repair is thought as an option. In sector repair, electron beam can be oriented more precisely at the defect location. It will also have the advantage that it minimizes weld spatters, back wall impingement, etc in comparison to full length re-weld. In the present study, sector re-weld up to R4 has been carried out and for simulating the same; three test rings were cut from hemispherical forging protrusions. These rings simulating liner interface were electron beam welded (R0). The R0 weld seam was re-welded sector wise with slope-in, weld and slope-out configuration. Evaluation was carried out at slope-in, weld and slope-out regions to find out UTS, % elongation. Micro hardness for R1-R4 welds has been measured and micro structure of weld, heat affected zone (HAZ) and base metal (BM) has been examined. R0-R4 weld properties were compared. It was found that there is marginal decrease in UTS and hardness and marginal increase in elongation as nos. of sector weld repair increased. However, these marginal increase and decrease will not be affecting acceptance criteria because these values were well above the design specification limit. It was found that, heat affected zone is increasing as numbers of weld repair increased. Mechanical properties in terms of % elongation and UTS are comparable for slope in, weld and slope out region. Micro hardness was found more in HAZ followed by weld region and least in base metal. It was concluded that sector weld repair in electron beam welding is a better method as compared to repeat cir-seam weld and is the preferred option for flight hardware.

***Keywords*—** *Electron Beam welding (EBW), Slope in, Slope out, Sector weld repair, TIG, Ti6Al4V*

Development of an Automated Crawler Device for Composite Sandwich Panel Inspection using an Instrumented Coin Tap equipment

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***Abstract*—** Aluminum or Composite Honeycomb sandwich panels are used extensively in the spacecraft industry primarily due to its lightweight. Top and bottom face sheets are adhesively bonded with a honeycomb core. The bonding has to be good without any defects like no-bond or de-bondedareas. A standard Non Destructive Test (NDT) inspection tool like Instrumented Coin Tap (ICT) systemis commonly employed to tap the surface and acquire data to indicate the bond quality. At present it is done manually on the panels. On large panels it is difficult to conduct the NDT tests due to inaccessibility to far-off areas, repetitiveness and time constraint. Manually holding the instrument for covering vast areas and moving constantly for long time is challenging, especially for bigger spacecraft structures.Since very large panels need to be inspected, it becomes almost impossible to cover the area manually with constant contact force and uniform speed of tapping. Hence it is thought fit to automate this job of moving the NDT tool on panels of any size. A crawling device was configured, designed anda prototype developed.A full-fledged wireless device isunder realization. It is designed to cover the inspection of entire area of the panels with the NDT tool (ICT) tapping at variable pitches of typically a few centimeters. A fixed frame based design was not adopted since portability was preferred, because the NDT tests are to be conducted at various labs.This paper gives details of the developmental efforts and methodologies considered.

***Keywords*—** *Aerospace, Debond Detection, Instrumented Coin Tap, NDE, Sandwich Panels*

Experimental And Numerical Analyis Of Resistance Spot Welded Joint Strength On 15CDV6 Steel

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***Abstract*—**Resistance Spot Welding (RSW) has grown in popularity as one of the most efficient methods for sheet metal joining. It offers several advantages, ranging from high speed and adaptability of automation and thereby facilitating large-scale production. Among the numerous fields in which RSW finds its application, the automobile industry, aerospace industry and the marine industry are some of them where the method is extensively used. These are the domains where mass optimization becomes vital. This will be accomplished in general through the proper selection of materials, design optimization, fabrication process optimization and so on. Efficient designing of RSW joints would help in considerable reduction on structure mass without sacrificing the strength and rigidity requirements. This project work mainly focused on mechanical property analysis of resistance spot welded lap joint through experimental method and compares the test results with mathematic model generated through the software MSC Apex SP1. Here, Finite Element Analysis of the designed software model is done with the help of the software Simufact. weld.6.0. and joint strength simulation is performed. On future aspects, it aims for design of resistance spot weld joints for improved hardware assembly strength and optimize its stiffness.

***Keywords*—** *Resistance Spot Welding, Sheet Metal Joining, Mechanical properties, Design Optimization, Finite Element Analysis.*

Design & Simulation of Manufacturing Processes & Tools for Productionising Double Walled Nozzle Extension of Cryogenic Engine (CE-20)

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***Abstract*—**Cryogenic Engine (CE-20)[1] developed by India, delivers around 200kN High Thrust for upper stage of GSLV Mk-III Satellite Launch Vehicle. GSLV Mk-III is set to become a game-changer in Indian Space Program with prominent Planned Missions like Gaganyaan, Chandrayaan-3, Shukrayaan, etc. CE-20 Engine has already completed 3 successful Flights and it is now required to productionize & ramp-up the delivery of the CE-20 Engines to meet the rising needs of Indian Space Program.

This paper provides an over-view of selected Design, Development & Simulation solutions evolved for manufacturing process stages & Tool Designs of forming & machining of CE-20 Nozzle Extension, which is one of the critical components of CE-20 Thrust Chamber.

- Problem Statement Design, Development & Simulation of Production friendly Manufacturing Process & Tools for Double Walled Nozzle Extension of CE-20 Engine
- Methodology 2D/3D CAD Software Tools are used to evolve Manufacturing Processes & Design Tools in Virtual CAD Environment. FEA Software Tools are used to validate the Process & Tooling Elements.
- Salient results Modelling & Simulation of Manufacturing Process & Tools enhanced capabilities in problem identification, visualization and clear communication which helped in solving several practical challenges at Design Stage itself which otherwise would have got slipped through & transferred to be solved at Manufacturing Execution Stage. Re-usability of Parametric Digital Design Data helps in easier Adaptability for similar components.

Emphasis is given on utilizing design & simulation studies to evolve solutions for these manufacturing processes/tools in order to obtain flexibility (to accommodate improvements) during development phase and also to achieve consistent quality over time during production phase.

***Keywords*—** *CE-20, Design & Simulation, Manufacturing Process, Nozzle Extension, Tool Design*

Design and Fabrication of Low Noise Pressure Regulating Valve for the Trisonic Wind Tunnel

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***Abstract*—** Vikram Sarabhai Space Centre (VSSC) is establishing a Trisonic Wind Tunnel (TWT) at TERLS, Thiruvananthapuram. The TWT is a blowdown type wind tunnel capable of achieving a wide range of Mach numbers and stagnation pressures at wide range of attitudes of the models. The air used for blowdown is compressed and stored at a pressure of 20 bar (a). During the blowdown, pressure in the storage tanks drops. In order to maintain the mass flow rate and stagnation pressure of the blowdown, a pressure regulating valve (PRV) is provided upstream of the settling chamber. The PRV provides variable area during blowdown based on pressure feedback from the settling chamber to regulate mass flow into the tunnel. It is also designed for quickly filling the settling chamber at the start of blowdown to increase the run time of the tunnel.

Perforated holes (cage) are provided within the PRV and a sleeve progressively opens during the blowdown to maintain the constant mass flow in the tunnel. The valve stroke versus the opening area is designed to cater entire range of mass flow and pressure of the tunnel operating envelop. A 1:10 scale model of the PRV is fabricated and tested at National Research Council, Canada (NRC). 3 nos. of perforated cage with different hole orientation are tested and the best case is selected which meets the mass flow and pressure requirements and noise spectrum.

ASME Boiler and Pressure Vessel Code is followed for the design, fabrication and testing of the pressure bearing parts of PRV. The PRV is designed using calculations are per Section VIII, Division 1 of BPVC and finite element analysis is carried out for the PRV parts as per Section VIII, Division 2 of BPVC. PRV is fabricated using welding qualified as per Section IX and Non-Destructive Examination (NDE) as per Section V of BPVC. SA 516 Grade 70 is used for the pressure bearing cylindrical and conical portions of the PRV. The functional parts of the PRV viz., the perforated cage and sliding sleeve are made of stainless steel of grade 50.

The fabrication activities for the shell involved procurement of raw material plates, rolling, longitudinal seam welding to form segments, joining segments by longitudinal seam welding. Combination of shielded metal arc welding (SMAW) and submerged arc welding was used employed. A meticulous quality assurance plan is followed for the fabrication activities. Quality is assured by multi-level inspection in various stages of fabrication viz., raw material, welding, NDTs, heat treatment, testing, machining and assembly. All the butt-weld joints are fully (100%) radiographed. In case radiography is not possible in the pressure bearing welds, ultrasonic examination (UT) is performed. Die penetrant test (DPT) or Magnetic particle examination is also performed to detect surface defects.

Simulation of transient thermal profile of cryogenic engine on Cu-Cr-Zr-Ti alloy and evaluation of mechanical properties

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***Abstract*—** Cu-Cr-Zr-Ti (CRZT) alloy containing 0.6%Cr, 0.04%Zr and 0.04%Ti is used for combustion chamber of cryogenic rocket engines, where the flame temperature is as high as 3000K This alloy is age hardenable and possesses high strength, good corrosion resistance, and high thermal conductivity. The strength of fully aged CRZT alloy is nearly twice that of pure copper. Regenerative cooling requires that the combustion chamber is a double-walled construction with coolant passage channels in between, fabricated from shells joined by vacuum brazing. During fabrication of combustion chamber, CRZT alloy is brazed with Ti stabilized austenitic stainless steel. CRZT alloy is processed through induction melting followed by thermo-mechanical processing to realize plates of required thickness. These plates are multi-stage deep drawn for forming the convergent and divergent sections of combustion chamber with intermittent annealing and are vacuum brazed at high temperature. In view of the large strains involved during forming and subsequent high temperature exposure to brazing operation, the microstructures of the initial material and final product are entirely different. Further, the combustion chamber during flight undergoes rapid heating and is maintained at the designed temperature for the entire duration of engine operation. In order to establish the design margins on the strength of the material during engine operation subjected to rapid heating conditions in the final vacuum brazed condition, it is essential to simulate the transient thermal profile on tensile specimens subjected to brazing heat treatment cycle. The present work compares the indigenous and imported CRZT with the indigenous CRZT meeting all materials specifications, manufacturing and application requirements of this alloy in the extreme thermal conditions involved in cryogenic rocket engine operation.

***Keywords*—** *Cu-Cr-Zr-Ti alloy, age hardening, brazing, cryogenic engine, thermal simulation*

Design and manufacturing of a spherical AA6061-T6 pressure vessel liner for aerospace applications

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***Abstract*—** Lightweight composite overwrapped pressure vessel is essential in aerospace applications because of their high strength and stiffness weight ratios. The particular work mainly focuses on developing an aluminium alloy (AA) 6061-T6 pressure vessel liner intended for its use in launch vehicles. The present approach deals with the development of punch and die forming system, which can be repeatedly used to draw the sheet metal by forming process, and develop hemispherical domes. Furthermore, an end adapter was manufactured after machining a AA6061-T6 billet. The parts of liner (dome and end adapter) are planned to be joined using Cold metal transfer (CMT) welding process. Butt joint was fabricated to assess the mechanical properties of weldment using uni-axial tensile and Vickers micro-hardness test.

***Keywords*—** *AA6061-T6, CMT welding, high pressure forming, mechanical properties, pressure vessel liner.*

Structural integrity assessments of Ni-Cr-Mo-V Steel

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***Abstract*—** Ni-Cr-Mo-V steel finds applications in various heavy-duty structures where high strength and fracture toughness are of prime importance. This alloy is primarily used in aircraft landing gear, shaft and axles for power transmissions. Fatigue and fracture are the typical failure mode of these components, and therefore, structural integrity assessments with respect to metallurgical and mechanical loading are always required. This work analyses the fatigue crack growth behaviour under sinusoidal variable loading and sinusoidal loadings with overloads after every 15000 cycles. Digital Image Correlation was used to analyze the effect of overloads on the strain generated in the loading direction. Overloads significantly reduce the crack growth rate for some cycles due to crack closure and the evolution of the plastic zone near the crack tip. A microstructure processing fatigue fracture relationship has been established by experiments.

***Keywords*—** *DIC, EBSD, Fracture, SEM, Steel*

Design and fabrication of cylindrical shell for flow conditioning in wind tunnels

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***Abstract*—** The 1.2 m Trisonic Wind Tunnel being established at VSSC, Thiruvananthapuram has stringent flow quality requirements. Settling chamber is a very important part of the tunnel in determining flow quality which primarily functions to maintain a uniform and steady flow in the downstream test section. The sizing of various flow elements in settling chamber is done using aerodynamic tools. The aerodynamic design of the settling chamber involves the study of various parameters that affect flow quality and arriving at the optimum configuration that minimizes the turbulence and acoustic levels in the test section of wind tunnel. The mechanical design of settling chamber is done to meet the requirements of ASME BPVC Section VIII Division 1. The design, fabrication, transportation, alignment and erection of settling chamber are completed.

***Keywords* —** *Pressure vessels, wind tunnel, design, fabrication*

Design and Development of thrust transfer structure – NCA of LVM3-X/CARE Mission of ISRO

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Abstract- Crew module Atmospheric Reentry Experiment Mission (CARE mission) was carried out in the first experimental flight of GSLV Mk-III. The thrust transfer structure of the solid booster stage of GSLV Mk-III, which is named as Nose Cone Adaptor (NCA), is primarily designed to transfer concentrated load of 3912 kN at an eccentricity. The design was required to be done with a tight time schedule within a lot of fabrication/design and functional constraints. The paper describes in detail the various criticalities from design constraints to the validation of the design through structural qualification test. The final configuration of NCA is arrived at taking into account the material availability and fabrication easiness while meeting the functional requirements. The results of the FE analyses and structural qualification level test are also briefly summarized. The designed structure while satisfying all listed specifications meets the main design constraint of rotation of thrust transfer bracket. The designed structures had flown in LVM3-X CARE and LVM3 D1 missions.

Keywords-*Thrust Transfer structure, Solid booster, Nose Cone Adaptor, Design constraints, Structural qualification test.*

Development of Composites Overwrapped Pressure Vessels (COPVs) for Aerospace Application : PLM Perspectives

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***Abstract*—**Highly compressed gases are required for propulsion system of spacecraft and liquid propellant upper stages of launch vehicles which are stored in pressure vessels. Criteria for selection of materials and technology are inert weight of the pressure vessel along with high level of impermeability. Hence Composite Overwrapped Pressure Vessel (COPV) with metallic liners have become the technology of choice as it offers highest efficiency for the given pressure and internal volume. Aramid and Carbon / Epoxy COPVs with Ti6Al4V liner for aerospace application, with operating pressures ranging from 250 bar to 330 bar to meet generic requirements have been indigenously developed. Challenges involved in the development were selection of liner & composite materials, evolution of design methodology and composite overwrap construction, generation of processing parameters & overwrap winding programme and generation of finite element model to capture all realized features for static & dynamic analysis. Generation and implementation of various tests to validate the design & processing parameters, qualification of the COPV for service, mounting and environmental conditions as well as for specific mission requirements pose additional challenges. In this paper product life cycle management approaches followed for the development & qualification of COPV for generic requirements and its qualification for specific missions are discussed.

Keywords*—composite overwrapped pressure vessel, metal liner, carbon / epoxy*

Enhanced Smart Quality Management System to implement Agile based In-built Quality Product Life Cycle Management of Space Systems

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***Abstract*—** As per Quality 4.0, The Quality function shall become the driver of value in the organization by enhancing product safety, mission assurance and Stakeholder value, improving efficiency, and reducing cost through AI enabled system management by leveraging digital to the best possible extend. Smart Quality Management system is a successfully implemented proto type of this kind of system management. It has been made integrated and collaborative, using the horizontal and vertical integration of Organization's value chain. The system capability spans across the project level Quality planning, Configuration control, inspection scheduling, Supply chain Quality control, vendor evaluation and calibration management system. By applying smart quality principles and the latest technologies, sQMS is reducing turnaround time and improving stakeholder experience. sQMS is now providing the raw data for the decision making. As a foundation to the next level, the captured data will be segregated using appropriate data anlyistics techniques, to train the AI algorithm. This algorithm will be enabled with value added steps so that it can handle the humongous amount of data that comes from various repositories. AI will augment the decision making process, take over routine tasks & follow-ups and in effect act as a Business assistant. In this way, expert minds can be freed from Routine task to and can be utilized for other mission critical activities.

