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Infrared Signature Modeling of Aircraft Exhaust Plume

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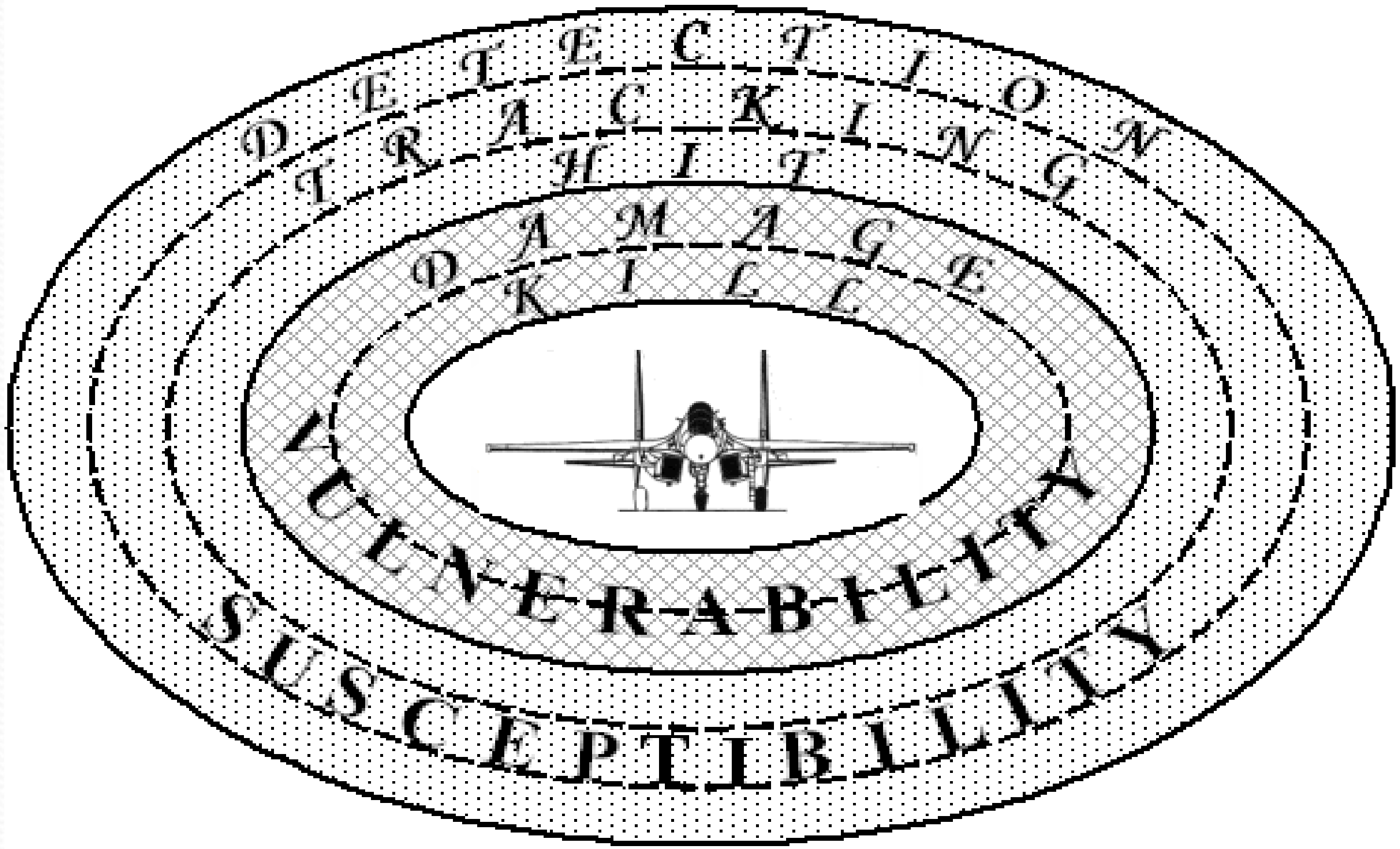
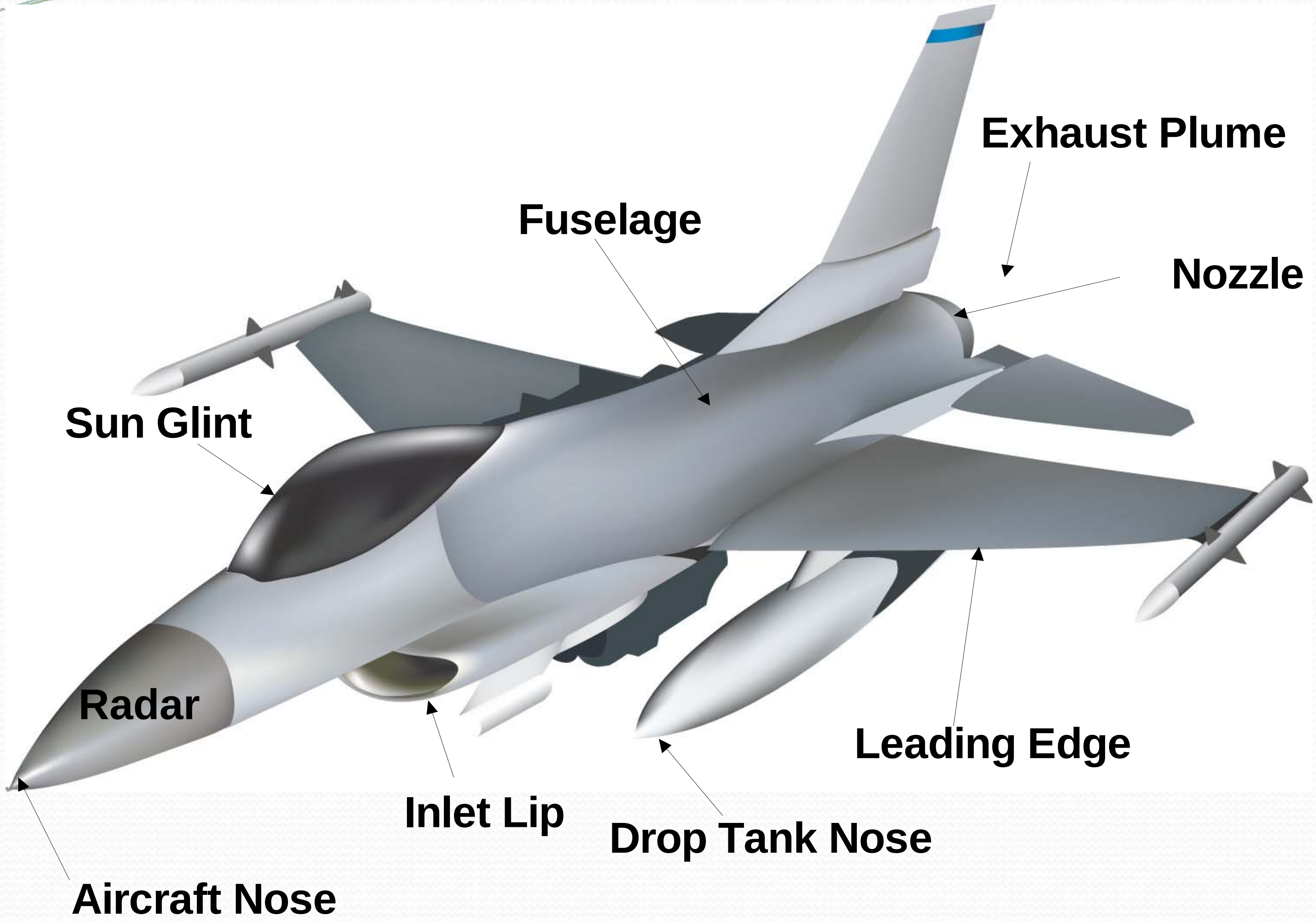
Delft University of Technology
Faculty of Aerospace Engineering

