DESIGN OF THE BRAZILIAN 14-X HYPERSONIC AEROSPACE VEHICLE

Felipe Jean da Costa, felipejean@ieav.cta.br
Paulo Gilberto de Paula Toro, toro@ieav.cta.br
Tiago Cavalcanti Rolim, rolim@ieav.cta.br
Giannino Ponchio Camillo, giannino@ieav.cta.br
Roberto da Cunha Follador, follador@ieav.cta.br
Marco Antonio Sala Minucci, sala@ieav.cta.br
Instituto de Estudos Avançados/IEAv - Trevo Coronel Aviador José Alberto Albano do Amarante, nº1 Putim CEP. 12.228-001 São José dos Campos, SP - Brasil.

Viliam Sinka, sinka@univap.br
Faculdade de Tecnologia de São José dos Campos - FATEC Prof. Jessen Vidal - Rodovia Presidente Dutra km 138,7 Eugênio de Melo CEP. 12.247-004 São José dos Campos, SP - Brasil.

Abstract. *A new generation of scientific aerospace vehicles, using advanced hypersonic air-breathing propulsion based on supersonic combustion "scramjet" technology, is in development at several research centers. This new propulsion system (scramjets) is economically and ecologically more attractive than the conventional rocket propulsion. The Brazilian 14-X Hypersonic Aerospace Vehicle, designed at the Prof. Henry T. Nagamatsu Laboratory of Aerothermodynamics and Hypersonics, at the Institute for Advanced Studies (IEAv), is a technological demonstrator using:i) "waverider" technology to provide lift to the aerospace vehicle, and ii) "scramjet" technologyto provide hypersonic airbreathing propulsion system based on supersonic combustion. Pure waverider aerodynamic as well as scramjet power off have been experimentally investigated at the T3 0.60-m. nozzle exit diameter Reflected Hypersonic Shock Tunnel, funded by The State of São Paulo Research Foundation (FAPESP). Pressure measurements at pure waverider external upper and lower surfaces and scramjet power off on internal surfaces provide wind-tunnel data to design the full 2-m. long 14-X Hypersonic waverider scramjet Mach number 10 Aerospace Vehicle to atmospheric flight at 30km altitude.*

Keywords: *14-X Hypersonic Aerospace Vehicle, waverider, Hypersonic Airbreathing Propulsion, scramjet.*

1. INTRODUCTION

The Brazilian 14-X Hypersonic Aerospace Vehicle, VHA 14-X, Fig. 1, named after 14-Bis developed by aviation pioneer Alberto Santos Dumont, is a new generation of scientific aerospace vehicle, designed at Prof. Henry T. Nagamatsu Laboratory of Aerothermodynamics and Hypersonics (Rolim, 2009, Rolim et al., 2009, Rolim et al., 2011), at Institute for Advanced Studies (IEAv), which is part of the continuing effort of the Department of Aerospace Science and Technology (DCTA), to design, to develop, to manufacture and to demonstrate, in free flight, a technological demonstrator using: i) waverider technology to provide lift to the aerospace vehicle, and ii) scramjet technology to provide hypersonic airbreathing propulsion system based on supersonic combustion.

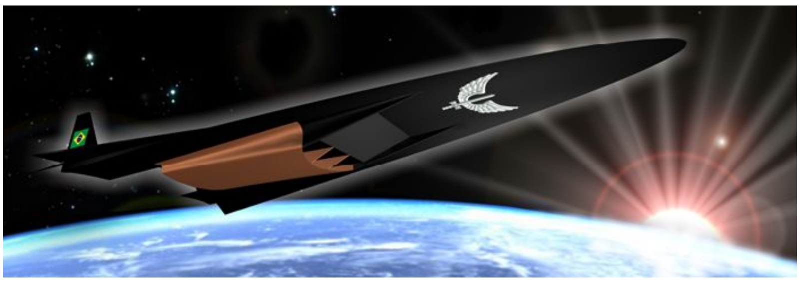


Figure 1. Brazilian 14-X Hypersonic Aerospace Vehicle.

Aerospace vehicle using waverider technology, Fig. 2, could be defined as a supersonic or a hypersonic vehicle which uses the high pressure zone on its lower surface caused by leading-edge attached shock wave to generate lift surface. Therefore, the attached shock wave in a sharp leading edge isolates the high pressure zone (lower surface) from the low pressure zone (upper surface), which inhibits the flow spillage. In general, the upper surface is aligned with the free stream hypersonic flow. Atmospheric air, pre-compressed by the leading-edge attached shock wave, which lies between the sharp attached leading edge shock wave and lower vehicle surface may be used in hypersonic airbreathing propulsion system based on "scramjet" technology.

