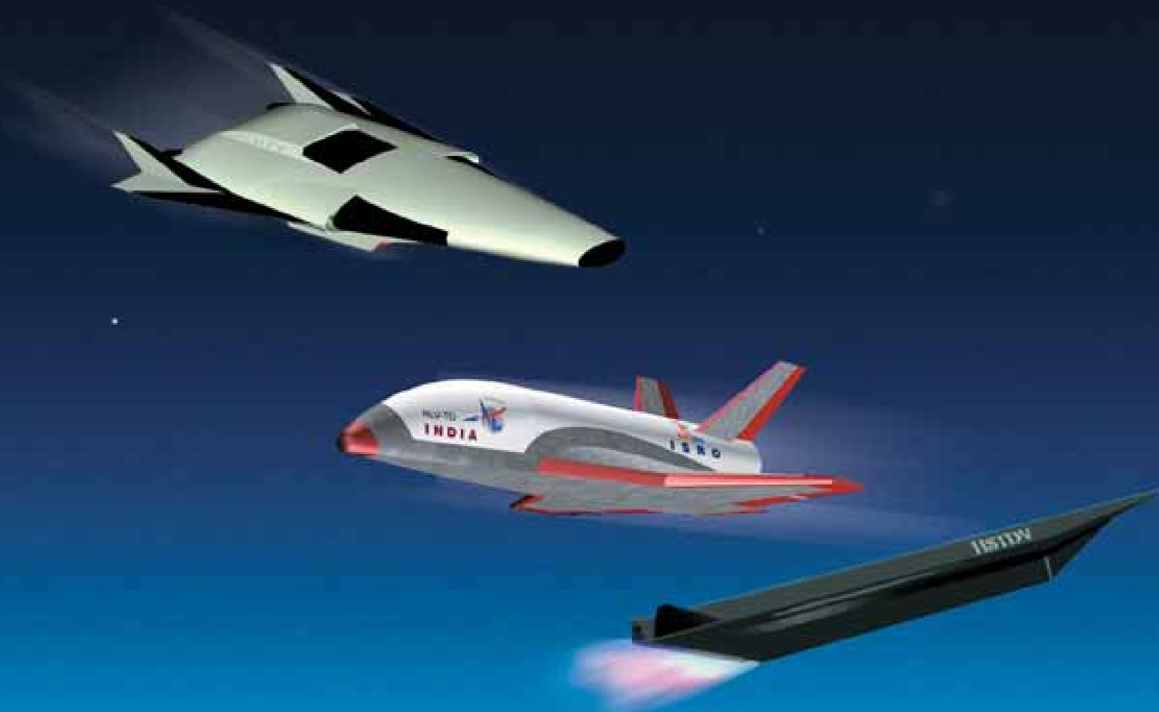
Challenges in

High Speed Transatmospheric Air & Space Transportation



Proceedings of the first International Conference on High Speed Transatmospheric Air & Space Transportation, June 2007, Hyderabad, India

Aeronautical Society of India
&
Astronautical Society of India
Hyderabad - Bangalore - Thiruvananthapuram

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Cover Photographs

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HTV (top), RLV-TD (Middle), HSTDV (bottom)

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HSTDV (top), Futuristic Space Plane (bottom)

FOREWORD

Technological advances are driving forces of institutional and market growth within business cycles. India competitive advantage among nations is that it is one among the few select countries that has an advanced aerospace R&D and industrial capability to conceive, design, develop and manufacture supersonic aircraft, light transport aircraft, unmanned aerial vehicles, guided missiles, space rocket launchers and space satellites. Over the last two decades, its knowledge base in hypersonic flight has rapidly advanced. Its R&D/industrial capabilities in airbreathing and rocket propulsion, composites and new materials, software and advanced design engineering tools, mathematical modeling, simulation and simulators, are now well established at a cost far lower than in the advanced countries.

