# DEVELOPING AN IR SIGNATURE SPECIFICATION FOR MILITARY PLATFORMS USING MODERN SIMULATION TECHNIQUES

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## ABSTRACT

This paper describes a generic approach to generating the IR signature specification of a military platform. A generic naval Frigate is used as a sample platform to demonstrate the process.

This paper shows how various simulation techniques can be used to design and specify subsystems that affect the ultimate IR signature of a vehicle. These subsystems can then be specified in detail for the construction of the platform. Once built, the platform performance relative to the contract specification can be evaluated using well defined methods with correction to reference test conditions using available simulation technologies.

## INTRODUCTION

The IR suppression of a military platform is a complex process with many technical issues. However all of this must be boiled down to the bare essentials when it comes to specifying it in a ship construction contract.

A systematic approach is needed in specifying the IR signature requirement for a platform. The methods used to meet that requirement can be clearly defined based on well established engineering knowledge and experience.

The analysis of a platform IR signature must consider all of the components that make up the platform signature including:

i) Internal sources: engines and plumes, internal heat
ii) External sources: solar heating and background signature

Once these are defined it is then necessary to apply various levels of suppression including:

i) Cooling visible hot metal and plume
ii) Thermal insulation and ventilation of internal spaces
iii) Cooling sun heated ships hulls with water wash-down

The objective is to achieve an integrated solution which includes a balanced approach to signature reduction. There is no point to reducing the signature of one component to absolute zero and leave other significant sources untouched. We know it is impossible to make the platform disappear, but we can make it a low grade blurred target that is more likely to fade into the background clutter.

**IR SUPPRESSION**

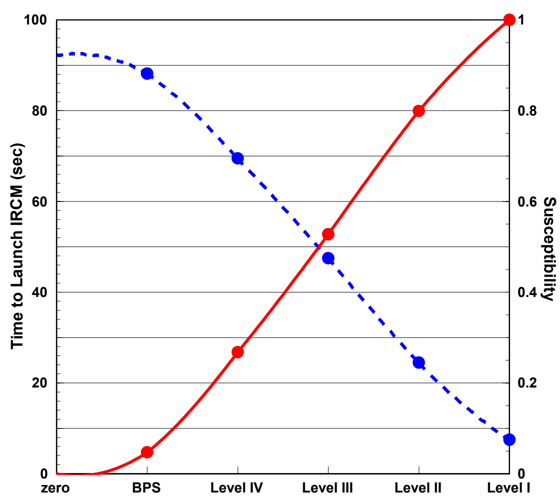
Based on many years of experience of IR suppression of ships and aircraft it has been concluded that most IR suppression schemes can be organized into a four level system. The basic levels are:

i) no suppression (baseline platform)
ii) basic cooling of visible exhaust duct metal, and skin cooling with available means (NBC water wash for ships)
iii) exhaust duct cooling, plume cooling to 250 $^{o}$C, and skin cooling with available means
iv) duct cooling, plume cooling to 150 $^{o}$C, full skin cooling (with dedicated water wash for skin cooling for ships)

The final selection of level depends on the perceived threat and on the system cost. Most modern naval ships tend to opt for level ii) or iii). Several ships currently in the design stage are looking at level iv).

The ultimate effectiveness of an IR suppression system can be measured in terms of reduced IR susceptibility. This can be done using well established analysis tools such as the NTCS code. Confidence in codes like this are increasing as validation with sea trials testing matures. The analysis presented in this paper was done using NTCS. Further details on this code can be found in the references listed at the end of this paper.

Figure 1 shows how the various levels of IRSS affect the platform susceptibility and the effectiveness of active IRCM. With analysis tools like NTCS it is possible to predict the benefits or IRSS in terms of the time available to use IRCM. This ability to quantify benefits in these terms gives more meaning to the cost-benefit analysis.




- Assume IRST detects threat at 27-28 km range
- Assume threat flies at 300 m/s

Figure 1 Real World Impact of IRSS

The following sections present the step-by-step approach to selecting an IR suppression specification. The example given is a generic Frigate.

