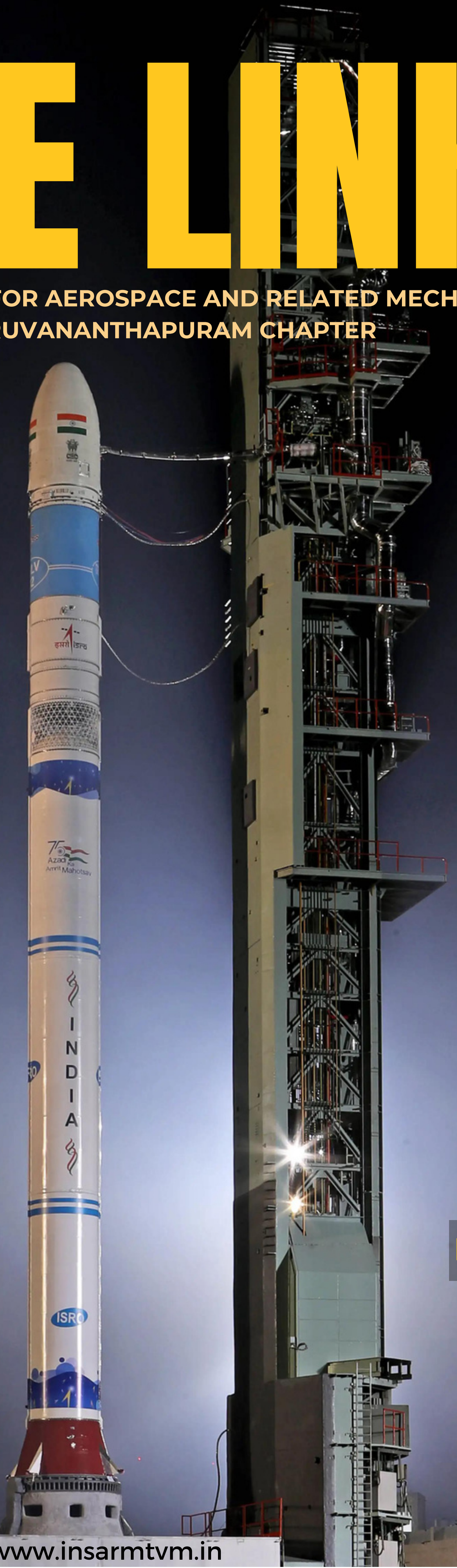
THE LINK

INDIAN NATIONAL SOCIETY FOR AEROSPACE AND RELATED MECHANISMS (INSARM)
THIRUVANANTHAPURAM CHAPTER



TECHNICAL ARTICLE

Human rating of aerospace ordnance systems

AGM 2022

Lecture series, Cultural program

QUIZ / PUZZLE

Trivia Enhances Memory.

BEST M.TECH THESIS AWARD

In the area of Mechanisms

NATIONAL CONFERENCE

FAST 2023
Frontiers of Aerospace Systems and Technologies

NOVEMBER 2023

www.insarmtvm.in





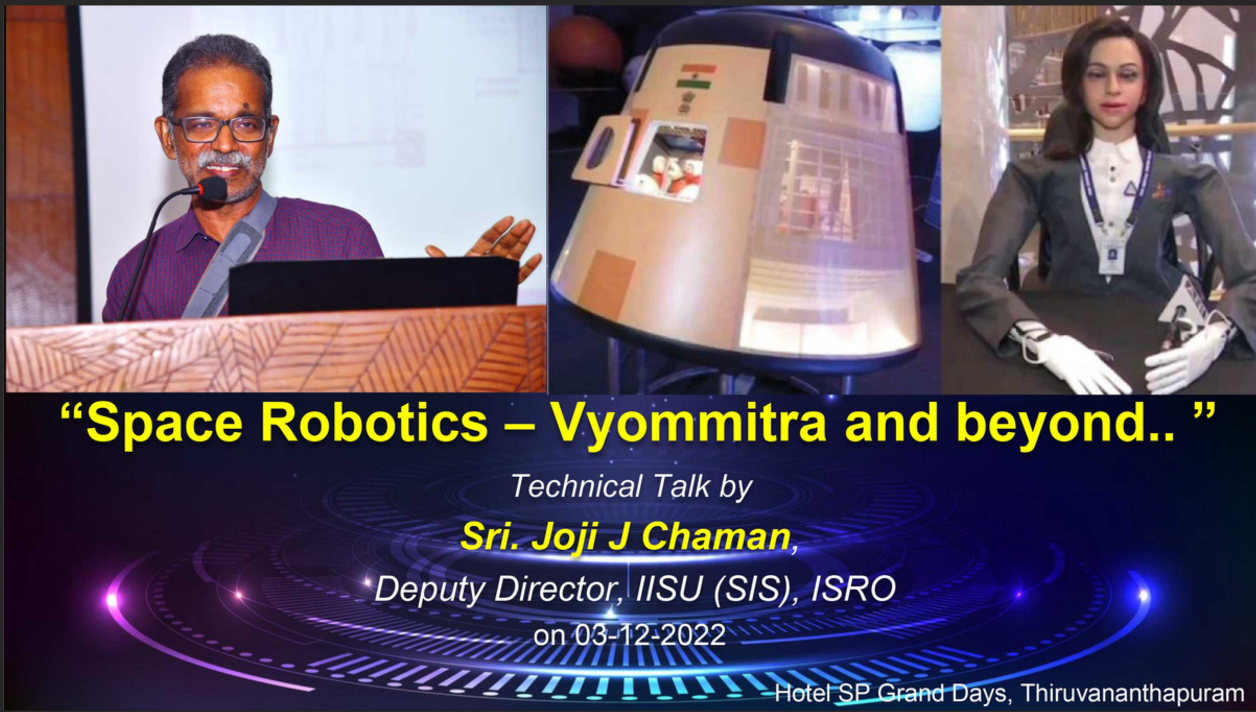

AGM 2022

The Thiruvananthapuram chapter of INSARM held its Annual General Body Meeting (AGM) on December 3, 2022, at Hotel SP Grand Days. The AGM started with the welcome address by President of INSARM Thiruvananthapuram Chapter Shri. U A Subramanian. The Annual report was presented by chapter Secretary, Shri Shiju G Thomas followed by the audit report for the year 2022 by chapter Treasurer Shri. Aasik V. Shri. Joji C Chaman then gave an informative talk on "Space Robotics – Vyommitra and Beyond".