***Keywords*—** *Quality 4.0, Quality management Systems, Artificial Intelligence (AI), raw data, Vertical and Horizontal integration, Operational Effectiveness (OE), Industrial Internet of Things (IIoT), smart Quality management system (sQMS),Docker, Kubernetes.*

Design and Development of Turbine Exhaust Gas Expansion Nozzle for a Cryogenic Engine Gas Generator

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***Abstract*—**An upper stage cryogenic engine developed by Liquid Propulsion Systems Center uses a supersonic expansion nozzle to generate thrust from the turbine exhaust gas. A nozzle with a unique profile is designed and developed for turbine exhaust gas disposal meeting the design constraints of engine envelope and requirements of supporting the nozzle on the engine, at the same time, maximizing the thrust generated. As part of development of the TEG (Turbine Exhaust Gas) nozzle, design analysis, testing and performance verification was done before induction of the nozzle in the flight program. The design was successfully proved in flight. The present work details the design of the nozzle, flow, thermal and structural simulations for design assessment, development tests carried out and the flight performance verification. Performance of the nozzle in terms of thrust generated and specific impulse closely matched with estimated design performance.

***Keywords*—** *Cryogenic engine, turbine, Gas Generator, nozzle, qualification.*

Thermal Design aspects of Electronics Packaging for Airborne applications

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***Abstract*—** Quest for reduced Size, Weight and Power (SWaP) and rapid growth in power density is demanding efficient cooling for safe and reliable performance of the electronics. This is continuously challenging the packaging industry. When the packaging needs to be airborne, the requirements are much more stringent in terms of pre-defined space, narrow cooling paths and exposure to harsh environment. This paper explores the research on electronics packaging in the perspective of a thermal designer. An example is illustrated with an air-cooled power supply unit of 687 W heat dissipation. It had a thermal failure initially. The packaging is re-designed after heat sink optimization. For the same weight, maximum temperature is brought down by 12°C. Cooling requirements are specified for the unit for safe performance.

***Keywords*—** *Avionics, Packaging, Standards*

Load Estimation Cycle of a Launch Vehicle from Initial Design Phase to Launch

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***Abstract*—**Launch vehicle designers aim for optimum structural efficiencies for each stage in order to optimize the payload and this leads to a flexible vehicle design. As a result, launch vehicle experiences significant dynamic loads as the vehicles traverse through the dense atmosphere. Hence in the launch vehicle load estimation process combined rigid body and flexible body loads are estimated. Estimated loads for each structure is defined in terms of Shear Force (SF), Axial force (AF), Bending Moment (BM) and Equivalent Axial Load (EAL). During the design phase of the launch vehicle, loads on structures are estimated considering the vehicle as a rigid body and augmentation of these loads due flexibility, buffet, sudden application of control force and wind gust are accounted through suitable flexibility factors. These loads are further increased to qualification levels and used for structural design. As part of mission analysis of each Launch Vehicle missions, a more realistic load estimation process is being carried out by using a flight simulation package. In this process measured winds of the season and corresponding flight trajectory parameters are considered as inputs. Mode shapes of the launch vehicle are used here directly in load estimation process instead of using flexibility factors. The buffet is an aero-elastic phenomenon happens at transonic Mach numbers which causes additional bending moment. These values are directly added to the analytically estimated bending moments. The load experienced during flight is monitored using strain gauges mounted on selected structures, in two orthogonal planes. Flight loads derived from these stain data are compared with theoretical loads as part of post flight Analysis for each mission. This paper describes the load estimation/analysis cycle from initial design phase to launch.

***Keywords*— Aerodynamic forces, Buffet, Launch Vehicle loads, Vehicle flexibility, Wind gust**

A tapered common bulkhead dome for the cryogenic stage of an Indian launch vehicle

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***Abstract*—** The evolution of existing launch vehicles to minimize mass, maximize payload capacity, and enhance reliability is a need of the hour to sustain the space industry's globally competitive market. This paper presents a common bulkhead tank as a substitute for the current truss-type intertank structure for the cryogenic stage in GSLV MkIII. A sandwich-type common bulkhead (CBH) dome with a suitable core material between two aluminum alloy sheets was found appropriate for this application. The foam-filled honeycomb core offered a mass advantage over other core types, such as foam core, honeycomb core, etc., for a uniform thickness of the CBH dome. However, manufacturing the CBH dome with a foam-filled honeycomb core is challenging and futuristic. A novel design of CBH cores with tapered profiles was explored as a recourse, which favored foam-type CBH dome in terms of mass and manufacturing feasibility. The manufacturing feasibilities for the following are discussed. A similar foam-type sandwich test sample with artificial defects of different sizes and types was subjected to various Non-Destructive Testing (NDT) techniques to detect possible defects emanating during manufacturing and integration. The capacity of NDT techniques such as X-ray radiography, Ultrasonic Testing (UT), and Infra-Red Thermography (IRT) was derived using the mentioned experiments. X-ray radiography is well suited for volumetric defects and can be used for a planar defect with image processing. UT has shown the capability to detect the subsurface and interfacial defects in the sandwich structure. A thermal setup was built to demonstrate the efficacy of the foam material in its thermal performance. The following novel design of the CBH dome can offer mass savings of up to 488 Kgs compared to the current launch vehicle configuration.

Keywords *— Common Bulkhead, Foam-filled honeycomb, Intertank, Non-destructive techniques, Radiography, Thermography*

Design and Assessment of Composite probe for soil surface temperature measurement

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***Abstract*—** The purpose of the composite probe is the in-situ measurement of the surface temperature and to measure the thermal conductivity of the soil. The probe is equipped with ten numbers of thermal sensors and one tape heater. The probe material is Cyanate Ester with Chopped glass fibers and glass Micro Balloons. The probe is provided with a sharp metal tip of 28° apex angle made of Titanium ELI grade material. The probe will be inserted in to the soil to a depth of 100mm using the penetration mechanism. The thermal sensors flushed on the surface of the probe measures the soil surface temperature. The tape heater wound around the probe will be used to heat the soil. Probe geometry, load calculation, material properties, qualification tests and FE analysis are discussed in the paper in detail.

Keywords*—Composite probe, surface temperature measurement, thermal conductivity measurement, Cyanate Ester*

Design options for a metallic tori-spherical nozzle closure for Semi-Cryo engine

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***Abstract*—**A semi-cryogenic stage with high performance engine is planned as a replacement for the existing core booster liquid stage of GSLV Mk-III launch vehicle for payload improvement. As semi-Cryo stage is an air-lit stage the propulsion systems and engine nozzle are to be protected from hot exhaust plumes during the firing of solid strap-on. The propulsion systems are protected by a thermal shroud and the exposed portion of engine is protected by a nozzle closure. Since the geometry of nozzle closure involves doubly curved shells (spherical & toroid shells), buckling under external pressure is a major criterion for nozzle closure design. The actual external buckling pressure of spherical shells can be as low as 14% of the pressure of a perfect shell based on NASA guidelines. Recent literature on buckling of spherical shells indicates that the NASA criterion is quite conservative. Recent developments in the design of spherical shells show improved shell buckling design factors which results in reduction in weight of structure and will be useful especially in aerospace applications. This paper covers different design configuration studies conducted for the nozzle closure structure based on NASA guidelines as well as improved shell buckling factors based on recent literature. Finite element analysis is carried out for estimation of buckling pressure for the above configurations.

Keywords*—Nozzle closure, Tori-sphere, sphere, buckling pressure, external pressure, semi-cryo engine, design factors, finite element analysis, knockdown factor (KDF), NASA standard.*

Design and prototyping of a variable diameter wheel for exploration vehicles

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***Abstract*—** The exploration of other planets is gaining interest among fellow researchers. To explore the unexplored regions, exploration vehicles are needed. Wheeled rovers are one among them which help researchers to visit, conduct scientific experiments and collect data from various sites. This work proposes the concept of an expandable wheel that can be used for these vehicles. The development of the final configuration of the expanding wheel and its initial designs are presented.

***Keywords*—** *Expandable wheel, mobile robots, planetary rover, variable-diameter wheels*

A pragmatic approach in an indirect health prediction of critical launch vehicle components through dynamic response analysis

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***Abstract*—** An unforeseen shock was measured during the launch vehicle upper stage while integration at launch pad and it was necessitated to find the response of critical electronic package locations and compare with their tested levels. Since the measured location of the shock was far away from the occurrence of the hitting, the input needs to be generated matching the measured response. A pragmatic method was adopted to generate the input and this input was used to carryout transient analysis to find the response at the critical locations of the stage. Shock response spectrum was generated and compared with each package environmental test level specification. All the responses were found to be well within the test levels and no further test was recommend to evaluate the performance A successful flight performance was observed without degradation of the performance of each package.

***Keywords*—** *Launch Vehicle shock, handling shock, shock response spectrum, transient analysis*

Integrated Numerical Modeling and Machine Learning Approaches to Predict Melt Pool Dimensions during Deposition of SS316L Single Tracks using Laser Powder Bed Fusion Process

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Abstract — Laser Powder Bed Fusion (LPBF) process is an additive manufacturing technique that produces intricate parts with fine resolution for aerospace, biomedical and automobile applications. LPBF process provides design freedom to conceptualize and fabricate designs that were earlier not possible by conventional manufacturing techniques. However, components built using LPBF suffer from porosity, residual stress-induced distortion, elemental segregation, and anisotropy in mechanical properties. A consistent melt pool size is required in the LPBF process to achieve consistency in build conditions and to avoid defects such as porosity. This work uses integrated numerical modeling and machine learning techniques to predict melt pool dimensions during single track deposition of SS316L alloy using the LPBF process. The numerical model used is a transient thermal finite element (FE) model carried out using the commercially available FE package ANSYS™. The predictions from the numerical model were compared with experimental data published in the literature. Results reveal a good agreement between predictions of melt pool dimensions from numerical models and experimental measurements. Further, results from numerical models were used as synthetic data to train and test the Machine learning (ML) model such as Artificial Neural Network (ANN) to find an empirical relationship between process parameters and melt pool dimensions. The ANN architecture was optimized to formulate the best generic hypothesis with minimum mean squared error for any testing parameters used. The formulated ML model is capable of predicting melt pool dimensions for given input process parameters (laser power, scan speed) with an error of less than 1% in testing data sets.

Keywords — *Artificial Neural Networks, Laser Powder Bed Fusion, Machine Learning, Melt Pool, Numerical Modeling, SS316L, Single Track.*

Repair of Aerospace Component using Additive Manufacturing

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***Abstract*—** This paper describes a method for restoration of an aerospace component using reverse engineering and additive manufacturing to extend the life of the component. The rejection of component in aerospace industries is very common at inspection stage, during operation, and after completion of its life. These discarded components carry a significant amount of cost with them, and it becomes very import to find a method/process that allows manufacturers to repair these components such that the repaired unit has the same properties as that of an original and can be reused. A combination of two technologies, reverse engineering which enable regeneration of CAD model from a physical component with high level of accuracy and metal additive manufacturing that allows metal depositing techniques to form a physical component from the CAD model enable such a repair of rejected or worn-out parts. The steps involved in this are - Scanning the worn out or damaged part, construction of its CAD model, digital comparison of the nominal and generated CAD model of the worn part to identify the region to be repaired, pre-process the region through machining for metal deposition, generation of instructions for depositing material using additive manufacturing, finishing the part by local machining to match the nominal CAD model.

This paper describes these steps using the repair of a worn out and damaged Turbine Blade as an example.

***Keywords*—** *Aerospace, Reverse Engineering, Additive manufacturing, CAD*

Optimization of Post-Processing Heat Treatment Cycle for L-PBF Processed Al-4.8Mg-0.3Sc Alloy

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***Abstract*—** The most extensively used additive manufacturing process, laser powder bed fusion (LPBF), is gaining popularity due to the tremendous design freedom it provides. Owing to the low density of the created alloys, LPBF manufacturing of aluminum alloys has piqued interest in a variety of disciplines. The unique solidification conditions that the molten metal encounters during the process, as well as its layer-by-layer nature, result in a variety of microstructural anomalies, such as the formation of metastable phases and supersaturated solid solutions, severe microstructural refinement, and residual stresses. Consequently, post-build heat treatments, which are routinely used on conventionally produced aluminum alloys, may need to be modified to adapt to the particular metallurgy of aluminum alloys generated using LPBF and solve the process' specific issues. More recently, addition of Sc to Al-Mg alloys of the 5XXX family has been extensively researched for numerous advantages of precipitating Al3Sc.Thepresent work intends to provide a broad understanding of the relationship between the induced microstructure and the mechanical behaviour that manifests as a result of various heat treatment cycles on LPBF processed Al-4.8Mg-0.3Sc alloy. An appropriate post processing heat treatment cycle for obtaining optimum mechanical properties in this alloy is also suggested based on this study.

***Keywords*—** *Al-4.8Mg-0.3Sc alloy, additive manufacturing, LPBF, optimization, heat treatment cycle, post processing*

Effect of post processing and comparative study of Indigenous and Imported IN718 alloy powders for additive manufacturing

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***Abstract*—** Inconel 718 alloy is being used as a work horse material in making aerospace parts due to its outstanding properties such as high strength, better low and high temperature properties, etc. and additive manufacturing is very helpful in realizing complex shaped parts in IN718 alloy. This paper mainly focuses on the effect of post processing of additive manufactured IN718 alloy and also on the impact of usage of Indigenous IN718 powders in comparison with the imported IN718 powders while fabricating the parts through additive manufacturing using laser powder bed fusion (LPBF) method. IN718 powders realized through gas atomization technique from both different sources as discussed. After realization, detailed powder characterization such size, shape, flowablity and microstructural analysis carried out for better understanding. Samples are fabricated in LPBF method at different orientation such as X, Z, 45° directions. Post processing Heat treatments and hot isostatic pressing carried out followed by mechanical properties evaluation and material characterization to study its impact on both the batches. It is found that Indigenous powders met all the specified properties as similar to the specification met by imported powder for realizing the parts through additive manufacturing in IN718 after standard heat treatment cycle(STA). Even better flow rate and finer sizes are obtained in indigenous powder's batch compared to imported powder's batch which resulted in marginal improvement in mechanical properties in all orientations of samples and better ductility obtained in samples Z- orientation samples. Both batches exhibited anisotropy in mechanical properties at different orientations. But, samples underwent HIPing followed by standard heat treatment cycle (STA) exhibited isotropic properties in all the different orientations such as X, Z, 45°. Significant improvement in ductility and marginal reduction in strength values are obtained after HIPing. Grain coarsening observed after HIPing was the reason behind the marginal reduction in properties. All most all the micro level defects are fully healed after HIPing which inhibited the pre-mature failure of the material while under load. Direct aging heat treatment also attempted and better strength values with anisotropy in properties obtained. The results of this study clearly indicates that indigenous powders can be used to make IN718 parts which are much comparable to imported powders and even better properties obtained in indigenous batch. HIPing helped to increase the reliability of the additively manufactured parts by healing the defects which were not detected in conventional NDT techniques.

Keywords*—HIPing, IN718, defects.*

Parametric Investigation of LPBF of IN625 at Poor Overlap Index (30%) and at Higher Layer Thickness (100 µm)

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***Abstract*—** This study aims to parametrically investigate the effect of laser power and scan speed on the Laser Powder Bed Fusion (LPBF) of IN625 bulk structures at higher layer thickness (100 µm) and poor overlap index (30%).Using higher layer thickness and poor overlap index in the LPBF might lead to high turbulence and poor melt pool fusion leading to high porosity and poor strength. The problem lies in determining the process parameters that can yield highly dense structures while improving the build rate by using higher layer thickness and poor overlap index. LPBF is used to build IN625 bulk structures following a design matrix consisting of 3 laser powers (150 W, 300 W and 450 W) and 3 scan speeds (0.02 m/s, 0.05 m/s and 0.08 m/s). Following studies are performed on each sample: (i) Porosity, (ii) microstructure (iii) hardness and (iv) X-Ray Diffraction (XRD). It is observed that the 90.82% dense structures are obtained for structure built at 450 W and 0.08 m/s. Porosity decreases with the increase in both laser power and scan speed. Cooling rate decreases when either the power is increased or the scan speed is decreased. Hardness is observed to decrease with the increase in laser power or the decrease in the scan speed. XRD studies of the samples reveal no extra phases.

