IEI Centenary Publication

Dr Vikram Sarabhai Memorial Lecture

A Compilation of Memorial Lectures
presented in

National Conventions of Aerospace Engineers

35th Indian Engineering Congress

December 18-20, 2020

The Institution of Engineers (India)

8 Gokhale Road Kolkata 700020

Background of

Dr Vikram Sarabhai Memorial Lecture

Dr Vikram Sarabhai was not only an imaginative and creative scientist but also a pioneering industrialist and astute planner. He made significant contributions in the field of cosmic ray physics and in the development of nuclear power and space programmes. He took up the nuclear programmes with a challenge and added fresh dimensions to the space research programmes in 1966 when he became the Chairman of the Atomic Energy Commission.

Dr Sarabhai was born on August 12, 1919 at Ahmedabad in a rich industrialist family. His early education was in a private school and Gujarat College at Ahmedabad. He then went to Cambridge, England and from St John's College obtained his Tripos in 1939. He came back to India and started research work in the field of cosmic rays with Sir C V Raman at the Indian Institute of Science, Bangalore. In 1945, he went back to Cambridge to carry out further research on cosmic rays and there in 1947 obtained Ph D Degree. It was as early as 1942, Dr Sarabhai conceived the idea of starting the Physical Research Laboratory in Ahmedabad. Soon after his return from Cambridge in 1947, Sarabhai started looking for a place for this project. He got a few rooms at the M G Science Institute to start the laboratory and the laboratory was formally opened in April 1954. Dr Sarabhai made the Physical Research Laboratory virtually the cradle of the Indian Space Programme.

Dr Sarabhai not only encouraged science but also devoted a good deal of time to industry. For over 15 years, he nurtured a pharmaceutical industry.

Dr Sarabhai helped to build the Ahmedabad Textile Industry's Research Association (ATIRA) in 1947. During 1949-56, he remained an Honorary Director of ATIRA. In 1962, he helped to found the Indian Institute of Management at Ahmedabad and during 1962-65, he remained an Honorary Director of this Institute.

Today the success of space programmes in our country is largely owing to the groundwork prepared by him in this regard. Due to his efforts only, India could launch its first satellite, Aryabhatta just three and half years after his death.

Dr Sarabhai was a world-renowned figure in the field of space research. He was awarded Bhatnagar Memorial Award for Physics in 1962; Padma Bhushan in 1966 and posthumously Padma Vibhushan. He was elected the Vice-President and Chairman of the U N Conference on peaceful uses of outer space in 1968. He also presided over the Fourteenth General Conference of the International Atomic Energy Agency. Dr Sarabhai died on December 30, 1971 at the age of 52 when he was at the peak of his achievements.

In memory of his dedicated service, The Institution of Engineers (India) instituted an Annual Memorial Lecture in his name during the National Convention of Aerospace Engineers.

Dr Vikram Sarabhai Memorial Lecture

presented during **National Conventions of Aerospace Engineers**

New Frontiers for Indian Aerospace Explortion beyond the Earth Orbits

Dr V Adimurthy

Associate Director
Vikram Sarabhai Space Centre Thiruvananthapuram

SUMMARY

Indian aerospace achievements have come a long way during the past four decades. We have achieved self-reliance in developing space systems in tune with our own societal and technological requirements. In the integrated development of space technology and applications, we today enjoy a very unique position and respect in the world scenario among all the space faring nations. In all these developments we continue to be driven by the vision of Dr. Vikram Sarabhai who looked at space technology as a tool to be used for the benefit of the common man. While the undercurrent of this vision continues, we have in some sense completed the technological agenda foreseen by this great visionary. At this moment, we are looking ahead towards new frontiers of space science and technology, but still in tune with the basic premise laid down by Sarabhai. The main parameters of this new Indian challenge are low cost access to space through reusable launch vehicle technology, air breathing propulsion, and reaching inter planetary space for scientific exploration, resource utilization and possibly new vistas of planetary defence. Many new and The Institution of Engineers (India), Kerala State Centre innovative ideas have been introduced in the recent years. This talk highlights some of these exciting technical and scientific possibilities, which. are sure to inspire and occupy the new generation of Indian space scientists and engineers.

INTRODUCTION

The Indian space programme has its origin with the establishment of the Thumba Equatorial Rocket Launching Station (TERLS),which became operational on November 21, 1963 with the successful launching of a two-stage sounding rocket, Nike-Apache. Through a well-orchestrated programme, India has come a long way in achieving self-reliance in designing and developing space systems in tune with our own societal and technological requirements. The uniqueness of the Indian space programme in providing end-to-end solutions to the national development is described succinctly in Ref. [1]. Two major satellite systems have been established, the Indian National Satellite System INSAT, and the Indian Remote Sensing System IRS. Having learnt the technology through SLV-3 and ASLV programmes, we now have two operational launch vehicles PSLV and GSLV. From the vantage point of space, we address and provide solutions to issues of national development; particularly in the areas of communication, broadcasting, education, and health, timely and precise information about natural resources, meteorological observations and natural disaster management. In the integrated development of space technology and applications, we today enjoy a very unique position and respect in the world scenario among all the space faring nations. In all these developments we are guided by the vision of Dr. Vikram Sarabhai who has said:

" ... we must be second to none in the application of advanced technologies to the real problems of man and society ... "

" ... there is a need for a constant interplay between the basic sciences, technology, industrial practice and management if economic progress is to result ... ".

While the undercurrent of this vision continues, we have in some sense completed the technological agenda foreseen by this great visionary. At this moment, we are looking ahead towards new frontiers of space science and technology, but still in tune with the basic premise laid down by Sarabhai. The main parameters of this new Indian space challenge are low cost access to space through reusable launch vehicle technology, and reaching inter planetary space for scientific exploration, resource utilization and possibly new vistas of planetary defence.

In the area of space transportation, the new challenges will be in the area of hypersonic flow research, management of severe aero thermal environments, development of supersonic combustion air breathing propulsion technology etc. Several study programmes are taken up the world over, driven by the need to reduce the launch cost per kilogram of payload by an order of magnitude compared to conventional launch vehicles. These new generation of space vehicles are expected to fly at hypersonic Mach numbers at relatively low altitudes and hence are required to face severe aero-thermal environments. In this context, a number of complex viscous and shock interactions, high temperature boundary layer transition effects become important. To fully understand these phenomena, there is a strong need to develop state-of-the-art computational as well as experimental facilities in a wide spectrum of areas like aerothermodynamics, thermal protection system design, control and stability.

Coming to interplanetary missions, many new and innovative ideas have been introduced in the recent decades, and applied successfully in the field of aerospace dynamics. The high investments needed for space programmes demand that maximum returns are extracted from the launch system. Trajectory optimization is routinely done for every space launch, and the methods are being continuously improved as more and more complex mission scenarios and constraints are considered. While the pre-1980 lunar missions take the conventional route of lunar transfer from low-Earth parking orbits, recent optimal mission designs open up new avenues for lunar and planetary programmes. Precise transfer trajectory design is important for targeting the moon and other planetary bodies.

While scientific exploration and resource utilization are the main reasons for reaching planetary and asteroid bodies, there is yet another dimension in dealing with near Earth asteroids, which is that of planetary defence. It is widely recognized that there is a small but definite probability of large near-Earth asteroids (NEAs) impacting on our planet. Unlike many other natural calamities, it is possible to predict an asteroid strike well in advance using data bases presently being generated and updated by the world scientific community. Today's technology is mature enough for formulating suitable mitigation measures to avert a NEA impact catastrophe should such a need arise. There are several possible options, which may well become the theme of many space missions of the future.

HYPERSONIC FLOW RESEARCH FOR FUTURE SPACE MISSIONS

Several study programs are taken up the world over, driven by the need to reduce the launch cost per kilogram of payload by an order of magnitude compared to conventional launch vehicles. The future roadmap of Indian Space Research Organisation also envisages several such studies. These new generation of vehicles are expected to fly at hypersonic Mach numbers at relatively low altitudes and hence are required to face severe aerothermal environments. In this context a number of complex viscous and shock interactions, high temperature effects and studies on boundary layer transitions become important [2]. For example, with strong viscous-in viscid interactions, the use of Navier Stokes models becomes imperative. Because of high temperatures involved in the high-speed reentry flows, non-equilibrium processes have to be accounted. Radiation coupling with Navier Stokes solvers may be needed for inter planetary reentry. Rarefied flow computations may no longer be modeled by continuum formulations. Transport and chemistry models have to take into account ablation products as well. Hypersonic boundary layer transition prediction becomes very important in the design of thermal protection as well as in drag prediction and payload estimation. The aerothermodynamic problems and design approaches for the conventional expendable launch vehicles are described at length in Ref. [3,4]. The basic scientific and technical challenge in hypersonic flow research in developing our future space transportation systems is the theme of Ref. [5].

The challenges in hypersonic flows are broadly in the three areas of viscous interaction, high-speed boundary layer transition and high temperature effects. The prediction of transition at hypersonic flows continues to be a very difficult task. There are many factors like Reynolds number, Mach number, nose bluntness, free stream turbulence, wall temperature and surface roughness affecting the transition. One of the most important factors to be handled in the development of hypersonic technology is the high temperature due to aero heating during reentry. As the vehicle reenters the atmosphere it passes through free molecular regime, transitional regime and then finally through the continuum regime. The maximum heating occurs during the continuum regime when the atmosphere is denser. The following important aspects have to be considered:

a) Thermal non-equilibrium
b) Chemical non-equilibrium
c) Communication black out
d) Wall catalyticity
e) Radiating shock layers

Fig.l shows various types of viscous interaction problems encountered in a typical reusable launch vehicle.