Shri. Kishornath V, presenting awards to InToC 2022 Quiz Winners

The talk gave a detailed understanding of the Vyommitra, the humanoid developed by ISRO which will be sent in the crew module of Gaganyaan mission. After the talk, the winners of the online quiz competition & the members of the magazine team were felicitated by Shri. Kishornath V. The meeting was concluded by the vote thanks by Dr. R Suresh and was followed by Cultural program and dinner.

GLIMPSES OF TECHNICAL TALK



GLIMPSES OF CULTURAL PROGRAMME

Human Rating of Aerospace Ordnance Systems

Shete Mayuresh Kailas#, Bishwajyoti Dutta Majumdar#, N Vinod Kumar*
 # Scientist/Engineer, ASOE, * DD, VSSC (ASOE)

Abstract

Human-rating of aerospace ordnance systems, assumes special significance since they fall under both mission critical and safety critical category. Their "single shot" nature and unique safety constraints necessitate serious attention right from the conceptual design phase for human rating certification. The system design with failure tolerance, design for minimum risk and redundancy are important in the human rating process of aerospace ordnance systems. Reliability of the system can be enhanced by implementing various strategies in the design phase of the product such as providing redundancies and adequate margins of safety with respect to structural load, energetics etc. as well as by use of appropriate materials. This article discusses the salient points regarding the same and brings out the technological challenges in developing aerospace ordnance systems in human rated space applications.

1. Introduction

Aerospace ordnance, refers to a broad family of devices and systems utilizing high explosives or pyrotechnic compositions which are self-contained energy sources. They include initiators, detonators, cartridges, safe and arm devices, thrusters, valves, cutters, mortars, releasers, transfer lines, cords, shaped charges, ignition systems etc.

Ordnance systems or pyros, perform a multitude of functions related to the rocket and the spacecraft such as ignition of solid and cryogenic stages, operation of various mechanisms, spent stage separation, heat shield jettisoning, deployment of spacecraft, deceleration of re-entry modules and are also used in crew escape system of human space missions. In addition, a flight termination system is also provided which shall be called upon in the unlikely event of an anomalous performance of the rocket.

Ordnance systems are advantageous over equivalent mechanical systems as they possess high reliability, high power to weight ratio, a minimum volume to weight ratio, provide instantaneous and closely controlled operation, simultaneity, have relatively long-term storage capability, are rugged, are relatively inexpensive and require only low operating current with a simple firing circuit to function. However, their inherent demerits such as single shot nature and hence the inability to be functionally checked before flight, safety issues in handling, susceptibility to stray current, possibility of damage to other systems due to pyrotechnic shock, outgassing issues and contamination potential have led to development of several Non-Explosive Alternatives (NEA) to substitute many of the typical applications of space ordnance. However, the advantages of using pyrotechnic devices far outweigh the list of disadvantages. Fig. 1 gives a glimpse of the ever-increasing use of ordnance systems in ISRO space programmes.

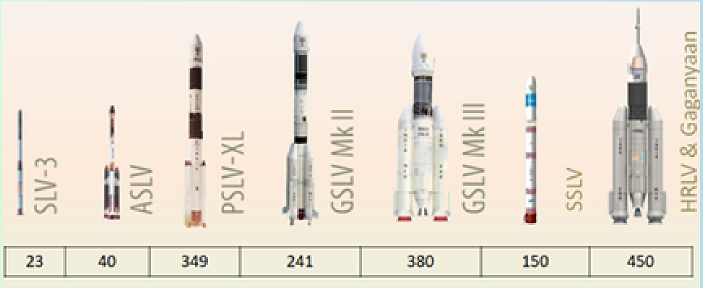


Fig. 1. Number of ordnance systems in ISRO launch vehicles

2. Human Rating Overview

2.1. <u>Concept of Human Rating</u> [1]

A human-rated system accommodates human needs and manages safety risks associated with human spaceflight. It provides, to the maximum extent practical, the capability to safely recover the crew from hazardous situations. Human-rating consists of three fundamental tenets:

1. It is the process of designing, evaluating, and assuring that the total system can safely conduct the required human missions.
2. It includes the incorporation of design features that accommodate human interaction with the system to enhance overall safety and mission success.
3. It includes the incorporation of Crew Escape System to enable safe recovery of the crew from hazardous situations.

Human-rating should only be taken as a certification for missions where safety risks are evaluated and determined to be acceptable for human spaceflight.

2.2. <u>Human Rating Requirements</u> [1]

Human Rating of a space system is generally comprised of three primary factors:

1. Demonstrated launch vehicle reliability.
2. Addition of an emergency detection system that would monitor critical systems and issue status, warning and abort commands.
3. Robust abort capability which ensures minimal catastrophic failures and thrust termination prior to any abort.

3.0. Human Rating Aspects of Space Ordnance

The human-rating of ordnance assumes special significance since these devices and systems fall under both mission critical and safety critical category. The failure to function or premature function of these systems could lead to loss of mission or loss of human life. Under these conditions, given the fact that their failure-tolerant performance cannot be demonstrated *apriori*, it is mandatory to have a ordnance system design and test approach which incorporates a fully redundant, failure-tolerant philosophy. The Fig. 2 gives glimpse of few pyrosystems proposed in a Gaganyaan mission.

Fig. 2. Pyrosystems in Gaganyaan mission

Specifically, in the case of ordnance systems, the important considerations taken related to human rating are failure tolerance, production lot / sampling, design, selection of energetic materials as well as hardware, metallic/ non-metallic materials, performance & sealing aspects, design life and safety considerations both with respect to stray electric environments and in the installation of an adequate flight termination systems. The design and check out of the electrical firing and monitoring circuits for the ordnance device also needs special attention.