## INPUTS TO THE SPECIFICATION

The inputs to the specification are all the parameters that affect the susceptibility of the platform to threats, including:

- i) background
  - a. geography
  - b. date and time
  - c. meteorological
- ii) platform
  - a. size and shape
  - b. materials and coatings
  - c. propulsion and auxiliary equipment
  - d. deck or surface mounted equipment
- iii) threat
  - a. waveband (MWIR, LWIR)
  - b. spatial resolution (scanner, imaging, etc.)
  - c. sensitivity (detector noise, clutter)

All of the above are inputs to comprehensive codes like NTCS. The analysis can account for:

- i) true 3D shape
- ii) realistic sea and sky effects
- iii) multi-surface reflections
- iv) atmospheric attenuation
- v) plume emissions

The details of this analysis process are beyond the scope of this paper and can be found in various references on NTCS.

## DEVELOPMENT OF A SPECIFICATION

The motivation for the application of IR suppression is obvious, it is to reduce the susceptibility of the platform to IR guided threats. However, the specification is ultimately defined by what can be done and at what cost. The following basic rules apply to the generation of an IR signature specification:

- i) the IR specification must address the perceived threats
- ii) the specified IR signature must be achievable and affordable
- iii) all significant signature components must be addressed in a balanced way
- iv) all components of the signature should be quantified under clearly defined environmental and operational conditions
- v) the result must be verifiable

The specification can be written it two basic ways. One method would be to specify the actual ship signature limits under well-defined conditions. These limits are usually specified in W/sr and would be based on predicted lock ranges with perceived threats. The other way would be to specify the hardware that must be installed on the ship to meet the desired signature levels, including:

- i) thermal insulation
- ii) internal space ventilation
- iii) paints
- iv) engine IR suppressors
- v) water wash system components, nozzle details, water flow rates

These details would be designed to ensure that the ship will meet the ultimate signature goal based on the perceived threats. Whoever writes the specification in terms of the design details will ultimately be responsible for the ship meeting the desired IR performance. This may be the buyer of the platform or a third party. The shipyard will automatically meet the IR specification as long as they follow the details of the hardware specification.

## PERCEIVED THREAT

The perceived threat is a very important input to this process. There is a wide range of IR seeker technology available in the world today. Some would argue that IR suppression is useless against the latest high sensitivity, smart, imaging seekers. However any threat analysis must consider the probability of meeting up with a specific type of threat. There is a much higher probability of meeting an older, less capable threat and in this case IR suppression can provide significant protection.

## VERIFYING THE SIGNATURE

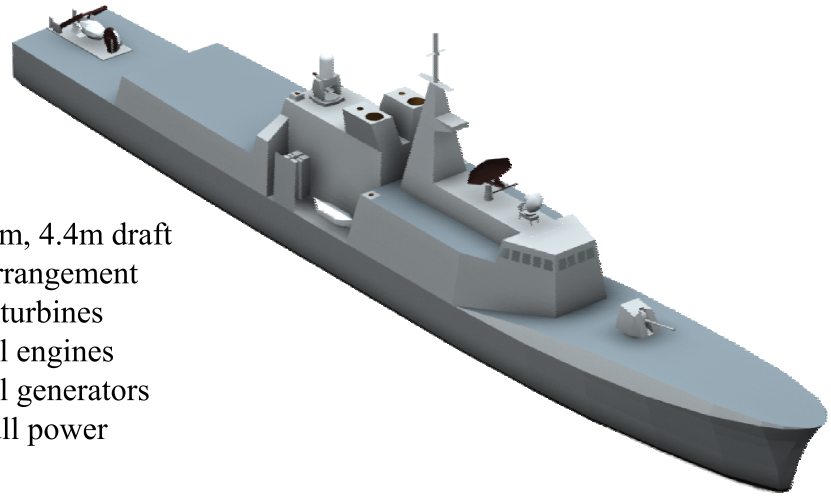
When the ship is built the buyer is going to want to verify that the signature spec has been achieved. This is usually done in a sea trial. The problem with sea trials is that the conditions of the trial cannot be controlled and as a result the conditions are usually not the same as the conditions specified in the IR specification. For this reason it is necessary to correct the trial results using a well accepted reference computer code such as NTCS. This approach is not widely accepted but it is really the only practical way to do it.