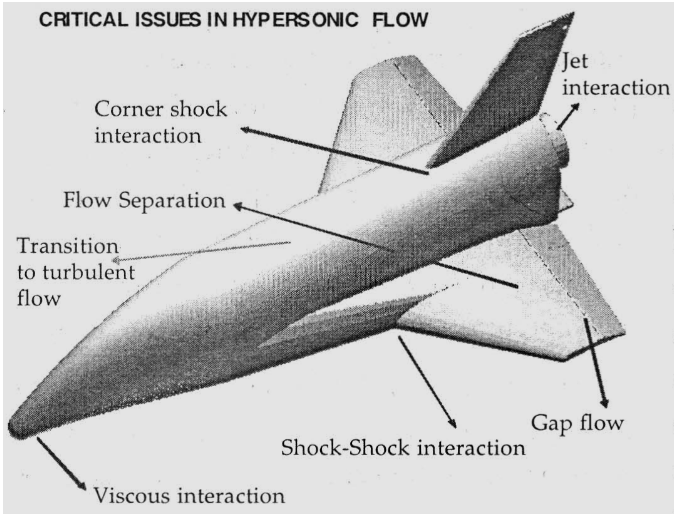


Fig. 1 – Critical issues in hypersonic flow

Both experimental and numerical simulations play a significant complementary role in hypersonic vehicle design. Basic experimental studies are required to understand the physics, and also to get sufficient data to enable the designer to model the phenomenon.

The computations playa dominant role in hypersonic flow mainly from the point of view of extremely difficult and costly experiments to simulate such flows. The initiatives taken in this direction are in developing the computational infrastructure and the PARAS computational system for complex aerodynamic flow calculations. Similarly utilizing existing facilities and developing new facilities address the requirements of experimental simulation. Hypersonic high enthalpy flow simulation poses additional challenges in facility development, instrumentation and flow diagnostics. Flight test programmes also provide valuable further source of measurement.

THE QUEST FOR PLANETARY MISSIONS

There is a substantial amount of application oriented research in the field of aerospace dynamics. Trajectory optimization is routinely done for every space launch, and the methods are being continuously improved as more and more complex mission scenarios and constraints are considered. Optimal guidance laws catering to diverse applications are generated. Aerodynamic shape optimization is a classical topic with reference drag minimization. Lunar and planetary mission studies offer the designer a challenging area for optimization. While all the pre-1980 lunar missions take the conventional route of lunar transfer from low-Earth parking orbits, recent optimal mission designs open up new avenues for lunar and planetary programmes. Many techniques and algorithms exist to generate the lunar transfer trajectory characteristics. The transfer trajectories generated using these techniques, achieves the target parameters with some error. These methods are analytical in nature and cannot model the asphericity of the target bodies that is Earth and the Moon. The asphericity of the Earth is a major perturbing force on these trajectories.

A first step for interplanetary missions is the mission to Moon. With the Chardrayaan-l around the corner there is great national and international expectation and excitement. Many techniques and algorithms exist to generate the lunar transfer trajectory characteristics. They are based on point conic, patched conic or pseudo conic techniques. The asphericity of the Earth is a major perturbing force on these trajectories. The only way to determine the precise transfer trajectory by including these perturbations is search by numerical simulation. Evidently, the search must be regulated using some optimization technique like a genetic algorithm. The precise transfer trajectory characteristics are generated using numerical simulation by search is the theme of the work reported in Ref. [6,7].

Lunar gravity assist trajectories to reach geostationary orbits (GSO) are indeed very interesting. It may look paradoxical, but it is true that under certain conditions, we can reach GSO more cost effectively by going via the

Moon. One can also reach several other interesting orbits via the Moon, for example a circular Earth orbit of the size of lunar orbit itself, without the need of any additional propulsive force. Some of these studies are reported in Ref. [8]. If one considers an initial transfer orbit of 300 × 36000 km at an inclination of 50 deg, going to GSO by conventional route would require a velocity addition of 2,350 m/s. But using lunar gravity assist, the total velocity requirement would be only 1,766 ml s resulting in a gain of 585 ml s. Typical design of the optimal trajectory is depicted in Fig. 2.

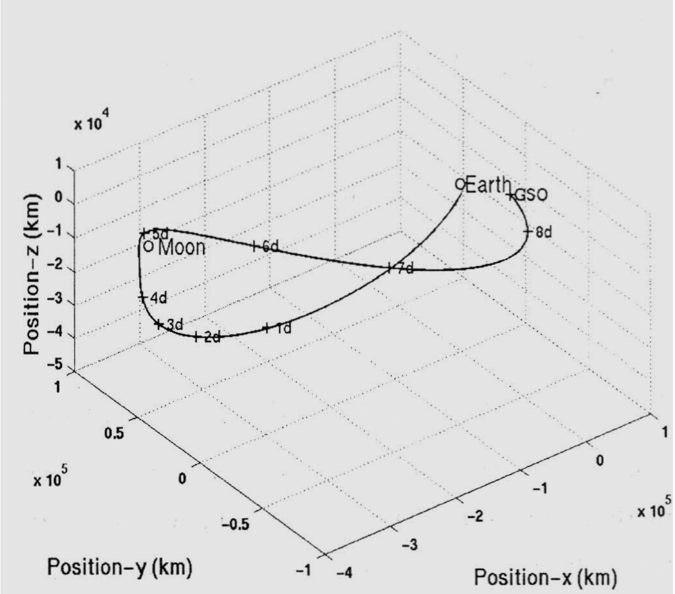


Fig. 2 – Typical Optimal Gravity Assist Trajectory

After reaching the Moon, the spacecraft is put into an orbit around the Moon. The inclination of the lunar orbit mainly influences the life of these spacecraft through Moon's aspherical gravity field. For example, a spacecraft in 90 deg orbit relative to Moon equator will crash into the Moon in about 180days if regular orbit maintenance is not carried out. However, by appropriate choice of inclination the life of the spacecraft can be extended for many years. Maintenance cost is reduced drastically. Ramanan and Adimurthy [9] discuss about proper choice of inclination and find that a spacecraft in about 85 deg or 95 deg inclination lives longer in the orbit. Such phenomenon is presented in Fig. 3. For the evolution a lunar gravity model LPI00J with degree and order of spherical harmonics 40 is used.

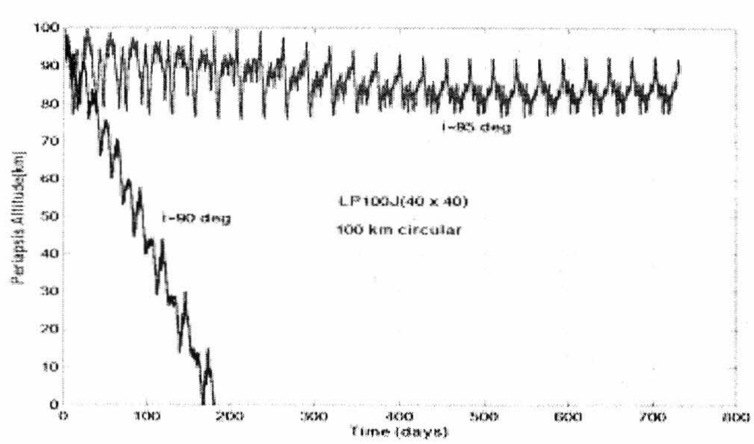


Fig. 3 – Evolution of Lunar orbits with different inclinations

PLANETARY MISSIONS

In the planning of planetary missions, establishing the transfer trajectory design is the first and the foremost requirement. The spacecraft, in such missions, passes through multiple gravity fields. In general, the trajectory design of planetary missions from the Earth involves three major phases: (i) geocentric hyperbolic trajectory phase (ii) heliocentric transfer trajectory phase (iii) planet centric hyperbolic trajectory phase.

The planetary missions, in general, are classified into two categories (i) Flyby mission (ii) Orbiter mission. In a Flyby mission, only the TPI impulse is minimized whereas for an orbiter mission the sum of the impulses required for TPI and POI (Planetary Orbit Injection) is minimized. Here, typical launch opportunities for Earth-Mars, Earth-Venus, Earth-Mercury and Earth-Jupiter missions are listed. The TPI and POI requirements are given for flyby as well as orbiter missions for the planetary missions. The parking orbit size is assumed to be 200 km × 36000 km and inclination of 18 deg is considered. An orbit size of 1000 km circular is assumed for planetary orbit insertion purposes.

Typical Earth-Mars, Earth-Venus, Earth-Mercury and Earth-Jupiter transfer opportunities for a flyby mission in are presented in Table 1. The minimum TPI impulse requirement varies with launch opportunities. It varies between 1.1 km/s to 1.5 km/s in one synodic cycle for Earth-Mars Mission. Typical orbiter mission opportunities and its TPI requirements are given in Table 2. Although impulse at the TPI is more than the flyby requirements, the total impulse requirements that includes the Planetary Orbit Insertion (POI) requirements are less. The total impulse requirement varies from 3.1 km/ s to 3.9 km/ s for Earth-Mars Missions.

Table 1 – Typical Minimum Impulse Flyby Mission Opportunities

Transfer	*Epoch*	*Flight Duration (days)*	*DELV_TPI (km/s)*
Earth-Mars	Jan. 2016	276	1.295
Earth-Venus	29 Oct. 2013	161	1.1352
Earth-Mercury	10 Oct. 2009	117	2.7299
Earth-Jupiter	12 July 2011	874	3.9396

Table 2 – Typical Minimum Impulse Orbiter Mission Opportunities

Transfer	*Epoch*	*Flight Duration (days)*	*DELV_TPI (km/s)*	*DELV_POI (km/s)*
Earth-Mars	Jan. 2016	308	1.097	3.884
Earth-Venus	15 Nov. 2013	161	1.5799	3.2960
Earth-Mercury	14 Oct. 2009	112	2.7746	10.9959
Earth-Jupiter	13 July 2011	887	3.9410	17.6007

ASTEROID MISSIONS

Several thousands of asteroids are our companions in the outer space. Majority of them are in the asteroid belt between Mars and Jupiter orbits. Some groups of asteroids are very close to Earth and they pose collision danger in future. So, the nature of the asteroids must be known for any precautionary measure. Many missions to asteroids have taken place and many of them are being planned. We have studied missions to some of the asteroids. Both flyby and orbiter missions are studied by minimizing the energy required. The Near Earth Asteroids Toutatis and Itokawa and Ceres, Vesta, the asteroids in the main belt, are considered in this study. Table 3 and Table 4 present the details of the launch opportunity, flight duration and the impulse required from an Earth Parking orbit (240 × 36000 km). On arrival for orbiter 1000 km has been assumed. The impulse requirements for flyby missions to Near Earth Asteroids are less than 1 km/ s where as for belt asteroids it is more than 2.5 km/ s.