In a typical human space mission, ordnance systems are employed in launch vehicle systems, space craft systems and crew escape systems. The recommended practices towards human-rating of ordnance systems are stated as the following:

- Wherever possible, ordnance systems and devices having an established heritage of high reliability are employed.
- Provision for redundancy to meet the desired failure tolerance is ensured i.e. complete system redundancy wherever possible or otherwise redundant cartridges or single cartridges with dual initiators are used along with complete redundancy in the firing circuitry. Redundancy should exist in sealing of explosive charges for isolating vacuum exposure and post fire leakage of product gases.
- Factors of safety and design margins, as demanded by the type of application are provided and validated through tests.
- Igniters for altitude-start engines and motors are tested under simulated conditions to characterize ignition. Safety systems such as safe and arm devices are employed wherever unplanned ignition can have catastrophic consequences.
- Design of pressure activated devices in such a way that they are capable of surviving the lock shut condition without hardware damage and without any debris.
- Energetic materials conforming to the applicable specifications with adequate and demonstrated shelf life are used. When exposed to thermal environments, adequately higher decomposition temperatures are ensured. Performance margin tests are performed at both lower and higher limits of the designed charge quantity under extremes of low and high temperatures.
- All forms of non-destructive test (NDT) methods such as radiographic techniques (X-ray, N-ray) are used for elimination of human errors and assembly adequacy towards acceptance.

3.1 Failure Tolerance

Failure tolerance is regarded as first line of protection against probable hazards. A failure tolerant system is defined as one that has capability to accomplish a function even in the after/during occurrence of a specified number of coincident, independent failure causes. It is a grave deficiency to lack failure tolerance for human-rated vehicles since under critical applications; a single failure could possibly lead to loss of mission (LOM) or loss of crew (LOC).

There are several classes of failure tolerance as follows:

- Single fault tolerant: Single failure or operator error shall not result in functional impairment of the system.
- Dual fault tolerant: Two failures, or two operator errors, or combination thereof shall not result in functional impairment of the system.

To initiate a failure tolerant design, ordnance systems and devices are first broadly classified as either mission critical or crew (safety) critical depending on the hazard potential (critical or catastrophic hazard). A generally accepted failure tolerance philosophy is as follows:

A failure of the system which results in a serious hazard (mission critical) is designed to be single fault tolerant. For a safety critical system, whose failure shall lead to a catastrophic hazard, the design shall be of minimum one failure tolerant with the specific level of failure tolerance (one, two or more) derived from an integrated design and safety analysis. However, the impact of having a blind high failure tolerance requirement would drastically affect mass, volume, and power constraints. Further, such a requirement, at lower levels, may introduce undesirable system intricacies.

Further, standard guidelines to be followed for failure tolerant design are listed below:

- Inadvertent functioning of critical systems must be deterred by minimum three inhibits. i.e. providing necessary safety breaks including Safe Arm devices. Typical examples of such devices are Remote Mounted Safe Arm (RMSA) an “all-purpose” safety device and Head End Mounted Safe Arm (HMSA), specifically designed for solid motor ignition. In case the electrical initiators housed in these devices get inadvertently triggered, functioning of the ordnance system is precluded by a mechanical barrier housed internal to the devices.
- Payload fairing longitudinal separation system based on linear bellow system, assembled on two halves of the system, can be made fault tolerant by providing a Shielded Mild Detonating Cord (SMDC) interconnecting the two halves.
- Initiators are provided at the bottom ends and in case one of these failing to initiate, functioning of SMDC will ensure successful Payload Fairing separation.
- Failure tolerant mechanisms having system level redundancy such as dual redundant bolt cutters, amplifier pyrobolts etc. are employed where failure of one complete chain is tolerable due to fault tolerant design feature.
- Adoption of failure tolerant system design philosophy such as deceleration systems, where redundant Parachutes are employed by considering failure of one complete chain e.g. drogue and/or main parachute system is tolerable.

3.2 Redundancy

Redundancy helps to control potential hazard by the use of multiple independent methods, The specific methods include cross strapping or functional interrelationships, similar or dissimilar redundancy. An important requirement in the application of failure tolerance is that all redundancies should be verifiable during system level testing. The redundancy strategies are categorized in different types as follows.

a. Design Redundancy – When redundant devices are of different designs, usually having different failure modes, it is called design redundancy. Any failure in the basic system configuration is overcome by providing a dissimilar system as redundant. e.g. providing a mechanical severance system as a redundant option for a pyro actuated system can be considered as design redundancy. When a critical system fails because of unexpected performance due to unforeseen conditions, similar redundancy can be futile in preventing complete loss of the system.

- Here, dissimilar redundancy provides an efficient solution. Example is, Head end Mounted Safe Arm (HMSA) interface with motor is provided with dual O-rings viz. a face seal and a shaft seal each. This configuration ensures dissimilar design redundancy towards leak tightness of the interface.

b. Single Redundancy - A single-redundant system [2] is one that will withstand one failure within an assembly or component and still hold the ability of performing the intended function. This level of redundancy is attained by adding one similar assembly or component to the system. Typical example in space ordnance systems include the following.

- Certain pyro systems are initiated using dual Safearm units. In the event of failure of one Safe Arm, the redundant device ensures successful functioning of the system. Such a scheme using RMSA for ignition of solid motors, which also incorporates Explosive Transfer Assemblies (ETA), Explosive Manifolds (M/F) and Through Bulkhead Initiators (TBI) is shown in Fig. 3.

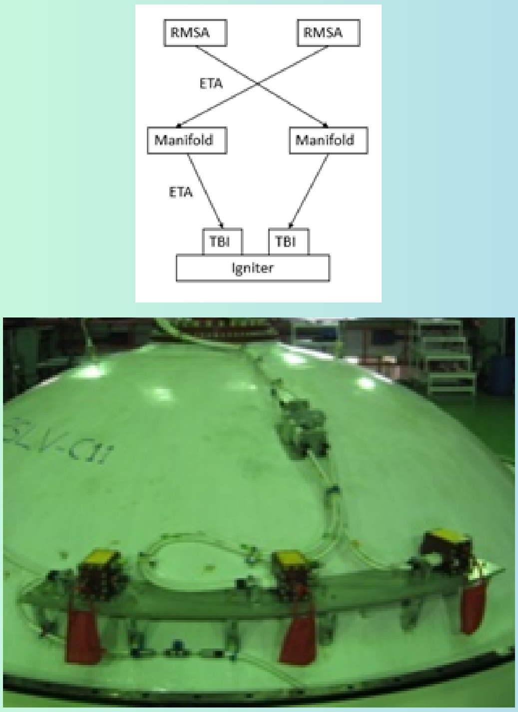


Fig. 3. Dual safe arm based ignition pyro-circuit

- For multi-point stage separation systems using bolt cutters, pyrobolts etc., two ignition cartridges are employed. This makes the system single redundant as in the event of failure of one of the cartridge, other will ensure the function.
- Usually redundant batteries are kept for initiation of pyro systems
- Typically, two separate and electrically independent systems operated in parallel provides complete redundancy in the firing circuitry.

c. Dual Redundancy - A dual-redundant system [2] is one that will sustain two failures of one assembly or component and still hold the ability of accomplishing the intended function. This level of redundancy is accomplished by adding two similar assemblies or components to the system.