Aircraft Survivability



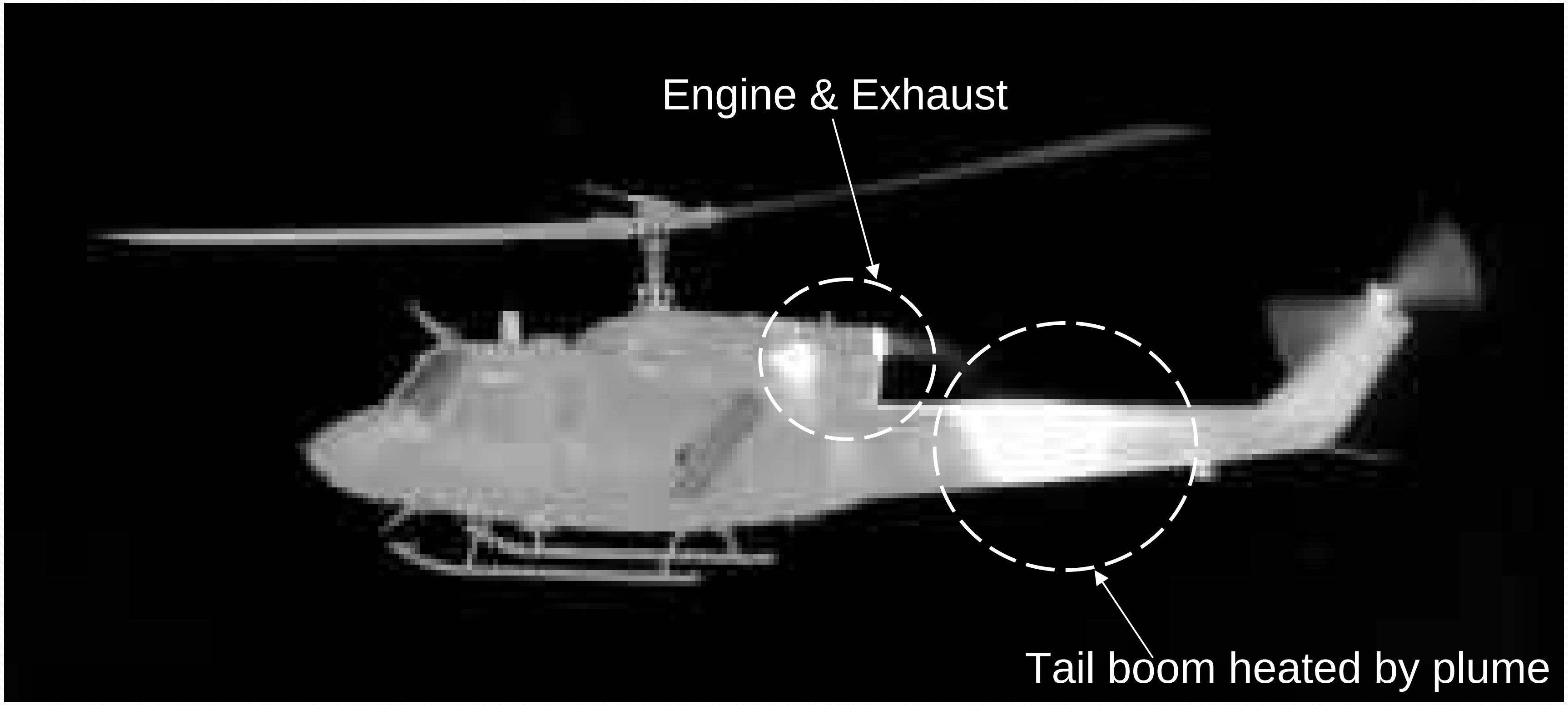
It has been observed that linear changes in aircraft survivability produce exponential changes in force effectiveness and aircraft attrition rates. Thus, stealth technology helps aircraft to avoid high aircraft loss rates and complete the mission objectives effectively

Sources of Infrared Signatures



Infrared Signatures Sources in a Helicopter

Exhaust plume, exhaust duct, tail boom heated by exhaust plume and the direct view of hot engine parts like turbine blades. Engine parts at a temperature of 600-700°C.