Table 3 – Asteroid Flyby Mission Opportunities in 2015

Asteroid Name	Departure Epoch (days)	Flight duration (km/s)	Del V from GTO to Asteroid
TOUTATIS	09-Mar-16	286	0.769
ITOKAWA	13-Sep-15	371	0.907
CERES	10-May-15	774	2.749
VESTA	22-Jun-15	515	2.345

Table 4 – Asteroid Orbiter Mission Opportunities in 2015

Asteroid Name	Departure Epoch	Flight duration (days) (km/s)	Del V from GTO to Asteroid (km/s)	DEL V for Orbiting the Asteroid (km/s)	Total Del V
TOUTATIS	30-Oct-15	1760	3.774	0.945	4.719
ITOKAWA	11-Jul-15	382	1.481	1.938	3.419
CERES	04-May-15	759	2.794	7.285	10.079
VESTA	26-Jun-15	521	2.380	4.369	6.750

DEFLECTING ASTEROIDS IN COLLISION COURSE WITH THE EARTH

It is widely recognized that there is a small but definite probability of large near-Earth asteroids (NEAs) impacting on our planet. The Earth has experienced several asteroid strikes in its 4.5 billion year history and about 170 impact craters have been identified on its surface. There is a 1.8 km impact crater in India at Lonar, which is estimated to have occurred about 50,000 years ago. A giant crater about 180 km across near Mexico is now definitely identified with an impact event about 65 million years ago which produced a major biological extinction marking the K-T boundary that separates the age of reptiles and the age of mammals. In 1908, an asteroid, perhaps 30-50 m across, exploded in the sky above the Tunguska River of Siberia producing an air blast that flattened about 2000 km^2 of forest.

Unlike many other natural calamities, it is possible to predict an asteroid strike well in advance using data bases presently being generated and updated by the world scientific community. Today's technology is mature enough for formulating suitable mitigation measures to avert a NEA impact catastrophe should such a need arise. An approaching asteroid can be deflected as a part of mitigation measure. Various plans of deflecting an Earth-bound asteroid fall into two categories; those that rely on brief but intense application of force, and those that involve gently pushing or pulling the body over a long time. The frequently mentioned technological options are kinetic impact, nuclear explosion, laserablation, solar radiation pressure, land-and-push etc. Adequate warning time is a prerequisite for efficient design and successful implementation of deflecting a hazardous asteroid. Accurate detection and tracking are equally essential. Technological and scientific missions that are currently planned by the space faring nations to reach and explore the asteroids will go a long way not only in providing invaluable scientific data and information on possible scarce resources, but also in consolidating the defection options for a planetary defence system.

There should be an international effort to disseminate the NEA knowledge to all the nations. This includes not only the databases and catalogues of the objects, but also sharing the expertise to analyze the information to enable participation in the process of risk assessment, exploration and mitigation. Scientific attitude to NEA risk assessment should be propagated to control alarmist predictions and responses. Some of these issues are focused at the 2004 Planetary Defence Conference. At this juncture, a forum like UN-COPUOS and the cooperative spirit of international scientific community may provide a basis for international cooperation in NEA research, so that a planetary defense system may be put in place for the whole humanity.

References

1. G. Madhavan Nair: 'Four Decades of Indian Launch Vehicle Technology'. Journal of Aerospace Sciences and Technolog.ies, Vol. 56, pp. 85-92, 2004.

2. J.H. Bertin, R.M.Cummings: 'Fifty Years of Hypersonics: Where we've been, Where we're going'. Progress in Aerospace Sci. Vol. 39 , pp.511-536,2003.

3. V. Adimurthy, A.N. Subash, P. Srinivasa, R. Balu: 'Synthesis of Experiment al, Analytical and Computational Approaches for Launch Vehicle Aerodynamic Design'. Proceedings of the Conference on Flight Vehicle Aerodynamics. Ed. by S. P. Govinda Raju et al., Indian Institute of Science, Bangalore, pp. 29-37, 1997.

4. V. Adimurthy, R. Balu et al.: 'Multidisciplinary Optimization in Aerospace Design, the Emerging Technology for Complex Systems'. Journal of Aerospace Sciences and Technologies, 57, pp. 79-92, 2005.

5. V. Adimurthy, 'Hypersonic Flow Research for future Space Missions', Proceedings of the 25th International Symposium on Shock Waves, Ed. G.Jagadeesh, E.Arunan, & K.P.J.Reddy, ISBN: 81- 7525-662-1, Bangalore, pp.67-74,2005.

6. R.V.Ramanan and V. Adirnurthy, 'Non Impact Lunar Transfer Trajectories Using the Pseudostate Technique', Journal of Guidance, Control, & Dynamics, American Institute of Aeronautics and Astronautics, Vol.28, pp. 217-225, 2005.

7. V. Adimurthy, R.V.Ramanan, S.R. Tandon, and C. Ravikumar, 'Launch Strategy for Indian Lunar Mission and Precision Injection to Moon using Genetic Algorithm', Journal of Earth System Sciences, Vol. 114, No. 6,pp. 711-716, December 2005.

8. R.V. Ramanan and V. Adimurthy, 'Precise Lunar Gravity Assist Transfers to Geo-stationary Orbits', Journal of Guidance, Control, & Dynamics, Vol. 29, pp.500-502, 2006.

9. R.V. Ramanan and V. Adimurthy, 'An Analysis of Near Circular Lunar Mapping Orbits', Journal of Earth System Sciences, Vo1.114, No.6, pp.619-626, December 2005.

Boom in Aviation, But no Boom in Aeronautics?

Prof Roddam Narasimha

Chairman
Jawaharlal Nehru Centre for Advanced Scientific Research Bangalore

India is experiencing an unprecedented boom in civil aviation. Industry is busy with production of several military aircraft on license. However this buoyancy in flying activity and in production is not matched by a similar spirit in research,, design and development. The lecture will argue that India is once again at the cross roads in its aeronautical history, and concerted and determined action will be required, in both private and public sectors, if an R&D boom has also to occur. Such a boom is entirely feasible, and the lecture will suggest how it may be made to happen.

Earth to Orbit: The Crucial First Step in Accessing Space

Padma Shri S Ramakrishnan

Director,
Liquid Propulsion Systems Centre, ISRO, Trivandrum
director@lpsc.gov.in

To reach Space from Earth, overcoming the deep gravity well, transcending the dense atmospheric shield, is the most energy intensive challenging task and the rocket propulsion based Satellite Launch Vehicles are the currently viable primary means of accessing space. The launch vehicle technology encompasses a wide spectrum of engineering and science disciplines. While propulsion systems or the 'rocket' constitutes the backbone for the multistage launch vehicle to perform a precise mission of deploying spacecraft into a specified orbit, the control/steering, guidance, navigation and staging systems are equally vital requirements.

Launch Vehicle development is essentially a multi-disciplinary complex engineering activity. While vehicle systems design and analysis is software intensive, realisation of a Satellite Launcher involves wide range of hardware with several subsystems and interfaces, requiring considerable efforts and resources for product design, detailed engineering and interface management tasks. Integrated vehicle for a new launcher-is reached through a process of evolution starting from mock-up, structural model, proto sub-assemblies etc., which are put through a variety of well-planned tests on ground.

The Flight vehicle integration and checkout and preparation of the vehicle and the spacecraft for launch takes place at the Launch Complex and is repetitive for each mission. Trajectory design/Mission analysis and Range safety implementation are also unique for every launch.

The first step in accessing space is to reach a payload to an orbit around earth from where one can navigate the spacecraft for a rendezvous with Moon, Mars or any other planetary body. The remarkably versatile PSLV which has so far accomplished an unbroken string of nineteen successful missions provides India an assured access to space and enables the country to undertake more complex planetary missions. The operationalisation of GSLV and the development of LVM3 launcher will further enhance this capability in the coming years.

Indian Aerospace Perspectives

Prof Rajaram Nagappa, *FNAE, FAeSI*

Visiting Professor and Head
International Strategic and Security Studies Programme
National Institute of Advanced Studies, Bangalore

Indian aerospace perspectives are examined relevant to the theme of the seminar on Expanding Frontiers in Aerospace Technologies. The background of the early Indian aircraft and space capability is examined. The current levels of achievements are seen to be below what we are capable of. Playing catch-up is a good way to start, but at what point we jump to the caught-up and go beyond is equally important. In this scenario, harnessing and developing indigenous technology plays an important role as opposed to continuous procured and licenced technology. China has made rapid strides in both aircraft and space technology and it makes sense to compare the developments in the two countries, as the technology level in both the countries were comparable in the 1960's. Certain level of focus on strategy drivers, organizational restructuring and greater levels of industry participation may be part of the solution.

Dr Vikram Sarabhai Memorial Lecture

Prof K M Parammasivam

Dr. Sarabhai was considered as the father of the Indian space programme. He was a great institution builder and established or helped to establish a large number of institutions in diverse fields. He was instrumental to establishing the Physical Research Laboratory (PRL) in Ahmedabad after returning from Cambridge to an independent India in 1947, be persuaded charitable trusts controlled by his family and friends to endow a research institution near home in Ahmedabad. Thus, Vikram Sarabhai founded the Physical Research Laboratory (PRL) in Ahmedabad on November 11, 1947. He was only 28 at that time. Sarabhai was a creator and cultivator of institutions and PRL was the first step in that direction. Vikram Sarabhai served of PRF from 1966-1971.

