Infrared Signature Modeling of Aircraft Exhaust Plume
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

- Aircraft Nose
- Inlet Lip
- Drop Tank Nose
- Sun Glint
- Radar
- Leading Edge
- Exhaust Plume
- Fuselage
- Nozzle
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

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

**Common heat-seeking missiles and their origin**
A Simple Mission

M = 0.8

90° (Zenith)

180°

SAM

0° (Horizon)

5km
The Modeling Strategy

1. Calculate engine operating conditions
2. Cal. engine, rear fuselage, & plume exit temp.
3. Cal. the visibility of aircraft parts
4. Aircraft position w.r.t. missile
5. Solve the plume Flow field by using CFD Solver
6. Cal. spectral radiance of Plume
7. Cal atm. / sky radiance
8. Cal atm. trans. for given range & conditions from LOWTRAN-7
9. a/c radiance transmitted by atm.
10. Compute irradiance on missile IR seeker
11. Cal. a/c Lock-on range
12. Missile IR seeker characteristics
\[ R_{LO} = \sqrt{\left( \frac{\sum_{i=1}^{N_{pl}} I_{i,pl} - I_{bg,pl}(1-\tau_{pl})}{A_{i,pl}} + \sum_{i=1}^{N_{fuse}} (I_{i,fuse} - I_{bg,fuse})/A_{i,fuse} + (I_{tp} - I_{bg,tp})/A_{tp} \right) \cdot \tau_{atm}} \]
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

Spectral Intensity (W·m⁻²·Sr⁻¹·µm⁻¹)

Wavelength (µm)

H₂O, CO₂, CO

H₂O, CO₂

CO₂

CO

Atm. Trans

Plume intensity

Non-dimensionalised plume intensity/Atm. trans
La Rocca, A. J., “Artificial Sources,”
The Infrared Handbook, 1985

Spectral intensity from aircraft plume for Boeing passenger aircraft

Plume spectral radiant intensity as transmitted by atmosphere
Lock-on Range due to the Plume Radiation
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$_2$O present in the plume.

Since the exhaust plume and the atmosphere have same radiative participating species, namely H$_2$O, 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

SEE I GET RID OF AIRCRAFT.
F117 Nozzle Configuration for IR Signature Reduction

Exhaust pipe of F-117A

F117-A, Night hawk

Vertical tension posts (21 per tailpipe)
Schematic of the basic Centre Body Tailpipe used on Bell 205 (UH-1H)

Bell 205 using Infrared Flares to deceive an incoming IR missile