India's growing participation in intercontinental trade, pivotal geo-strategic relationships, globalization, and its central location to South-South air routes, from Australia, via-India to South Africa and Brazil, makes it an ideal hub for high-speed transcontinental air transportation systems. The mastery of hypersonic flight in the transatmosphere would establish synergies and capabilities for safe, affordable low cost orbital transportation systems, that have multiple commonalties with civil air transportation in flight regime, fuels, materials, airframe, engine navigation and control system technologies. Low cost access to space in turn would open new markets for India's participation in space industrialization, to launch multi-role satellite constellations, missions for energy from space and space tourism. Thus mankind's long cherished dream of seamless entry into space, directly from runway take-off, with multi-role aerospace systems for high speed air transportation would emerge in the most cost-effective manner, with broad applications reducing costs, and speed driving the price.

To enable this transition from supersonic to hypersonic flight capabilities and capacities take place effectively, there is a requirement to consolidate knowledge domains developed in India over the last two decades in high-speed air and space transportation. Advancements in aeronautics and space have, over the last half-century, taken place in isolated compartments, and the knowledge available is fragmented, scattered over many centres, working in isolated fashions without any integrating vision with broad national and international perspectives. Integrating these fragmented knowledge domains, capabilities and infrastructure into a cohesive whole is vital for synergizing various aerospace S&T disciplines, and bringing together all the potential users, developers and producers in shaping the futuristic missions in missions for transatmospheric high speed air and space transportation.

This Conference might thus be seen in perspective as India's stepping - stone into the world's second industrial revolution, i.e. space industrialization, at the dawn of the 21st Century. It would signal India's entrance into the global arena for mankind's new thrust into safe, affordable access to space for space industrialization, and provide options to the global aerospace community for a peaceful, cooperative and unified approach to master space for all mankind. Inter alia, the Conference would nucleate India's entry into high-speed air transportation for civil aviation requirements.

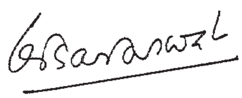
In this backdrop, the Aeronautical Society of *India (Hyderabad, Bangalore* & *Trivandrum Branches) and the Astronautical Society* of *India have decided to jointly conduct the First Joint Aeronautics and Space Conference on Transatmospheric, High Speed Air* & *Space Transportation" at Hyderabad during June 2007, with the participation* of *approximately fifty eminent scientists and eminent aerospace science and technology visionaries from India and interested nations.* Based on the outcome of this First Conference, it is proposed that a series of further Symposia and Conferences be conducted at the international level.

I am sure this conference would provide ideal platform to exchange, consolidate and integrate the knowledge gained, and expertise established in India in transatmospheric, high-speed air and space transportation; and envisions the future for aerospace transportation systems and missions of the 21st Century.

The deliberations in the Conference would bring out the capabilities established in this area in India's Institutions and professional communities of aeronautics, space and guided missiles and indicate potential for international cooperation. It would bring together, for the first time, work done in these institutions on systems and technologies that have a strong bearing on future national and international revenue-earning missions in transatmospheric, high-speed air and space transportation of the 21st Century.

All these thoughts, deliberations and excellent papers by eminent experts from India and abroad have been put together in the form of Technical Proceeding to give reader a glimpse of the growing state-of-the art in Hypersonic Transatmospheric air and space transportation. This mammoth task has been completed in very short span of time, for which I express my sincere sense of gratitude to the Editors and all members of the Organizing committees.

With best wishes



Dr V.K. Saraswat
Chairman
Aeronautical Society of India

From Editorial Team

The Aeronautical & Astronautical Societies of India have invariably played pivotal roles in promoting the aerospace activities in India. Over the years these Societies have served as very useful platforms in bringing together aerospace scientists, engineers, academicians, industry and students from various organizations from India and abroad to share and exchange information on the latest developments in aerospace sector.

The two Societies are jointly organizing an International Conference on Transatmospheric air & Space Transportation" at Hyderabad during 29-30 June 2007. There was a magnificent response from Invited as well as Contributed Papers. Because of space and time limitations, twelve invited papers and about forty contributed papers were selected by the Review Committee. The Invited Talks by eminent speakers as well as Contributed papers in this Conference will become the basis for the future course of action.