He was also Chairman of the Atomic Energy Commission. He along with other Ahmedabad based industrialists played a major role in the creation of Indian Institute of Management, Ahmedabad.

Some of the most well-known institutions established by Dr. Sarabhai are:

1. Physical Research Laboratory (PRL), Ahmedabad
2. Indian Institution of Management (IIM),Ahmedabad
3. Community Science Centre, Ahmedabad
4. Darpan Academy for Performing Arts, Ahmedabad (along with his wife)
5. Vikram Sarabhai Space Centre, Thiruvananthapuram
6. Space Applications Centre, Ahmedabad (This institution came into existence after merging six institutions/centres established by Sarabhai)
7. Faster BreederTest Reactor (FBTR), Kalpakkam
8. Variable Energy Cyclotron Project, Calcutta
9. Electronics Corporation of India Limited (ECIL), Hyderabad
10. Uranium Corporation of India Limited(UCIL), Jaduguda, Bihar

Indian Space Programme:

The establishment of the Indian Space Research Organization (ISRO) was one of his greatest achievements. He successfully convinced the government on the importance of a space programme for a developing country like India after the Russian Sputnik launch. Dr. Sarabhai emphasized the importance of a space programme in his quote:

"There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flight."

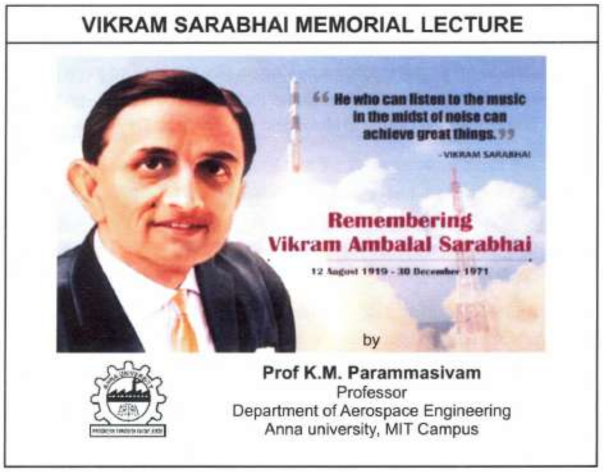
"But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society."

Dr. Homi Jehangir Bhabha, widely regarded as the father of India's nuclear science programme, supported Dr. Sarabhai in setting up the first rocket launching station in India. This center was established at Thumba near Thiruvananthapuram on the cost of the Arabian Sea, primarily because of its proximity to the equator. After a remarkable effort in setting up the infrastructure, personnel, communication links, and launch pads, the inaugural flight was launched on November 21, 1963 with a sodium vapour payload.

As a result of Dr. Sarabhai's dialogue with NASA in 1966, he Satellite Instructional Television Experiment (SITE) was launched during July 1975 - July 1976 (when Dr. Sarabhai was no more).

Dr. Sarabhai started a project for the fabrication and launch of an Indian Satellite. As a result, the first Indian satellite, Aryabhatta, was put in orbit in 1975 from a Russian Cosmodrome.

Dr. Sarabhai was very interested in science education and founded a Community Science Centre at Ahmedabad in 1966. Today, the Centre is called the Vikram A. Sarabhai Community Science Centre.



Contents of Presentations

- Introduction
- Research activities
- Aerodynamic Studies on Hypersonic configurations at low speeds
- Aerodynamic of Missile with Planar and Grid Fins
- Morphing Wing Technology
- Aerodynamics of Wind turbines
- Aerodynamics of Road Vehicles
- Flame stabilization with Porous Materials
- Gas Turbine film cooling
- Single Expansion Ramp Nozzle flows
- Conclusions

Introduction

Man's desire to know the unknown has taken him to different parts of the earth. To the depth of the oceans, to the top of the mountains, up in the atmosphere, above the clouds to Moon and now to Mars. This is the search for unknowns.

This spirit of science has made this adventure a worthwhile learning experience. From the invention of the Camel-cart to the development of the Chandrayan — is one great transition made by man as he used science and technology to satisfy his wandering curiosity.

12th August, is the day to remember a luminous scientist, Dr. Vikram A. Sarabhai, popularly known as Father of India's Space Programme, who belongs to this Aerospace Research field and made everybody proud for his pioneering work and contribution.

Vikram Ambalal Sarabhai (12 August 1919 - 30 December 1971) was an Indian physicist. He is considered to be "Father of the Indian space program."

He was born in the city of Ahmedabad. The establishment of the Indian Space Research Organization (ISRO) was one of his greatest achievements.

He successfully convinced the government of the importance of a space programme for a developing country like India after the Russian Sputnik launch.

Vikram Ambalal Sarabhai was born in Ahmedabad, India on August 12, 1919.

His early education was in the family school directed by the mother. His higher education was at the Gujarat College in Ahmedabad and later at St. John's College, Cambridge (U.K.). He received his doctorate degree in 1947 after doing research in photo-fission at the Cavendish Laboratory at Cambridge.

In 1966, Dr. Sarabhai was appointed as the Chairman of the Atomic Energy Commission of the Department of Atomic Energy, Government of India.

The newly forming space program of India was initially started under this commission.

Dr. Sarabhai set up the Thumba Equatorial Rocket launching station in South India and initiated the program for the manufacture of the French Centaure sounding rockets in India.

Like Bhabha, Sarabhai wanted the practical application of science to reach the common man. He saw a golden opportunity to harness space science to the development of the country in the fields of communication, meteorology, remote sensing and education.

For Sarabhai, science is a vehicle to carry India forward and to be prepared to apply the advancements in technology in the real problems of society.

Sarabhai received many awards, including, Bhatnagar Medal (1962), Padma Bhushan (1966),

He was President of the Physics section of the Indian Science Congress (1962).

President of the General Conference of the I.A.EA, Vienna (1970),

Vice-President, Fourth U.N. Conference on peaceful uses of Atomic Energy (1971).

Dr. Vikram A. Sarabhai passed away in his sleep on December 31, 1971. He was truly a rare combination of an innovator, scientist, industrialist and visionary.

On his auspicious Memorial Lecture let's offer our sincere regards and respects to this Great Indian Scientist.

Great minds like Dr. Vikram Sarabhai, who dedicated their lives and resources to the cause of fulfillment of our destiny of being a great nation, embodying the use of advanced Science and Technology to improve the lives of people.

Let us ALL and our younger generation inspire by the works and dedication of Dr. Vikram A Sarabhai.

Research Activities

- Aerodynamic studies on Hypersonic configurations at low speeds
- Aerodynamic of Missile with Planar and Grid Fins
- Morphing Wing Technology
- Aerodynamics of Wind turbines
- Aerodynamics of Road vehicles
- Flame stabilization with Porous Materials
- Gas Turbine film cooling
- Single Expansion Ramp Nozzle flows

Aerodynamic Studies on Hypersonic configurations at low speeds

According to the desired configuration, the vehicle with this design will be taking off from the ground using the sweep back angle of 34 degree and it will increase its sweep back angle to fly at higher Mach number.

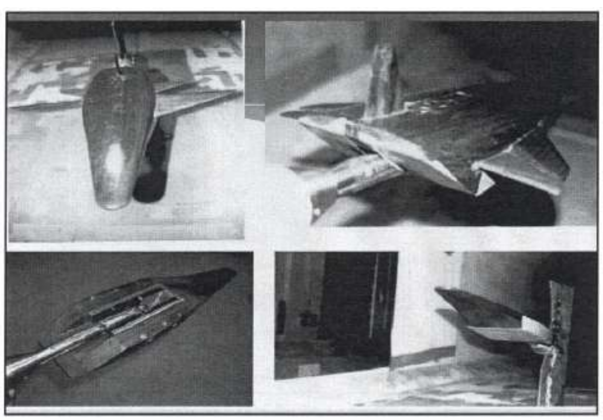
Vehicle with curved forebody produces more lift comparing with the flat forebodies. The curvature in the forebody produces positive lift at zero AOA.

The vehicle with blunt nose configuration will produces more drag at low speeds.

The L/D ratio of the vehicle is maximum for the sweep back angle of 34 degree (body with wing I configuration). This is suitable for low speeds and the same configuration is not suitable for the high speeds. The continuous change in sweep back angle will help to improve the performance of the vehicle at high speeds.

"What, therefore, is a government at its best? It is a government that "governs" least and instead finds ways to mobilize the energies of our people."

-Vikram Sarabhai



Aerodynamics of Missile with Planar and Grid Fins

The research work is focused to obtain the aerodynamic coefficients at large angles of attack on the following configurations using CFD and validating with data from wind tunnel experiments.

- Body alone configuration
- Body with grid configuration
- Body with planar finned configuration

Sl.No	Details	Dimensions
1	Diameter of the ogive cylinder body	70 mm
2	Length of the ogive nose section	2.142d
3	Length of the mid section body	4.285d
4	Length of the aft body	6.714d
5	Total length of the body	7.14d
6	Slenderness ratio (l)	7.14

"Once wants permissive individuals who do not have a compelling need to reassure themselves that they are leaders."