## SHIP SIGNATURE MODELLING

The starting point of a specification is the definition of the baseline signature of the platform before IR suppression measures are applied. This is done using a code like NTCS.

The analysis needs to be done under a range of operational and background conditions. This allows us to define the range of signature expected. The limits of this range are defined by the “best possible signature” or BPS, and a “worst possible signature” or WPS. This is usually defined at an observers range of 1 km, with standard atmospheric conditions, looking at the starboard side of the ship.

Figure 2 shows a generic frigate which will be used here as an example platform.



- 2400 ton frigate
- 113m long, 13.7m beam, 4.4m draft
- CODOG propulsion arrangement
  - 2 x 20000 kW gas turbines
  - 2 x 4000 kW diesel engines
  - 3 x 1000 kW diesel generators
- 20 kts cruise, 30 kts full power

Figure 2 Generic Frigate Model

Figure 3 shows a sample bar graph for the generic frigate showing the externally generated (solar effects) BPS and WPS with the ship dead in the water with no engines running. As can be seen the range is very large illustrating the difficulty in specifying a single signature value in a requirement. The BPS is usually at night time conditions with the ship dead in the water. The worst possible signature is usually the ship side on to the sun, dead in the water with no relative wind.

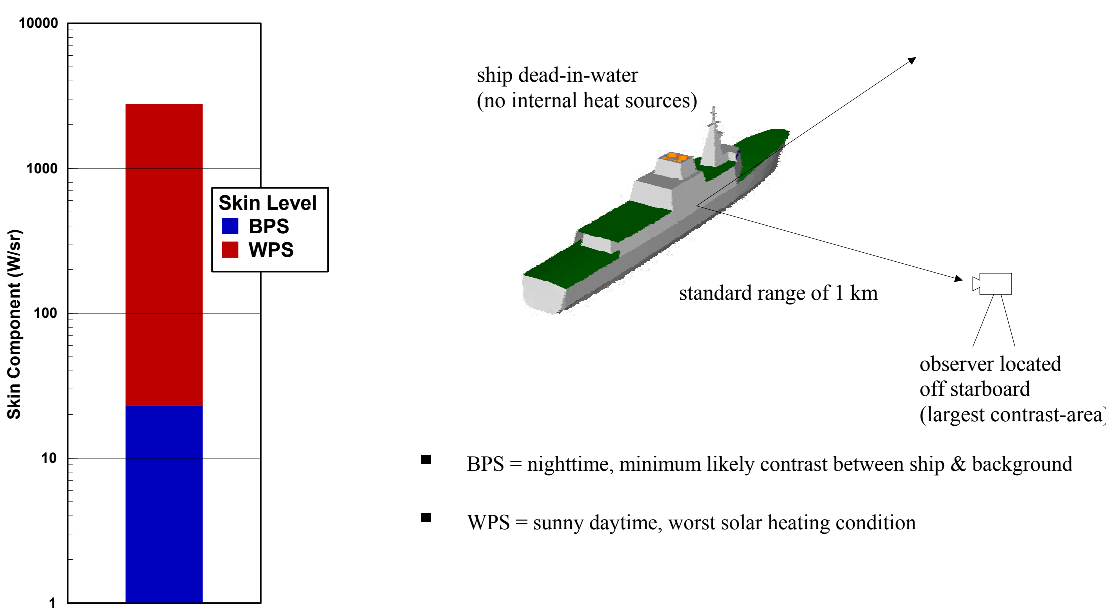
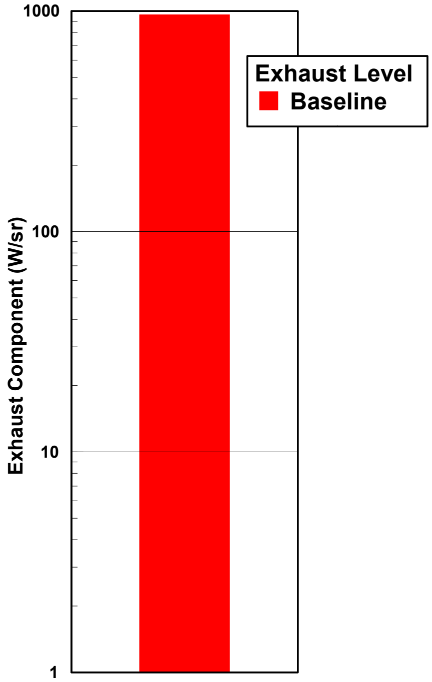
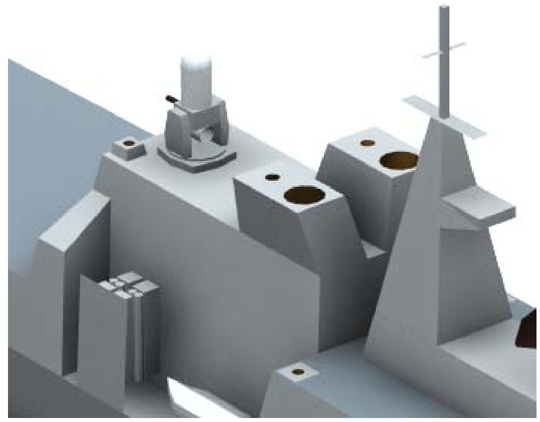