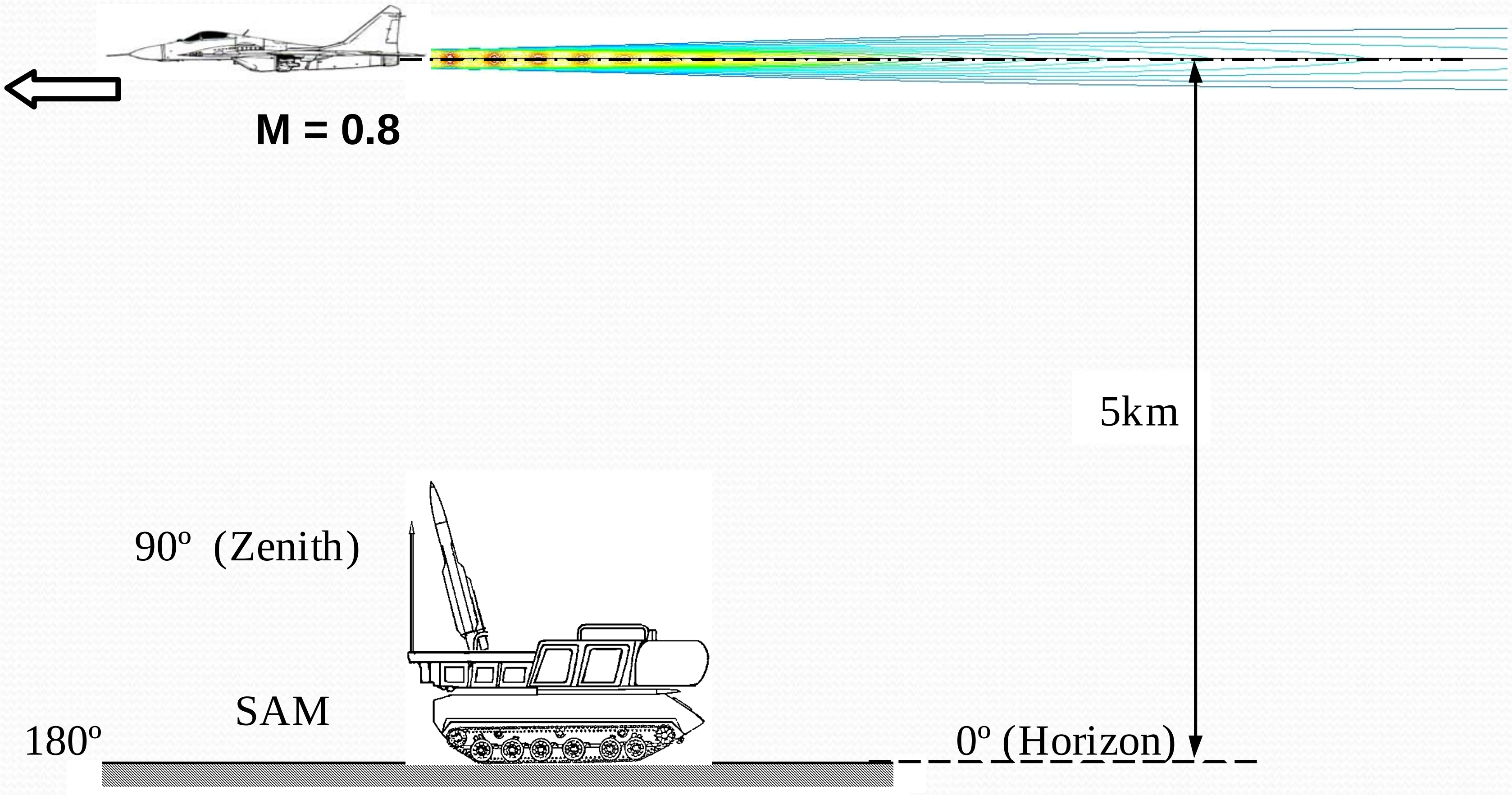
The IR Threat

Missile Type	Soviet Block Missile	Western Missiles
Surface to Air (SAM)	SA-7, SA-9, SA-13, SA-14, SA-16, SA-18	Chaparral, Mistral, Redeye, Stinger
Air to Air (AAM)	AA-2, AA-3, AA-5, AA-6, AA-8, AA-10, AA-11, PL-2, PL-5B, PL-7	AIM 4D, AIM 9L/M (Sidewinder), ASRAAM, MICA, Mistral, Python-3, R.530, R.550, Shafrir, Stinger

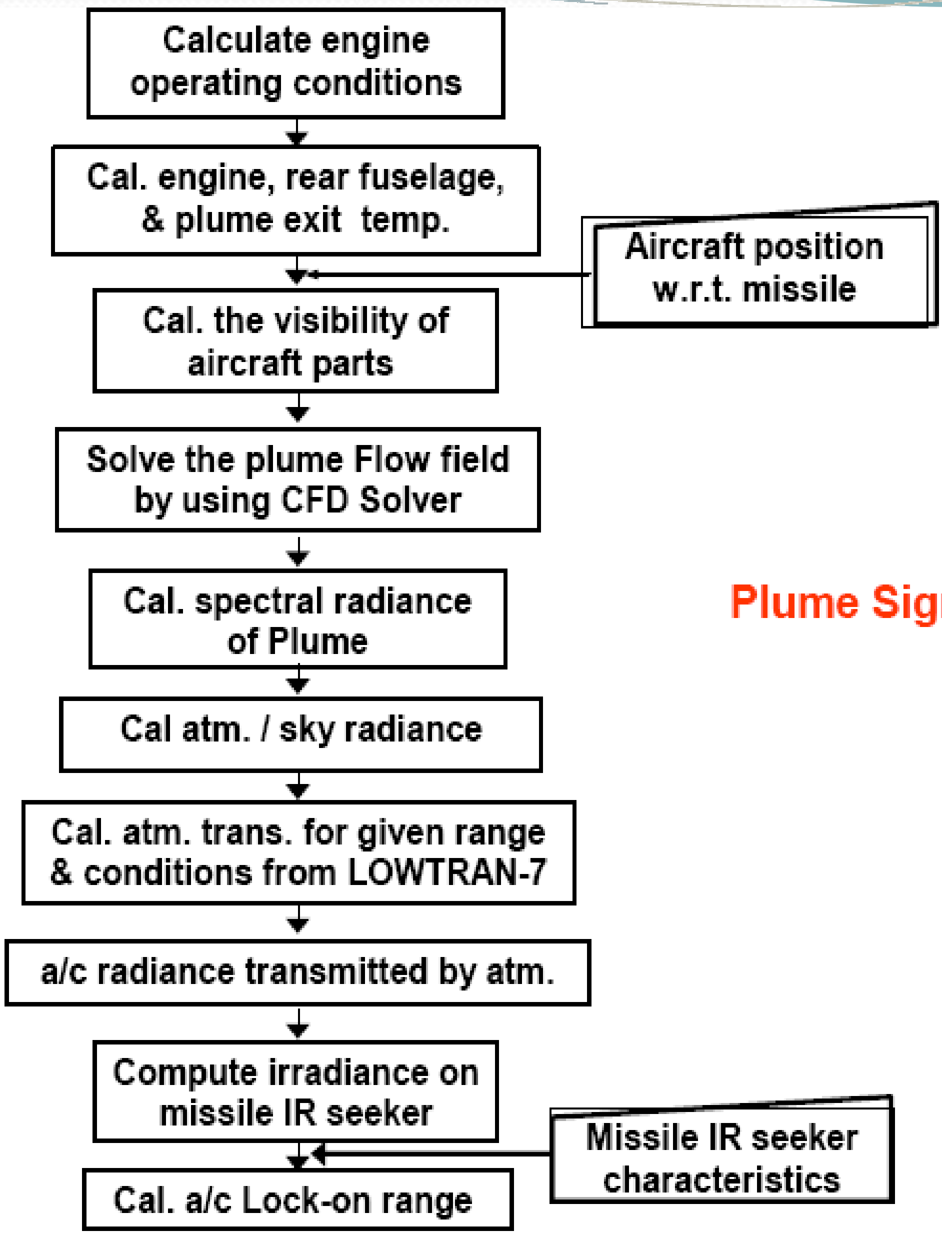
Common heat-seeking missiles and their origin