***Keywords*—** *Laser Powder Bed Fusion, IN625, cooling rate, layer thickness, overlap index.*

Characterization of Laser Powder Bed Fusion AM Processed AlSi10Mg Components for Liquid Engines

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***Abstract*—** The major attraction/advantage of the Metal Additive Manufacturing route is the realization of complex geometries with fewer processing steps and shorter lead times. Feedline Inlet Elbows and Support Clamp components required for a rocket liquid engine were processed in Aluminium Alloy AlSi10Mg material through Laser Powder Bed Fusion (LPBF). LPBF is a commonly adopted additive manufacturing technique for producing intricate parts with a fine resolution for aerospace applications. These components were earlier made using Aluminium Alloy AS7G in T6 temper condition through casting route. AlSi10Mg was selected for the process, as it is a workhorse 3D printable aerospace alloy, the powder of which is easily available and gives similar physical, chemical and mechanical properties as that of AS7G casting alloy in the T6 condition. AlSi10Mg is characterized by good strength and hardness as well as high dynamic load-bearing capacity and hence it is typically used for parts with thin walls and complex geometries subjected to high loads. Detailed manufacturing plan and qualification plan were generated for processing and characterization of these parts through the LPBF process as per applicable international standards and qualifying them for aerospace applications. This includes powder characterization, physical and mechanical property evaluation, dimensional inspection and non-destructive testing using computed tomography. The 3D printing parameters were chosen from the EOS datasheet for AlSi10Mg alloy and qualification of the same was done through an exclusive build of test coupons representing thin and thick sections in the actual components and tested for various chemical, physical and mechanical properties. The components and test coupons were 3D printed using EOS make M400-4 DMLS machine and subjected to post-processing heat treatment as per the SR1 condition specified in ASTM F3318-18. Test coupons 3D printed along with the components were also tested and the products were qualified. This paper brings out the results of material characterization and non-destructive testing performed to qualify the additively manufactured parts in AlSi10Mg alloy for the intended aerospace application.

***Keywords*—**Additive Manufacturing, Laser Powder Bed Fusion, AlSi10Mg, Characterization

Understanding the Effect of Interlayer Delay on Hastelloy-X Wall Structures built using Laser Directed Energy Deposition based Additive Manufacturing

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***Abstract*—** In the present work, Laser Directed Energy Deposition (LDED) of Hastelloy-X (Hast-X) wall structures are used to understand the effect of the interlayer delay. Unidirectional deposition strategy with 10 s, 20 s and 40 s delay between consecutive layers is used for deposition. It is observed that the average wall height increases and average wall width decrease with an increase in the interlayer delay period due to a reduction in the outward flow of the melt pool. Macro-structural examination revealed deposition without cracks and the presence of few pores at isolated locations. Microstructural examination shows cellular and dendritic growth in all the cases, with cellular primarily in the lower to middle layers and dendritic from middle to top layers with classical secondary arms. It is observed that the size of the dendrites reduced with an increase in the interlayer delay period. An increasing trend is observed for the micro-hardness, yield strength and ultimate strength with an increase in interlayer delay. This study provides a path to control the properties of the wall structures by incorporating an interlayer delay period during the deposition for fabricating complex-shaped engineering components.

Keywords*—Laser Additive Manufacturing; Directed Energy Deposition; Wall structures; Geometry; Characterization.*

Prediction of IN617 deposit track features in Directed Energy Deposition using Machine Learning

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***Abstract*—** This study models the track geometrical features with the help of different supervised machine learning models (SMLM). Since experimental techniques can be exhaustive and numerical techniques can be computationally expensive, it is required to identify a proper SMLM to predict the laser directed energy deposition (LDED) built track features correctly and in a reduced time. The study is performed by depositing IN617 tracks using LDED at different process parameters and developing different SMLM for a set of the tracks and validating the models using the other set. In the present work supervised machine learning technique - Decision Tree (DT), (Random Forest), Extreme Gradient Boosting (XGB) and Artificial Neural Network (ANN) are modeled for prediction of track features of LDED built IN617 tracks using main input process parameters. These machine learning models are trained and tested on randomly split experimental data. It is observed that the XGB model yields minimum Mean absolute percentage error (MAPE) and higher coefficient of determination (R2) value as compared to other developed models. The obtained values by the XGB model of MAPE are track width (W ~4.2 %), Track height (H ~9.8%) and powder capture efficiency (Ep ~5.2%) and R2 values are W (=0.99), H (=0.96) and Ep (=0.93) on the testing (for validation) data set.

***Keywords*—** *Additive Manufacturing, Laser Directed Energy Deposition, Inconel617, Machine Learning*

Study on Geometrical Features of FDM Components Based on Integrated Material-Process Design Using Multi Criteria Decision Making Method

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***Abstract*—** Building an engineering component layer-by-layer is one of the unique characteristics of additive manufacturing (AM), that facilitate the realization of relatively complex parts with intricate internal geometries. Fused deposition modelling (FDM) is one of the AM methodologies that gained wide popularity for rapid prototyping of engineering models which cater to the need of various experimentations/validations. Slicing of CAD file in stereolithography format is an important phase that regulates build parameters such as layer height, raster orientations etc. The dimensional accuracy of FDM 3D printed components directly depends on the above phase, in addition to the machine and the material characteristics. Along this line, proposed research focuses on the dimensional performances of acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) components manufactured using FDM. The influence of build orientation and print temperature on dimensional accuracy of FDM components, printed using three different raster orientations 00, 450, and 600 have been investigated in this paper. Dimensional analysis on print components were performed using a coordinate measuring machine, using systematic measuring strategies. The dimensional accuracy of the FDM component for features of flatness, cylindricity, concentricity angularity, dimensional, accuracy and repetability are measured. The results are observed to have mixed responses/correlations with the input parameters. In addition to the validation and interpretation of these observations, present paper also attempted a multi criteria decision making (MCDM) methodology for the assessment of input variables and process design, as typical examples for selected components.

Keywords*—Additive manufacturing, fused deposition modelling, dimensional accuracy, MCDM*

Characterization of L-PBF 3D Printed High Strength Aluminium Alloy Al4.8Mg0.3Sc Bracket for Aerospace Application

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***Abstract*—** High strength Aluminium alloys are the preferred choice for aerospace applications due to their high specific strength and superior corrosion resistance. Metal additive manufacturing (AM) processes have garnered considerable attention in recent years due to their unique ability to form fully dense complex 3D geometries using micro-sized metallic powder in a layer by layer fabrication methodology. Laser powder bed fusion (L-PBF) is one of the most versatile AM processes which is capable of achieving a high degree of complexity and closer geometric tolerances. Unfavourable microstructure formation during rapid directional solidification is limiting the development of high strength wrought Aluminium alloys through AM route. Researches carried out in this direction have led to the development of alloys having scandium and zirconium added in a small percentage to refine the grain structure. One of the bracket components used in the light alloy structure of a satellite launch vehicle was 3D printed using Al4.8Mg0.3Sc aluminium alloy and subjected to detailed material characterization to assess the suitability of the alloy to replace conventional wrought aluminium alloys such as AA2014 for aerospace application. Detailed manufacturing cum qualification plan was generated for processing and characterization of the bracket through Laser Powder Bed Fusion AM Process. Bracket and test coupons were 3D printed using an EOS make M290 DMLS machine and then subjected to post-processing stress relieving heat treatment. Test coupons 3D printed along with the bracket were tested and the product was qualified. This paper brings out the results of material characterization and non-destructive testing performed to qualify the additively manufactured bracket component for the intended structural aerospace application.

***Keywords*—**Additive Manufacturing, Laser Powder Bed Fusion, High strength aluminium alloy, Al4.8Mg0.3Sc, Structural application, Characterization

Role of SLM in a Modern Military Aircraft Development Program

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***Abstract*—** There is a need to establish right digital methodology for managing the aircraft product and process data during all stages of its lifecycle. Off late, it has been realized that in the absence of Service Bill of Material (sBOM), silos of service information getting created during aircraft development phase in standalone systems either go waste or partially utilized. Service Lifecycle Management (SLM) being an extension of Product Lifecycle Management (PLM) system, its Change and Configuration Management functionality plays a crucial role in integrated Bill of Material (BOM) management. This paper brings out the role of SLM in creating the complete digital thread for a military aircraft program to cater for effective management of Equipment Standard of Preparation (ESOP), 'As-built As-maintained' product structure, tracking of Line Replaceable Units (LRU), Technical Publication, Failure Reporting and Corrective Action System (FRACAS), interface with Enterprise Resource Planning (ERP) and Enterprise Asset Management (EAM) systems. The SLM database could be used as a master source of information to be shared across all stakeholders to facilitate data analytics, dashboard reports etc.

Keywords: *PLM, SLM, sBOM, Tech Publication, FRACAS*

A Life Cycle Perspective on the Development of a Test Rig for ISRO Smart Limb

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***Abstract*—**Vikram Sarabhai Space Centre (VSSC), as part of ISRO, has always been in the forefront in utilizing the developed technologies for the betterment of society in the form of spin offs. One such spinoff development currently being pursued in the centre is the development of ISRO Smart Limb, a microprocessor controlled prosthetic limb for transfemoral amputees. The ISRO Smart Limb has undergone preliminary characterization trials. The developed prosthesis needs to be validated under varying load conditions to qualify for human trials. A major challenge was to make available an even more significantly complex test rig for characterizing ISRO Smart Limb. Towards this, an automated test rig has been designed using the in-house expertise on space technologies and realization is taken up through industry for simulating human gait cycle during walking and running conditions. The Test rig development involves (a) mathematical modeling of human limb and simulations to generate time varying profiles of velocities and loads at various joints (b) configuring test rig and simulations (c) sizing of hardware (d) realization through industry. The Test Rig has been realized and gait cycle simulation has been successfully demonstrated upto 5kmph walking conditions.

***Keywords*—** *Gait cycle, ISRO Smart Limb, Prosthesis, Test rig, Trans-femoral amputee*

Possibilities and Challenges to migrate PLM on Cloud in R&D

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***Abstract*—** Cloud computing is versatile, scalable and dematerialized digital information paradigm.It is establishing itself as a most well-liked resolution in response to the fast rise in data and information. However it needs a radical culture amendment for adapting Cloud to the Defense sector.

In Defense, a cloud platform makes it potential to form a secure collaboration surroundings facilitating the sharing of a lot of or less crucial data between the various civilian or military entities of the Defense ecosystem.

Main motivation is to explore the possibilities, however R&D information will get in cloud by analyzing the problems edges and planned solutions revealed in numerous literatures.

CLOUD computing and product lifecycle management (PLM) are the most recent concepts in respect of collaboration and universal connectivity. PLM is much related to product designing, collaboration, manufacturing, and other aspects of the product lifecycle, while the cloud is computing model, which support through Internet.

Cloud PLM is a hybrid of two technologies viz., PLM and cloud, however effective integration of both is challenging as direct migration of PLM to cloud facility is time consuming. Also, choice of the collaboration method could be a severe concern for rigorous utilization and responsibilities.

Main motivation of this paper is to analyze various possibilities of migration of R&D defense data into cloud by reviewing the available solutions from the literature and comparing their benefits and challenges.

Key Words: *Challenges, Cloud, Migration, Product Lifecycle Management (PLM)*

Product Life Cycle Modelling in Launch Vehicle Avionics Components

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Abstract - In launch vehicle avionics, electronics components are having major role in the design and development of avionics subsystems. From the design of a prototype model to final model, the availability of desired electronics components is very much important as the systems are designed for critical applications. To meet the continuous requirements, Product Life Cycle modelling based techniques are simulated and adopted to maintain the availability and quality of such critical components. Life cycle stages of components – Introduction stage, Growth Stage, Maturity Stage, Decline Stage and Obsolescence stage- are considered in terms of both acceleration and reliability based models. In this paper the various models used to simulate the various life stages of the avionics components are explained in detail along with examples and results.

Keywords: *Components. Life cycle, accelerated tests, reliability, failure rate, temperature, humidity, vibration etc*

PLM and Process Automation Tools for Critical Systems of Launch Vehicles

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***Abstract*—**Vikram Sarabhai Space Centre (VSSC) is the lead center of the Indian Space Research Organisation (ISRO) for rocket research. In this paper, we discuss the benefits of Product Lifecycle Management (PLM) and Process Automation (PA) software. We also discuss the challenges that an organisation faces in the realization of enterprise applications including PLM and PA software. We briefly discuss various methods that are available for realization of such applications. We share the experience of VSSC in the realization of various such applications. We provide a brief overview of a number of such applications namely Synergy, E-Documentation, LVDMS, Mythri and Tharang. We describe how these applications have improved the overall efficiency of the system. We conclude the paper by discussing the future direction of the work happening in this area of realization of a larger ecosystem that incorporates many of these applications as part of a uniform entity.

Reliability Centered Product and Process Development in PLM by Real Time Integration of Various Business Tools using RPA

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***Abstract*—** Building a high reliability space system though being expensive and time consuming, is essential. Since unreliability would prove to be much more detrimental. Design for Reliability (DfR) is very important and plays a significant role in new product development, in identifying key design parameters and potential failure rates that may be intrinsic to a design. Effective dissemination of data, information, knowledge and communication across the value chain is important for quicker and efficient product development. Our Reliability centered Product Development has been developed on the framework of standard guidelines of AS9145 Aerospace Series – "Requirements for Advanced Product Quality Planning and Production Part Approval Process". The integration of reliability during the initial stage of product lifecycle, creates a closed-loop connection between the design & physical product. Thus, DfR aims to improve system reliability, boost bottom line by reducing warranty costs incurred due to product returns/ failures/ recalls and enhance customer satisfaction. The purpose of this paper is to demonstrate a system architecture that integrates Product Lifecycle Management (PLM) system with Reliability Management System (RMS) complemented by the Knowledge Management (KM) system using Robotic Process Automation (RPA) tool. Thus, allowing engineers to control changes and cascade reliability requirements in a closed-loop environment across the value chain to improve the product and process design.

***Keywords*—** *Reliability, Product Development, Knowledge Management, Design for Reliability, Product lifecycle management, Enterprise Resource Planning, Reliability Management System, Robotic Process Automation, Equivalence Class Transformation, Intelligent Automation, Artificial Intelligence*

Requirements Capture and Schedule Management for a Transport Aircraft Using a PLM Tool

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***Abstract*—**Product lifecycle management on a digital platform as opposed to physical documents offers many advantages for large and complex projects. The design cycle for a small commuter aircraft has been initiated on a Product Lifecycle Management (PLM) Tool. Cultural resistance to changing from a paper-based system was overcome by having five dedicated Subject Matter Experts (SME's) in the systems engineering team addressing each major discipline in the transport aircraft. Each SME first captured all the customer and regulatory requirement for the discipline under their charge. They also developed a typical design activity chart which was then reviewed by the design teams. The programming of the PLM was undertaken by a separate PLM implementation team. Migrating to a PLM platform has resulted in important benefits like communication between all the stakeholders, management of design artifacts, single source of truth, tracking the requirements and control via stage-gates at various phases of the design process for the project.

***Keywords*—** *product lifecycle management, requirements capture, schedule management, digital twin*

Product Life Cycle of an Ordnance Device-A Case Study

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***Abstract*—**This paper presents the product lifecycle aspects of a typical ordnance device. As a case study, "Explosive Nut" is selected which is used in launch vehicle stage separation systems. This separation system uses the energy of the high explosive which is converted to useful work by severing a notch in the nut. The mechanism involves various types of ordnance elements starting from the squib with a deflagration output which gets converted to a high explosive shock wave. In this paper, various aspects of the product lifecycle management concepts are studied and an implementation plan for the explosive nut is addressed, which can be extended to any similar launch vehicle ordnance system. The mature phase of the product or the service period of the product is the longest duration in the "life cycle". However, the limitations of using a pyro element and the fact that it deteriorates over time adversely affects its shelf life and usability. Hence, extension of shelf life greatly increases the value addition of the product.

***Keywords*—** *Explosive Nut, Product Life Cycle, Development life cycle, Operational life cycle, Human rating*

Aerodynamic Design of Crew Escape System for Gaganyaan

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Abstract - One of the most important missions of ISRO is Gaganyaan mission where ISRO is aiming to put human in an orbit for some duration and bring back to earth safely. The safe return and recovery of the crew is the top most priority in this mission even in case of abort or failure of the mission. The Crew Escape System (CES) is designed only for the purpose of safe recovery of crew which pulls Crew Module (CM) away from the launch vehicle and takes it to a safe altitude and range in case of abort during the ascent phase in atmospheric regime. Design of such a system is very challenging. One of the reasons to make the vehicle aerodynamically stable is the absence of active control in this vehicle and placing of propulsive motor nozzles that are projected to the flow at the centre of the vehicle. Crew Module (CM), the heaviest component is located near the base shifts the CG of the vehicle close to the base. Moreover, presence of jets during abort reduces the effectiveness of the fins. Hence, making the vehicle aerodynamically stable is really challenging in abort scenario. Reduction of external acoustic levels during ascending is also another design criteria. Proper shaping of CES has been carried out to take care this. In a nutshell, aerodynamic design of the CES has been carried out to minimize the acoustics load and improve aerodynamic stability. The present paper discusses regarding the steps followed to overcome the above challenges aerodynamic characteristics of the finalized configuration.