Figure 3 Worst and Best Possible External Signature Component

The internal WPS is also determined with all engines running at full power. This adds visible hot metal in the uptakes and hot plumes. It may also add to the skin signature. This is shown in a bar graph in Figure 4.

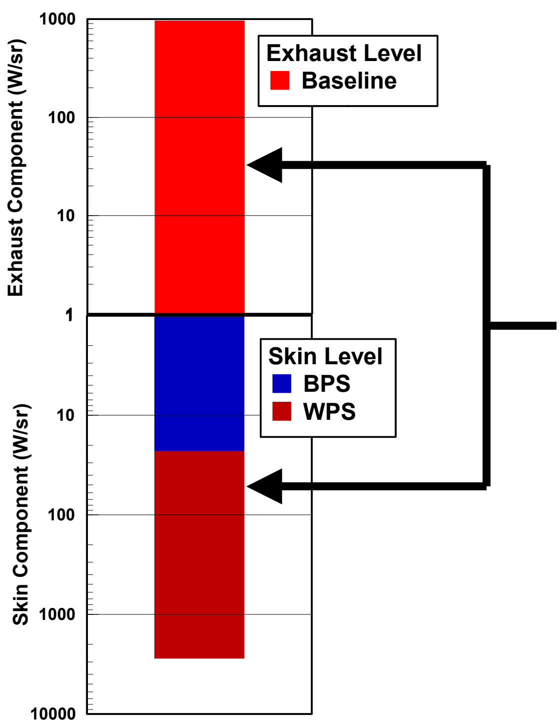


- BASELINE: no exhaust treatment
- FULLPOWER: 2x Gas Turbines + 3x Diesel Generators

Figure 4 Worst Possible Internal Signature Component

The internal and external WPS and BPS can then be combined to give the overall integrated signature range for the baseline ship. This is shown in Figure 5 for the generic frigate.




- IR Signature Specification will lie somewhere within this range

Figure 5 Combined Internal/External Ship Signature

## APPLICATION OF IR SUPPRESSION

Once the baseline signatures are defined then it is possible to apply various levels of IR suppression. The IR suppression applies to engine exhaust systems and the ship surface/skin.

## ENGINE EXHAUST IRSS

Based on experience there are basically four levels of suppression for engine exhaust systems:

- i) no suppression (baseline)
- ii) visible uptake metal cooling to T ambient + 30$^{o}$C
- iii) metal cooling + plume cooling to 250$^{o}$C
- iv) metal cooling + plume cooling to 150$^{o}$C

Figure 6 shows a number of systems currently in use for engine IRSS. These systems incorporate film cooling, and air eductors. For some systems water spray is used to further reduce the plume temperature.