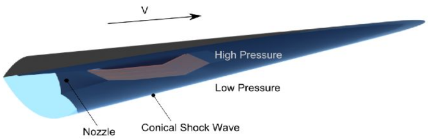


Figure 2. Hypersonic waverider vehicle concept.

Hypersonic airbreathing propulsion, that uses supersonic combustion ramjet (scramjet) technology, Fig. 3, offers substantial advantages to improve performance of aerospace vehicle that flies at hypersonic speeds through the Earth's atmosphere, by reducing onboard fuel. In fact, the use of atmospheric air as oxidizer permits air breathing to propulsion vehicles to substantially increase payload weight. Basically, scramjet is a fully integrated airbreathing aeronautical engine that uses the oblique/conical shock waves generated during the hypersonic flight, to promote compression and deceleration of freestream atmospheric air at the inlet of the scramjet. Fuel, at least sonic speed, may be injected into the supersonic airflow just downstream of the inlet. Right after, both oxygen from the atmosphere and on-board hydrogen fuel are mixing. The combination of the high energies of the fuel and of the oncoming hypersonic airflow the combustion at supersonic speed starts. Finally, the divergent exhaust nozzle at the afterbody vehicle accelerates the exhaust gases, creating thrust.

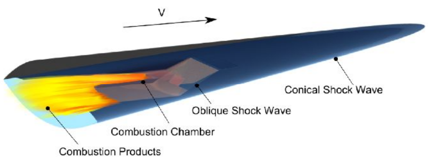


Figure 3. Hypersonic scramjet airbreathing propulsion concept.

2. METHODOLOGY

Firstly, a 718.28-mm. long stainless steel "waverider" model, Fig. 4, designed by (Rolim, 2009, Rolim et al., 2009, Rolim et al., 2011) and drawn by Costa (2011), instrumented with seven piezoelectric pressure transducers on the compression surface, was experimentally investigated on the equilibrium interface mode operation at the T3 0.60-m. nozzle exit diameter Hypersonic Shock Tunnel T3 (Romanelli Pinto et al., 2011) at freestream Mach number from 8.9 to 10 with stagnation pressures between 2176-2938 psi and temperatures at the range of 1558-2150 K (Rolim, 2009, Rolim et al., 2009, Rolim et al., 2011).

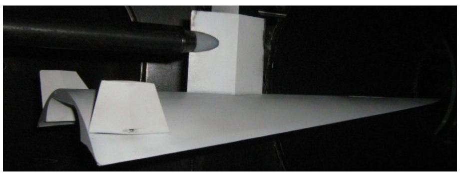


Figure 4. Instrumented "waverider" model installed at T3 Hypersonic Shock Tunnel.

The schlieren photographs (Rolim, 2009, Rolim et al., 2009, Rolim et al., 2011) take from the 5.5° waverider leading edge and the 14.5° deflection compression ramp (20° aligned with the upper surface) designed to capture the entire air flow compressed by the 5.5° waverider leading edge, provide enough experimental data to design combustion chamber of the 14-X Hypersonic Aerospace Vehicle.

A 265.1-mm. long, 80-mm. wide and 35-mm. high combustion chamber was coupled at the lower surface of the 14-X Hypersonic waverider Aerospace Vehicle between the end of the 14.5° deflection compression ramp and the beginning at the 15° expansion ramp, Fig. 5, defined by the 14-X waverider aerodynamic experimental results (Rolim, 2009, Rolim et al., 2009, Rolim et al., 2011).

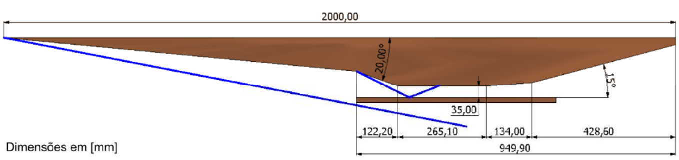


Figure 5. The 14-X waverider scramjet Mach number 10 model main dimensions.

3. RESULTS AND DISCUSSIONS

The T3 Hypersonic Shock Tunnel, which has 0.60-m. diameter by 1.40-m. long test section, which does not allow accommodating model bigger as the full scale (2-m. long by 0.83-m. wingspan) 14-X waverider scramjet Mach number 10 model, Fig. 5.

Therefore, only one nacelle of the combustion chamber of the 14-X waverider scramjet model, Fig. 6, truncated before the 14.5° deflection compression ramp was designed. The 5.5° waverider leading edge surface of the truncated model was aligned with the free stream hypersonic flow, so that there is not conical shock wave generated by the 5.5° waverider leading edge.