- For instance, in the pyro firing circuit, if one battery is required to provide a source of firing current, dual redundancy is provided by two additional batteries.

3.2.1 Practical implementation of redundancy in pyro systems

The inherent single shot nature of the pyro devices requires utmost attention on redundancy aspect, being non-testable apriori, which is suitably addressed by providing redundancy. The redundancy is built-in by one of the following methods:

a. System redundancy: This indicates the highest level of and implies the use of more than one device/system to perform the same function so that the system will work if any one device/system functions. The provision of two bolt cutters in Merman Band based separation system falls under this category.

b. Initiator redundancy: This can be either in the form of two separate ignition/ pressure cartridges, each having their initiators on a device or, alternately, a single cartridge with dual initiators. Any one set functioning will accomplish the mission.

c. Bridge wire redundancy: Here, there shall be only one initiator/cartridge which is equipped with two bridge wires. Hence it has electrical redundancy and also redundancy in the bridge wire -primary charge interface.

Even though it is always desirable to have the highest level of redundancy, the choice of a particular scheme is based on criticality, technological heritage and also considering constraints such as space, availability of energy source etc.

3.3 Design for minimum risk

Human rating of ordnance systems specifies a minimum tolerable level of risk and describes the procedure to obtain a certification that this level is achieved. For the cases, where the design can not achieve full level of failure tolerance, the approach known as design for minimum risk is conceived. The design areas of projected minimum risk must be identified and formal approval to classify them as such must be obtained by the design team. Applicability to Space Ordnance Systems is as follows:

- The margin of safety for human-rated system should be adequate to take care of the uncertainty related with the load estimation, process variations and material property dispersion. The structural design is ensured to take care of 120% of limit load as proof load and 140% of limit load as ultimate load.
- All pyro actuated separation systems such as Flexible Linear Shaped Charge, Expanding Tube Assembly and devices such as bolt cutter should be designed such that the margin on cutting thickness should be 20 % higher than nominal and also should be capable of meeting the cutting requirement with 80% of nominal charge quantity. In case of Linear Bellow System (LBS), separation system should be designed with 20 % margin on rivet resistance.
- The pressure vessels are designed with 1.2 times MEOP for proof pressure and 1.5 times MEOP for ultimate pressure. The qualification hardware has to undergo ultimate pressure tests and every hardware shall be demonstrated through proof pressure testing.

3.4 Reliability

Pyro devices are designed for inherent reliability at component level. But system engineering also should ensure the reliability against random failures. The separation devices generally used are classified into continuous (Linear Shaped Charges, expanded tube assembly, Linear bellow systems etc.) and discrete types (pyro bolt, pyro puller, collet based release mechanism etc.) Pyro shock produced by multi-point systems are one order lesser than continuous separation systems and hence the former is used in separation systems in vicinity of crew occupancy.

On the other hand, application of multi-point release system is a great challenge in terms of reliability because of more number of actuation points for satisfactory system functioning. The approach for improving reliability of such systems is give below:

- Reliable performance of multipoint release systems can be ensured by providing adequate redundancy at system initiation level. For a typical system, reliable system performance can be ensured by providing four-point initiation for system actuation through two initiator configurations for each mechanism [3] (Refer Fig. 4).

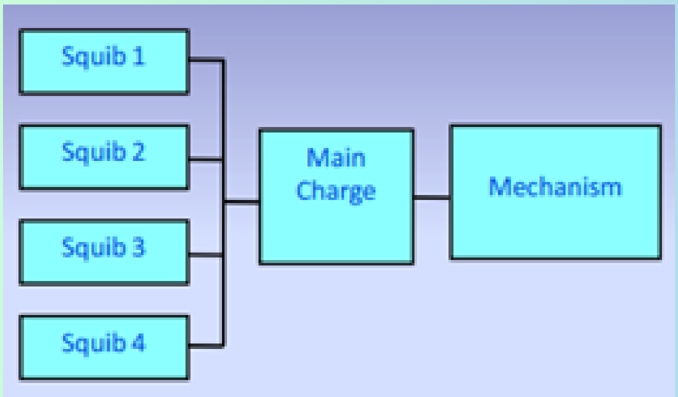


Fig. 4. Four-point initiation with single main charge to improve reliability

- Another option that can be considered for flight critical systems like crew escape system separation mechanism, (multipoint release systems) is the four point initiation redundancy followed by charge level redundancy[3] (Refer Fig. 5).

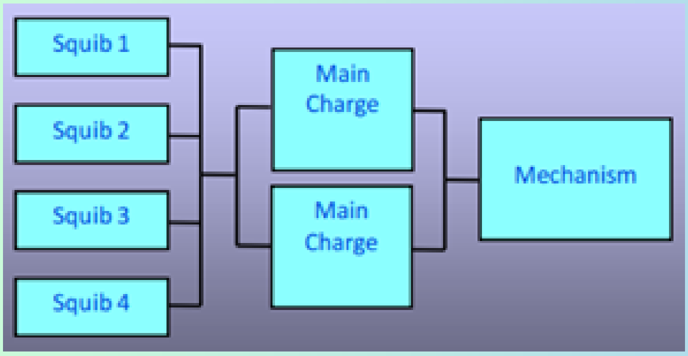


Fig. 5. Four-point initiation with redundant main charge to improve reliability

- Many aerospace Ordnance System chains consists of explosive train starting from Safe Arms, explosive transfer lines, explosive manifolds, detonation transfer joints, TBI etc. The detonation transfer at the interface shall be end to end to ensure positive & reliable detonation transfer. The end to side detonation transfer also is recommended practice whereas side to end transfer shall be avoided in explosive trains (Refer Fig. 6) [4].

