

Ray Trace Math Model and Windows Software Implementation for a Focused Infrared Lamp Projection System



ET Ice
Mitigation

A ray trace math model was developed to predict the intensity of infrared (IR) heat energy that could be projected from a halogen lamp, or cluster of lamps, to heat a target. The target in this particular case is the Space Shuttle External Tank (ET). The mathematical ray trace model developed for this special application can easily be extended to accommodate other optical, as well as acoustic, ray-tracing applications, where the approximation of ideal reflecting surfaces and incoherent waves is appropriate.

When the Shuttle's ET is filled or in the process of being filled with the cryogenic fuel components (liquid oxygen and liquid hydrogen), moisture from the atmosphere forms water ice on the external surface and possibly under the ET's sprayed-on foam insulation (SOFI). This ice formation can lead to several potential problems: (1) integrity of the SOFI can be threatened, leading to the possibility of a foam chunk falling onto critical Shuttle components at high velocity during the first few minutes of launch, (2) falling pellets of ice may become projectiles during launch, and (3) foam chunks with embedded hard ice pellets may become projectiles.

Two solutions to the problem have been considered: blowing hot dry air over the surface to prevent ice formation, and projecting electromagnetic energy (light) to heat the ET surface. This project concerns projecting focused IR light onto the surface using halogen lamps and focusing reflectors. In this case, the light hardware must be located far from the launch pad (435 ft). A big challenge is to select design parameters that will lead to an efficient projection system where a large percentage of the lamp wattage is projected to the ET surface area of interest.



Parabolic projector proof of concept.

Many software packages are available for ray tracing (ray tracing is a technique that has been practiced for centuries). However, only in recent years has the numerical computing power of PCs made it possible to combine Monte Carlo integration techniques with ray-tracing geometry. Even though commercial off-the-shelf software may be available to solve this problem, it was decided that developing the capability from scratch would provide a better solution and one that could be customized to this specific problem.

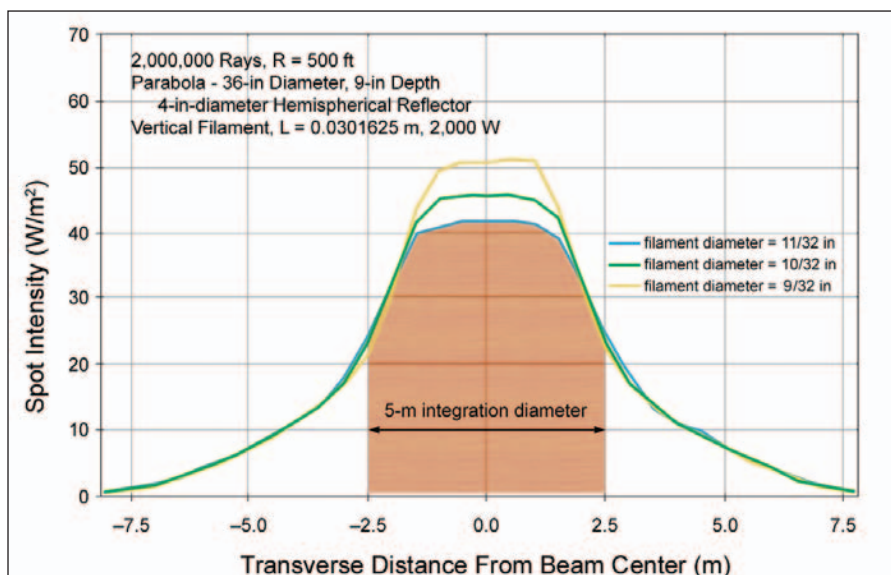
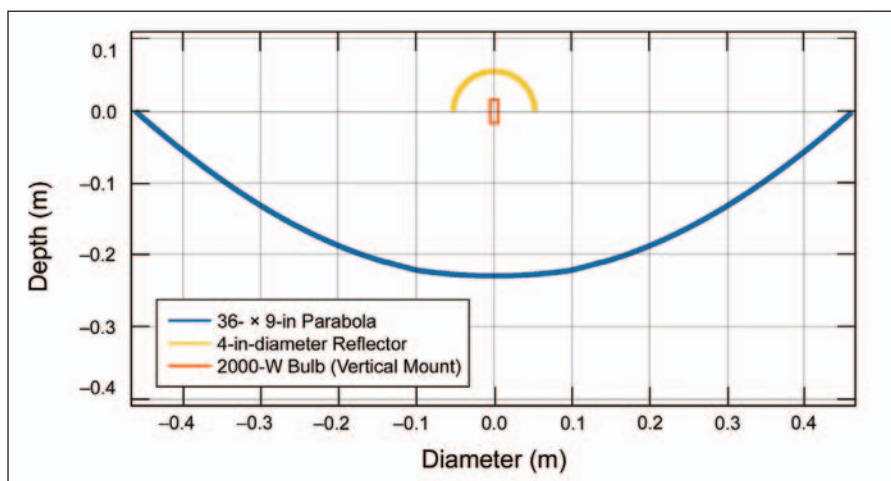
The current version of the model and software assumes ideal parabolic surfaces and ideal reflectors. This limitation could be improved with more work. However, for the current application, this limitation is not considered a major disadvantage.

Key accomplishments:

- Developed a generalized ray-tracing math model, incorporating a cylindrical source, a parabolic reflector, and a semispherical forward reflector.
- Implemented the math model in FORTRAN 90.
- Implemented the math model in C, with a graphics output section, using dynamic link libraries compiled from FORTRAN.
- Compared model predictions to measured data.

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Output of Ray Tracer software for a typical configuration. Top: Beam intensity profile; Bottom: Reflector geometry, including filament, bulb, and front reflector.