Plume IR Signature Modelling

A Simple Mission

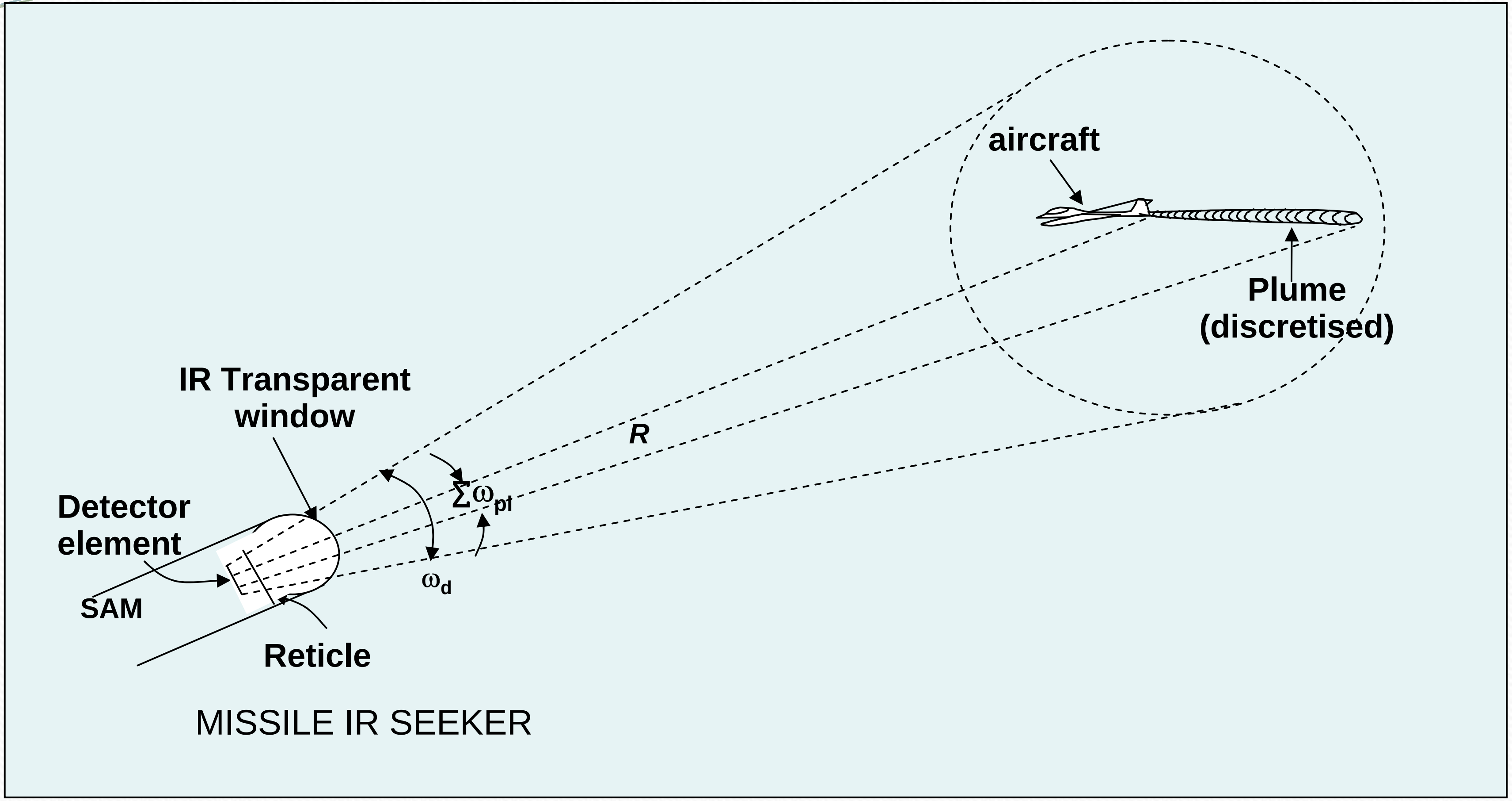


The Modeling Strategy



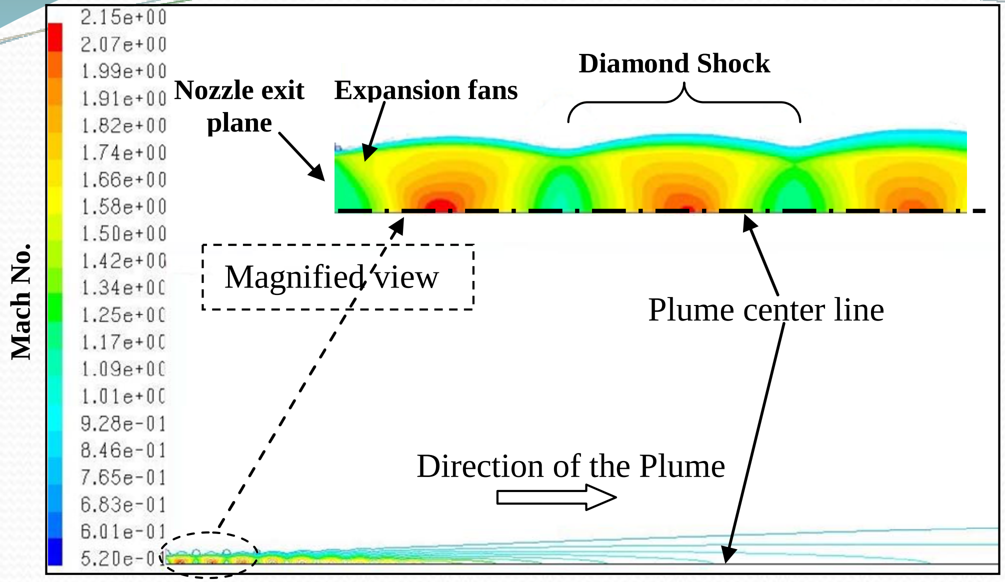
Plume Signature

SAM IR Seeker (instantaneous field of view)



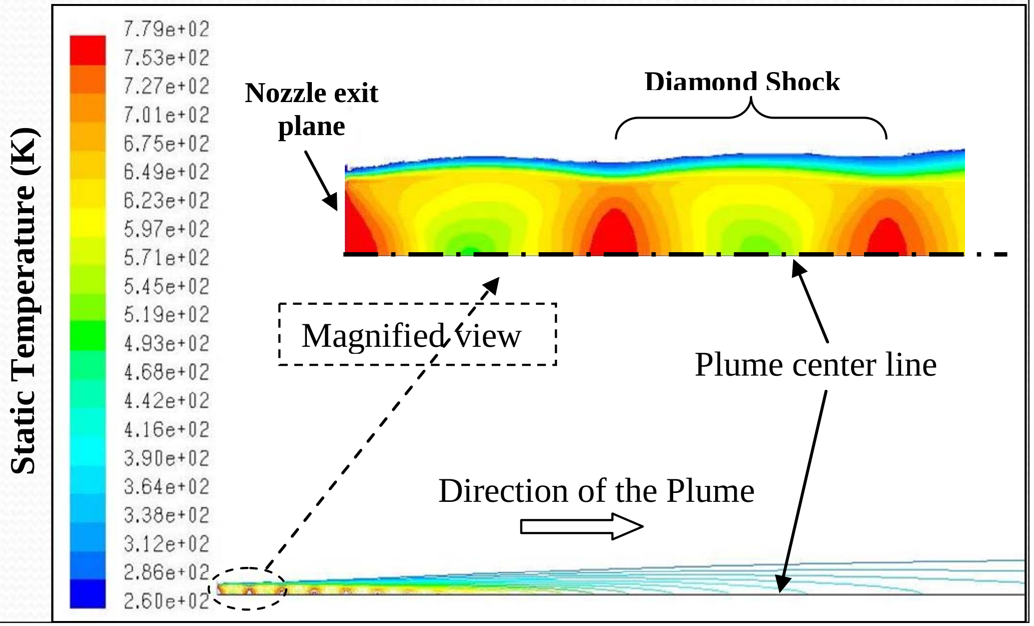
$$R_{LO} = \sqrt{\frac{\left\{\sum_{i=1}^{N_{pl}}\left[I_{i,pl} - I_{bg,pl}(1-\tau_{pl})\right]A_{i,pl} + \sum_{i=1}^{N_{fuse}}\left(I_{i,fuse} - I_{bg,fuse}\right)A_{i,fuse} + \left(I_{tp} - I_{bg,tp}\right)A_{tp}\right\}\cdot\tau_{atm}}{\left(NEI\xi_{\min}\right)}}$$