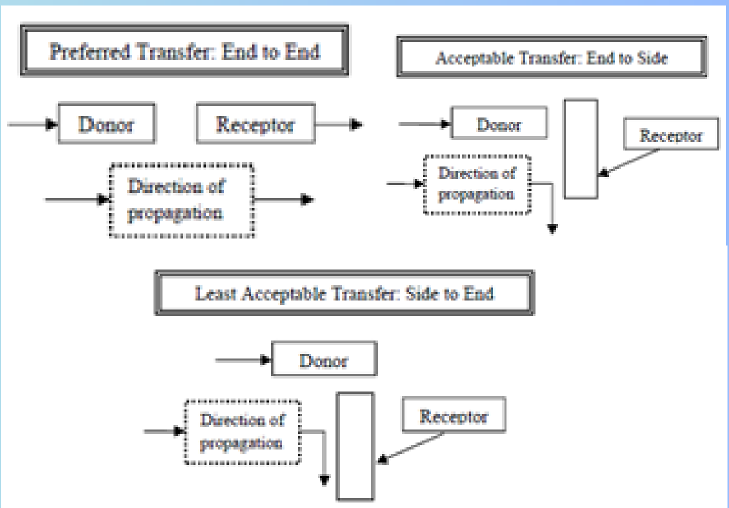


Fig. 6. Detonation transfer modes [2]

3.5 <u>Approach for material selection & Processes</u>

Selection of material is a very important consideration for human rating. Following points should be considered for choosing the material at design phase of the system:

- A-basis material properties are being implemented in the design to guarantee the highest consistency, confidence and performance
- Tighter individual/total impurity contents
- Resistance to Stress corrosion cracking (SCC) & fatigue
- Atmospheric corrosion resistance

- Oxygen compatibility for the pyro devices proposed for cabin pressure control system
- No toxic outgassing for the pyro devices proposed for crew module
- Low outgassing properties in vacuum
- Resistance to uncontrolled fire hazard
- All processes like heat treatment, chemical passivation etc. has to be carried out as per standard practices.
- Strict process guidelines have to be followed to avoid hydrogen embrittlement related problems in the realization of critical flight items like fasteners.
- Strict quality procedures and process capability have to be ensured for realization of systems with high functional reliability.

3.6 Testing aspects

Pyrotechnics, unlike other engineering designs, cannot be functionally verified prior to use. This calls for stringent single-lot control, rigorous testing to develop confidence with very high reliability and quality assurance. Among these, environmental Qualification Test Programme (QTP) and Batch Acceptance Tests (BAT) for functional verification provides the final and the most important check point before flight integration. The test scheme has to be finalized considering the following aspects:

- Adequate no. of tests at appropriate levels to meet the reliability goal.
- Adequate number of samples from the batch for design qualification levels.
- Margin demonstration tests to verify the structural and energetic margins.
- Redundancy verification e.g. single initiator firing tests for devices carrying multiple initiators or firing trains.
- Functional tests under simulated flight environment.

3.7 Safety

The basic philosophy of safety towards human rating of launch vehicle is to have ability to provide a habitable and safe environment for the crew. Following points are to be considered while designing ordnance systems for human rating requirements:

- All initiators should have adequate no-fire rating to take care of all stray electric charges likely to be generated at launch pad and in flight. All pyros should have adequate safety breaks (inhibits) like safe and arm devices for large calibre ordnance systems. These breaks should be closed as late as possible during flight.
- All separation systems near to crew vicinity should be designed in such a way that there should not be any flying debris during functioning of the systems. For this, suitable debris capturing mechanism have to provided, if called for.
- Similarly, the full containment of the products of combustion on actuation of the pyro devices close to the Crew module has to be ensured by designing those items with hermetically sealed unit.
- Another aspect that should be considered during selection of pyro based system for mechanism near to the crew module is the locked shut capability; i.e., the system integrity has to be ensured through functional testing with piston in locked condition at initial position.
- A suitable shock attenuation system shall be designed so that pyroshock generated due to its function shall be within acceptable limits.

4.0 Performance evaluation of Explosive systems

The new generation pyrosystems are designed using modern numerical modelling techniques through optimization of various critical performance parameters towards achieving the required reliability by ensuring adequate margins against all possible failure modes. The validation of these critical performance parameters is also established through various state-of-the art diagnostic tools like high speed photography, Digital Image Correlations, Photonic Doppler Velocimetry, Multi-channel Optical Analyzer, Flash X-Ray Radiography etc towards building the confidence in the prediction methodologies and less number of tests for making the things first time right. This end to end approach makes the design robust within the constraints of cost and schedule.

4.1 Numerical Modelling

Explosive actuated systems have a non-linear transient function which poses challenges to designers in capturing the associated physics such as sudden release of energy from explosives. The process involves large elasto-plastic deformation under high strain rate, material fracture under dynamic loading etc. In most cases, it is impossible to solve these problems either by using conventional analytical equations which are highly idealized or by using empirical relations which have limited fidelity. Thus, modelling of explosive systems using numerical methods has become mandatory in the design and development cycle for design optimization and for reducing development cost & time. Early resolution of issues related to system engineering in the choice of configuration design is another necessity towards having prediction in system performance available much before conducting actual tests.

Various types of analysis are necessary for explosive systems to ascertain adequacy of their design for meeting all the functional requirements well before performing actual experiments. With the availability of modern high speed computers and the well-established numerical codes, the classical pyro design philosophy of “build and break” has been modified to “predict and make”. With the available output data from these analyses, the designer can predict the performance and provide associated inputs to system engineers and plan the experiments with appropriate instrumentation in a more meaningful way to establish design margin on functional critical parameters.

The adequacy of any design under multiple constraints like envelope size, reaction load, Pyroshock level etc. can be verified through numerical modelling and the performance bounds can be predicted much before realization of actual system which enables the system engineer in planning the mission accordingly. The robustness of the design can be verified at the very beginning by carrying out simulations with various off nominal likelihood bounds of critical performance parameters such as material properties, environmental levels, ballistic performance of explosives, variations in assembly conditions etc. Numerical analysis plays a vital role in virtually creating the worst case combinations of various critical parameters where it is difficult to simulate physical experiments such as performance under lowest bound of energy with highest bound of resistance load at lowest temperature limits etc. Thus numerical modelling is used in designing and performance prediction of all Gaganyaan devices right from the very beginning.