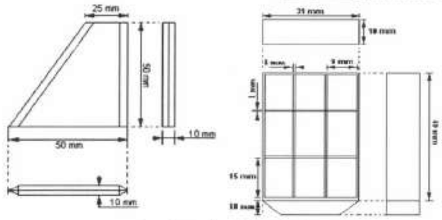
-Vikram Sarabhai

Aerodynamics of Missile

Details of the planar and grid fin configuration

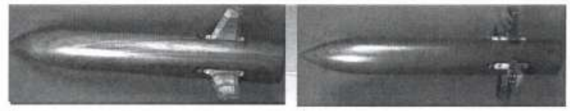
Sl no.	Details	Dimensions
1	Platform	Trapezoidal – double wedge
2	Tip chord	0.35 d
3	Root chord	0.7 d
4	Location of mid chord	1.07 d

Sl no.	Details	Dimensions
1	Span	0.7 d
2	Chord	0.4 d
3	Web thickness	1 mm
4	Spacing along X- axis	0.1 d
5	Spacing along Y-axis	0.2 d
6	Number of rectangular cells	9



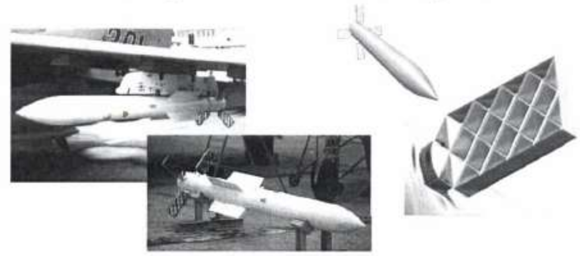
Planar fin and gird fin with dimensions

Aerodynamics of Missile



Planar fin configuration

Grid fin configuration



Aerodynamics of Missile – Observations

NORMAL FORCE COEFFICIENT

Maximum deviation between the computational and experiments for the normal force coefficient was 22% for body alone configuration at $\alpha = 5^{\circ}$ with velocity of 31 m/s and the minimum deviation was 5% for grid fin configuration at $\alpha = -10^{\circ}$ with velocity of 31 m/s. Planar fin configuration had the deviation of 4% to 53% with velocity range of 38 m/s.

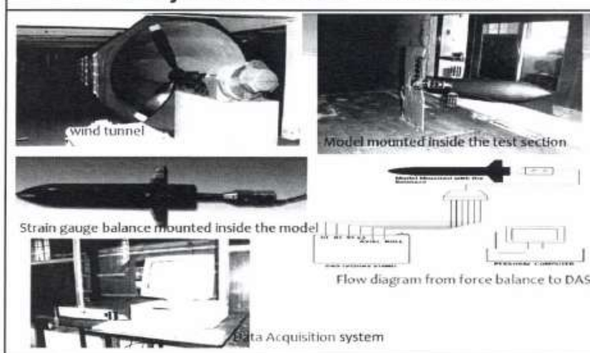
AXIAL FORCE COEFFICIENT

Maximum deviation between the computational and experiments for the axial force coefficient was 22% for body alone configuration at $\alpha = 5^{\circ}$ with velocity of 31 m/s and the minimum deviation was 5% for grid fin configuration at $\alpha = -10^{\circ}$ with velocity of 31 m/s. Planar fin configuration and the deviation of 4% to 53% with velocity of range of 38 m/s.

SIDE FORCE AND ROLLING FORCE COEFFICIENT

The side force and rolling moment coefficients are less effective when compared to that of the other aerodynamic coefficients. The rolling force coefficient has a maximum difference of 38% for the body along configuration at $\alpha = 0^{\circ}$. The side force values almost have negligible range of values when compared to that of the other aerodynamic coefficients. In the comparison of CFD and experimental measured one the side force seems to have the maximum difference when compared to that of the other aerodynamic coefficients. For side force coefficient the maximum and minimum difference falls in the range of 8% to 47% for the body along configuration.

Aerodynamics of Missile – Wind tunnels



Morphing Wing Technology

Aircrafts with morphing ability have a actively adaptive structures which can change their shape to achieve mission requirements with high efficiency.

Advancements in smart actuators such as piezo-ceramics and SMA have helped in achieving smart morphing mechanisms with less weight penalty.

A morphing mechanism which adaptively changes the twist of the wing using shape memory alloy wires presented in this project.

Variable washout is provided by means of a suitable smart actuation mechanism to adapt the wing twist with respect to the mission requirements.

Computational study is applied on a suitable wing model with and without morphing mechanism at a constant velocity of 30 m/s for various angles of attack and washout angles.

The computational analysis of the morphing using model results in decrease in the overall drag due to the adaptable washout and high increase in aerodynamic efficiency.

Also from detailed study of various literatures regarding the flexible material for skin of the wing, it is concluded that the usage of combination of latex sheets with a thin sheets of polypropylene will be best suited for morphing wing.

Aspects related to the smart actuator mechanism which is to be embedded into the using structure for adaptive morphing of the wing.

Aerodynamics studies on Wind Turbines with winglets

The present study explores the possibility of increasing the efficiency of the small horizontal axis wind turbine rotor by adding winglets at the top of the blade.

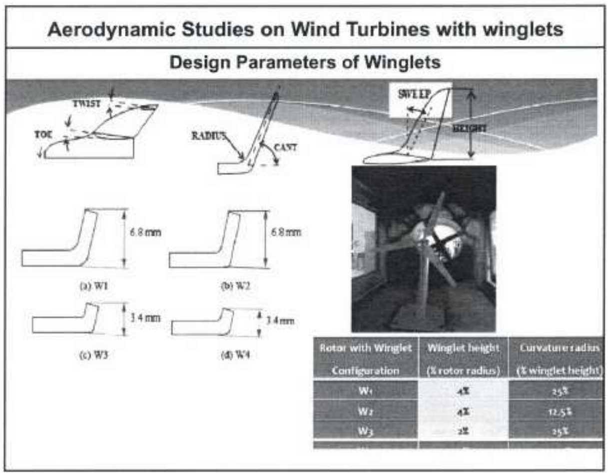
The effects of changing the winglet configuration with the blade on the power performance of small wind turbine rotor models were investigated experimentally.

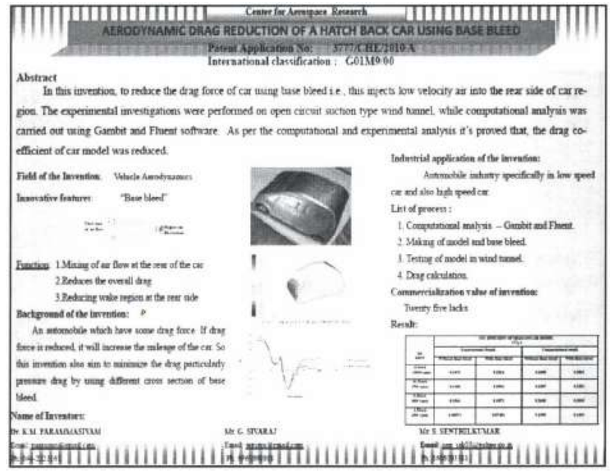
The blades with four different configurations of winglets are fabricated using Glass Fibre Reinforced Plastic materials and are used for the study.

Experiments were conducted for all rotor models with and without load conditions in the wind tunnel for various conditions. The power output is measured for the rotor models with load conditions.

The maximum power coefficient obtained for an effective winglet configuration is about 0.43. It is observed that presence of winglet at the tip of the wind turbine blade will improve the power coefficient for low wind speed regions.

It is recommended that the smaller curvature radius with sufficient winglet height added to the wind turbine rotor captures more wind energy in low and speed region as againt wind turbine rotors without winglets.




Center for Aerospace Research

AERODYNAMIC DRAG REDUCTION OF A HATCH BACK CAR USING BASE BLEED

Patent Application No: 3777/CHE/2010 A

International classification : G01M9/00

Abstract

In this invention, to reduce the drag force of car using base bleed i.e., this injects low velocity air into the rear side of car region. The experimental investigations were performed on open circuit suction type wind tunnel, while computational analysis was carried out using Gambit and Fluent software. As per the computational and experimental analysis it's proved that, the drag coefficient of car model was reduced.

Field of the Invention: Vehicle Aerodynamics

Innovative features: "Base bleed"

Function: 1.Mixing of air flow at the rear of the car 2.Reduces the overall drag 3.Reducing wake region at the rear side

Background of the invention:

An automobile which have some drag force. If drag force is reduced, it will increase the mileage of the car. So this invention also aim to minimize the drag particularly pressure drag by using different cross section of base bleed.

Industrial application of the invention:

Automobile industry specifically in low speed car and also high speed car.

List of process :

1. Computational analysis – Gambit and Fluent.
2. Making of model and base bleed.
3. Testing of model in wind tunnel.
4. Drag calculation.

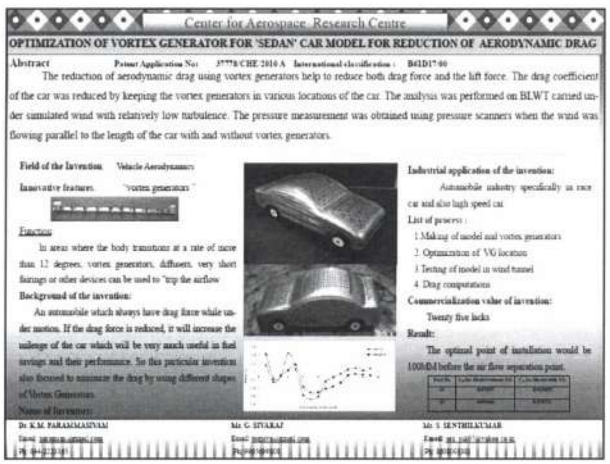
Commercialization value of invention:

Twenty five lacks

Result:

Name of Inventors:

Dr. K.M. PARAMMASIVAM · Mr. G. SIVARAJ · Mr. S. SENTHILKUMAR


Center for Aerospace Research Centre

OPTIMIZATION OF VORTEX GENERATOR FOR 'SEDAN' CAR MODEL FOR REDUCTION OF AERODYNAMIC DRAG

Abstract — Patent Application No: 3778/CHE/2010 A — International classification : B62D17/00

The reduction of aerodynamic drag using vortex generators help to reduce both drag force and the lift force. The drag coefficient of the car was reduced by keeping the vortex generators in various locations of the car. The analysis was performed on BLWT carried under simulated wind with relatively low turbulence. The pressure measurement was obtained using pressure scanners when the wind was flowing parallel to the length of the car with and without vortex generators.