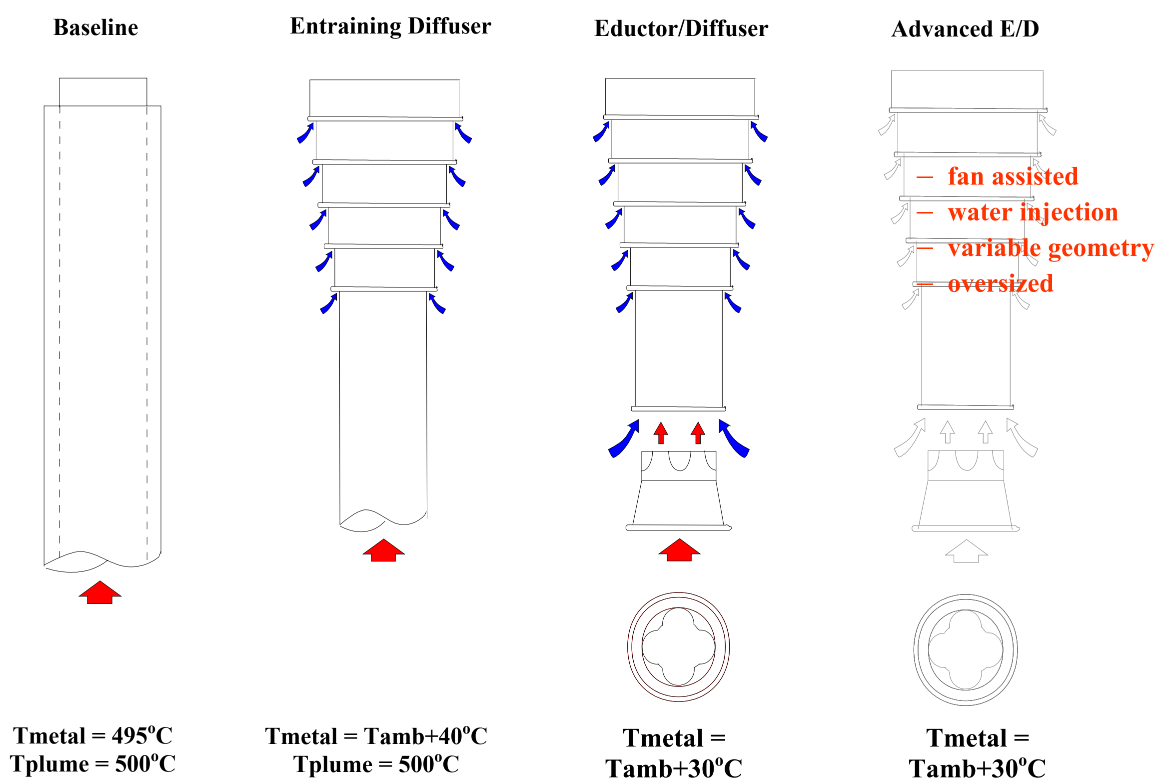



Figure 6 Engine IRSS Systems

As the level of suppression is increased, so is the cost and complexity. This is illustrated in Figure 7. As can be seen the cost of the IRSS is directly related to the cost of an unsuppressed exhaust system. For example a level II suppression system (metal cooling only) costs about 2 times as much as a baseline uptake, while the level IV system (metal cooling with 150 $^{o}$C plume) costs about 5.5 times the cost of an unsuppressed uptake.


Figure 7 Suppression vs Cost and Complexity

Figure 8 shows how ship signature and lock range varies with level of exhaust suppression.

