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Polaris
Sensor Technologies, Inc.

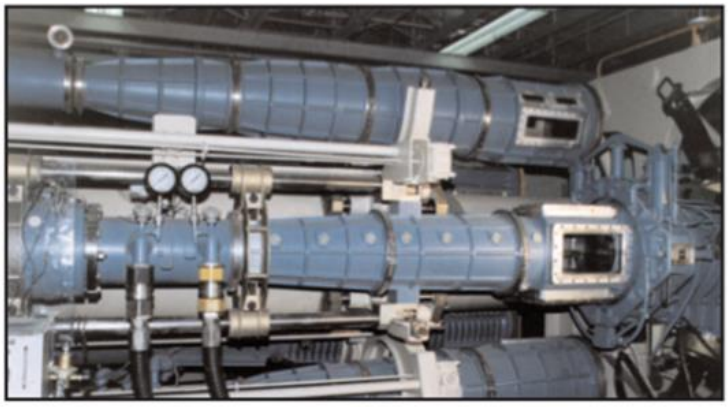
Hypersonic Aero Optics

the study of the effect of induced compressible turbulence on the performance of an optical seeker

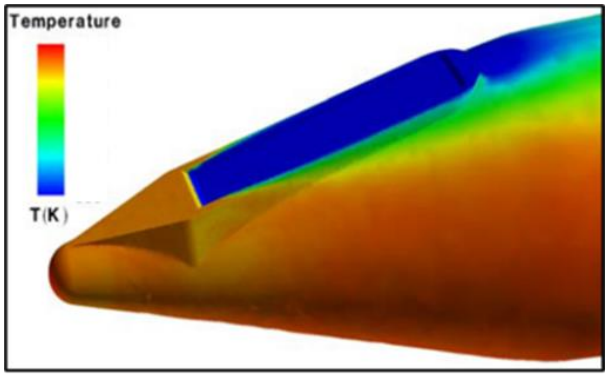
(Image credit: Russian Defense Ministry Press Service/AP)

The rapidly emerging capabilities of hypersonic-velocity weapons from a variety of different countries requires the acceleration of technologies that can maintain the United States' role of 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 operation of our intercepting airframe, seeker, and seeker window remains nominal. Acting against the desired performance in these flight regimes are the resulting aero-optical effects which can be extremely severe from blinding the seeker to even causing catastrophic failure of the window. Polaris is developing a novel suite of instruments to characterize these effects at heretofore impossible ranges and accuracies for a variety of applications ranging from Ground Test Facilities (GTF) to advanced tactical *in situ* applications.

Current GTF are instrumented with advanced sensors to support this investigation, but a set of aero-optical instruments require sizable physical space, are unique to each facility, and require 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).



Sandia National Laboratories Hypersonic Wind Tunnel



Hypersonic flight's significant thermal effects on the seeker window

The AOK instrument suite will maximize the aero-optical data captured from a single test run, reduce costs, minimize the number of runs necessary to complete the characterization, and provide ubiquitous capability. The AOK will offer new insights into time-resolved flow fields and is suitable for high-Mach numbers and enthalpies. It will measure 3 different aero-optics effects: basic image performance, window effects, and flow effects.

The AOK is being designed to provide real-time, onboard measurements mounted inside the test article of cooled and uncooled seeker window performance. Initially the system will

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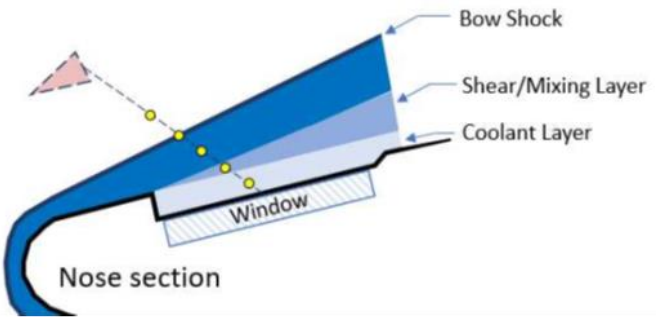
fit into a common Advanced Interceptor Technology (AIT) forebody test fixture for use in hypersonic test facilities. The instrument suite minimizes, if not eliminates, the need for specialized test setups and tunnel modifications. The AOK promotes the ubiquity of aero-optic test capabilities from one GTF to the next.



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 set up sensors to measure wavefront error, point spread function, bore-sight error, jitter, and window deformation in the AEDC Hyper-velocity Wind Tunnel No. 9 in the late 1990's. The generated data sets thoroughly characterized the aero-optic effects in the flow field of Mach 7 heated flow to simulate high-speed seeker flight at lower altitudes. The measurements were path-integrated along the line of sight and temporally averaged. Much of this data is documented.[i, ,ii] Polaris's staff also developed modeling and simulation tools to predict the heat induced deformation of the window to the transmitted wavefront and was instrumental in reducing and interpreting the data collected from a series of wind tunnel runs at Tunnel No. 9 during this same time period. Polaris is currently developing requirements and the solutions for the next-generation aero-optic tool sets for hypervelocity testing in GTF. Polaris's team is creating new solutions to provide realistic hypersonic imagery, window effects, and flow effects measurements. GTF measurements are made more accurate by including AOK test fixtures completely within the interceptor test object and eliminating test structures and mounts in the air flow. Polaris is also increasing test efficiency by enabling multiple measurements to be made concurrently. AOK products will provide previously unavailable realistic data which can both verify and improve scientific models.

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:

- 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.
- Helps develop and validate models the next generation seeker window.
- Extensively leverages Phase II SBIR and STTR programs to support hypervelocity aero-optical instrument development.
- Aero-optical measurement SMEs with nearly 120 years of combined T&E development experience
- Capability to support planning, development, and T&E execution of in-flight flow-field hypervelocity measurements.

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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.