Field of the Invention: Vehicle Aerodynamics

Innovative features: "vortex generators"

Function

In areas where the body transitions at a rate of more than 12 degrees, vortex generators, diffusers, very short fairings or other devices can be used to "trip the airflow

Background of the invention:

An automobile which always have drag force while under motion. If the drag force is reduced, it will increase the mileage of the car which will be very much useful in fuel savings and their performance. So this particular invention also focused to minimize the drag by using different shapes of Vortex Generators.

Name of Inventors:

Industrial application of the invention:

Automobile industry specifically in race car and also high speed car

List of process :

1. Making of model and vortex generators
2. Optimization of VG location
3. Testing of model in wind tunnel
4. Drag computations

Commercialization value of invention:

Twenty five lacks

Result:

The optimal point of installation would be 100MM before the air flow separation point.

Dr. K.M. PARAMMASIVAM · Mr. G. SIVARAJ · Mr. S. SENTHILKUMAR

Aerodynamic Braking System of Wind Turbine using Chordwise Spacing

Wind turbine with spacing alters the pressure distribution of the turbine blade at high wind velocity.

The parameters such as position of the spacing from leading edge, position of the spacing from hub, width of the spacing, inclination of the spacing, number of spacing and length of the spacing are analyzed experimentally.

The spacing at 0.35C from the leading edge is found to be the suitable position for the spacing.

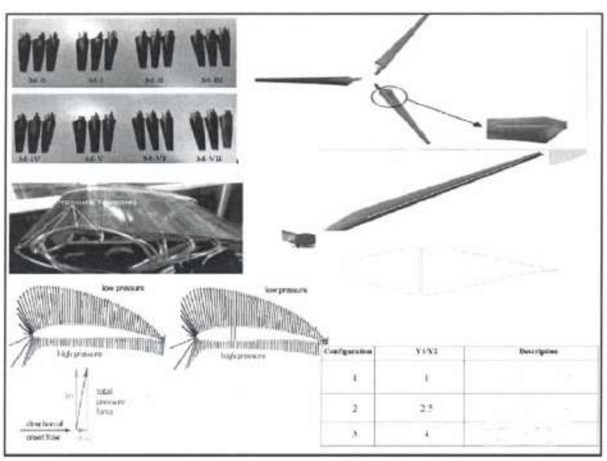
The 0.01C width spacing provides better results when compared to other configurations.

The rate of fluid flow can be increased by providing the spacing at an angle 60o.

The 10% (0..5/5 m) of the span length is found as the optimum length of spacing.

Though the spacing provided in the turbine blade slightly affects the lift and thereby power generation, it can be prevented by providing simple closing and opening mechanism.

This mechanism ensures that the spacing remains closed at low velocity and the spacing opens only at high velocity. This aerodynamic braking system can be effectively used to control the over speeding of the wind turbine at high velocity.



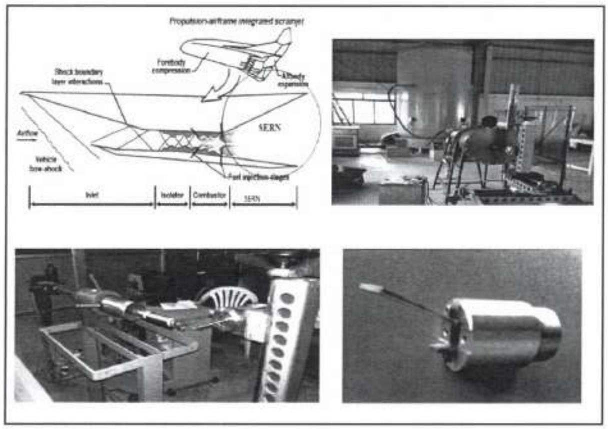
Single Expansion Ramp Nozzle Flows

The experiments were carried out in supersonic free jet facilities on SERN with 18° ramp angle without cowl for centerline total pressure measurements for the computation of total pressure loss, Mach number and thrust ratio.

Varied the ramp angles from 18°, 20° and 22° ramp angles and repeated the experiments. Experiments were carried out on 18° ramp angle and fixing the cowl length (throat height) as 1h, 2h, 3h and 4h and repeated the measurements for other ramp angles also.

The experiments were also carried out for the effect of the operational parameter of NPRs on SERN for a range of NPRs from 2 to 6 for the combinations of ramp angles and cowl lengths.

A Schileren and Shadowgraph setups were used to visualize the flow characteristics in the SERN for various ramp angles, cowl lengths and NPRs. The present experimental data can be used as the base data for the further research work in SERN flows.



Flame Stabilization

In lean combustion, the heat release from the flame is maximum due to complete burning of fuel in the excess of oxygen.

Lean combustion also exhibits twin occurrence of instability due to vortex shredding and acoustics developed due to heat release.

The instability will lead to blowout and shrinkage in length of the flame. The flame inheritance to vortex is studied with the 60 degree V-gutter bluff body.

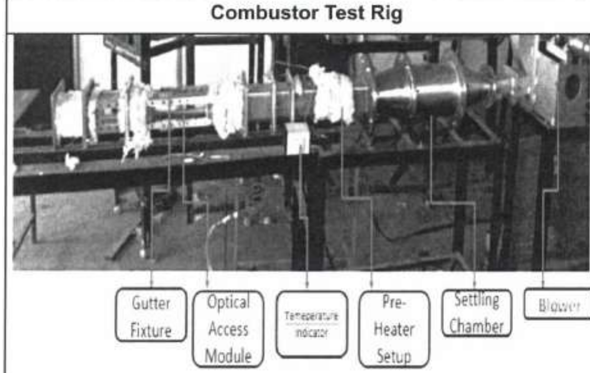
The exit of V-gutter acts as a nozzle by accelerating the flow, enabling the formation of recirculation zone.

The non-reactive measurement is made to understand the velocity field downstream of the V-gutter distributed along the length of the combustor.

The recirculation zone length is predicted about 70 mm downstream off the combustor.

The vortex structure approaching the blowout is studied in reactive flow, using image processing technique. The vortex flow and the net heat release rate are altered in the flow field and are visualized on the flame approaching blowout.

Combustor Test Rig



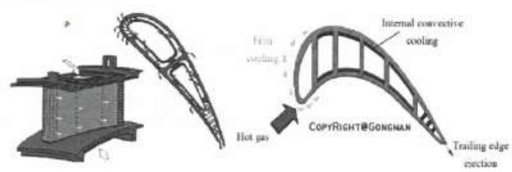
Gas Turbine Film Cooling

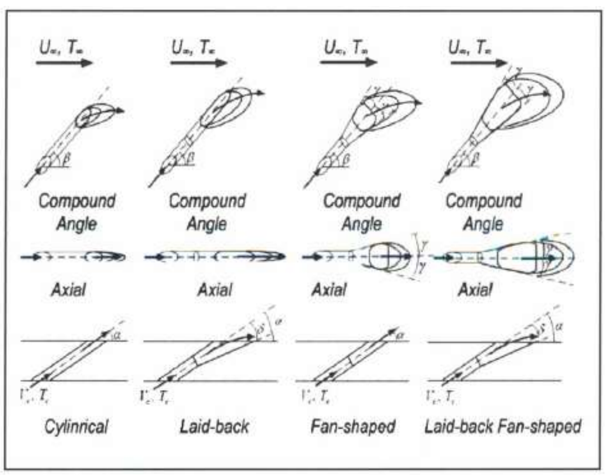
The modern turbine inlet temperatures exceed the melting point of the turbine blade materials and therefore blade protection is required.

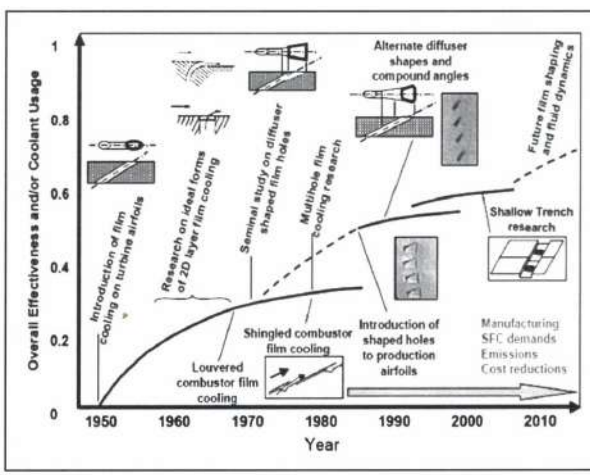
An external cooling applications, cold air bled from the last compressor stages, is injected onto the hot blade metal surface in order to create a thin protective layer. This cooling method is known as film cooling and finds great applicability in industrial and aeronautical applications.

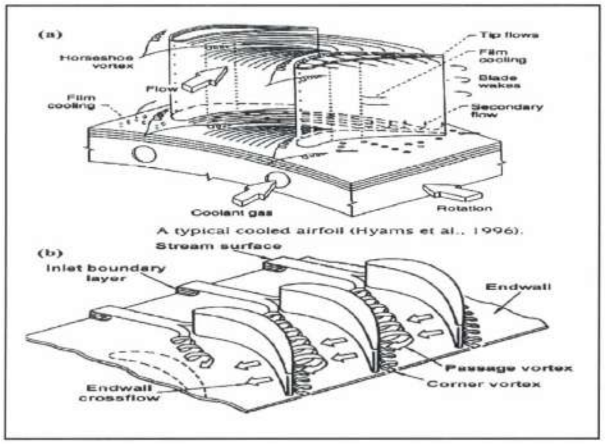
Film cooling performance is highly depended on a number of parameters such as injection geometry, surface curvature and roughness, turbulence, coolant properties and mass flow.