Keywords— *Crew escape system, acoustic, stability, conical, cone-ogive, man mission*

Soft Computing Approach for Dynamic Calibration of a Stress-wave Force Balance

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***Abstract*—**In high-speed atmospheric vehicles, the aerodynamic drag force imposes serious concerns due to their hazardous behaviour on the vehicle surface. Therefore, ground-based experiments are performed using similar models to predict such forces. The calibration of such impulsive forces (expected in real experimental environments) needs to be performed prior to real-time experimentation. Therefore, in the present study, a calibration task is performed by integrating a stress-wave force balance with a bi-cone model. The balance is equipped with a strain gauge module that records strain signals corresponding to the impulsive force applied on the nose of the model. The strain signals are captured for the different magnitude of impulsive forces and these force and strain signals are used for training and recovery of unknown forces. Here the forces recovered through ANFIS techniques are compared with the known forces and also with each other. This provided an insight into the feasibility and applicability of the soft computing approach towards the inverse recovery of unknown forces for short-duration experiments.

Keywords*—ANFIS, short duration force recovery, soft computing, strain gauge, impulsive force.*

VR flight simulator with cognitive load estimation feature

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***Abstract*—** This paper discusses the design and development of a virtual reality (VR) based flight simulator with built-in feature for cognitive load estimation. Realistic target tracking and context of the battlefield is designed in VR and various environments (dawn, dusk, midday, night), and terrain conditions (plains, hilly areas, ocean) are simulated. We have proposed an AI based agent model that shall interact with the actual aircraft model to simulate battlefield scenarios. Head mounted eye gaze tracker and EEG headset are used for acquiring pupil diameter, gaze fixation and theta, alpha, and beta band power data at real time. We evaluated the system section both university students and later with frontline military aviation pilots; each for six realistic task conditions. We used DWT based multi resolution analysis of pupil diameter (PD) to compute the PD features. Median of the EEG band power is computed as another cognitive load measure. We analyzed the variations in participant's cognitive load in comparison with his/her flying performance. We found that for similar flight performance, EEG beta band power of student participants was significantly higher than real pilots. Results also suggest significant increase in cognitive load when participants perform target tracking along with secondary task.

Keywords*—virtual reality, agent, flight simulator, ocular parameters, pupil dilation*

Effectiveness of ADS-B integration in Airborne Surveillance Mission

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***Abstract*—**Automatic Dependence Surveillance – Broadcast Automatic Dependent Surveillance – Broadcast (ADS-B) is a surveillance technology through which an aircraft establishes its geographical position using satellite navigation and broadcasts its position periodically. This enables it to be tracked by others. ADS-B In function facilitates the real time display of ADS-B tracks on a display computer whereas ADS-B Out function facilitates the periodic broadcast of precise aircraft position and velocity information along with other information like call-sign and ICAO number.

This paper considers a multi-sensor airborne surveillance system with sensors like radar, IFF etc. and the value addition brought by ADS-B integration. It is shown that ADS-B integration is highly effective during the full life cycle of airborne surveillance system as a test instrument during testing of sensors, as a situational awareness sensor during operation and as a calibration sensor during maintenance. We provide a scheme of integrating ADS-B sensor with the multi-sensor system. The paper also describes laboratory integration test bed for ADS-B along with Mission Management System (MMS) and Multifunctional Tactical Console (MTC), which are constituent components of airborne surveillance.

Keywords: *Airborne Surveillance, Automatic Dependent Surveillance- Broadcast, Radar, Situational Awareness, Mission Management System (MMS), Multifunctional Tactical Console (MTC).*

Ultrathin Wideband Metamaterial based Microwave Absorber

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***Abstract*—** This paper focuses on design and development of hybrid structures using graphene in-conjunction with metallic pattern based metamaterial radar absorbing structures. The design optimization of graphene-based fractal structure has been carried out. The structure is designed using FEM-based electromagnetic simulation tools. A computational engine based on a multi-objective particle swarm optimization technique has also been created for structural optimization. The proposed structure exhibits an absorption of more than 98% across a frequency range of 8GHz to 20GHz. Graphene based radar absorbing structures are suitable candidates in the military aviation domain due to their reduced thickness and enhanced bandwidth characteristics.

***Keywords*—** *Fractal, Graphene, Metamaterial, Multiobjective particle swarm optimization, Radar Absorbing Structures.*

Study of Controlled Fragmentation of Cylindrical Warhead Casing

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***Abstract*—**In this paper, the analysis of stress concentration, notch matrix consideration, formation of cubical shape of fragment and the desired thicknesses for various masses of fragments generated from cylindrical warhead casing has been presented. Stress concentration factors are analyzed as case notch geometry. Complete case fracture of the warhead case will occur at a smaller case radius and fragment velocity will be lower as compared to a natural fragmentation case. Notch matrix geometry must consider the design of the notch in such a way that it utilizes the maximum strain and maintains symmetric shape with respect to the strain space. The notch matrix configuration should be designed based on the circumferential strain rather than axial strain because axial strain is much smaller than the circumferential strain. The optimum case break up can be achieved at 60° notch matrix angle. A cubical shape of fragments can be generated from warhead casing by giving internal notching of v-cut and external notching with rectangular cut. The fragment size is a function of the case thickness and distance between the notches. The optimum grid spacing should be within the limit of 1.0 to 1.5 times the case thickness. Cylindrical warhead prototypes of various thicknesses have been designed using internal notching based configurations and combination of internal-external notching with AISI-4340 steel alloy. Finally, comparative study has been carried out for analytical and experimental results of these warhead prototypes in terms of number of fragments and mass of fragments.

Keywords*—detonation, controlled fragmentation, warhead casing, stress Concentration, internal notching, symmetric notching*

Hot Shut Off Valves for Hypersonic Wind Tunnel

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***Abstract*—**The indigenous establishment of large size hypersonic wind tunnel by ISRO / Vikram Sarabhai Space Centre (VSSC) involved design, development, and manufacturing of many critical valves. These critical valves perform 'positive isolation' function of a high-pressure high temperature system and isolates the test section. To generate high velocities above the order of Mach 5, these valves are required to open very quickly at high pressures and high temperatures.

The main hot shut off valve HSV-4 is required to maintain leak tightness at 110 bar pressure and needs to open very quickly in less than 3 seconds (part of the travel in 0.2 seconds). Due to the high velocity flow from high pressure section to vacuum section, temperatures of the sealing surfaces & valve internals reach up to the order of 1550 K (1277 ˚C). The hot shut off valves are required to operate for many thousands of cycles with trouble free operation facing such high temperatures for short span of time. This demands very careful and meticulous considerations in design for robust and consistent product performance.

Keywords *– Hypersonic Wind Tunnel Systems, Indigenously developed Hot Shut Off Valves for critical high pressure & high temperature applications, film cooled, water cooled, fast acting hydraulic actuated.*

Novel Equipping Fixture Design for Composite Aircraft Parts Bonded Assembly to Enhance Productivity using 3D CAD

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Abstract— Traditionally the bonding of small-sized aircraft composite sub-structure parts such as spars and ribs to the skin is carried out with the layout method. There is no separate assembly jig, in general, used to perform the bonded assembly for sandwich skin, spar and rib involving lightweight foam as a core material. Alternatively, bonding carried out in-situ on the mould using layout method and application of load performed for bonding using sandbags, leading to lack of positional accuracy, non-uniformity in loading, and overall time-consuming process for bonded assembly. It is necessitated by the fact that the enhanced method is required to speed up the assembly process, improve the accuracy of part positioning and achieve better bonding. In this work, the novel equipping fixture has been designed for a typical aircraft wing to bond sub-structure parts to the skin. This multipurpose fixture is attached to the wing mould and is used to locate, support and hold the spar cap, spar web and ribs through a locating template. Provision is given in the fixture to apply uniform load on sub-structure parts during bonding with the skin through a loading template. This article brings out the effective utilization of 3D CAD to model the fixture along with wing parts and to simulate the actual assembly sequence of each part digitally before proceeding with fixture fabrication. The wing was successfully manufactured using the equipping fixture. Fixture design in support of 3D CAD enables greater accuracy in bonded assembly, improved part quality, and reduced lead time.

Keywords— *Equipping fixture, CAD model, Assembly simulation, Bonding*

Practice of Agile Scrum in Product Development

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***Abstract* —** Through this document we would like you to walk along with us on our journey to switch from the traditional waterfall model to Agile development. How the agile mindset helped the organization to adapt agile scrum from team to team there by achieving the best productivity with high quality. We also ensured to consistently maintain the level of productivity with regular trainings and support to the teams to stick to the new PLM.

As part of the PLM, we employed new application lifecycle management tools that helped using in capturing our customer pain points, challenges, new advanced features they want to build into their product. Once we capture our customer voice, our R&D gets into action and does a rigorous brainstorming session to come up with requirements or features as per customer needs and requests. We then break those requirements into EPICs and the epics are broken further down into small units as STORIES which are owned the respective associate and delivered story by story to epic; from there epic by epic to the final product in iterative manner using Agile Scrum.

***Keywords* —** Agile, Epic, Iteration, Scrum, Story, Velocity.

Artificial Intelligence as a Force Multiplier in Airborne EO/IR System

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***Abstract*—**Airborne EO/IR camera system provides multi-spectral, high definition (HD) imagery of an area of interest and are thus an essential sensor system in both aerial and maritime surveillance scenarios. They capture images simultaneously using a plethora of optical sensor payloads in the Visible (VIS), Short-Wave IR (SWIR) cameras and Medium-Wave IR (MWIR) spectrum. Exploitation of the images/videos from this gamut of sensors can have a force multiplication effect for the operator. While Artificial Intelligence has made great strides in the civilian domain in the task of exploitation of the output images/videos of these systems, translating this success into the military domain is still a major challenge. In this paper, we propose an AI-based, segmented, modular system architecture that can be interfaced with the Airborne EO/IR Camera and tactical display, for effective exploitation of its multi-spectral output. This provides force multiplication effects in terms of Automatic Target Recognition (ATR).

Keywords*—Artificial Intelligence, MWIR, SWIR, Airborne, Maritime, Surveillance, ATR, MTI, CNN, RNN.*

Systems and methods for automation of layout generation for automotive transmission graphs

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***Abstract*—** Designing an automotive automatic transmission is a complex and highly skilled task. Depending upon the various speed ratios needed, a transmission engineer decides the gear dimensions, number of individual components like planetary gear set, clutch & brake components, and sequence of their engagements. This is usually done in early conceptual phases of product development, a term popularly known as generative engineering, although the generative engineering also addresses the later part of design (for example controller design). The challenge here is to make a cost effective and compact transmission design with minimal power loss. As the number of speed ratio increases, the design complexity increases manifold. There are various algorithm and tools which helps an engineer to optimize the design. Once a design is ready, it's architecture needs to be created in the form of a 2D layout, which is axisymmetric projection of the actual 3D design. One of the biggest challenges during 2D layouting is to ensure that none of the lines intersect each other as it violates the assemblability constraint, also known as planarity violation. In this work, authors are proposing a methodology to automatically generate 2D graphs for the automatic transmission. The methodology has been tested on few designs ranging from 4 to 9 speed automatic transmission. It successfully finds the architecture without violating the planarity condition.

***Keywords*—** *2D Graph, Auto layout, Line search, Planarity check, Generative engineering, Conceptual exploration*

Generation of Parametric Modeler for CAD automation using Knowledge Based Engineering (KBE) Tools available in 3D Experience (CATIA) Software

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***Abstract*—**Multidisciplinary Design Optimization of Space Launch Vehicle Systems involves many iterations of design change within the feasible design space to capture the optimum design intent. In the process, it results in repetitive Computer Aided Design (CAD) based modeling of components, which often leads to simple but repetitive and tedious tasks resulting in human errors, procedural delay and less productivity in the quality of output delivery. In such cases, Automation is a powerful tool to reduce human dependency and speed up the entire process. The main purpose of this work is to develop a simple Knowledge Based Engineering (KBE) template for CAD Automation. A parametric modeling approach comprising of a Multi Model Generator (MMG) is developed which is capable of generating a family of cylindrical panels having Orthogrid/Waffle and Isogrid structures having applications in Interstages of Launch Vehicle Projects as per the iterative design requirements by reusing the same parameters. Inbuilt kernels and Feature Based Modeling tools are used in 3D EXPERIENCE (CATIA) Software. The design inputs are collected from the designer and stored inside the parameters, which are used to model the features. The formulae link different dependent parameters for defining all possible inputs required for 3D modeling. Thus, the repetitive task of modeling a large number of features can be avoided. Also, the edition of features and their locations in the structure becomes automated based on the minimum number of independent design parameters enabling us to reduce human errors and improve the overall output quality and productivity significantly.

Keywords*—Automation, CATIA 3D Experience R2020x, Computer Aided Design, Explicit Modeling, Feature Based Modeling, Kernels, Knowledge Based Engineering, Multidisciplinary Design Optimization, Multi Model Generator, Parametric Modeling, Waffle Structure*

Implementation of Digital Manufacturing for Aircraft Development – A Case Study

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***Abstract*—**Digital manufacturing holds a prime stake in digital product development lifecycle. Particularly in aerospace manufacturing, where product cycle times are very long, so it's very important to ensure validation of complete manufacturing cycle in digital environment right from planning to final assembly. This can be achieved through digital manufacturing simulation and validation of the manufacturing processes in context of tooling and factory environment. This also plays a significant role in finalizing design of tools and resources. In digital thread that spreads across product lifecycle, design and manufacturing are key phases in ensuring the build quality of a product. This aids in assessment of time and cost in manufacturing. Digital manufacturing applications helps in defining manufacturing process digitally from part manufacturing to factory planning including verification with human ergonomics. Introduction of Model Based Definition (MBD) in design, mandates all down the line processes to work with 3D data which is possible only in digital environment. In concurrent engineering, process planners are encouraged to assess the designs for manufacturability before release, digital manufacturing tools significantly helps process planning and methodizing teams to quickly assess the design. The complete manufacturing process up to rollout can be simulated digitally. This paper discusses an implementation experience of digital manufacturing in aerospace from process planning to supply of 3D based visual work instructions to shop floor. This process starts from importing of Engineering Bill of Material (EBOM), creation of Manufacturing Bill of Material (MBOM) followed by process planning through verification & optimization in digital environment. Finally manufacturing data transferred to ERP system for manufacturing execution.

Keywords *– Digital Manufacturing, Process Planning, Concurrent Engineering, MBD*

Finite Element Analysis of Stiffness of Bio-inspired Two-hierarchial (2H) Stairwise Staggered Composite with Regular Staggered Composite (SR) as Platelets

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***Abstract*—**Biological composites such as nacre, bone possess versatile mechanical properties such as high toughness and stiffness compared to that of their constituent at the basic level. These excellent mechanical properties are attributed to various factors such as the material and geometry of the constituents, especially the hierarchical arrangement of the staggered platelets inside the matrix. Bio-inspired composites are synthetic composites, whose design is inspired by biological composites. In this study, we conduct a finite element analysis to find out the stiffness of a two hierarchical (2H) stairwise staggered composite composed of regular staggered composite (SR) as platelet. The obtained results are analyzed for different combinations of platelet aspect ratio and volume fractions. Also, the results are compared with the available analytical model. These results could help the advancement of design strategies adopted in the field of bioinspired hierarchical composites.

Index Terms*—bio-inspired, hierarchical, regular staggered, stairwise staggered*

Additive manufacturing process development for realization of Fuel Pump Impeller of LOX hydrocarbon based rocket engine using 17-4 PH material

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Abstract— Fuel pump of LOX hydrocarbon based rocket engine employ impeller realized through conventional casting process and made by stainless steel alloy 04X13H5M5K9Л. The pump impeller is shrouded, centrifugal flow impeller with backward curved blades. It operates with inlet pressure provided by the inducer and delivers the fuel at the required flow rate and pressure to thrust chamber. The rejection rate of the realised hardware is high, due to the inherent casting defect. Hence an alternate route for realization of main fuel pump impeller is planned. The present study has been carried out to realised Fuel Pump Impeller of LOX hydrocarbon based rocket engine through Additive manufacturing process using 17-4 PH material in place conventional casting route.