The preparation of the Conference Proceedings could not have been possible without the continuous support, guidance and encouragement provided by Dr V.K. Saraswat, Chairman, Advisory Committee and Shri P. Venugopalan, Chairman, Organizing Committee. Our special thanks are due to Dr S Paneerselvam for his valuable advice and support.

We would like to express our grateful appreciation to invited speakers and authors of contributed papers for their co-operation in providing the manuscript in accordance with the specified format, well within the stipulated time. We also express our gratitude to Members of the Review Committee from different organizations for sparing their invaluable time to review the Abstracts and full-length papers for the proceedings.

We are also thankful to Mr JVS Moorthy, Mr CH.Surya Kiran, Mr Avnish Kumar, Mr Sumit Sharma who have been actively involved right from the beginning towards the preparation of these Proceedings.

Our compliments are due to M/s Kala Jyoti Process Private Ltd, Hyderabad for their cooperation in bringing out these Proceedings in time and in a befitting style.

We acknowledge the devoted work of all the people who have contributed to the publication of this volume and dedicated their valuable time and resources towards realization of the proceedings

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International Conference on High Speed Transatmospheric Air & Space Transportation, June 2007, Hyderabad, India

ADVANCED SPACE TRANSPORTATION SYSTEMS: NEEDED TECHNOLOGIES & FACILITIES

Dr. BN Suresh, Director, VSSC

The theme for advanced space transportation is low cost access to space and could be achieved through use of atmospheric air for propulsion and by reuse of launch vehicle hardware. Advancement in the areas of hypersonic aerodynamics/thermodynamics and high-speed propulsion are key to this and Indian Space Research Organization (ISRO) is putting concerted efforts in these enabling technologies. In addition to developing a strong theoretical base and necessary computational tools, establishing major test facilities and well thought of flight test programs are in focus.

ISRO has successfully proven the reentry capability through SRE (Space capsule Recovery Experiment). Severe heat fluxes of 250W/ cm^2 and above encountered during atmospheric flight has been withstood. 1MW Plasma Jet Facility was established and the SRE Thermal Protection System (TPS) was extensively tested at the specimen level for integrated heat load & shear simulation. Based on the success, establishment of 6MW Plasma Wind Tunnel is being taken up. This would enable sub system level testing for gas enthalpies of 32MJ/kg with heat flux ranging up to 500W/ cm^2. Further flight tests of SRE are planned (with advanced TPS materials) for enhanced database on reentry/recovery technology.

Air Breathing Propulsion can drastically bring down the size of the launch vehicle as about 75% of the propellant is consumed within 50km altitude and oxidizer constitutes about 60% of the take off mass. ISRO has made success in demonstrating stable supersonic combustion through a series of ground tests for equivalent flight Mach number of six to seven. Following this success in supersonic combustion, DMRJ-FTD (Dual Mode Ram Jet-Flight Technology Demonstrator) flight tests are planned on a novel economical platform using sounding rocket. The mission is specially designed to provide required dwell time for scramjet evaluation within the “Mach number-dynamic pressure” window of interest. A major Scramjet Propulsion Test Facility capable of 20kg/s airflow rates is being established and this facility can test & evaluate scramjet combustors up to flight Mach number of eight.

Atmospheric descent & landing for reuse calls for high lift configurations suitable for ‘hypersonic-supersonic-subsonic’ flight. Major effort is being put to realize a 1m diameter Hypersonic Wind Tunnel expected to be commissioned shortly. It will be capable of testing aerodynamic models at

Mach 6 to 12 simulating Reynolds number up to 80 million per meter and temperatures up to 1750K. RLV-TD (Reusable Launch Vehicle-Technology Demonstrator) program is envisaged to master hypersonic aerodynamics and the double delta wing demonstrator vehicle would be boosted using a solid rocket motor and evaluated during descent flight. Progressively, RLV-TD flights would evaluate high temperature material/thermal protection systems, powered cruise flight/autonomous landing and vehicle integrated air-breathing propulsion in real flight conditions.