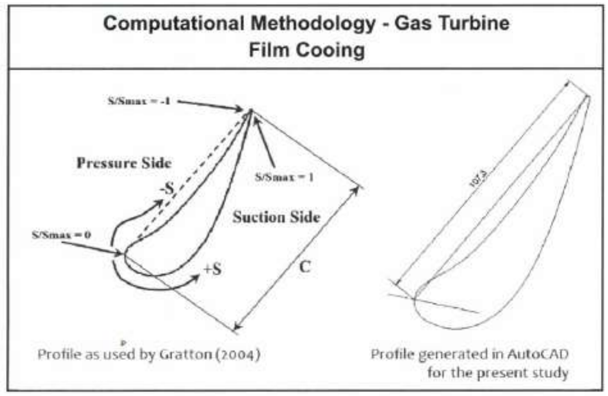
GTT performs experimental work for the evaluation of film cooling effectiveness at d.





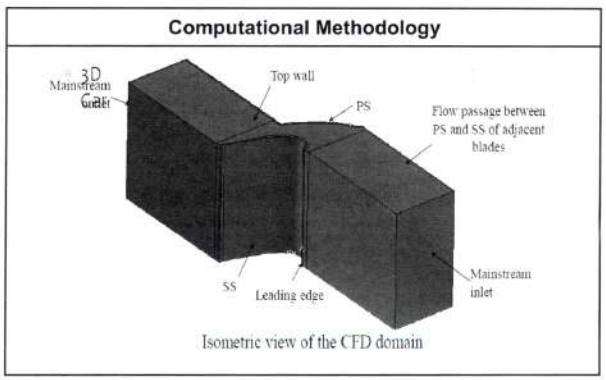


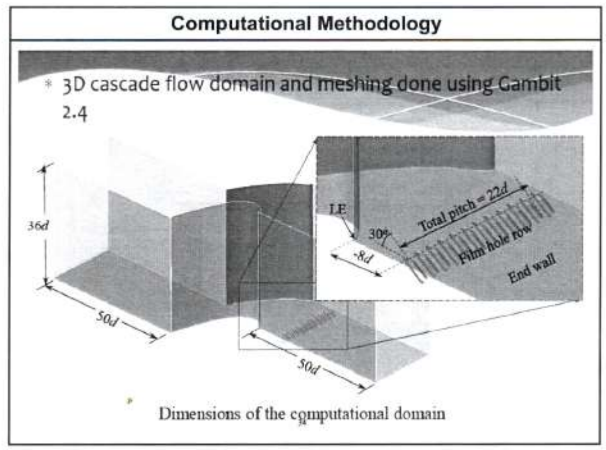




" ...Choosing to lead one kind of life means putting aside the desire to pursue other options."

-Vikram Sarabhai



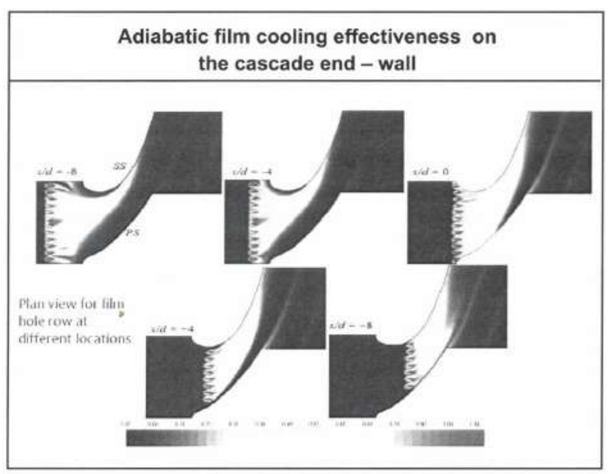


"... failure is not about not succeeding. Rather it is about not putting in your bet effort and not contributing, however modestly, to the common good."

-Vikram Sarabhai

Important Parameters

Parameter of the blade	Unit	Value(s)
Actual Chord, Ch	mm	107.3
Pitch to chord ratio, P/Ch	-	0.90
Blade height to chord ratio, h/Ch	-	1.34
Reynolds number, Re	-	2E + 05
Mainstream fluid, m	-	Air
Collant fluid, c	-	CO2
Blowing ratio, M	-	0.6
Temperature ratio, Tm / Tc	-	1.034
No. of film hole rows	-	1
Film hold diameter, d	mm	4
Film hole pitch, P	-	2d
Locations where film row was tested, x/d	-	-8, -4, 0, +4, +8



References

PN Selvarasu Parammasivam KM, Numerical and Experimental Investigations of drag force on scaled car model, Thermal Science, year 2016, Vol 20, Suppl4, S1153-S1158, TVelmurugan, Parammasivam, KM, ACFD analysis of controlled Flutter Phenomemon, Thermal Science, year 2016, Vol 20, Suppl4, S955-S965,

Parammasivam KM, Suganya G, Abdul Basidh N, Devanathan D, Experimentation of Flame Stabilisation using Flat Plate Gutter made of Porous Materials for After burner Applications, JoAET (2016), vol 5, issue 2, pp 71-76,

B, Navin kumar, K,M. Parammasivam, M, Prassanna and A.Z,G, Mohamet Karis, Computational Fluid Dynamic Analysis of Aerodynamic characteristic of NACA4412 Vs S 809 Airfoil for Wind turbine applications, Int J Adv Engg TechNol. VII/Issue III/July-Sept., 2016/168-173,

T. Velmurugan, and K,M, Parammasivam, Investigation on the Design Parameters of an Aeroelastic Wind Energy Generator, Journal of the Balkan Tribiological Association Vol. 22, No 1A-11,844- 860 (2016)

Veeranagouda Patil, P. Shanmugam, Divijesh, S, Raja, K.M. Parammasivam "Design and Realization of Single Axis Mechanism for Morphing Wing UAV', International Journal of Innovative Research in Science, Engineering and Technology, vol 5, Special Issue 9, May 2016, pp 873-878,

Saravanan P, Parammasivam KM, "Wind Forces on Rotating Small Wind Turbine Blade TIP using Wind Tunnel Measurements', Asian Journal of Research in Social Sciences and Humanities, Vol 6, No 5, May 2016, pp 41-52,

Arivarasan N, Velmurugan E, Parammasivam K,M, "Modelling and analysis of a crankshaft in a single cylinder four stroke petrol engine", Journal of Chemical and Pharmaceutical science, ISSN 0974-2115 (2016) 9(2), pp,954-957,

T. Velmurugan, M, Ranjithkumar and K,M Parammasivam, "Performance and Emission Evaluation of a VCR Diesel Engine using Algae Methyl Ester", International Journal of Applied Engineering Research (IJAER), Volume 10, Number76 (2015) Special Issues, pp. 113-117,

Suresh Chandra Khandal, Paramamasivam K.M "Effect of Cowl Length On the Jet Characteristics of the SERN", Internal Journal of Applied Engineering Research (IJAER), Volume 10, Number4 (2015), pp. 10825-10840,

Navinkumar S, Parammasivam KM, "Wind Turbine Aerodynamic Braking System Analysis Using Chord Wise Spacing", Applied Mechanics and Materials, vol 787 (2015) pp 217-221, August 2015,

Kirubhakaran K and Parammasivam KM, "Design and Experimentation of Simulated Combustor Model for Aircraft After burner Applications", International Journal of Turbo & Jet Engines, Volume 33, issue 2, pp 175-183, June 2016,

Ravi D and Parammasivam KM, "Taguchi Based Regression Analysis of End-wall Film Cooling in a Gas Turbine Cascade with Single Row of Holes", International Journal ofTurbo & Jet Engines, vol 33, issue 3, pp 275-292, July 2015,

"Kirubhakaran K and Paramasivam K M," Understanding Blowout Phenomena to the Induced Angle of V. Gutter-Stabilized Flames", International Journal of Turbo & Jet Engines, Volume 33, issue 1, Pages 81 - 85, ISSN (Online)2191-0332, ISSN (Print) 0334-0082, DOl: """April 2015

Selvaraju P N, Parammasivam K M. Shankar, Devaradjane G," Analysis of drag and lift performance in sedan car model using cfd", Journal of Chemical and Pharmaceutical Sciences, ISSN: 0974.211, Special Issue 7:2015, pp 429-435,

Selvakumar K and Parammasivam K M (2015)," Experimental investigations on aerodynamic characteristics of a hatchback model car using base bleed", Journal of Chemical and Pharmaceutical Sciences, ISSN:0974-211, Special issue 7:2015, pp 365-367,

Vadivelu P, Shanmugam P and Parammasivam K M (2014),"Three Dimensional Computational Studies on Aileron Morphing and Variable Wing Sweep Morphing'. International Joumal of innovative Science Engineering & Technology, Vol. 1 Issue 10,pp9-14, December2014.

Suresh Chana Khandai, and Parammasivam K M (2014), "Experimental Study of Single Expansion Ramp Nozzle Flows (SERN) at Low Supersonic Speeds', International Journal of Mechanical & Mechatronics Engineering UMML IJENS Vol: 14 No:0584146205-9191IJMME IJENSOctober20141JENS

Vadivelu P and Parammasivam K M (2014). "Computational Studies on ailer on Morphining in IJAV (Variable trailing edge)", International Journal of General Engineering and Technology (IJGET) ISSN (P), 2278-9928;9928; ISSN (E) 2278-9936, VOL3, Issue 5, Sep2014, pp 23-32.

Thiyagamurthy G and Parammasivam K M (2014).' Flutter Analysis of a Space Vehicle International Joumal of Frontiers in Aerospace Engineering, vol3, issue3, pp6469, August2014.