4.1.1 Types of Numerical Modeling in pyrosystems

Based on the types of design problems encountered in the field of explosive systems and devices, following types of numerical modelling and analysis (Refer Fig. 7) are required to assess the design adequacy.

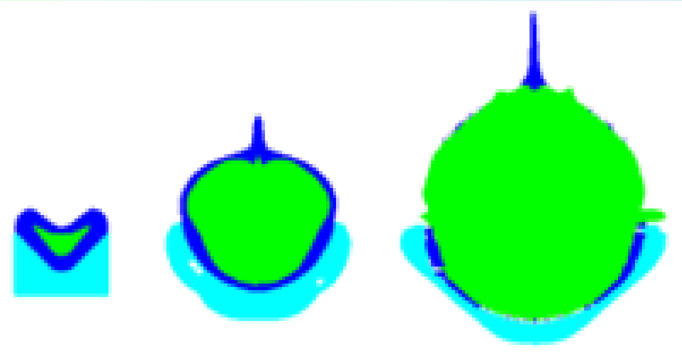


Fig. 7. (a) FLSC hydrocode modeling

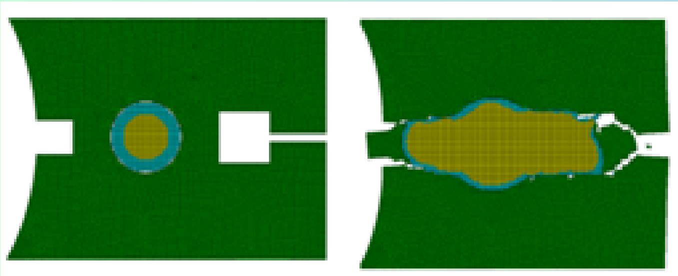


Fig. 7.(b) Explosive Nut hydrocode modeling

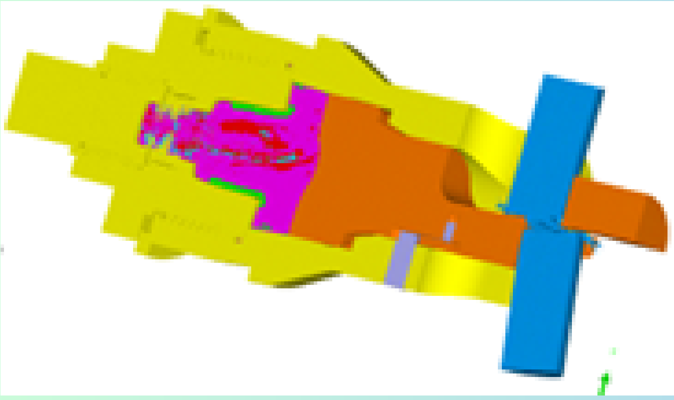


Fig.7.(c) Dia 12 bolt cutter

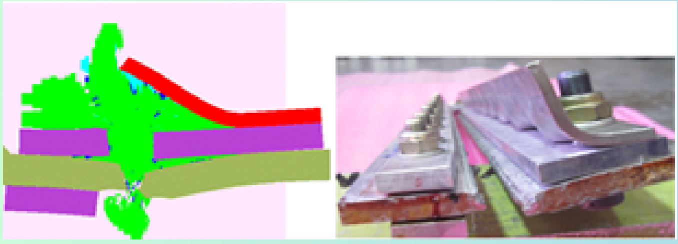


Fig. 7.(d) PS1 separation hydrocode analysis & comparison with flat plate functional test

Structural Analysis: For all structural load bearing components under static and dynamic environments, structural finite element analysis is used. For the loads which are not varying with respect to time for a considerable duration, static structural analysis is adequate to assess structural design margins. However, for time varying loads under dynamic conditions, appropriate dynamic analysis is carried out for predicting the performance of the systems. If natural frequencies and corresponding mode shapes are of interest, modal analysis is carried out to extract all necessary information.

Ballistic Analysis: Systems like igniters, cartridge actuated devices (CAD) and expanding bellow based systems where the pressure generated by the combustion of explosives and propellants are utilized to do intended work, are assessed through ballistic analysis. In this analysis, dynamics of combustion reaction and flow of product gases are modelled along with dynamics of the component and material fracture. Based on complexity of the problems, the ballistic analysis is coupled with other numerical analyses such as explicit dynamics, gas dynamics, heat transfer analysis etc. for incorporating strain rate dependent material properties, flow associated physics, heat loss and thermo-structural response.

Hydrocode Analysis: It is a special class of dynamic analysis, which is essential when the loads are highly transient and the shock wave is involved in the structure due to sudden variation in the load with time. These transient loads are developed due to high velocity impact or blasting of explosives. Systems with high explosive detonations as well as the low explosive deflagrations with a very small pressure rise time, fall under this category of analysis.

Thermal and Flow Analysis: These analyses are essential for initiators and igniters involving thermo- chemical reaction and the flow of hot gases and particles. Based on the applications, both static and transient with reactive flow analysis are required to assess the design and to predict their performance.

4.2 Experimental evaluation

Performance evaluation is carried out for high energy materials, devices and systems used in space ordnance. For example, the performance of high explosives and pyrotechnic charges are verified through chemical analysis, calorimetric evaluation, thermal characterisation and kinetic evaluation. Friction, impact, Electro Magnetic Interference (EMI) and spark sensitivity are evaluated as standard tests for safety. Initiators, including pressure and ignition cartridges, undergo closed bomb pressure tests for ballistic performance evaluation and Bruceton tests for determination of no fire, all fire and recommended fire currents. Outputs of detonators are evaluated using ‘Trauzl’ lead block tests, Plate Dent Tests and Flyer Plate Velocity Measurement tests using Photonic Doppler Velocimeter and Flash X-ray. High explosive based mild detonating cords, FLSC systems undergo Velocity of Detonation (VoD) measurements for assessing the performance in addition to plate dent tests and functional tests to confirm severance of the specified type and thickness of target material.

A few devices, generally samples drawn from the batch, after completion of processing, undergo environmental exposures which include thermal, humidity, vibration and shock testing and thereafter, are functionally tested for confirming adequacy of performance.

