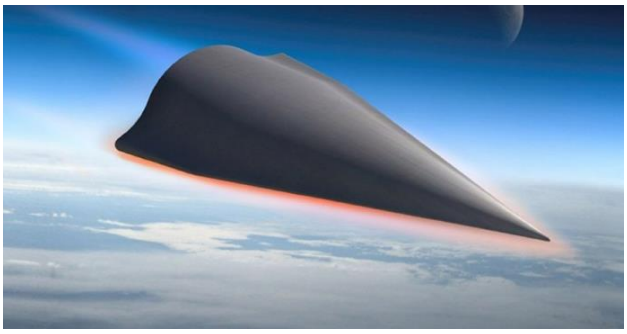
Hypersonic Aero-Optics

Evaluating the effects of aerodynamic flow on the performance of an EO/IR seeker in hypersonic flight regimes



The rapidly emerging capabilities of hypersonic-velocity weapons from a variety of countries requires the acceleration of technologies that will maintain the United States' military dominance both at home and abroad. Currently, 23 nations have demonstrated varying degrees of expertise in hypersonic technology, a number that continues to grow daily. As the flight profiles for these weapons expands to ever-higher velocities (Mach 18+) and ever-lower altitudes (< 15km), critical technologies are needed to ensure the successful performance of our intercepting airframe, seeker, and seeker window.

Aero-optical effects induced by the hypersonic flow field degrade the performance in these flight regimes, with severity ranging from reduction in seeker performance to completely blinding the optical sensor, or even causing catastrophic failure of the window. Polaris is developing a novel suite of instruments to characterize these effects for a variety of applications ranging from Ground Test Facilities (GTFs) to advanced tactical *in situ* applications.

Current GTFs are instrumented with advanced sensors to support this investigation, but a suite of aero-optical instruments requires sizable physical space, is unique to each facility, and requires highly trained engineers to operate. Testing at more than one GTF is not uncommon, and some facilities do not have the physical space to accommodate traditional aero-optical instrumentation. To address these needs and more, Polaris is developing an Aero Optics Kit (AOK). The AOK instrument suite will maximize the aero-optical data captured from a single test run, reduce costs, and minimize the number of runs necessary to complete the characterization. The AOK will offer new insights into optical effects of aerodynamic flow in the hypersonic regime and is suitable for high-Mach numbers and enthalpies.

The AOK is being designed to provide real-time, onboard measurements of aero-optical effects on seeker performance. It will measure imaging performance, window effects due to aerothermal heating and pressure loading, and aerodynamic flow structures including turbulence with multiple, synchronized sensors. The AOK is designed to be mounted inside a test article with either a cooled or an uncooled window; the initial system will fit into a common Advanced Interceptor Technology (AIT) forebody test fixture for use in hypersonic test facilities. The instrument suite minimizes, if not eliminates, the need for specialized test setups and tunnel modifications. GTF measurement accuracy is enhanced by incorporating the AOK test fixtures completely within the interceptor test object and eliminating test structures and mounts in the flow. The AOK promotes the ubiquity of aero-optic test capabilities from one GTF to the next.

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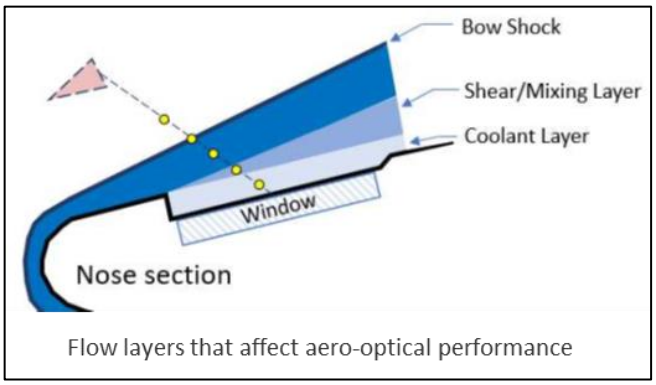

Flow layers that affect aero-optical performance

Polaris's subject matter experts are on the cutting edge of hypervelocity aero-optics research. Polaris's key staff provided Modeling and Simulation (M&S) predictions and defined sensor requirements, set up optical sensors, and analyzed measured instantaneous wavefronts and time-integrated point spread functions for the AEDC Hyper-velocity Wind Tunnel No. 9 testing in the late 1990's. The generated data sets characterized aero-optical effects on both uncooled and cooled windows in the flow field of Mach 7 heated flow simulating high-speed seeker flight at low altitude.

Polaris is currently advancing next-generation aero-optical evaluation in GTFs with advances in state-of-the-art aero-optical M&S predictions and the development of the AOK to measure the seeker imaging performance in hypersonic flight conditions, as well as isolate and fully characterize the aerothermal window effects and flow effects for anchoring of these high-fidelity M&S codes. These AOK developments rely on relationships with several governmental agencies and GTF to help develop and test aero-optic tools. AOK and associated research can be customized to support customers' missions to defeat a myriad of emerging threats.

Polaris Corporate and Personnel Experience:

- Planning, development, and T&E execution of in-flight flow field hypervelocity measurements.
- Development of aero-optical modeling and simulation codes for uncooled and cooled window configurations to evaluate static flow features, evolving flow structures, and shear layer turbulence over cooled windows, as well as the effects of window deformation and thermal gradients.
- Evaluation of aero-optical effects on supersonic and hypersonic systems, as well as for hypersonic wind tunnel test planning and model validation efforts supporting a diverse customer base including MDA, AFRL, Navy, AvMC.
- Developed methodologies for hit-to-kill phenomenology modeling and included it in its own optical fire ball model for kinetic kill interceptors.
- Developed phenomenological models for the thermal and optical effects of intercept debris and its impact on the Arrow Weapon System fire control system.
- Designed and tested a cryo-vac compatible IR polarized scene generation system to enable AEDC to test the next-generation space sensors for space situational awareness and missile defense.
- Extensively leverages Phase II SBIR and STTR programs to support hypervelocity aero-optical instrument development.

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i. William J. Yanta, W. Charles Spring III, Michael S. Smith, Rita L. Bell, John F. Lafferty and Arnold S. Collier, Robert W. Cayse, **David B. Chenault, Anne-Marie Dorsett**, James Y. Baltar, Henry L. Moody, William C. Rose, "Interceptor Seeker Window Aerothermal and Aero-Optical Testing at the AEDC Hypervelocity Wind Tunnel No. 9", presented at 11th Annual AIAA/MDA Technology Conference and Exhibit, AIAA-15-3, 2002.

ii. William J. Yanta and W. Charles Spring, III, John F. Lafferty, R. James Copland, **Larry Pezzaniti, Michele Banish**, and Russell Shaw, et. al., "Near- and Farfield Measurements Of Aero-Optical Effects Due To Propagation Through Hypersonic Flows", presented at the 21st AIAA Aerodynamic Measurement Technology and Ground Testing Conference, AIAA 2000-2357, 2000.

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