CFD Simulation of the Exhaust Plume

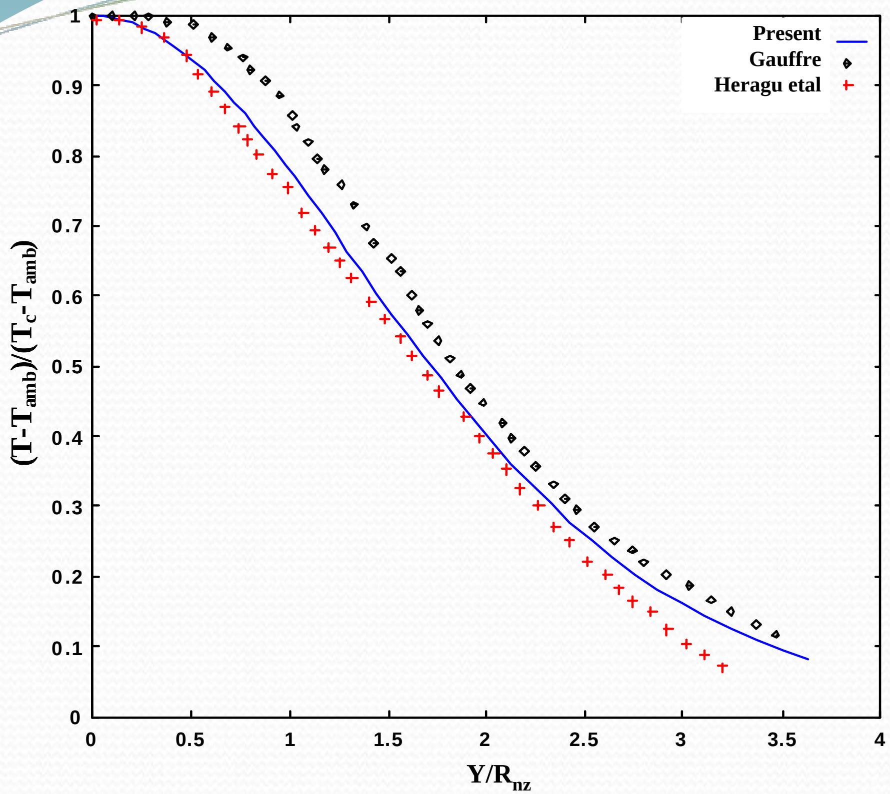


Plume Mach number contours obtained from CFD

Plume static temperature contours obtained from CFD

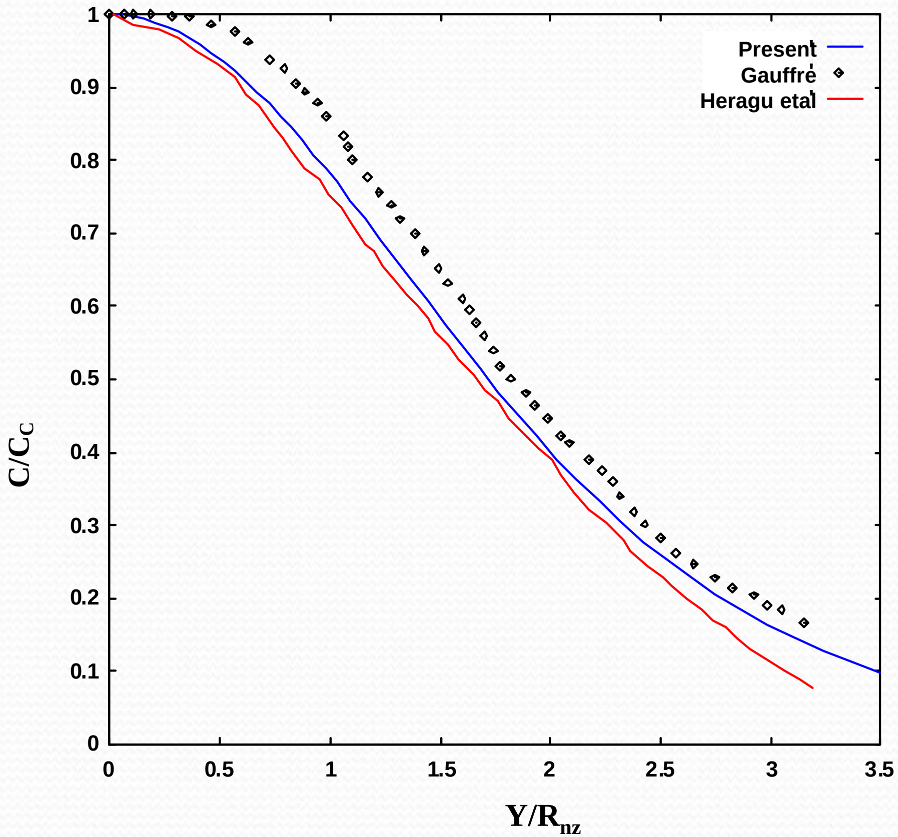


Validation of the Exhaust Plume Simulation

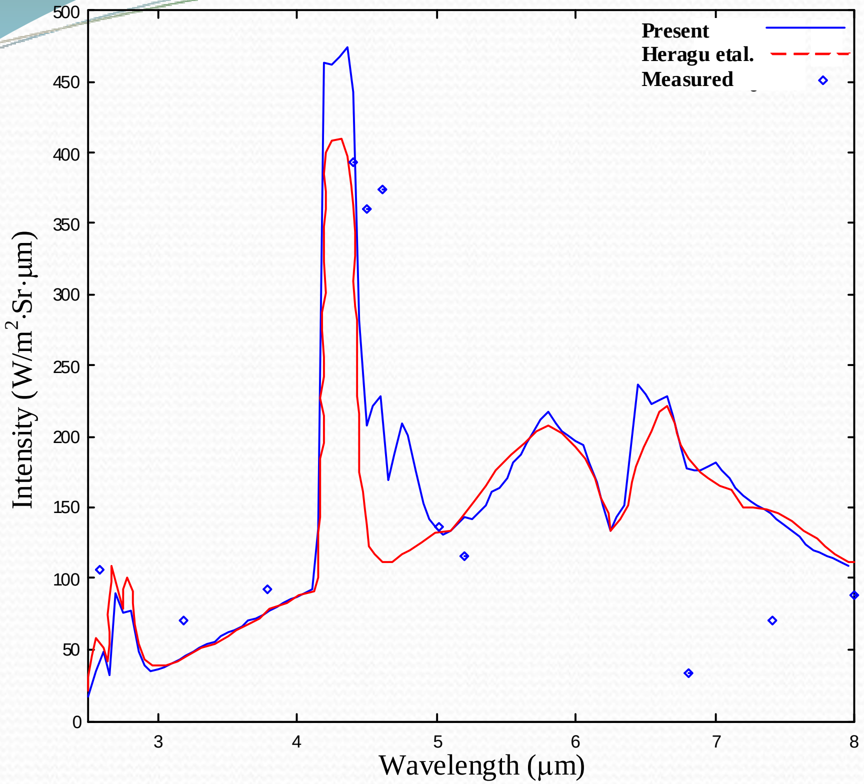