Technology demonstration flight programs of SRE, DMRJ-FTD and RLV-TD along with major test facilities of Hypersonic Wind Tunnel, Plasma Wind Tunnel and Scramjet Propulsion Test Facility will provide necessary technology inputs for design and realization of advanced space transportation systems. Going from where we are today with operational launch vehicles PSLV & GSLV and GSLV MKIII launch vehicle for which the maiden flight is planned shortly, the near term technologies aim for a Two Stage To Orbit (TSTO) vehicle by 2020 & the road map leading to fully reusable Single Stage To Orbit (SSTO) vehicle by 2030.

International Conference on High Speed Transatmospheric Air & Space Transportation, June 2007, Hyderabad, India

FROM EARTH TO ORBIT IN TRANSATMOSPHERIC AIRBREATHING VEHICLES

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ABSTRACT

Transatmospheric vehicles (TAV), flying like an aircraft, from runway take-off directly to near earth orbit, have many revenue earning societal missions, that include small satellite launching and recovery, solar energy from space, and space tourism. TAV technologies have much in common with hypersonic transportation for civil aviation.

The system and technology design choices of over 20 TAV system design concepts made in 1980's and 1990's are brought out. These design choices had resulted in very large vehicles with low payload-to-structure ratios. Without adequate ground and flight testing, hypersonic vehicles weighing hundreds of tonnes at take-off are highly risky to develop and operate. Hence, even though some of the required critical airbreathing propulsion and materials technologies were ground tested on small scales, a functional, full-scale airbreathing TAV for safe, affordable access to space is yet to be realized by any nation.

Critical design factors affecting TAV design are identified and their effect on safety and affordability of the vehicle are discussed. Four fundamental design criteria for an aircraft to ascend directly from runway take-off to near earth orbit are brought out. These criteria are fuel weight fraction at take-off, mission average specific impulse, thrust-to-drag ratio and propulsive efficiency. It is shown that for direct ascent to orbit of an aircraft, like a single stage rocket vehicle, a minimum 56% hydrogen fuel fraction is required at take-off. This is feasible only if oxidizer tanks are empty on take-off, and liquid oxygen is collected in flight.

A high-speed flight regime for in-flight liquid oxygen collection and storage has been determined. Numerical simulation tools, to optimize 26 interactive vehicle system design variables, were used to maximize vehicle payload performance. Airbreathing ram-scramjet engines are used in the air collection and oxygen liquefaction regime, a concept that is called 'aerobic' flight. It is seen that using air-breathing engines with in-flight oxygen liquefaction and storage, results in low mission-average fuel consumption, low propellant fraction and high payload fraction. These attributes in turn enables geometrically down-scalable configurations and hence design and development of small size orbital vehicles is economically viable.

Extensive studies for aerobic vehicles up to 275-tonnes take-off weight reveals that an aerobic TAV weight as low as 25-tonnes is the minimum weight for direct ascent like an aircraft into earth orbit with positive payload fraction. However, many system and technology design premises

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Challenges in

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About the book

This book contains a collection of papers presented at the International Conference on "High Speed Transatmospheric Air & Space Transportation, held at Hyderabad during 29-30 June 2007, Hyderabad, India. The conference was jointly organised by Aeronautical Society of India, Hyderabad, Bangalore & Thiruvananthapuram Branches and The Astronautical Society of India.

These papers address the recent developments and the challenges in hypersonic flight in the transatmosphere.

Topics covered include :

Conceptual design of Transatmospheric vehicles, Low cost access to space, RLV Technologies, Hypersonic transportation perspectives, Scramjet engines, Hypersonic aerothermal test facilities, High temperature materials, In-flight Liquefaction technologies, space industrialisation, global cooperation etc.

This book will be highly useful for practicing engineers, scientists, academicians and students working in the forefront of research in High speed transatmospheric air & space transportation. Many of the papers will be of interest even to the lay reader having interest in hypersonic areas.

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