In addition, system level tests are carried out where devices are assembled in full-fledged systems and its intended functions are assessed. Pyroshock survivability tests form another critical test scheme wherever such a requirement exists.

The modern techniques are incorporated for evaluation of explosive systems in addition to present conventional methods which includes high speed diagnostic tools like Flash X Ray, Photonic Doppler Velocimetry (PDV), High Speed Camera, Digital Image Co-relation (DIC), High Speed Pyrometer, High Resolution Source Measure Unit for Electro Thermal Response (ETR) Test, Ballistic parameter evaluation through high resolution and high sampling rate pressure measurements, Pyroshock is measured using high ‘g’ shock accelerometers and high speed data acquisition systems. Split Hopkinson Pressure Bar (SHPB) aids material characterisation in terms of constitutive relations and damage parameter evaluation under high strain rates which provides necessary design inputs towards numerical modelling (Refer Fig. 8).

ADRL facilities

SHPB – used for AA2219, Inconel 718, XBS rivet, AISI304L evaluation

Flash X-Ray

PDV

Fig. 8. Newly established facilities at Advanced Detonics Research laboratory (ADRL)

Conclusion

The foregoing sections provide a comprehensive overview of the human rating, strategies adopted for space ordnance human ratings. Human rating is the process of designing, evaluating and assuring that the entire system can safely and reliably carry out the required human space missions. The human rating aspects and technological challenges in developing aerospace ordnance systems are discussed in this article. The important considerations while designing these systems are failure tolerance, provision of redundancy and design for minimum risk strategies. The reliability considerations shall be thought in the design phase of the system itself so as to incorporate redundancy and improving structural and ballistics margins of ordnance systems. The qualification and batch acceptance program towards human rating should be 'Test as you fly'. The testing program should include sufficient number of margin and redundancy demonstration tests. Consideration of safety is another important aspect and human rating of launch vehicle should have ability to provide a habitable and safe environment for the crew in all phases of the mission. A long list of references has also been provided to obtain more detailed information on all these aspects.

In the Indian space arena, the PyroLab, established in the year 1967 under the leadership of Dr. APJ Abdul Kalam, has steadily grown in stature and size and is currently the Aero Space Ordnance Entity (ASOE) catering to the diverse needs of various space missions. With decades of experience of using ordnance systems with success, Team ASOE will ensure the delivery of reliable pyrosystems to ISRO's ambitious Gaganyaan program in days to come.

References:

1. "NASA human-rating requirements", NPR 8705.2C
2. Pyrotechnic System Specification MSFC-SPEC-3635
3. Gary Musgrave et al. 'Safety Design for Space Systems'
4. "Atlas and Delta Capabilities to Launch Crew to Low Earth Orbit", Jeff A. Patton and Jonathon D. Barr
5. Srinath. V. Iyengar et al. " Ordnance Safety Requirements for Space Launch Vehicles"
6. Bernard F. Kutter et al. "Ongoing Launch Vehicle Innovation at United Launch Alliance"
7. "Rocket Propulsion Elements", George P. Sutton, John Wiley & Sons, New York, 1963.
8. NASA-SP-8051, "Solid Rocket Motor Igniters", National Technical Information Service, Springfield, VA., March 1971.
9. "Explosive Engineering", Paul W Cooper, Wiley-VCH, 1996
10. Walters. W. P., Zukas. J. A., "Fundamentals of Shaped Charges", Wiley Inter-science, 1989.
11. "Demystifying Explosives", Venugopalan S, Elsevier, 2015
12. "A Manual for Pyrotechnic Design, Development and Qualification", Laurence J. Bement, Morry L. Schimmel, NASA-TM-110172, NASA Langley Research Center, Hampton, Virginia 23681-0001, June 1993.
13. "Aerospace Ordnance Handbook", Frank B. Pollard, Jack H. Arnold Jr., Prentice Hall Inc., New Jersey.
14. " Handbook of Pyrotechnics", Karl O Brauer, Chemical Publishing Co. Inc., New York, 1974.
15. "Theory of Ignition of Solid Propellants", Price E. W, Bradley Jr. H. H., Dehority. G. L., and Ibiricu. M. M., AIAA Journal, Vol. 4, No. 7, July 1966.

AWARDS

2023

INSARM
Thiruvananthapuram Chapter

BEST M. TECH THESIS AWARD

IN THE AREA OF MECHANISMS

APPLICATION TIMELINE

APPLICATION SITE OPENING
01 - 06 - 2023
FINAL DATE OF ONLINE APPLICATION
30 - 06 - 2023
DECLARATION OF RESULTS
DECEMBER 2023

AWARDS

1. Rs. 30000/-
2. Rs. 20000/-
3. Rs. 10000/-
4. & 5. Rs. 5000/-

+91 9895415368, 9447340599, 9400459330
Email : info@insarmtvm.in
Web : www.insarmtvm.in

Awards will be presented at a function hosted by INSARM Thiruvananthapuram Chapter.

NATIONAL CONFERENCE

Indian Society of Systems for Science and Engineering (ISSE)
Thiruvananthapuram Chapter

Indian National Society for Aerospace and Related Mechanisms (INSARM)
Thiruvananthapuram Chapter

FAST- 2023

(Frontiers of Aerospace Systems and Technologies)

National Conference on

Landing & Recovery systems for Aerospace Vehicles (LaRA)

DATES

Date of conference	:	30th June & 1st July 2023
Venue	:	VSSC, Thiruvananthapuram

IN ASSOCIATION WITH

VIKRAM SARABHAI SPACE CENTRE
THIRUVANANTHAPURAM

LIQUID PROPULSION SYSTEMS CENTRE
THIRUVANANTHAPURAM

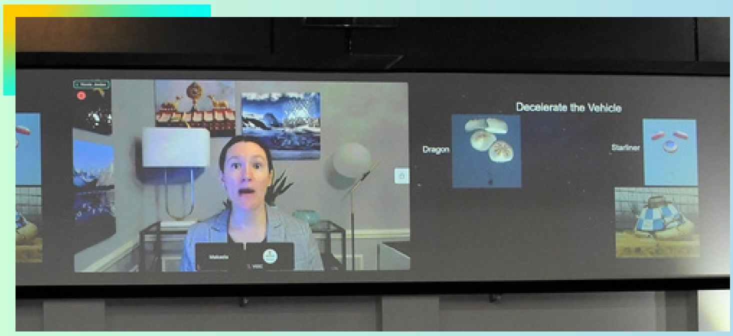
ISRO PROPULSION COMPLEX
MAHENDRAGIRI

ISRO INERTIAL SYSTEMS UNIT
THIRUVANANTHAPURAM

INDIAN INSTITUTE OF SPACE SCIENCE & TECHNOLOGY
THIRUVANANTHAPURAM

*Inaugural Address by Shri. S. Somanath,
Chairman ISRO/ Secretary DOS*

*Presidential Address by Dr. S. Unnikrishnan Nair,
Director, VSSC & IIST*



*Keynote Address by Ms Nicole Jordan,
Program Officer, NASA Commercial Crew Program Office*