Keywords—17-4 PH, LOX, Additive manufacturing, Powder bed fusion

Challenges and Lessons Learnt in Additive Manufacturing Technology for Realization of Wind Tunnel Models for Combat Aircraft

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This paper brings out the functional requirements of low speed wind tunnel models, resulting into manufacturing complexities for realization through additive manufacturing, for a typical combat aircraft program. Benefits of adopting additive manufacturing technology for realization of wind tunnel models were briefed.

The paper elaborates mainly the design challenges Viz., Orientation selection meeting strength requirement, size shrinkage compensation, thermal distortion, sharp edges, thin surfaces thickness limitations, etc. and also the manufacturing challenges Viz., support material removal, part size limitations, hole irregularities, achieving fine tolerances and good surface finish, internal porosities, insufficient melt due to power shutdown, etc. The inspection challenges viz., creating datums and reference surfaces were also discussed in this paper.

Case studies were covered highlighting the design, manufacturing and inspection challenges. Also the best practices to mitigate each of the challenges were also elaborated.

Wire Arc Additive Manufacturing of Near-net-shape Ti6Al4V Parts for Aerospace Applications using GTAW

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***Abstract*—** Wire Arc Additive Manufacturing (WAAM), also known as Directed Energy Deposition – Arc (DED-Arc), is an additive manufacturing technology that utilizes arc-welding process to melt and deposit the metal-wire feedstock, layer upon layer, to achieve the required near-net-shape part. Unlike a vast majority of Metal Additive Manufacturing techniques, WAAM operates without the constraints of a rigid build chamber, thereby enabling the production of parts that are larger than those which can be produced through the other techniques. This dimensional freedom, in conjunction with higher productivity, shorter lead times, lower cost per part, and the variety of compatible materials readily available in wire format, makes WAAM the most promising manufacturing process for large structural components, especially in the aerospace sector. The objective of the research is to explore whether WAAM process is adequate to produce parts of required quality, for critical applications such as Gas Bottles, Fuel Tanks and Grid Fins made up of Ti-6Al-4V. This paper presents the methodology adopted, the process variables selected, and the effect of each of these variables on the stability and quality of the deposition process, along with the mechanical properties achieved with heat treat treatment process and the resulting microstructure observed on the printed coupons.

***Keywords*—** *Wire Arc Additive Manufacturing • DED-Arc • Near-net-shape manufacturing • Titanium Alloys • GTAW • Heat Treatment • Microstructure • Mechanical Properties*

Development of Hardware for Biology in Spaceflight: Exploring the Prospects of Design for Additive Manufacturing (DfAM)

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Abstract

The announcement of Human spaceflight from Indian soil has opened a Pandora's Box of opportunities and challenges. Space biology experiments, propelled by the inquisitiveness to understand life in space, demands huge engineering support in terms of customized hardware to meet the functional requirements of each experiment[1]. Any designconsideration for space biology hardware need to fulfil invariably two prerequisites- i) requirements specific to the biological specimen under study and ii)ability to withstand launch load vibration with minimal/null disturbance to the experiment.In the case of an internal payload with animal subjects, contamination of crew module is a concern which need to be addressed by providing multi-level containment and life supporting systems. Considering the demands of customisation, complexity, and specific strength for design of the spaceflight hardware, additive manufacturing was explored as a promising technology. By applying the philosophy of Design for Additive Manufacturing (DfAM)[2], we designed and developed a spaceflight hardware as an internal payload to conduct autonomous biology experiment in the LEO for 5-7 days. The envisaged biocompatible hardware could support whole animal models enclosed in experimental vials. The designed hardware could hold 20 vials and was provided with two levels of containment, vents for proper airflow and dampers to withstand load vibrationsduring launch and splash down. First level of geometry design was done with all the requirements of hardware followed by different iterationsperformed by considering minimum mass and volume and proper air flow conditions.The final design (Fig.1)was optimised by following the design for Additive Manufacturing philosophy, wherein the geometry of window and air flow vent was changed to elliptical to minimise the use of support material during printing. All the vibration analyses were carried out using Ansys Workbench 2020 R1 Academic. First modal analysis frequency was 893Hz, which was far above the critical frequency. From the all analyses,maximum stress (VonMises) of 105 MPa was obtained from Random vibration analysis in normal mounting plane (Fig.2). The Margin of Safetywas calculated and found to be 0.31, indicating the capability of hardware to withstand the vibration launch loads.For evaluating the biological experiments on Earth, an optimised geometry prototype was manufactured by Fused Deposition manufacturing.

Did we "build" it correctly ? – Exploring automation possibilities of on-orbit inspection for in-space additive manufacturing

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For most space exploration missions, it cannot be denied with veracity-based reasoning that there does exist an analogous similarity between the same with an excursion visit executed by the likes of the public. The stance is that the journey with ardent possibilities of potential mishaps and unaccounted anomalies must be equipped with all possible and cautionary precautions – be it in the number of resources that could be carried or the reason why they are being carried. However, lately, since the focus of major space agencies has been distracted towards the clearer understanding behind the lack of any reasoning for such idiosyncrasies of the kind, the question of whether the products and tools we require in space, be manufactured in space ?

Whilst the same does exist as an interesting question to ponder upon, it also acts as a possible opportunity for the field of additive manufacturing to take the step on leading strides in the same. Consequently, in-space additive manufacturing became a research discipline for individuals, organizations, and governments as the possible aim for harnessing the next space revolution [6]. The attention of various space agencies in the same was reflected in how various sub-teams, dedicated research groups, and individual research objectives occupied the official stance for many space agencies [4].

While the opportunity of building tools and products required for space in space appeared lucrative, its mechanical and technical feasibilities were a perspective to be explored. Ranging from the likes of polymers for simple mechanical tools to metal for aerospace engineering operations, in-space additive manufacturing opened possibilities of enabling sustainable, flexible, and environment-friendly space exploration missions [5]. In 2014, under the partnership and collaboration with Made in Space, NASA successfully established the first 3D printed on the International Space Station with the capacity to print in three different polymer materials. in 2021, ISRO's Research Goals document Yukti Sanchita identifies on multiple locations the need for additive manufacturing for producing aerospace superalloys with enhanced fracture properties, PCBs, etc [2-3].

However, post-production of in-space additively manufactured tools, an eminent challenge that arises is that of in-process monitoring and on-orbit inspecting. It essentially translates to the fact that given the in-space crew does not own the same technical capacities to assess, inspect, check and qualify the manufactured products in-space, their certification for use in space and further deployment becomes difficult. Consequently, the need to inspect these tools in orbit for dimensional and volumetrical accuracy becomes crucial.

In this paper, we explore the possibilities of the same. At first, we review the existing literature available on on-orbit inspection techniques for AM tools. We carry out throughput analysis for each of these techniques to analyze their potentials and drawbacks. Finally, we divert our attention towards ML-based automation of on-orbit inspection techniques using strides made recently in the field of computer vision [1].

Topology Optimization of Additively Fabricated VTM brackets using SS316L

Objectify Technologies Pvt Ltd: Bhrigu Ahuja

Additive Manufacturing (AM) with its unique Layer by Layer Fabrication methodology is often considered as a disruptive technology to the conventional manufacturing processes. The ability of AM to fabricate complex designs without the need for any tooling or fixtures has resulted in application of design concepts such as Topology Optimization and Design for Additive Manufacturing. This enables the fabrication of lightweight structures, parts consolidation, conformal cooling channels etc, which were previously considered infeasible using conventional manufacturing processes.

The presented paper demonstrates the use of L-PBF (Laser Powder Bed Fusion) process to fabricated load bearing VTM brackets for in-flight application. The paper also discusses the application of topology optimization on the VTM brackets in order to achieve lightweight structures critical for apace applications. L-PBF, classified as a direct metal AM process, uses high intensity laser beam to selectively melt micro sized metal powder in order to achieve fully dense 3D structures. Parts fabricated using L-PBF have demonstrated mechanical characteristics equivalent to conventionally fabricated parts. This enables the use of AM process for end use applications in critical sectors such as space technology.

A STUDY ON METHODOLOGY OF TOPOLOGY OPTIMIZATION FOR AIRBORNE STRUCTURES USING FINITE ELEMENT ANALYSIS SIMULATION

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Abstract— The main objective of this research effort is to study a methodology for topology optimization by using numerical methods such as Finite Element Analysis, and a mathematical model of the topology optimization problem is brought out here. Optistruct is used as solver for optimization and finite element analysis. The objective function is to minimize the weight of the components keeping the shape of the component as design variable. The stress developed in the structure due to gravity loading is defined as constraint in the topology optimization problem. Weight saving of 20% is found out during the study.

Keywords: Gravity, Minimize, Optimization, Optistruct, Stress, SIMP, Topology, Weight

Performance optimization and production of U-Fitting bracket using LMD technology

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First titanium 3D-printed part installed into serial production aircraft 3D-printed parts are already flying on some of Airbus A320neo and A350 XWB test aircraft. These include metal printed cabin brackets and bleed pipes. Value proposition: CATEC & CiTD Engineering started experiencing the potential of Meltio LMD technology for aircraft and aerospace parts from the very beginning. As application example to explore capabilities, part proposal was an aircraft U-fitting bracket. Several units of the bracket were manufactured with the M450 metal 3D printer with Stainless Steel 316L pursuing to verify dimensional and mechanical properties of Meltio's metal wire printing at different layer heights and with/out Heat Treatment. The first study stage concluded that dimensional deviation was really low (± 0,2 mm), thus the part had really few excess/lack of material vs. nominal CAD. Moreover, brackets were not influenced by distortions typically caused by thermal stresses associated with laser based metal AM processes. The promising results motivated to follow further investigations with most suitable lightweight materials such as Aluminum and Titanium.

Prediction of Fastener Nut Factor Value using Machine Learning Technique

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ABSTRACT

Fasteners are the devices that mechanically join two or more objects together and they play an important role in the assembly of aerospace structures. A typical bolted joint is held together by a clamping force which must be retained for the entire duration of its service. Clamping force is created when we tighten the bolts by torquing during assembly to create tension in them, by turning the nut or bolt while holding the other. Reliability of a bolted joint is highly dependent on magnitude and stability of this clamping force and some critical joints require precise clamping force owing to design requirements. In such critical joints, the torquing process has to be accurately controlled to control the accuracy with which the clamping force is provided.

In a typical launch vehicle, there are numerous critical joints and nut factor is necessary to be evaluated for each such joint. Nut factor evaluation is an involved process with unique test setup, measurements and analysis. It is reported that a scatter of about 26% is expected in the preload achieved at a given input torque for as-received steel fasteners from a large number of sources, as reported by Bickford. In order to have better pre-load control, each batch of fasteners can be tested for the same joint configuration, which is a rigorous and mundane task. By testing enough samples and getting a statistical mean value of K, a desired level of confidence can be achieved even with corresponding scatter for in the values. In such a scenario, latest state of the art techniques can be applied to predict the nut factor based on the data of the fasteners from a particular batch. Over the years, different types of fasteners in numerous combinations have been tested and voluminous data is available. This paper proposes machine learning based algorithm for such an application to predict the nut factor through systematic simulation.

A new approach to Electrical System Design for Aero and Space platforms

Siemens: Prashant Gandhi

Modern day Aero and Space platforms present a tremendous challenge in terms of Electrical complexity due to exponential rise in the Electronic content. Data Integrity and collaboration across domains and in all phases of product development is a key concern. On top of it ever-increasing need to innovate and shrinking development cycles, brings in additional risk.

As E/E content increases in all aspects of the platform, semi-automated development methods and information silos are no longer adequate and, in many situations, counterproductive. Moving to an Integrated and digital approach provides a way forward.

This paper explores many challenges Aero and Space companies face today vis-à-vis Electrical System design and how a Model based approach and cross domain collaboration can help address these challenges.

Model Based Digital Risk Twin for Space Systems

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Abstract-A Digital Risk Twin (DRT) is a model of a system used to simulate the functional and physical risks that can impact safety and mission assurance (SMA) attributes of platforms, stages, and equipment in a space environment. The Digital Risk Twin enables digitization of System Engineering processes and ensures that design decisions are made with an understanding of the implications for system reliability, availability, and cost of ownership.

The DRT plays a crucial role throughout the Systems' lifecycle from requirements and conceptual design to operation. Various pieces of engineering specifications are captured through these phases to iterate and concurrently analyse the system to ensure systems' operational reliability and sustainability. A typical DRT subsumes the function of requirement management and enables traceability of the intended design, ensuring compliance with design specifications. This paper will explain how a Digital Risk Twin can be integrated with other engineering environments like PLM etc to analyse and mitigate these risks concurrently during the design phase and verify that system SMA requirements are met with a specific design configuration.

Effect of Roller Burnishing on Fatigue Life of Alloy Steel Fasteners for Landing Gear Applications

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***Abstract*—** Burnishing is a super finishing operation which not only improves the surface finish but also induces residual compressive stress on the surface. Alloy steel fasteners of AISI 4140, AISI 8740 and AISI 4340 are generally used in landing gear applications. All these fasteners have the stringent fatigue life requirement as these fasteners undergo cyclic loads. The effect of roller burnishing on fasteners made of AISI 8740 for the fatigue life improvement was studied. The results show that fatigue life of fasteners improved drastically after roller burnishing is introduced in the manufacturing process.

***Keywords*—**Roller Burnishing, Fatigue Life, Alloy Steels Residual compressive stress

Gating design for Complex Casting using ProCAST and its validation

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ABSTRACT-Investment casting process also known as lost-wax casting process is widely used for the realization of aerospace cast components with complex geometries, close dimensional tolerances and good surface finish. Proper metal feeding and gating system plays a significant role in realization of good quality castings with minimal defects. With the advancement of computing technology and simulation process, casting simulations are widely used in the modern foundries to predict and eliminate casting related defects. This paper explains the simulation iterations done using ProCAST software to optimize the gating system and actual casting pouring trials done for realizing aerospace quality turbopump investment casting.

Keywords-Gating system optimization, Hot spots,Investment casting, Niyama, ProCAST.

Design, fabrication, installation and testing of slender air storage vessels

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***Abstract*—** Air storage vessels of Trisonic wind tunnel aresized to provide the required run times for the blowdown facility.The vessels have a length to diameter ratio of 11 and dimeter to thickness ratio of 132. The vessels are designed meeting the requirements of ASME Boiler and Pressure vessel code. These vessels are intended to be used for a period of 50 years (or two lakh cycles of operation). The number of life cycles of the vessels is estimated using the results of finite element analysis at two extreme operating conditions that gives the highest stress range, along with the design fatigue curves of the ASME code. Being slender in nature, the vessels are handled with techniques to prevent distortions while fabrication, transportation, assembly and erection. The vessels are fabricated following a rigorous quality assurance plan. The design, fabrication, transportation, alignment, erection and testing of the air storage is executed meeting the relevant standards.

***Keywords* —** Pressure vessels, wind tunnel, design, fabrication

Design of Forging Process for Manufacturing Inconel 718 Hemispherical Forgings for Oxygen Storage by Modelling and Simulation

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***Abstract*—** This paper deals with the design of forging process by optimization of technological parameters for closed die hammer forging using modelling and simulation with an aim to produce defect free forgings. This approach has been applied to hemispherical forgings of nickel based superalloy (Inconel 718) with nominal size of 300 mm diameter with a wall thickness of 25 mm. Simulation has been used for the optimization of process parameters such as forging temperature, die temperature, amount of deformation, transfer time and forging equipment. Metal forming simulation software FORGE has been used to visualize the metal flow in the die cavity and distribution of the temperature, strain, strain rate, and stress. Based on these parameters, an optimized process was designed and implemented in industry for the manufacture of hemispherical forgings meeting the metallurgical requirements.