Temperature profile across the jet at $X/D_N = 10$

Concentration profile across the jet at $X/D_N = 10$

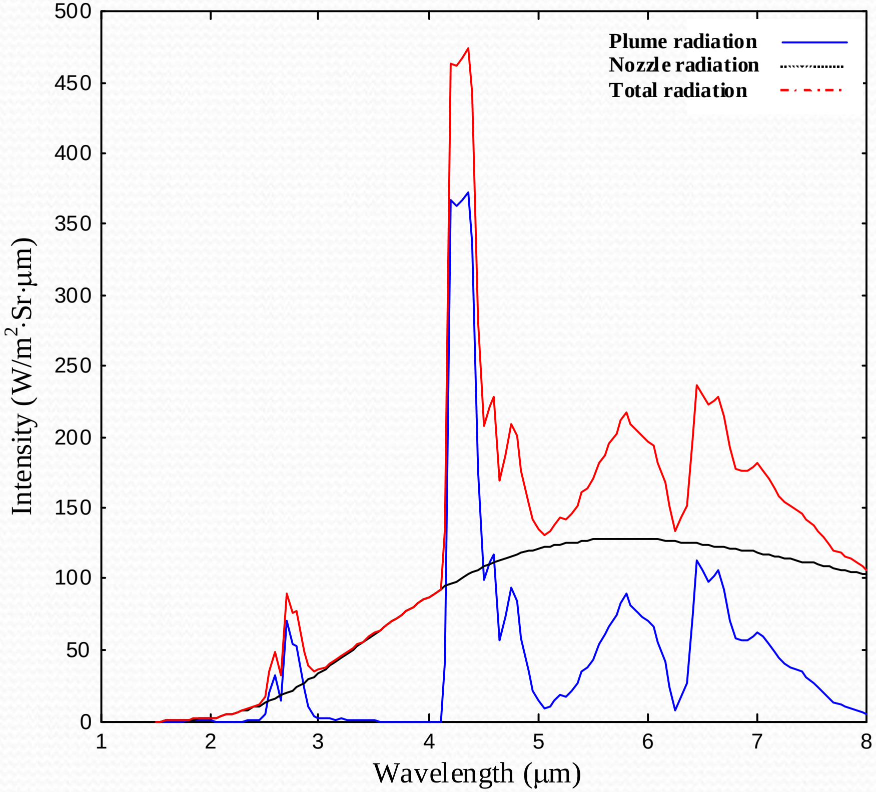


Validation of the Exhaust Plume Simulation

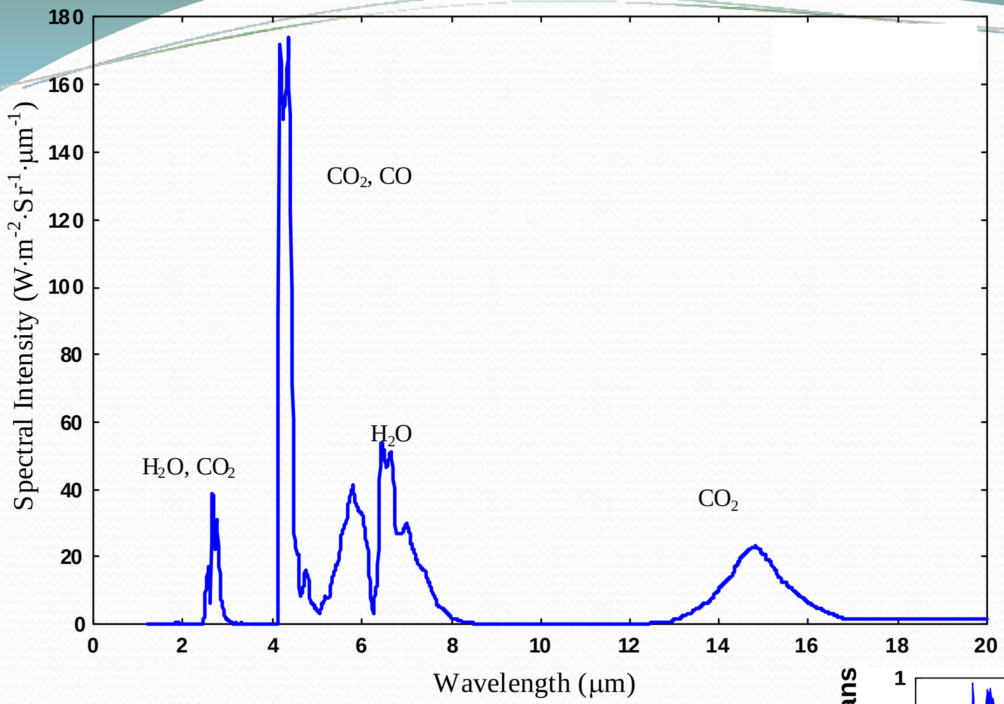


Comparison of predicted infrared intensity (Plume + Nozzle)

predicted infrared intensity (Plume + Nozzle)