Sivaraj. G, Parammasivam K M and Gokulraj M (2013), "Computational Analysis of flow behavior over the multi stage launch vehicle with trapons". Journal of Mechanical Engineering & Technology, vol 1, issue 1, pp 54-65 IISN 2347-3924

Saravanan P, Parammasivam K M and Selvi Rajan (2013), "Experimental investigation on small horizontal axis wind turbine rotor using winglets'. Journal of Applied Science and Engineering, Vol No.16, No.2, pp-159-164(2013) DOI:10.618/jase.2013.16.2.07.

Suresh Chana Khandai, Ashwin Kumar K and Parammasivam K M (2013).

"Computational Study of the Effect of Geometric Parameters on the performance of Single Expansion Ramp Nozzle Flows"(IJMIE)ApriI8th 2013-Goa, ISSN No.2231-6477, Vo1.3, Iss-1, 2013, pp.67-71.

Keerthana M, M. Sriramkrishnan, T Velayutham, A. Abraham, S. SelviRajan and Parammasivam K M (2012). "Aerodynamic Analysis of a small horizontal axis wind turbine using CFD' Journal of Wind and Engineering, Vo1.9, No.2, July2012, pp.14.28.

Saravanan P, Parammasivam K M and Selvi Rajan (2012), "Pressure Distribution of Rotating Small wind turbine blades with Winglets using Wind Tunnel, Journal of Scientific and Industrial Research' (JISR), Vol. 71 pp.425-429, June2012.

Vinayagamurthy G. Parammasivam K M, S. Nadaraja Pillai (2011), "Flutter Analysis of Wing, Booster Fin and Vertical Tall" Applied Mechanics and Materials Vols.(AMM) 110-116 pp 3500-3505. Trans Tech Publications, doi 10.4028/www.scientific.netiAMM.11 0-26-3500.

Jayakumar M, Rajani, Sekhar Majumdar and Parammasivam K M (2009), "Numerical Simulation of Turbulent Flow past a Conical Water Tank Structure' in Journal of Wind & Engineering, Vo1.6, No.2, July 2009, pp-42-50.

Selvi Rajan.S, Santoshkumar.M, Lakshmanan.N, Nadaraja Pillai.S and Parammasivam K M (2009). "CFD Analysis and Wind Tunnel Experiment on a Typical Launch Vehicle Model' in Tamkang Journal of Science and Engineering Vo1.12, No 3,223-229.

Sundaravadivel T A, S.Nadaraja Pillai and Parammasivam K M (2009). "CFD Prediction of Wind Pressures on Conical Tank", Journal of Wind and Engineering, Vol 6, No 1, Jan 2009, pp 32-40 ISSN 0973-0613, India.

Saravanan P, S. Nadara Pillai, Parammasivam K M (2009). Aerodynaimc Characteristics of Hypersonic Vehicle with Variable Sweep Back Wing Configuration' Journal on Future Engineering & Technology, Vo15, No. pp 44-50.

Pillai S N, Kumar M S, Sundaravadivel T A, Parammasivam K M, Jayaraman K (2004), Aerodynamic analysis of Flat and curve shaped Hypersonic fore bodies at low speeds", ASCE (American Society of Civil Engineers), (Special issue for Earth & Space-2004) Vo 1153, pp 1023-1030.

Thank You For Your Kind Attention

Disruptive Approaches in Propulsion and Space Transportation Systems and ISROS Approaches to Face the New Challenges

Shri S Somanath

Director, VSSC

Dr.Vikram S Sarabhai as the father of the Space Program in India laid a solid foundation in the space technology developments and given the vision for the application of space technology for the common good of the nation. The developments so far in the area of space transportation systems, spacecrafts and applications have surpassed the goals set by him and the later leaders like Prof. Satis Dhawan in achieving the required capabilities and bridged the gap existed between the developed nations and India in this niche area. Presently we are one of the six nations having the indigenous capabilities in building our own satellites for any application and to launch it from our soil.

The disruptive approaches today seen in the space transportation and application sector required to be assessed very well and ISRO has to re-orient to meet the challenges to maintain the leadership and take ISRO to further heights of achievements and to remain useful to the society. The presentation addresses the plan of ISRO specifically in the area of space transportation sector to meet the challenges especially in bringing down the cost of transportation, increase the availability and capacity and adopt new technologies progressively to achieve the goals.

The production and launches of the present launch vehicle fleet is being carried out with the support of the industries. The numbers of launches are to be increased form the present rate of 5 to 6 to almost 12 to 20 in the next few years to meet the national demands itself. We should also bring down the cost of access to space to that the new players can use the capability to increase the economic activity associated with space. The plans to increase the industries capability to take up more and more integrated level work in the launch vehicle manufacturing, testing and launches are highlighted. This is presently targeted to achieve by industrialising the production and launch of PSLV through a consortium of industries. A new launch vehicle called Small Satellite Launch Vehicle (SSLV) to meet the emerging market of the small satellites is planned to be developed in short time and deployed through industrial commercial production and launch service. To bring down cost of launch, the development of re-usable technologies requires new thrust. The vertical landing demonstration done elsewhere has created a new interest in this area. ISRO is also working on this approach for a demonstration mission with a new vehicle being developed for this purpose. The winged reusable launch vehicle continues to be a possible option in the future. ISRO has successfully demonstrated the capability to design and develop such a vehicle in a scaled model sometime back. This is being taken further and a new mission with an orbital launch and recovery is planned with a capability to deploy a satellite or to carry out a scientific mission and return back to a landing site. Some of the new propulsion technologies to be perfected to achieve the reusability are being addressed including throttlable engines, LOX-methane engines and engines with electrically operated turbo pumps.

The air breathing technology was one of the sought after technology is being developed by many countries. ISRO was successful in achieving supersonic scramjet engine demonstration using a low cost test bed. This is planned to be scaled up and achieve a further scaled demonstration in a vehicle which can produce a level flight with acceleration using multiple scramjet engines.

Recently announced Gaganyaan has created a new spurt of activities and interest in academic and industrial sectors. ISRO is planning to achieve the capability of human space flight capability in less than four years. ISRO has been working on the enabling technologies for a few years. This is to be taken up vigorously. further in developing human rated launch vehicle capability and human centric technologies to construct crew module and life support systems.

In the area of materials and manufacturing disruptive approaches are taking over the production of engines and launchers. Additive manufacturing, nano technologies, extensive use of composites and engineers materials and being proposed more and more in aerospace sector. The conventional approaches to manufacturing and testing are likelyto change in the coming years. Faster to market and cost effective and simple design approaches are being considered. These are being applied in avionics, energy systems, pyro systems, simulation test beds and testing. The research and developments in these areas are to be strengthened further.

The interest shown by the start-ups in developing launch vehicle technologies and propulsion systems world over is a new phenomenon. ISRO is planning to support such initiatives so that more capabilities are developed in this country. The approaches taken by ISRO in facing the new challenges in the space transportation sector are described in the presentation. However the innovative approaches happening elsewhere are bound to create new opportunities and challenges to ISRO and we are getting ready to face them with confidence.

About Aerospace Engineering Division Board

The Aeronautical Engineering Division of The Institution of Engineers (India) was constituted in the year 1978, which was further renamed as Aerospace Engineering Division. This Division consists of quite a large number of corporate members from Government, Public and Private sectors.

Aerospace Engineering Division organize different technical activities, that include All India Seminars, All India Workshops, Lectures, Panel Discussions etc, at various State/Local Centres of the Institution. Apart from these, National Convention of Aerospace Engineers, an Apex activity of this Division is organized each year on a particular theme approved by the Council of the Institution. In the National Convention, several technical sessions are arranged on the basis of different sub-themes along with a Memorial Lecture in the memory of '**Dr Vikram Sarabhai**', the eminent Scientist and former Chairman of Atomic Energy Commission, Govt of India, which is delivered by the experts in this field.

Due to multi-level activities related to this engineering discipline, this division covers different thrust and emerging areas such as:

- Application of Laser Techniques for Diagnostic and Repairs of Aerospace Structures
- Compliant Structures at Nano and Multiple Scales
- Nano-Technology and its application in different fields of Aerospace & Aviation
- Smart Materials and their application to Aerospace, Mechanical and Civil Structures
- Application of Smart Materials on Human Systems
- Air Traffic Control (ATC)
- Reusable Launch Vehicle
- Micro and Nano Air Vehicles and their Sensors
- Micro-thruster and Fuel Cells for Propulsion
- Management of Infrastructure in Aviation
- Development of Micro and Nano Satellites
- Magneto Hydro Dynamic for active flow control of hypersonic vehicles
- Separation dynamics of multi body systems
- Aerodynamic characteristics for rarefied flows
- Morphing wings design
- Flying wing aircrafts for low radar cross sections
- Aero acoustics
- Sea Plane/Hydro Plane
- Human Factors for Aerospace System
- Bio Fuels for Aerospace Applications
- Ergonomics for Aerospace System
- Combustion instability on Rocket Engines
- Hypersonic Aerodynamic Propulsion
- Flight Control, Guidance and Navigation System
- Health Monitoring, Failure Detection and Isolation in Aerospace System
- Reconfiguration of Aircrafts
- Life Extension of Aircrafts
- Damage Tolerance Design for Aircraft
- Smart Materials and its' Applications to Aerospace

In order to promote the research and developmental work in the field of Aerospace Engineering, the Institution also publishes **Journal of The Institution of Engineers (India): Series C** in collaboration with M/S Springer which is an internationally peer reviewed journal. The journal is published six times in a year and serves the national and international engineering community through dissemination of scientific knowledge on practical engineering and design methodologies pertaining to Mechanical, Aerospace, Production and Marine engineering.

The Institution of Engineers (India)
8 Gokhale Road, Kolkata 700020
Phone : +91 (033) 2223-8311/14/15/16, 2223-8333/34
Fax : +91 (033) 2223-8345
e-mail : technical@ieindia.org; iei.technical@gmail.com
Website : http://www.ieindia.org