***Keywords*—** Forging, Inconel 718, Modelling and Simulation

Transforming Manufacturing Work Instruction in Digital way- Efficiently

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Abstract

In today's competitive world manufacturers are seeking solutions to address the challenges in manufacturing process and Quality. Regulated industries such as in aerospace must invest significant efforts to define and implement high standard shop floor documentation. In many cases, government regulations mandate that shop floor documents meet certain criteria. Even today companies are following inexpensive software tools to author documents. These tools do not connect to the engineering design and manufacturing planning processes. The work instructions are often difficult to understand and visually insufficient. In addition, its not always clear if the instructions were up-to-date and consistent. Moreover these standard tools & process do not satisfy intra-company formatting and layout standards thus deviating compliance and paving way for quality issues. In order to overcome these issues , Electronic work instructions (EWI) is the solution to have computerized visual tools to instruct shop floor workers to perform their jobs. Unlike paper-based work instructions, EWI may also include 3D models of the parts to be assembled, information about the tools as well as product and manufacturing information (PMIs). In addition, EWI may be interactive, allowing the reader to manipulate the 3D view, play animated assembly sequences as well as browse through a sequential list of steps to be performed per job order. Electronic work instructions has become a standard for many manufacturers. To get the most from this tool, companies should implement a reliable system that allows smooth change management, minimizes data conversion and provides state-of-the-art, 3D-based, interactive authoring. Various publishing strategies can be applied, according to the company's needs. Wisely implementing enterprise work instruction authoring tools may lead to significant savings in engineering time as well as minimizing time spent by manufacturing experts on the shop floor.

Optimization of process parameters for Thermal Protection System (TPS) application on structures of launch vehicles to increase quality with productivity using CNC manipulator.

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***Abstract*—**The cylindrical & conical structures are integrated for launch vehicles to place satellites in the definite orbit. During launch, the cylindrical & conical structures experience aerodynamic friction which results in heat generation to the tune of 500 degree Celsius. Thermal Protection System (TPS) application is needed on outside surface of cylindrical & conical structures to withstand aerodynamic friction and heat.

Conventionally, the TPS application is carried out by manual spray / brush application along the length of cylindrical & conical structures zone wise for launch vehicles using skilled workforce. The process is time consuming, laborious, hazardous and expensive approach. Further, various quality issues like thickness variation & weight variation, variation in paint deposition used to be observed with manual application of TPS.

For technological advancement (to optimize the process of Thermal Protection System, to minimize variation of thickness, to control the deviation in weight above its specification, to minimize the paint dripping / sagging and obtain better texture/glossy finish), the TPS application is mechanized and automated for finding the process parameters for linear feed of manipulator boom and rotary speed of turn table in automation using Computer Numerical Control (CNC) to get the exact closed helical path of spray pattern while carrying out TPS application throughout the large sized cylindrical & conical structures for launch vehicles to reduce cycle time, operation cost, operators fatigue due to exposure with hazardous chemicals and also to increase the effectiveness of the process.

***Keywords*—**TPS, PSLV, GSLV Mk2, GSLV Mk3, Isoscope FMP 30 & Probe FA 14, Curator, critical path, MOS, AOS, DBTL, LR grade, Polysiloxanes, PC-10 Red, PC-10 White, Eddy current, Heating.

Development of Processing Technique to Eliminate Reheat Cracking of XH67MBTIO alloy

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Abstract—Nickel based super-alloy XH67MBTIO (~67% Nickel) in various forms is used for fabrication of ISRO's liquid engine main turbine parts for launch vehicles. Higher nickel content in this alloy compared to conventional nickel based super-alloys gives superior ignition and oxidation resistance at higher working temperature. Post Weld Heat Treatment (PWHT) is an essential process on this material after forming/welding to relieve the stresses. Also, being a precipitation hardened alloy, post weld heat treatment is essential to achieve adequate strength. During the process of realization of main turbine components, material exhibited severe cracks after post weld heat treatment. For nickel based super-alloys, this problem is known as Strain Age Cracking or PWHT cracking. Based on studies carried out, welding in over-aged condition and solution heat treatment with very high heating rate (> 60˚C/min) are the two solutions to overcome above problem. Due to metallurgical complexities of welding in over aged condition, a cycle with higher heating rate was selected to avoid cracking problem. Hence study towards different heating techniques was done to achieve heating rates greater than 60˚C/min with the available furnaces. Initially induction heating followed by transferring the assembly to resistance furnace was envisaged. A technique to carry out induction heating was developed with multiple trials. All components heat treated with above established technique did not exhibit PWHT cracking phenomena thereby establishing the developed process. This paper brings out the details highlighting the methodology for achieving higher heating rate in Nickel super alloys.

Keywords: PWHT Cracking, Induction Heating, Solutionising, Over-aging

Eco-friendly anodization process for the corrosion protection of aircraft Al alloys: Pilot plant establishment and demonstration of process technology

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Abstract-Chromic acid anodization (CAA) process based on hexavalent chromium (Cr6+) is widely used for the corrosion protection of aircraft aluminium alloys. Due to carcinogenicity and toxicity associated with Cr6+, CAA process need to be phased out by eco-friendly alternatives. In this direction, modified tartaric-sulphuric (TSA) process followed by sealing in permanganate based bath has been proposed. Towards this, optimization and initial evaluation of sealing formulation was carried out in a Lab scale setup. The coating process leading up to certification was carried out in a pilot scale anodizing plant (400 L) and subsequent evaluation was carried out as per MIL-A-8625F specifications. The performance of the permanganate sealed TSA anodized aluminium alloys was found to be comparable with that of the conventional CAA coatings. This paper elucidates the overall process evolution spanning from the conceptualization of novel formulation to setting up of a pilot plant to demonstrate bigger area substrates/components and further, to obtaining of process clearance certification.

Keywords- Anodization; corrosion protection; eco-friendly; RoHS; self-healing

Thermal and Structural Modelling of Maraging Steel Welding

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ABSTRACT

Welding produces residual stresses near the weld region. These self-equilibrating stresses often result in distortion and loss of performance. This can be seen in the reduction of fatigue life and early component failures. In this study, the evolution of residual stresses and distortion for maraging steel (M250) multi-pass weld will be predicted using mathematical models. A coupled thermal and structural transient numerical model is developed to simulate the welding process in Comsol. This model can account for a moving heat source as well as the transient metal deposition occurring during welding. A material model is also developed to account for melting, elasto-plasticity and thermal expansion behaviour. The thermal results are validated using the experimental melt pool dimensions. The thermal results do show the cooling rates and maximum temperatures experienced due to each pass. Maximum temperature and cooling rates decrease as we move away from the weld. Distortion in the plate is observed to increase with each pass. The heat-affected zone (HAZ) exhibits higher von Mises stress than other regions.

Keywords: Welding, Model, Multi-pass, Heat affected zone, Maraging

Airborne Sensor Simulators: A cost effective solution for Training and System Evaluation

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***Abstract*—**Any Airborne surveillance system has multiple sensors and communication links on board for detection, tracking, Identification and classification so as to provide a Recognizable Air Situation Picture (RASP) of a scenario of interest. All the airborne sensors work in a cohesive manner to provide effective surveillance over the region of interest. In addition, the system also has communication links to transfer RASP to the ground station. The performance proving of such system is challenging and requires deep knowledge about sensor behavior under different dynamic scenarios. Such an Airborne surveillance system is complex and has a long life cycle. An important aspect is to characterize the performance of such a system against the Measures of Effectiveness (MOEs). Also the individual Measures of Performance (MOPs) needs to be evaluated. Another important aspect is operationalization of such system which requires trained operators. Training in air is time consuming, costly and restricted due to the environment.

This paper provides the architecture of integrated sensor simulation for operator training and performance evaluation in Airborne surveillance systems. The representative sensors that are consider are Primary Radar (PR), Identification of Friends or Foe (IFF), Electronic Support Measure (ESM) and Communication Support Measure (CSM). An important aspect of such sensor simulator is the fidelity with which the simulation matches the actual sensor output. Hence the simulation has to be built around an architecture that can transfer the statistical performance of the real system to the simulated system. Also it needs to be have a modular architecture to be scalable with respect various interfaces and other components.

***Keywords*—**FPT, Primary Radar(PR), Identification of Friends or Foe (IFF), CSM, ESM

Detection of lightning-prone zones of fighter aircraft utilizing CAD data by Rolling Sphere Method

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Abstract-Lightning zoning process detects the surfaces/zones of the aircraft, susceptible to lightning strike and identifies region susceptible to stroke attachment and the regions which would only carry the stroke current. Lightning zoning is the prime input for implementing the lightning protection scheme to protect the aircraft from both direct and indirect effects of lightning. Rolling Sphere Method (RSM) is a conventional method used for the design of suitable shielding to ground based structures. This method has been applied for detection of initial lightning attachment regions of fighter aircraft. The current work outlines application of RSM on digital product definition data of fighter aircraft, for upfront identification of lightning-prone zones. The paper mainly brings out the CAD data usage for lightning attachment evaluation of fighter aircraft.

Keywords- Lightning Zoning, Rolling Sphere Method

Preliminary Studies on Design and Modeling of Advanced Ceramic Heaters for Space Applications

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***Abstract*—** Ceramic heaters are in great demand for various applications including space. The electrical power requirements of a spacecraft are met by the clean and environmentally friendly photovoltaic conversion system. It utilizes a Solar Array Restraint and Release System (SARRS) consisting of a Kevlar cord and thermal knives for controlling and releasing the solar panels. Before the launch, the solar panels are held in their folded configuration by securing them with a Kevlar cord around the spacecraft. On reaching the orbit, the electrically powered thermal knives cut the Kevlar cord within seconds on command and thereby the solar panels will be deployed. Basically, the thermal knife consists of a ceramic substrate heater element, with a distinct electrical resistance trace pattern. Ceramics like alumina or aluminum nitride are used as substrates and the heater is made by screen printing Pt paste. It is very important to optimize the ceramic heater design as it determines the uniform distribution of heat and also ensures the life of the ceramic heater. In the present study, a ceramic heater that finds application in a thermal knife has been modeled and the results of the same will be presented.

***Keywords*—** Ceramic, heaters, Modeling, Pt paste

A Review Paper On Rocket Engine Nozzle Cooling

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- **Abstract**. Modern Rockets Used In Space Missions Have Thrust Generated Of Thousands Of Newtons. Thrust Generated Due To Burning Of Propellants And Oxidiser Results In Huge Temperature And Heat Generation. Most Heat Flux Occurs Near Proximity Of Nozzle Throat Which Needs Cooling As Combustion Temperature And Heat Is A Threat To Structural Metals. This Paper Reviews Different Cooling Methods And Efficacy On Rocket Chambers And Nozzles. In This Paper Experimental And Numerical Modelling Investigation Done By Researchers Is Also Highlighted With Results And Discussions. This Paper Also Brings In Light Of Critical Research Gap To Be Addressed By Future Generations.

- Keyword : Rocket Thrust, Nozzle, Propulsion Engine, Heat Transfer, Cooling.

Enhancing Space System Design and Modelling

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***Abstract*—** We are living in a time full of technological advancements in the products, manufacturing technology and the move to Industry 4.0 are changing the way systems are made. The emergence of 5G and connected technologies are gaining traction and are going to play a key role in next generation technology. This has opened doors for a lot of private organizations backed by venture firms and billionaire investors in launching Satellites and putting the Man in Space missions.

The key to designing for purpose is to ensure first time right. Today's software solutions are on the forefront of innovation for developing a comprehensive product digital twin that can turn ideas into reality in record times. These solutions help address multiple engineering challenges which are introduced by the new age products. It is important to embrace new age digital solutions that help reduce the overall product development cycles with comprehensive digital twin and upfront validation increasing the confidence on the integrity of the system and achieving the goal of first time right faster. This paper will highlight current product development methodologies and how new technological trends can be utilized to devise a faster comprehensive digital product development process for realizing better products.

Development of Sealing configuration between Crew Escape Motor and Shroud of Crew Escape System(CES)

ProductLifeCycle – SpaceSystemsPerspective

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ABSTRACT

Crew Escape System (CES) mainly consist of different types of solid motors which are sized and fired such that the Crew Module (CM) is pulled away from the Launch Vehicle during any exigency occurring while the Launch Vehicle (LV) is on the launch pad or during its initial ascent phase. Four numbers of CES Escape Motor (CEMs) are mounted on Thrust transfer Structure and are covered by Ogive Shroud. Cutouts are provided on the Ogive Shroud for the assembly of CEM Nozzle divergent which are projecting outwards. Multilayer sealing is proposed to fill the gap between CEM and Ogive Shroud which allows differential deformation of the interfacing structure. Multilayer Sealing also provides adequate thermal protection and prevents CEM exhaust gas entry into CES compartment and protects the avionics packages assembled inside and maintain safe environment. An innovative way of sealing the interface between the nozzle region and shroud was conceived along with assembly procedure with complex interfaces. By combining different materials and taking into account their thermal and mechanical resistance as well as their fatigue properties, multilayer fabric is proposed to meet the functional requirements. Kevlar material coated with Polychloroprene is planned for impermeable structural layer, Aluminised silica cloth for thermal/heat resistant layer Fabric level testing at room temperature and elevated temperature are carried out for generating design inputs. Towards this product development, detailed solid modelings of the components are generated; assembly sequences are worked out and demonstrated the feasibility of realisation and assembly operations through mock hardware. This technical paper describes the criticalities and challenges in configuring the sealing configuration, characterization of the fabric material at room temperature & elevated temperatures and assembly sequence between the CEM nozzle and Ogival shroud.

Keywords:Crew Escape System, Ogive Shroud, CEM, Sealing

A Comprehensive PLM approach for Aerospace Fasteners used in Launch Vehicles of ISRO

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***Abstract*—** Aerospace industry is one of the fastest growing industries. In this emerging market, speed and efficiency are quintessential, along with highest quality requirements. Various aspects of the supply chain management and life cycle management of this industry are very well studied to understand the ways and means to achieve these requirements. It is a well known fact that fasteners play a vital role in the assembly of aerospace structures and that their supply chain is not often given the importance it deserves. Though there have been few studies on the supply chain management of fasteners in aerospace industry, their life cycle management is largely overlooked. A large number of fasteners in numerous types are used for each launch vehicle and each type of fastener has a unique lifecycle. Considering their importance and also the variety of fasteners used in aerospace applications, particularly in launch vehicles, it is an essential requirement to study the life cycle management of fasteners in detail. With their variety and quantity, they pose unique challenges in meeting the quality and schedule requirements. Fasteners have the potential to disrupt the entire supply chain, if all the factors are not considered while managing their supply chain. A proper understanding of the fastener life cycle is essential to manage it effectively, which can help immensely in maintaining an effective and an efficient fasteners supply chain. This paper presents a comprehensive and sustainable approach towards the PLM practices for fasteners in launch vehicles.

***Keywords*—** Fasteners, PLM, launch vehicle, aerospace, supply chain management

Concept of a Specialised Project Manager Module – "Project HandBook"

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***Abstract*—** The world is racing tech savvy right from ordering food to building rockets. Today we've moved into digital era where we are constantly surrounded by new apps and tools and project management is becoming largely a digital experience. With the advent of mega scale projects there is a need for better project management tools, to achieve greater performance through good project management practices. It's time project management paces in the tech race. Traditional project management practices are being forgone and it is important for organizations to improve their practices. A project manager today is asked to not only to keep up with ever-changing goals and to manage a team with tasks and priorities but also to launch innovative products with demand and value. A project manager is also compelled to handle several projects at a time. Project managers report that they do not have access to adequate tools dedicated to project managers. The common issues faced by todays project manager in PLM are, there is no reserved space for him to manage the project, to define and describe all policies and directions for a project, secondly, he has time limited knowledge on the vast information available in PLM, subsequently, he is only able to partially associate the available information for decision making, and most importantly, he is not effectively sure what all the users are performing in PLM. Finally, at the closure of the project all the information lies scattered all around in PLM. This calls for an open framework where the project manager has an explicit workplace for himself to define all the project needs and tools for effective Project Management. He can formulate all the required information to flow along with him throughout the project. As a first step towards this, is the concept "Project HandBook". This distinct module includes handling the project requirements, holds guidelines as defined by Project Manager and selected tools for project execution and monitoring. Through this, a project manager gains knowledge and authority just as an "Air Traffic Controller" (ATC) in an airport on his project. The ATC in PLM is the "Project HandBook". A Project Manager once inside the Project HandBook will be able to establish and manage guidelines for the project, have access to all required information effortlessly in the form of chapters, analyse information from all round for assessment, manage users through the logs and reminders and when a project gets over Project HandBook will be the only source of information that will be needed to know about the entire project. So a "Project HandBook" is an all exclusive record managed by the project manager.

Keywords—Project Manager, PLM, Project HandBook, Module, guidelines, chapters, information.

Content Management using PLM Active Workspace in Aero engine Applications at GTRE

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ABSTRACT

The objective of this study is to disembark at a cumulative solution which facilitates accurate content extraction from a cascade of varied content of Gas Turbine Research Establishment (GTRE) aero engine applications across various data sources. The whole focus is to enable the user to create, manage, share and archive various kinds of content with flexible but secure and authorized access, thus moving towards a complete information management system which delivers digital content across platforms.