*Cultural Programme and Dinner at
Hotel Hilton Garden Inn*

Glimpses of the Cultural Programme

InToC
(Insarm TvmContests)

InToC 2023

InToC quiz was organized on **23rd July, 2023.** It was an exciting program mixed with fun and knowledge with excellent choice of questions, moderation and team work.

Quiz Master: Shri. Ashish Tomy

Moderator: Ms. Surbhi Baghotia.

Congratulations to the winners!

1 Tanmay Singhal
Balachandran C

2 Vishnu Vardhan

3 Dhanesh C

QUIZ

1. Which of the following types of engines is commonly used in commercial airplanes for propulsion?
a. Turboshaft engine
b. Turbofan engine
c. Turboprop engine
d. Rocket engine

2. What is the primary purpose of a control system in an aircraft?
a. To regulate the flow of fuel to the engine
b. To maintain stability and control of the aircraft
c. To provide oxygen to the passengers
d. To generate electricity for the aircraft's systems

3. Which of the following is an example of a flight control surface on an aircraft?
a. Wingtip vortices
b. Thrust reversers
c. Flaps
d. Horizontal stabilizer

4. What is the purpose of a hydraulic system in an aircraft?
a. To generate electrical power for the aircraft's systems
b. To regulate the temperature inside the aircraft cabin
c. To control the movement of flight control surfaces
d. To provide communication between the flight crew and air traffic control

5. What is the difference between a turbojet engine and a turboprop engine?
a. A turbojet engine is more efficient at high altitudes than a turboprop engine
b. A turbojet engine has a higher thrust-to-weight ratio than a turboprop engine
c. A turboprop engine is more fuel-efficient than a turbojet engine
d. A turboprop engine has a lower operating speed than a turbojet engine

6. Which of the following is a type of landing gear used in aircraft?
a. Skids
b. Pontoons
c. Wheels
d. All of the above

7. What is the purpose of a spoiler on an aircraft?
a. To increase lift
b. To decrease lift
c. To increase speed
d. To decrease speed

8. Which of the following types of engines is commonly used in helicopters?
a. Turboprop engine
b. Turbofan engine
c. Turboshaft engine
d. Ramjet engine

9. What is the function of the pitot-static system in an aircraft?
a. To measure airspeed and altitude
b. To provide electrical power to the aircraft's systems
c. To regulate the temperature inside the aircraft cabin
d. To control the movement of flight control surfaces

10. What is the purpose of a thrust reverser on an aircraft?
a. To increase lift during takeoff
b. To decrease lift during landing
c. To reduce noise during takeoff and landing
d. To increase the aircraft's top speed

11. What is the primary purpose of an anti-icing system on an aircraft?
a. To increase engine power output
b. To prevent ice formation on the wings and control surfaces
c. To reduce drag during flight
d. To improve fuel efficiency

QUIZ

12. Which of the following is a type of engine used in space vehicles such as satellites?
a. Solid rocket motor
b. Jet engine
c. Turboprop engine
d. Diesel engine

13. Which of the following types of engines is commonly used in military aircraft?
a. Turboshaft engine
b. Turbofan engine
c. Turboprop engine
d. Afterburning turbojet engine

14. What is the purpose of a ram air turbine (RAT) on an aircraft?
a. To generate electrical power for the aircraft's systems
b. To control the movement of flight control surfaces
c. To provide additional thrust during takeoff
d. To provide emergency power in case of engine failure

15. What is the purpose of a stall warning system on an aircraft?
a. To prevent the aircraft from exceeding its maximum speed
b. To prevent the aircraft from stalling
c. To provide navigation information to the flight crew
d. To alert the flight crew of an engine failure

16. Which of the following types of aircraft uses a rotor system for lift and propulsion?
a. Airplane
b. Helicopter
c. Glider
d. Balloon

17. What is the primary purpose of a vortex generator on an aircraft wing?
a. To increase lift
b. To decrease lift
c. To increase speed
d. To decrease speed

18. Which of the following is an example of an aerospace material used in aircraft construction?
a. Aluminum
b. Steel
c. Copper
d. Zinc

19. What is the primary purpose of an angle of attack indicator on an aircraft?
a. To measure airspeed
b. To measure altitude
c. To measure the aircraft's angle of attack
d. To measure the aircraft's fuel level

20. Which of the following types of landing gear is commonly used in military aircraft?
a. Tricycle landing gear
b. Tailwheel landing gear
c. Tandem landing gear
d. Bicycle landing gear

Send your answers to **surbhi_baghotia@vssc.gov.in**

GET THE

LIFETIME MEMBERSHIP

INVITE YOUR FRIENDS AND COLLEAGUES TO JOIN
INSARM THIRUVANANTHAPURAM CHAPTER

5000/-

INTERESTED MEMBERS CAN MAIL TO THE SECRETARY, INSARM THIRUVANANTHAPURAM CHAPTER @ SHIJUGT@GMAIL.COM

WWW.INSARMTVM.IN

Call For Volunteers For The News Letter Team

Contribute Articles for the News Letter.
Mail them to the
Secretary, INSARM Thiruvananthapuram Chapter @
shijugt@gmail.com

Suggest events & send your feedback to the
Secretary, INSARM Thiruvananthapuram Chapter
Shri Shiju G Thomas | shijugt@gmail.com

TEAM THE LINK

Surbhi Baghotia (Team Lead), Ashish Tomy (VSSC),
Vinay Kumar Yadav (VSSC), Chandan Saxena (LPSC),
Jishnu TR (LPSC), Adarsh Chandra (VSSC)