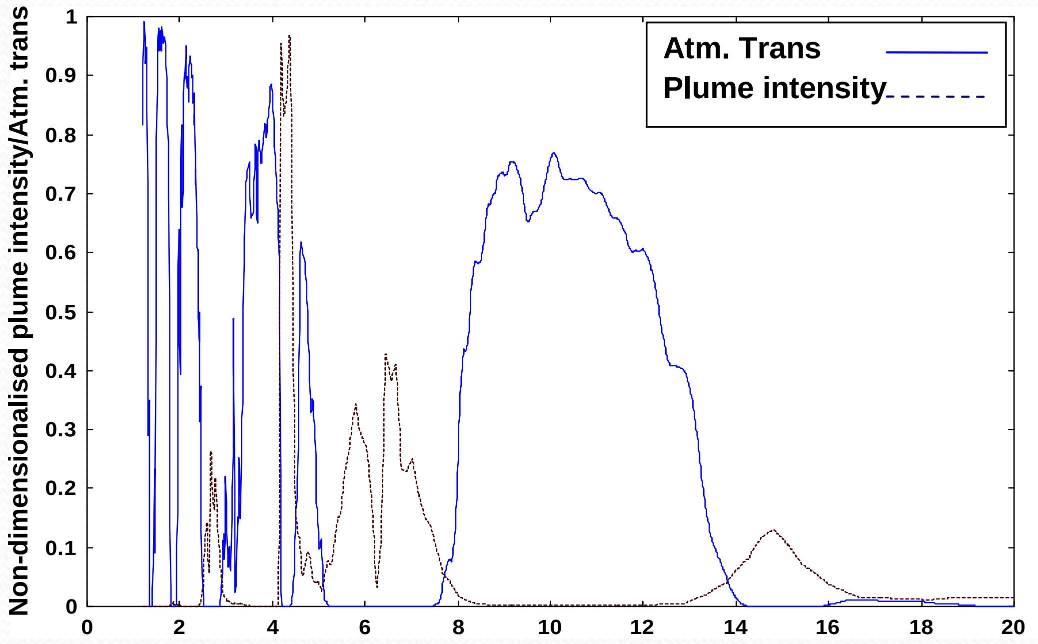


Validation of the Exhaust Plume Simulation

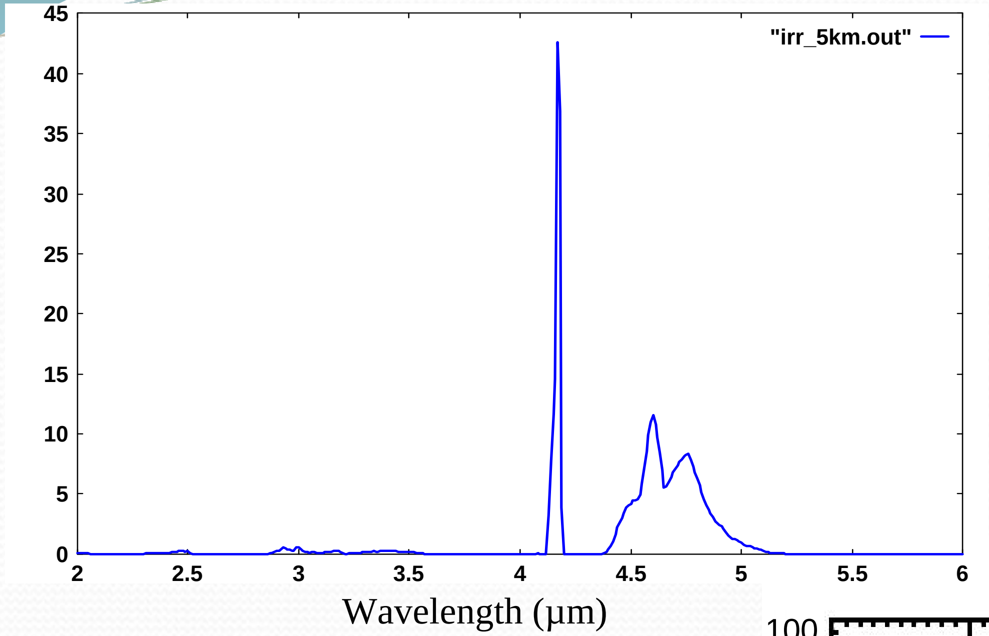


Spectral radiant intensity of aircraft plume

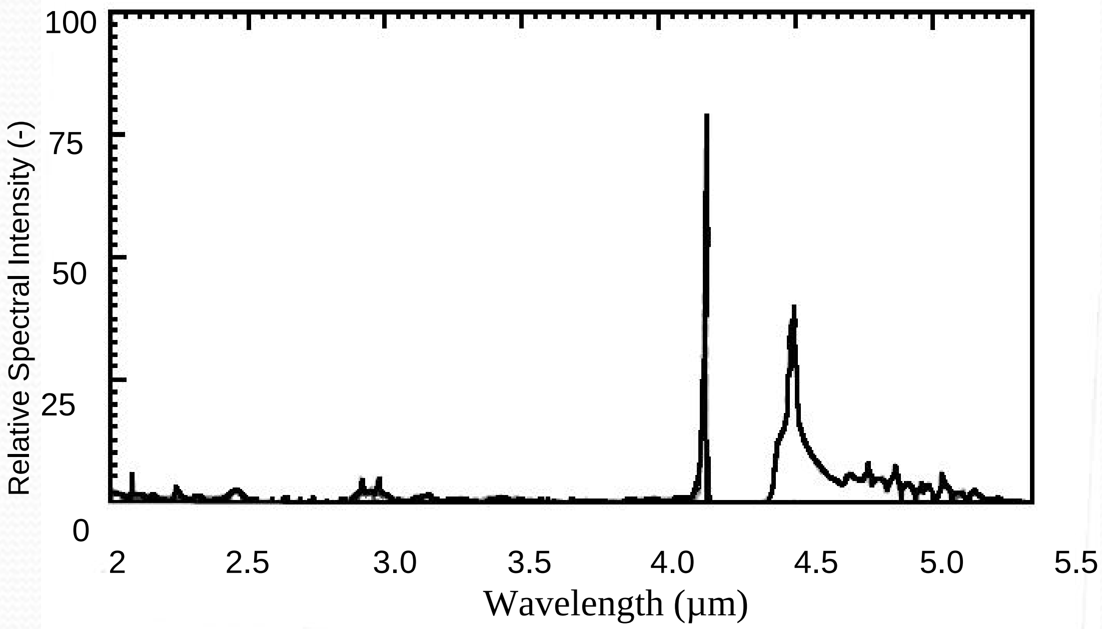
Plume emissive bands absorbed by the atmosphere



Exhaust Plume Solver Validation



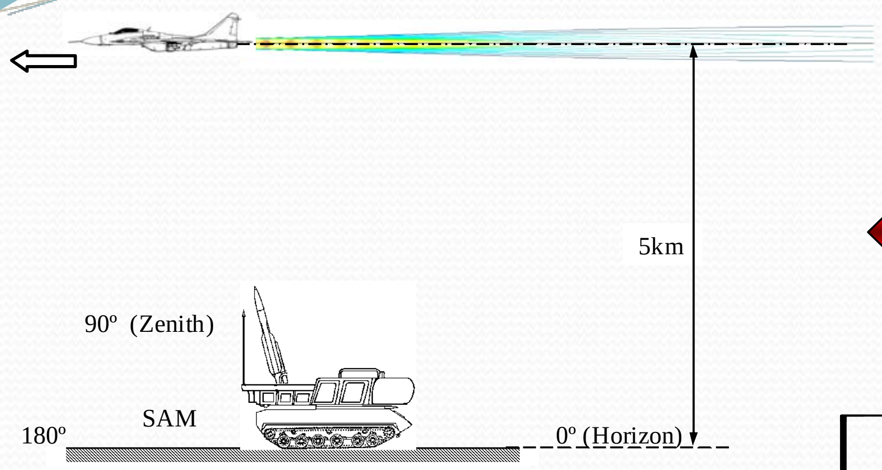
Plume spectral radiant intensity as transmitted by atmosphere