Content Management is an integral part of Product Lifecycle Management which can pose a challenge when there is a need to stored & manage content of GTRE's heterogeneous aero engine applications, with restricted access. While the system demands that the development efforts of any product needs to be in sync with the development process, a quick & controlled access along with the support of various formats are also the necessities of a decent Content Management system.

Information Technology Group (ITG) of GTRE is one of the major stakeholders in the PLM implementation along with design module groups and Project Management Office. ITG has tackled this challenge by deploying the Teamcenter Active workspace Client (AWC), which is an innovative and an easy-to-use intuitive user interface. It eliminates the factual confusion by leveraging a single source for secure content authoring, review and access to ensure proper distribution. The user access request is authenticated by Teamcenter Single Sign-On (SSO) through Windows Domain Control. Since AWC is a part of Teamcenter, the integration is seamless and simple.

The Content Management implementation using AWC is intended to secure the GTRE's digital assets, there by preserving the intellectual capital of the Organisation and also to reduce time and costs involved in search-and-retrieval of content, besides reducing the need to protect physical document storage and movement.

Keywords: Active Workspace Client (AWC), Content Management, Product Lifecycle Management, Single Sign-on (SSO)

i3PLM- A futuristic Product Lifecycle Management framework with interpretability, interoperability, and interactive capabilities

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ABSTRACT

In this paper, the focus is on the interpretability aspect of a futurist tool i3PLM - interpretability, interoperability and interaction. Right from the design stage up to product development, every product undergoes host of changes. Though several strategies have bee put in place to reduce the cycle time through product life cycle management (PLM), we believe that the use of powerful new tools machine/deep learning have not been effectively used in PLM. Along with traditional simulations, this work aims to show how the idea of 'interpretability' can be integrated in PLM.

Implementation of A Simple Production Management Tool for Avionics Systems

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Abstract: The paper describes a simple and cost-effective production management tool. A simple production management software which offers easy-to-use Graphical User Interface is described here. The software PROduction Growth Reporting & Evaluation Software System (PROGRESS) is used to streamline the entire Avionics Production process and manage product traceability. The work flow in production management and product life cycle of Avionics packages for operational launch vehicles are described in brief. The need for the production management tool and implementation aspects are covered in detail. The software is developed using Excel as a low-cost inventory management solution to meet the customized requirements of Avionics production. Coding is in Visual Basic Application (VBA) based Excel tool and Data is organized in excel files. The hurdles and deployment issues are also listed. The feasibility of linking with Electronic Production file software is also covered as avenues of future work.

Keywords: Avionics, Production Management, Advanced Mission Computers (AMC), Advanced Telemetry Systems (ATS), Graphical User Interface (GUI), Production Work flow

Simulation studies on the interaction of cutting edges and machining induced defects in CFRP composites

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Abstract—Carbon fibre reinforced polymer (CFRP) composites are generally classified as a "difficult/unfriendly to machine" material due to its anisotropic and nonhomogeneous behaviour. Defects such as fibre pull-out, fibre bending, fibre matrix debonding are commonly observed while machining these composites. Several experimental studies have provided useful information regarded damage mechanism for these composites. However, repetition of experiments for each and every situation under different process variables may be technically monotonous, time consuming, expensive and even health hazardous due to high amount of carbon dust. Numerical simulation studies may provide better alternative for understanding damage mechanism in CFRP while machining at various processing conditions. Hence, present work investigates the cutting behaviour and machining-induced defects on CFRP composites by modelling its interaction with single-point cutting edges. The simulation presented in this paper provides useful information regarding material removal mechanism of CFRP via plastic deformation/brittle fracture. The model was developed with proper consideration of actual mechanical characteristics of CFRP, considering fibre, matrix and fibrematrix interfaces individually. Experimental verification was performed using single point cutting tool at various processing conditions. Micrographs of machined CFRP surface were also analyzed to understand the machining induced defects. The proposed simulation study and its theoretical justifications may pave a platform for the researchers to understand failure mechanisms during machining of CFRP composites.

Keywords—CFRP, micro-cutting, defect, finite element mode

Functional Hazard and Fault Tree Analysis for a Transport Aircraft

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***Abstract*—**The paper presents the process of developing functional hazard and fault tree analysis at the Aircraft Level for a typical 19 seat twin engine Light transport turboprop aircraft. The Functional Hazard Analysis (FHA) has been performed at the aircraft level to identify and classify hazards that may compromise safe operation during flight. Further, a Fault Tree Analysis (FTA) has been performed for the catastrophic and severe major hazards identified from the FHA. The critical failure events that would lead to the loss of aircraft has been identified and the probability of occurrence of catastrophic events has been shown to be less than 1e-9 through a detailed fault tree analysis. The procedures to meets the requirement as outlined in FAR 23 Advisory Circular 1309-E has been explained in detail. The advantages of redundancy in design to avoid single point failures and satisfy the regulatory requirements for the catastrophic events has been explained through the functional hazard and fault tree analyses.

***Keywords*—**Aircraft Level Functional Hazard Analysis, Fault Tree Analysis, Preliminary System Safety Analysis

Role of Non-destructive Testing in the Life Cycle of Space Composite Structures – Current and Future Perspectives

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***Abstract*—** Composite structures are being used in space structures for their advantages such as higher specific strength, specific stiffness, tailorability of properties specific to required directions, realisaibility of near net shaped products. Non-destructive testing (NDT) plays a significant role in the product life cycle of these composite structures. Its use starts from the process feasibility studies, screening of specimens for mechanical property evaluation, feature based joint qualification studies, individual component as well as product (assembly) level quality assessments, at different stages of product qualification or acceptance tests, till its flight use and re-use if required. NDT methods for the composite products are varied, diversified and their application at each stage is dependent on the applicability and feasibility. This paper provides a brief summary of the contributions of NDT in the product development of a composite camera structure. Current and future perspectives provided on how the NDT and its results can be integrated into a digital twin for better product life cycle management (PLM).

***Keywords*—** Composite, qualification, NDT, digital twin, PLM

Wire Arc Additive Manufacturing of SS 321 for Aerospace Applications to Bear Static and Cyclic Loads

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***Abstract*—** Wire and arc additive manufacturing (WAAM) process is a fast-growing technology for the mass production of near net-shaped components with complex geometry. In this study, a multi-layered wall was fabricated via Gas Metal Arc Welding (GMAW) based WAAM process using ER321 filler wire. Optimal parameters were obtained from iterative trials. The as-deposited SS 321 wall was free from defects. The mechanical properties and microstructural evolution of the WAAM processed SS 321 wall was examined. The micrographs revealed the existence of columnar and equiaxed dendrites along the building direction, and recrystallization of grains was observed due to the re-melting of former layers. The microstructure was dominantly austenite with a small fraction of ferrite within the austenitic matrix. Comparable tensile properties were noticed for as-deposited SS 321 WAAM samples in comparison to wrought grade. This is attributed to the presence of equiaxed and columnar dendritic microstructure with a small ferrite fraction (FN). The hardness gradually reduced from bottom (250 HV) to top (199 HV) region in SS 321 wall and is attributed to the difference in microstructure with varying ferrite fraction (5.9 to 3.6 FN). The fractured tensile samples revealed the ductile mode of fracture. In addition, the cyclic loading behavior of as-built WAAM specimens along with fatigue crack growth analysis was performed in accordance with ASTM E1820-20b standard. The fracture toughness of wrought alloy and WAAM processed SS321 is 162 kJ/mm2 and 180 kJ/mm2. This study demonstrates the potential of WAAM technology for the fabrication of free-form structural components with comparable tensile and fracture strength in comparison to wrought alloy.

***Keywords*—** *Fracture toughness, Mechanical properties, SS 321, wire arc additive manufacturing, welding.*

Tailoring the microstructural characteristics and mechanical properties of Austenitic Stainless Steel 308L overlays deposited using Gas Metal Arc Welding process

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***Abstract*—** Gas metal arc welding (GMAW) based weld overlaying is an efficient and economical repairing process. In the present study 308L stainless steel was deposited on the 321 stainless steel substrate using the above technique. The mechanical properties: uni-axial tensile test and the microhardness analysis along the weld overlay and the interface section were investigated. The microstructural characteristics were studied in detail using optical microscope (OM) and scanning electron microscope (SEM). XRD analysis was made to examine the primary phase composition present in the weld overlay and the interface section. Tensile studies were conducted along three different orientations: 0º (LD), 45º (ID) and 90º (TD) along the welding direction. Tensile test results were higher for the interface section in ID orientation (IF-ID; UTS- 655 MPa, YS-404 MPa and EL-56.8%. In the case of HF sample ID orientation was higher (HF-ID UTS-571 MPa, YS-366 MPa and EL-55.2%). Alignment of ferrite phases in the overlay side to the loading direction has the effect on the strength. Microhardness values were higher on the overlay section (230 HV) and the interface section exhibited 218 HV. The results acclaim the good metallurgical bond between the 308L stainless steel and the substrate. At the interface between the overlay and substrate, microstructure featured epitaxial growth. The weld overlay is composed of mainly columnar and equiaxed dendrites as an effect of the cooling rate and the thermal gradient during the overlay process. Also, ferrite content usually increases on the overlapped weld beads. Hence a suitable deposition strategy shall be followed for repair applications to enhance the properties of the substrate.

***Keywords*—** Austenitic stainless steel, Mechanical properties, Microstructure, Weld overlay.

3D Printing / Additive Manufacturing (AM) Digital Transformation with the EOS's Digital Tools (Software) & Training

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***Abstract*—**The Covid Situation, and the increasing Digitization of the Technologies all over World Industries, Business owners and Leaders of the Nations are given a challenge to manage business remotely in order to manage the global demand in the Manufacturing.
This crisis is hitting companies who have not implemented the Digital Transformation in their production processes. Digital platform companies like Google, Amazon, Apple, Facebook, Swiggy, Zomato, Alibaba etc.. are running their business due to the digital nature of their business without much impact. So companies around the world are now looking to transform their production set up into digitally managed distributed work cells to handle the current crisis and also the future.

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Since 2004 LMW and its associate companies manufacture and supply components and products for the Indian Space programs and to the Defence Aerospace PSUs as well as global Aerospace Industry. Research and Development is the bedrock on which this conglomerate has been built. LMW and its associated entities have developed and delivered many critical systems to ISRO. LMW guidance from ISRO has designed and developed Solenoids, Control Valves, Fluid Control Components,Torque Motors, Gear Head Motors, Electrical Actuators, Pressure Transducers since 2004. These components are fitted and flown in every ISRO mission. Apart from ISRO, many precision systems and components for Aviation segment both Defence and Civil sector are being manufactured by LMW. These include Gimbals for Electro-Optic Payloads, Power Take-off Shafts and Retractable Landing Gear Systems. This manufacturing unit has been engaged with many DRDO projects as well.

In 2010, LMW has added the Advanced Technology Centre (ATC), a new plant to produce systems, modules, assemblies and components for Aerospace sector. The facility spans the composite and metallic arena. Aerospace Composite facility has international class processing and assembly facility to deliver a spectrum of composite and hybrid structures for space, aviation and strategic requirements meeting all the quality protocols. ATC is one stop solution to the Aerospace customer. In terms of infrastructure and capability, ATC has world class manufacturing facilities and its Quality Assurance standards are aligned to AS 9100 D Certification and NADCAP for special process viz chemical process, NDT, welding and Heat treatment. NADCAP qualification for composite is in progress. ATC has ongoing projects with Indian Space Research Organisation - Vikram Sarabhai Space Center, Defence Public Sector Units, Defence Research and Development Organisation and major OEMs in US, Europe. ATC has been identified as Indian Offsets Partner (IOP) in a few significant programs.

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Thrust for mammoth aspirations

SSLV (S-85 Motor)	PSLV (S-139 Motor)	GSLV (S-139 Motor)	MK-III (S-200 Motor)
• Tongue Ring • Groove Ring • Nozzle End Dome • AFT End Ring • Fore End Ring • Bucket Flange • Flex Seal Shim	• Head End Dome • Nozzle End Dome • Nozzle Convergent • Nozzle Divergent	• Head End Dome • Nozzle End Dome • Nozzle Convergent • Nozzle Divergent	• Fore End Ring • AFT End Ring • Compliance Ring • Flex Seal Re-inforcement Ring • Bucket Flange

PSOXL-Nozzle Convergent (15CDV6)

PSOXL-Nozzle Divergent (15CDV6)

S-139 Ring-Nozzle Convergent(15CDV6)

S-139 Ring-Divergent Fore End (15CDV6)

Ti Hemisphere

Intermediate Conical Component -Ti6AL4V

Ps4 Dome -Ti6Al4V

Conical Ring -15CDV6

LEM Nozzle Convergent-15CDV6

Equilibrium Regulator Body AISI 420 ESR

Principle Shaft AISI 420 ESR

Regulator Piston AISI 420 ESR

Bulk Head Forging - 15CDV6

Bharat Forge is a technology driven global leader in metal forming, having a transcontinental presence across ten manufacturing locations, serving several sectors including automotive, aerospace & defence, power, oil and gas, construction & mining, locomotive and marine. Bharat Forge has the largest repository of metallurgical knowledge in the region and offers full service supply capability to its geographically dispersed marquee customers from concept to product design, engineering, manufacturing, testing and validation. The world's largest forging company with manufacturing facilities spread across India, Germany, Sweden, France and North America, Bharat Forge manufactures a wide range of high performance, critical & safety components for the automotive & non-automotive sector.

Bharat Forge is the first Indian company to secure NADCAP approval for heat treatment of Titanium alloys. Bharat Forge is AS9100D, DGAQA, Cemilac and Testing Lab ISO-IEC 17025 certified and has over the past few years manufactured critical components for the Aerospace sector.

Bharat Forge Limited, Mundhwa, Pune - 411 036, INDIA, Tel: + 91-20-67042777, Email: info@bharatforge.com Website: www.bharatforge.com, www.kalyanigroup.com

CACPL Aerospace Division

Chakradhara Aerospace and Cargo Pvt Ltd was established in 1968 as LTE and in 2004 ventured exclusively into AEROSPACE business.

CACPL – Aerospace Division(earlier LTE)expertise in Pressure Sensors, Accelerometers, Solenoids, Torque Motors, Actuators, Control Valves & Modules and Precision Machining Components for Space. Our in-house facilities for design & development, machining, special process, assembly & testing under one roof made us to facilitate our customers by delivering our products & services with utmost quality and on time deliveries.

With the technical support &guidance from ISRO, CACPL has delivered more than 2500 sets of Control system Components for multiple missions. Since our inception of Aerospace business we are part of all the ISRO's launches and we are continuing our successful association with multiple business units of ISRO over the past 17 Years.

We are privileged to be associated with ISRO's special missions like Chandrayaan, Mangalyaan and the on-going nation's prestigious human space program "Gaganyaan".

With the technical expertise fromISRO projects, CACPL – Aerospace Division extended its business presence into Aviation segment both Defence and Civil sectors. Realised many precision systems, sub-system and high precision components for Indian and International customers. These include, Solenoid Valves, Flow Control Valves, Gimbals for Electro-Optic Payloads, Power Take-off Shafts for LCA and Retractable Landing Gear Systems for UAV's.

Chakradhara Aerospace and Cargo Private Limited

Aerospace Division

Formerly
(Lakshmi Technology and Engineering Industries Ltd.,)

Regd. Office: "Lakshmi", 34-A, Kamaraj Road, Coimbatore - 641018
Factory: 20, SITRA - Kalapatti Road, Kalapatti, Coimbatote - 641048. INDIA,
Phone: +91 422 2664100 | Fax : +91 422 2664221
Email: vijayakannan@lakshmitech.com | marketing@lakshmitech.com
www.lakshmitech.com

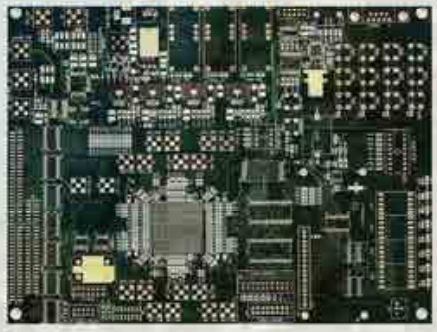
HI-Q ELECTRONICS PVT. LTD.

