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14. ABSTRACT

The objective of the Lecture Series is to provide clear guidelines regarding the design of the propulsion unit and integration into the airframe. First the intake physics, design and optimization was addressed. Turbine based cycles and rocket based cycles was considered. An important issue discussed was the thermal management of both the engine and vehicle. Issues related to the potential use of new synthetic fuels were also addressed. The Lecture Series was a unique opportunity to bring together experts from different horizons and raise fruitful discussions

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High Speed Propulsion: Engine Design - Integration and Thermal Management

(Propulsion à haute vitesse : Conception du moteur - intégration et gestion thermique)

Papers presented at the AVT-185 RTO AVT/VKI Lecture Series held at the von Karman Institute, Rhode St. Genèse, Belgium, 13-16 September 2010.

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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High Speed Propulsion: Engine Design – Integration and Thermal Management

(RTO-EN-AVT-185)

Executive Summary

Hypersonic systems will provide a revolution in commercial transport, space access (lower power density), and future NATO missions (global reach in 2 hours). Although hypersonic technology has significantly matured over the last 40 years technical challenges remain: intake design and optimization, combined cycle engines, integration engine – airframe, thermal management. The fact that several international research programs are running demonstrate a strong interest from several countries. Defence interest in a Mach 4 – 8 aircraft (hydrocarbon fuel) include theater aircraft and weapons, missiles (tactical and strategic) and transport. A Mach 8 to 18 (hydrogen fuel) would include global aircraft and weapons and missiles. Regarding survivability, today speed is more effective than improved radar cross section.

The objective of this special course was to provide clear guidelines regarding the design of the propulsion unit and integration into the airframe. First the intake physics, design and optimization was addressed. Turbine based cycles and rocket based cycles were considered. An important issue discussed was the thermal management of both the engine and vehicle. Issues related to the potential use of new synthetic fuels were also addressed. This short course was a unique opportunity to bring together experts from different horizons and raise fruitful discussions.

The main topic of this lecture series is the engine integration in high speed vehicles. An important concern to be treated is the thermal management of the engine, fuel, hot structures. Other topics to be covered comprise: intakes physics – design – optimization, overall engine cycle analysis, and new synthetic fuels. The program was completed with discussions on current demonstrator programs, based on the experience acquired in advanced demonstrators in USA, Europe and Asia.

Propulsion à vitesse élevée : Conception du moteur – Intégration et gestion thermique

(RTO-EN-AVT-185)

Synthèse

Les systèmes hypersoniques vont provoquer une révolution dans le transport commercial, l'accès à l'espace (densité de puissance plus faible), et les missions futures de l'OTAN (le monde entier à portée en 2 heures). Bien que la technologie hypersonique ait sérieusement muri tout au long de ces 40 dernières années, des défis techniques demeurent : conception et optimisation des entrées d'air, moteurs à cycle combiné, intégration moteur-cellule, gestion thermique. Le fait que plusieurs programmes de recherche internationaux soient en cours est la preuve du vif intérêt de plusieurs pays dans ce domaine. L'intérêt de la Défense pour un avion à Mach 4 – 8 (carburant hydrocarbure*)* inclut les avions de théâtre et les armes, les missiles (tactiques et stratégiques) et le transport. Un Mach de 8 à 18 (carburant hydrogène) concernerait la totalité des avions, les armes et les missiles. En ce qui concerne la survivabilité, la vitesse est plus efficace de nos jours qu'une surface équivalente radar améliorée.

L'objectif de cette session spéciale a été de fournir des directives claires concernant la conception de l'unité de propulsion et son intégration dans la cellule. En premier lieu, ont été traitées la physique, la conception et l'optimisation des entrées d'air. Les cycles turbines et les cycles fusées ont été abordés. L'importante question de la gestion thermique du moteur et du véhicule a été débattue. On a également traité les questions relatives à l'utilisation potentielle de nouveaux carburants synthétiques. Cette petite session a été une occasion unique de rassembler des experts de différents horizons et de susciter des débats fructueux.

Le sujet principal de cette série de conférence a été l'intégration des moteurs dans les véhicules à vitesse élevée. Un important sujet de préoccupation devait être traité concernant la gestion thermique du moteur, du carburant, des parties chaudes. D'autres sujets ont été couverts : physique – conception – optimisation des entrées d'air, analyse globale du cycle moteur, et nouveaux carburants synthétiques. Le programme s'est terminé par des débats sur les programmes actuels de démonstration, basés sur l'expérience acquise dans les démonstrateurs évolués aux Etats-Unis, en Europe et en Asie.

Preface

Hypersonic systems will provide a revolution in commercial transport, space access, and military missions. This RTO Lecture Series provides clear engineering guidelines based on research carried out in USA, Europe, Australia, Japan and Russia. Following the keynote lecture, turbine-based cycles are introduced, including variable cycles. A rocket-ramjet combined cycle engine is then proposed. A lecture on detonation propulsion focuses on fundamental properties; various design concepts with their theoretical and measured performances.

The second chapter demonstrates the design process of a ramjet intake through a design example for Mach 4 to 6. The next lecture presents engineering models of the aerodynamics and propulsion to evaluate the cruise flight performance of future long range missiles with special attention to vehicle-engine integration. The third note addresses the combined thermal loading due to the aerodynamic heating as well as reactive gas dynamics from the propulsion unit. Thermal equilibrium conditions of the structural parts are evaluated with and without active cooling. The fourth note is dedicated to the specific design of the scramjet intakes.

The third chapter will be dedicated to scramjets and dual mode operation. The first note presents design rules on the isolator and nozzle, in particular to the estimation of the heat loads on a scramjet or a dual-mode ramjet. Solutions to sustain such high energy will be proposed and how to combine materials, cooling techniques and system requirements.

The final chapter starts with the overall system analysis of scramjets, considering what is the optimum number of engine modules; comparison between fixed or movable geometry; effect of engine mass and size to on-trajectory-performance of an air-breathing space launcher. The second note presents an overview on EU funded research programs. The third note presents the major achievements and lessons learned from the Sanger II project, with emphasis on the selection of the combined cycle engine, propulsion operational modes. The last note will review the LEA program and its contributions to address key technologies considering potential future extensions.

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