Therefore, the truncated 14-X waverider scramjet model was designed and instrumented to experimentally investigate at the T3 Hypersonic Shock Tunnel, Fig. 7. In this configuration only the boundary layer will be established at the 5.5° waverider leading edge surface during the experimental runs. Quartz windows were designed to obtain schlieren photographs during the supersonic combustion runs.

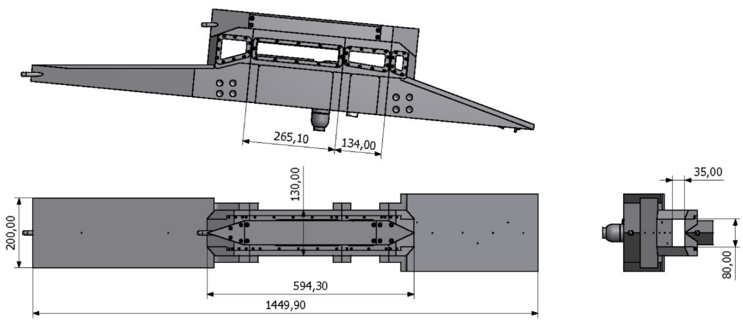


Figure 6. The truncated 14-X waverider scramjet model main dimensions.

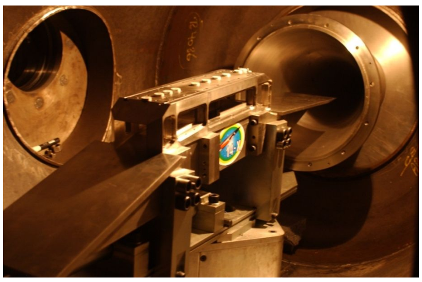


Figure 7. Instrumented truncated 14-X waverider scramjet model installed at the T3 Hypersonic Shock Tunnel.

Schlieren photograph, Fig. 8, shows the 19.85° oblique shock wave established at the manufactured 13.6° (designed 14.5°) deflection compression ramp as one may expect.

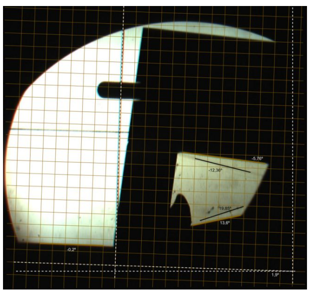


Figure 8. Mach number 7 flow past the model leading edge aligned if the horizontal.
Reservoir conditions: $P_0 =$ 2938 psi and $T_0 =$ 1706 K.

The 2-m. long 14-X Hypersonic Mach number 10 Aerospace Vehicle, Fig. 9, has been designed to flight for the first time, in Brazil, based on waverider (Rolim, 2009, Rolim et al., 2009, Rolim et al., 2011) and scramjet engine (Romanelli Pinto et al., 2012) experimental data as well as on the one-dimensional theoretical analysis (Toro et al., 2012).

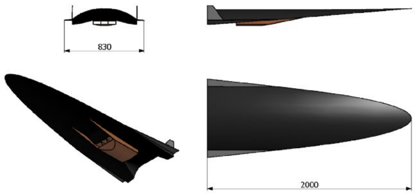


Figure 9. Brazilian 14-X Hypersonic Aerospace Vehicle.

The 14-X Hypersonic Aerospace Vehicle will be accelerated by the Brazilian Hypersonic Accelerator (two-stage, unguided, rail launched, solid rocket motors) to reach 30km altitude at desired speed.

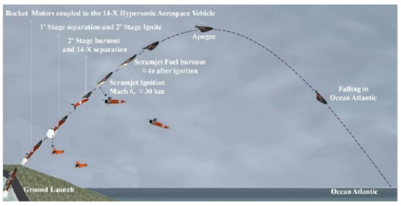
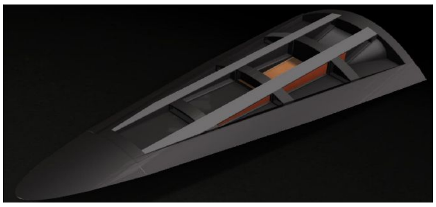


Figure 10. Hypersonic Accelerator Vehicle and 14-X Hypersonic Aerospace Vehicle in ballistic trajectory.

Internal configuration of the 14-X Hypersonic Aerospace Vehicle is being studied, Fig. 11, to determine the structural dimensions and materials considering the dynamic pressure and the aerodynamic heating during the ballistic trajectory, Fig. 10.



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