Plot No: 9, Industrial Estate, Hosur 635 109,
TamilNadu, INDIA
Contact : V. Sendyl , Mob : +91 9880231355
e-mail: rfq@hiqelectronics.com
website: www.hiqelectronics.com

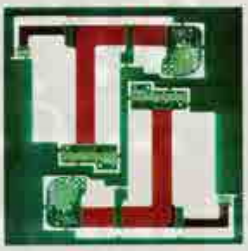
Quality PCBs serving for ISRO more than a decade

PCBs are supplied to various ISRO units including IISU, IIST, LEOS, LPSC, SAC & URSC

PCBs are supplied for various applications including space and ground use of ISRO , Aerospace, Defence applications manufactured in India



- Advanced automated manufacturing facilities located at Hosur
- Rigid Multilayer PCB's upto 38 layers
- Flex and Rigid-flex Boards
- HDI Laser Drilled Microvia PCB's
- Materials including Polyamide, Rogers,High Tg FR4 and Flex .
- Prototype / Medium quantities of PCB's
- Quality testing as per Space and Aerospace standards
- Quick deliveries-starting from 7 working days
- Comprehensive Quality testing including reliablity testing
- Minimum trace width / spacing : 3.2/3.2 mil
- UL Listed File # E156972
- Approved supplier to ISRO as per ISRO PAX 304
- AS9100 Rev D / ISO 9001:2015 certified with LCSO approval



Our major other customers are Elbit Systems Israel, Rafael Israel, Thales, BEL, Safran,Honeywell, Bosch, NPCIL,etc

SEC Industries Pvt Ltd

Hyderabad, Telangana

About Us:

- Manufacturing industry accredited with ISO 9001, ISO 14001, ISO 27001, ISO 45001, AS 9100 quality standards
- Committed to excellence in airborne, ground support and Naval products
- Maintanence, Repair and Overhaul (MRO) activities for AN32 and Dornier aircrafts.
- Alternate workcentre for Manufacturing and supply of 4000mm diameter and above closed isogrid structures.
- Established production source for manufacturing motor cases with 15CDV6 and MDN-250 steels in the rolled and welded route
- Production source for manufacturing Tanks with 15-5-PH steel

Vision:

- Excel in manufacturing and supply of specialised products for Global Defence and Aerospace requirements

Highlights:

- Defence offset partner approved by Government of India
- Supplier to Israeli defence companies for the past 15 years

Products

Airbone Systems

Light Alloy Structures:

- 4000mm dia X 2500mm height closed isogrid structures

Motor Casings:

- Motor casings with diameter ranging from 400mm to 2000mm and length from 1000mm to 7000mm with MDN250 and 15CDV6 steels in the rolled and welded route

Other Aerospace products:

- Nose cones, Engine bays , Thrust frames, Fuel Injection tanks, other welded and riveted structures





Ground Support Systems:

- EMI/EMC shelters, MIL grade Command and Control shelters, UAV Storage and Transport containers, Mobile launchers, Article containers, large Vacuum Test chambers, Pressure vessels, Radar turntables, Refueling systems, GDT trailers, Etc..

Naval Systems

- Weapon Handling & Loading systems, Main Thrust blocks, Ballast vent valves, Buoy release systems, Hull hatches, Cofferdam doors

MRO Operations

- Total Technical Life Extension activities of AN-32 Aircraft, Fuselage Construction of Dornier aircraft

Infrastructure

- Equipped with state of art Manufacturing, inspection and testing facilities. The following facilities have been augmented for the Aerospace division

1) CNC Lathe: Max Dia 3500mm ABC: 10500mm
2) Auto Tig Welding Station (AC/DC): Dia 3600mm, ABC: 10000mm
3) 5 Axis CNC VTM: Max Dia: 4500mm, Max Z axis stroke: 2000mm
4) CNC Drill Station: Max Dia: 3500mm
5) CNC Router: Table size: 4020mm X 2520mm
6) CNC Router: Table size: 6080mm X 2540mm
7) 3D CMM
8) Pressure test facility

Customers (Partial)

SEC Industries Pvt Ltd
Aerospace . Defence . Naval . MRO

6-25, Opp. IDPL Projects
Balanagar, Hyderabad,
Telangana- 500037
India

P: +91-40-23770260, 23773520
F: +91-40-23773613
E: marketing@secindustries.com
Contact: Mr. Revikumar Nanu- V.P Aerospace
Mobile: +91-9496020053, 9100033359

www.secindustries.com

CNC FILAMENT WINDING MACHINES AND PRODUCTS

CNC Technics is well established to take up composite products using CNC filament winding technology with winding capacities from Diameters 50 mm upto 3000 mm and lengths from 100 mm upto 13000 mm

- Polymide Pipelines
- Convergent-Divergent Tube
- Composite box section
- Tapered Pipes
- High Pressure NON-Metallic Cylinders
- Low pressure water treatment vessels
- Epoxy Pipes
- Special products
- Poles
- Pressure Vessels
- Pressure Filters
- Pipes
- Oxygen Cylinders
- Stretcher Rods
- CNG Tanks

We manufacture world class CNC filament winding machines and related accessories in our 34,000 sq.ft facilities spread over 3 units in Hyderabad and Vizag in India.

CNC FILAMENT WINDING MACHINE SPECIFICATIONS

- DIAMETER 10mm to 6000mm
- LENGTHS 200mm to 19000mm
- SIEMENS Controls
- 2 AXES to 6 AXES
- MULTI-SPINDLE
- CADFIL Winding Software

CRESCENT CONSULTANTS LIMITED

Our Clientele for over 220 winders, includes customers from

Australia	Dubai	Netherlands	Singapore	Venezuela
Argentina	Germany	Qatar	Thailand	Vietnam
Abu Dhabi	India	Russia	Turkey	
Brazil	Kuwait	Ras Al Khaima	Ukraine	
Colombia	Luxembourg	Sweden	United Kingdom	
Canada	Malaysia	Saudi Arabia	USA	

Our expertise is spread over three manufacturing units in India and equipped with CNC Filament Winding Machines, Curing Stations, Moulds, Hydraulic Extractors and Hydrotesters.

Convergent-Divergent Tube

Polymide Pipelines

Composite High Pressure Cylinders

Rectangular Plate Winding

2 SPINDLE 4 AXES MACHINE, USA

4 AXES WINDER, TURKEY

VESSEL WINDING

DUAL CONE WINDING

CNC TECHNICS PVT. LTD.

3A, Type-1, Kukatpally Industrial Estate, Hyderabad 500 072. INDIA.
Tel : +91 40-23078000, 23079414, Fax : + 91 40-23075498
e-mail : cnc@cnctechnics.com, Website : www.cnctechnics.com

The KCP Limited, Heavy Engineering Unit, Chennai, India. A 65+ Year Old Company
An ISO 9001-2008,ASME – "U,U2 & S stamp company

- Largest integrated manufacturing facilities for Heavy Casting, Fabrication & Machining.
- Supplies various equipment for Aero Space & Defense sectors, Cement, Power, Mineral, Oil & Gas, Industrial Gas.

Excellent In House Fabrication, Machining & Heat Treatment Facilities are available for Aluminum Alloy, 15CDV6, Maraging Steel, Stainless Steel, Carbon & Alloy Steel materials.

Infrastructure	
Single Piece Fabrication	250 Metric Tons
Rolling Capacity	250mm Tk.
Vertical Turning Lathe	Up to 12m Dia x 4.95m Ht
Horizontal Borer	160,200,250 Spindle Dia.
Gear Hobbing	Up to 8.5m Dia , 45 Module
Single Piece - Steel Casting	32 Tons (Finish Weight)
Liquid metal capacity	55 Tons

The KCP Limited,
Heavy Engineering Unit,
Post Box No: 2278,
KCP Road,
Thiruvottiyur,
Chennai – 600 019, India

Phone: +91 44 66772800
Ext: 349
Fax No: +91 44 66772802
Email: ds@kcp.co.in
Web: he.kcp.co.in

ANANTH TECHNOLOGIES PVT LTD

AN AS-9100D & ISO 9001:2015 CERTIFIED COMPANY

Committed Partner for Indian Aerospace & Defence Programs





Overview

- Inception in 1992
- Design and manufacture of Space and defence equipment
- Class 100K Clean Room with SMT production lines
- Contributed to 88 Satellites and 68 Launch vehicles
- India's premier private defense and space player
- In-house environmental test facilities

Product range

- Digital & Embedded systems
- EW systems & Simulators
- Laser & Optical Systems
- Sights for Tanks and weapons
- Telemetry & Tracking systems
- RF and Microwave systems
- Sensor Systems
- Navigation & Controls systems

Meeting Quality & Reliability Standards for Space & Defence programs

Dr. SUBBA RAO PAVULURI
CHAIRMAN & MANAGING DIRECTOR
Ananth Technologies Pvt Ltd., Ananth Info Park, Plot No: 39, Hitec City, Phase-II, Madhapur,
HYDERABAD – 500 081
Phone : 040 – 6615 6615; Fax : +91-40-6615 6531
E-mail : subbarao@ananthtech.com; mail@ananthtech.com
Website: www.ananthtech.com

Amphenol India

Connecting The World Together

Amphenol Interconnect India Pvt. Ltd. is a wholly owned subsidiary of **Amphenol** Corporation, USA. Established in India in 1972, **Amphenol** India designs, manufactures and markets wide range of connectors, interconnection products and value added electrical and electronic packages.

Amphenol Interconnect India Pvt. Ltd. has indigenised critical components for the Indian Space programs. Our product portfolio comprises of specialized connectors for space applications, cable and Loom assemblies, Electro-mechanical value added box assemblies, space grade PCB's and PCB assemblies.

Amphenol has wide range of Connectors for various applications such as Signal, RF, Power, Filter & Fibre Optic. Our product range includes Backplane solutions, Space grade Multilayer PCB's, Flex PCBs, ruggedized Ethernet switches & Media converters.

Amphenol Interconnect India primarily caters to Military, Aerospace, Marine, Space, Railways and other Industrial markets.

Amphenol India has established in-house testing facilities certified to MIL STD 1760 to test the end products and the facilities are ISO 9001:2000 , AS9100C and IRIS certified.

Applications






Connectors


MS & 97B


Pyrocatridge Hermetic Connector


MIL 389999


Micro-D


1553 Coupler

Value Added Cable Assemblies & Box Assemblies


Loom


Cable Assembly


Box Assembly


Electronic Pkg


Box Assembly


Panel Assembly


Integrated Systems


Panel Assembly

Amphenol Interconnect India Pvt. Ltd.

105, Bhosari Industrial Area, Pune - 411 026. India
Tel.: +91- 20 - 67360305, +91 (98230) 52247 Fax : +91 - 20 - 67360321
Email : svpatil@amphenol-in.com www.amphenol-in.com

ISO 9001-2015

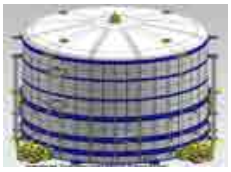
SHRI VENKATESWARA HI-TECH MACHINERIES PRIVATE LIMITED
COIMBATORE

Contact : T.Kaalimuthu - Chairman
T.Ramachandran- Managing Director
T.Govindaraju - Director
Address : SF.No. 518/1,2, Saravanampatti Main Road, Vellakinar Post, Coimbatore Pin: 641029, India
Tel : +91 90039 18024 to 90039 18029
Email : venkateswarahitech@gmail.com
Web : www.venkateswarahitech.com

Shri Venkateswara is an ISO 9001-2015 Company equipped with heavy fabrication, Machining and handling facilities. The main motto is to deliver quality products on assured delivery schedule with team work. The firm met all expectations of Indian Space Programme.

Shri Venkateswara Entered the space science Equipments fabrication by 1971 and from there on it is continuously engaged and our unit had successfully executed and commissioned many challenging products for Indian Space Research Organization (ISRO) in their SLV, ASLV, PSLV, GSLV projects. Collapsible mandrels for motor case winding, PSLV-propellant casting mandrels, INSAT-II integration fixtures, INSAT-II, Horizontal Transportation & Vertical Transportation containers, GSLV technological transportation container are some of the sophisticated items manufactured by the unit

The industry received many appreciation awards & certificates of merits from Indian Space Research Organization (ISRO) for its continued service with quality moto. And also manufacturing of other machineries and spares for Paper, Sugar, Cement and Process Plants, etc.



- RH 560 mandrels and collapsible type fiber glass winding mandrels and moulds to S3 & S4 for SLV project.
- Propellant casting mandrels and transport container systems for ASLV and PSLV.
- Technological transport systems, Throat entry mandrels, pressure chamber,
- payload adopter and Assembly fixtures, Ignitor casting mandrel, Vibration test fixture, Horizontal integration fixture, Test rings, Ignitor castings fixtures etc. for GSLV project.
- Various types of Satellite integration fixtures and satellite transport container systems to INSAT oxidizer tank, welding fixture of various type to satellite projects.
- Special Purpose Fixture , Spacecraft Transportation System, Large Manipulator and Vertical Transportation Container

SERVOCONTROLS Aerospace (I) Pvt. Ltd.

SERVOCONTROLS Aerospace (I) Pvt. Ltd. is one of the few Indian companies which has the capability with respect to Men, Machine, Technology and Finance to offer for Aerospace Industries.

Servocontrols has setup a 100% EOU brand new facility of 60000 Sq Ft in 14 acers of land, for Aerospace and defense systems, sub systems, Electromechanical systems, Electrohydraulic systems, servo valves, actuators, solenoid valves, manifold block systems, test rigs and ultra-precision machined parts for various applications.

We are a AS9100 Rev-D certified company backed by an unparalleled reputation for quality and extensive field experience. Servocontrols has the right combination of proven system architecture and high tech innovation that will make it a leading company in the field of Aerospace requirements and cater to Indian customers and international customers (Israeli customers like Israel Aerospace Industries (IAI), Rafael advanced Defense systems etc.).

In-house Facilities

• Design Engineering & Made to Print

Servocontrols has the capability to design as per the specifications and made to print products and systems, the Software's used are UG, CADCAM, SOLIDWORKS and AUTOCAD.

• Manufacturing

Machine Shop is equipped with 5- Axis, 4- Axis, 3- Axis CNC's with milling capability, Milling, Turning, EDM, Ultra precision Grinding, Honing, Laser Welding which requires extremely closed tolerances with very complex part designing on wide range of raw materials like Aluminum Alloys, Stainless Steel Alloys, Titanium Alloys, Inconel and special Alloys.

• Inspection, Final Assembly & Testing

Electrohydraulic and Electromechanical systems and sub systems, sub assemblies and complete assembly testing with jet fuels, Kerosene, Red Oil, MIL5606 in cleanroom and using Laminar Tables and variety of test rigs.

• Quality Control

As per AS9100 rev D established quality standards QMS with continuous improvements with respect to our products and processes.

Address:
SERVOCONTROLS Aerospace (I) Pvt. Ltd.
Sy. No. 683, Industrial Estate, Udyambag, Belgaum—590008.
Tel:+91-831-2407501/2/3/ 2481734/4201132

Contact: Dinesh Dhadute
Cell: 9845109022
E-mail: dinesh@servocontrolsindia.com

Website: www.servocontrolsindia.com **E-mail: dinesh@servocontrolsindia.com**

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Thane (West) - 400606, Maharashtra (India)
Telephone : +91 (22) 2588 8691 I 2585 5996
Fax : +91 (22) 2588 4594 Mobile : 98670 11744 / 46
E-mail : dabir.ind@gmail.com I dabirtools@gmail.com

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Ambernath : F-60, Engineering Zone,
Additional Ambernath MIDC Area, Ambernath (E),
Thane - 421506, Maharashtra (India)
Mobile : 91374 78226 I 98929 68290
E-mail : dabir.precitech@gmail.com

Thiruvananthapuram

Amphenol India

Connecting The World Together

Amphenol Interconnect India Pvt. Ltd. established in 1972,manufactures high performance connectors and interconnect products, cable assemblies and integrated solutions for Military / Aerospace, Industrial and Telecom markets.

Pune Operations

Bangalore Operations

QUALIFICATION & APPROVAL

Quality System	Customers Approvals	Product Certification
ISO 9001-2008	BrahMos	MIL-STD-38999
MIL-STD-790	ISRO	MIL-STD-24308
AS 9100 Rev C	LCSO	MIL-STD-26482
IRIS	C-DOT	MIL-STD-55181
CEMILAC	CACT	MIL-STD-55116
	BEL	MIL-STD-22992
	ICF	MIL-STD-24308
	HAL	VG 95234
		SAE 85049
		SAE 39029
		SAE ITC UK-Backshell and Bushes for Rolls Royce
		UL- Underwater Laboratories

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Thiruvananthapuram

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