Spectral intensity from airc`raft plume for Boeing passenger aircraft

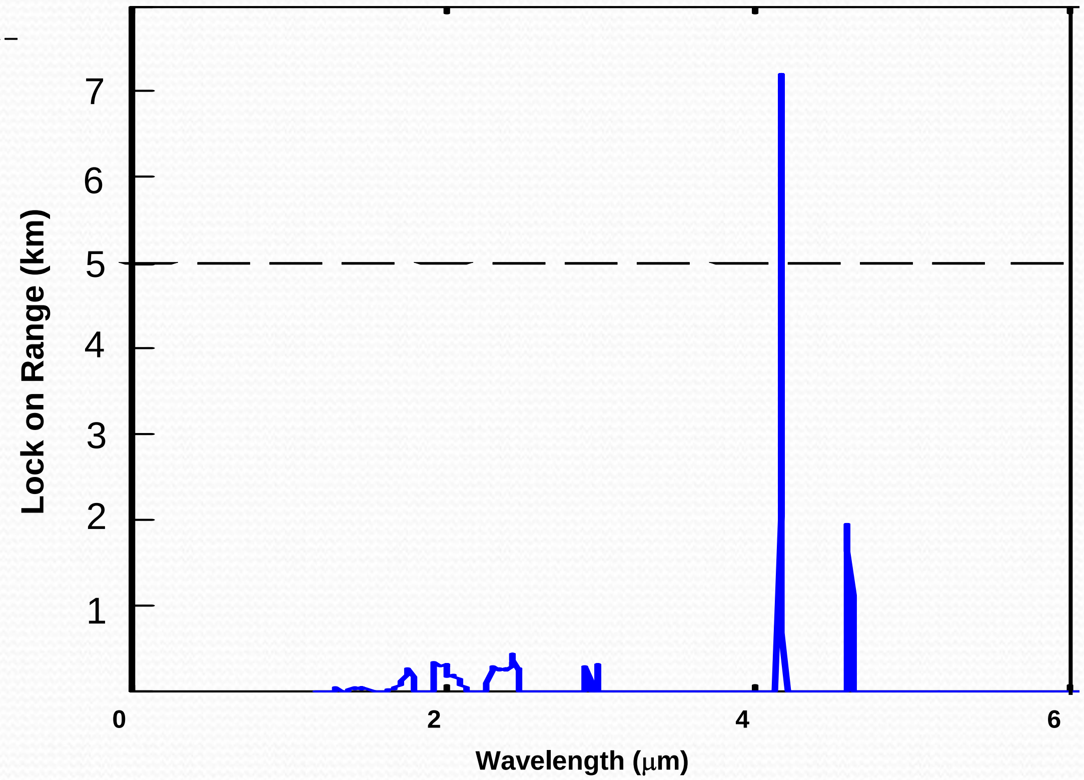
La Rocca, A. J., "Artificial Sources," *The Infrared Handbook,* 1985

Lock-on Range due to the Plume



Mission

Lock-on Range due to Plume Radiation



Exhaust Plume Dilution and Mixing for Bell 205 Aircraft

- A comprehensive methodology is presented to model the IR signature produced by the aircraft exhaust plume and to evaluate its susceptibility against an IR guided SAM.
- The results qualitatively match well with the results available in the literature.
- The prominent band for plume radiation are centered around 2.7 µm, 4.3 µm, 5.5 µm, 6.5 and 15 µm due to the emission by CO_2 , CO and H_2O present in the plume.
- Since the exhaust plume and the atmosphere have same radiative participating species, namely H_2O, CO_2, & CO, most of the IR radiation emitted by the plume is absorbed in the intervening atmosphere.
- Only the radiation emitted from the broadened wings of the plume emissive bands prominent in the 4.15-4.2 µm band reaches the missile IR detector in the non after burning mode.
- The aircraft is susceptible to ground based IR guided SAMs due to the radiation emitted by its plume.

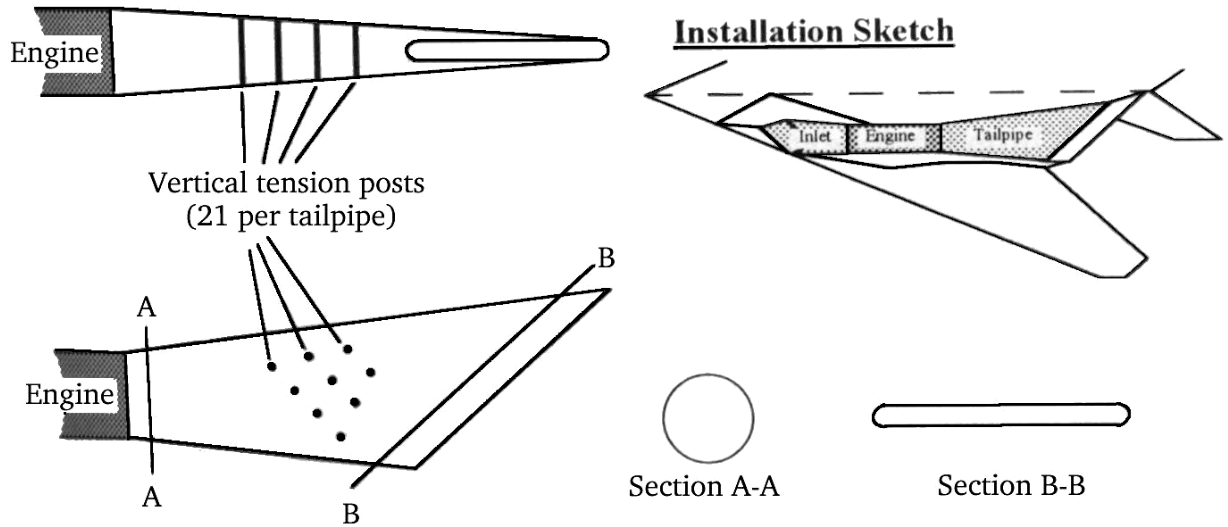
Todda Rabba

Infrared Signature Suppression

F117 Nozzle Configuration for IR Signature Reduction

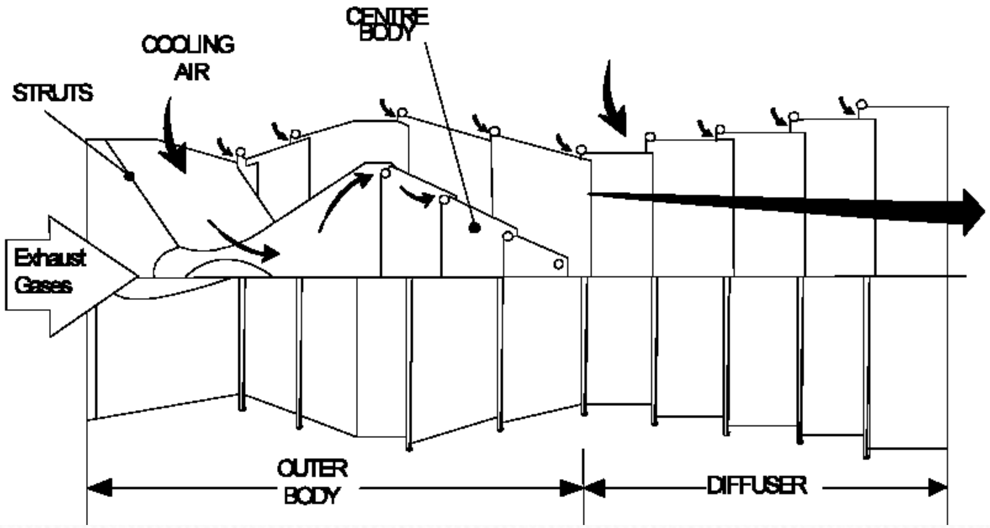
F117-A, Night hawk

Exhaust pipe of F-117A



Exhaust Plume Dilution and Mixing for Bell 205 Aircraft

Bell 205 using Infrared Flares to deceive an incoming IR missile



Schematic of the basic Centre Body Tailpipe used on Bell 205 (UH-1H)