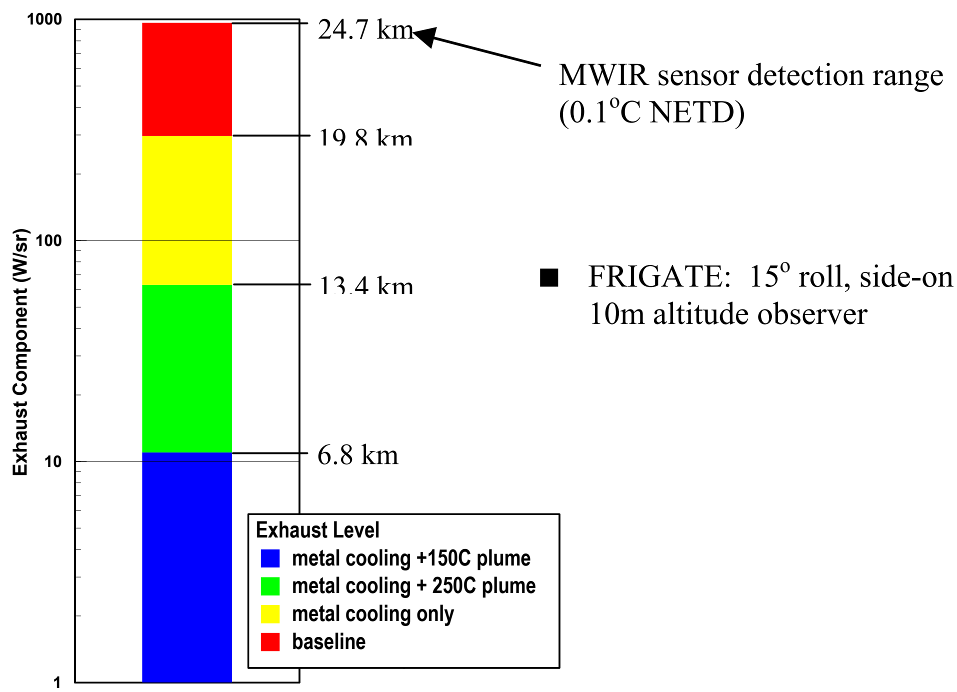



Figure 8 Engine IRSS Effectiveness

**PLATFORM SKIN IRSS**

The platform skin signature is due to solar heating and heat losses from internal spaces. For the internal heat losses, thermal insulation and ventilation are the solution. For solar heating, water wash and low solar absorbtvity paint are solutions.

Figure 9 shows the benefits of suppressing skin signatures. As can be seen, full water wash for IR suppression of the hull, applied to the worst case solar heating case reduces the ship signature by a factor of 30, and this reduces the expected threat (3-5 µm, NETD = 0.1˚C) lock range from 23 to 5 km. This shows a tremendous benefit from this skin suppression.

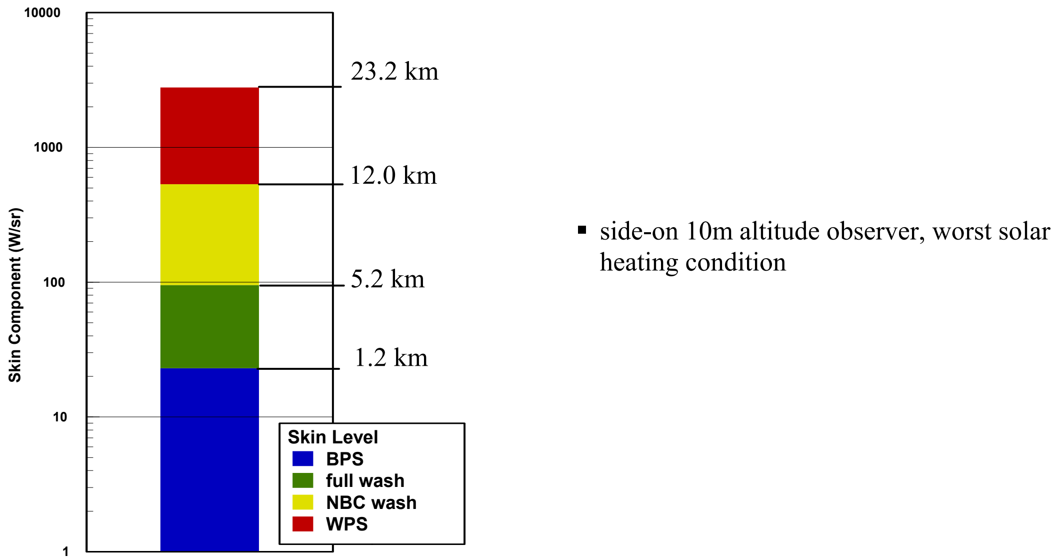



Figure 9 Skin Signature Suppression Benefits

Changing the paint does not provide nearly the benefit as shown in Figure 10.

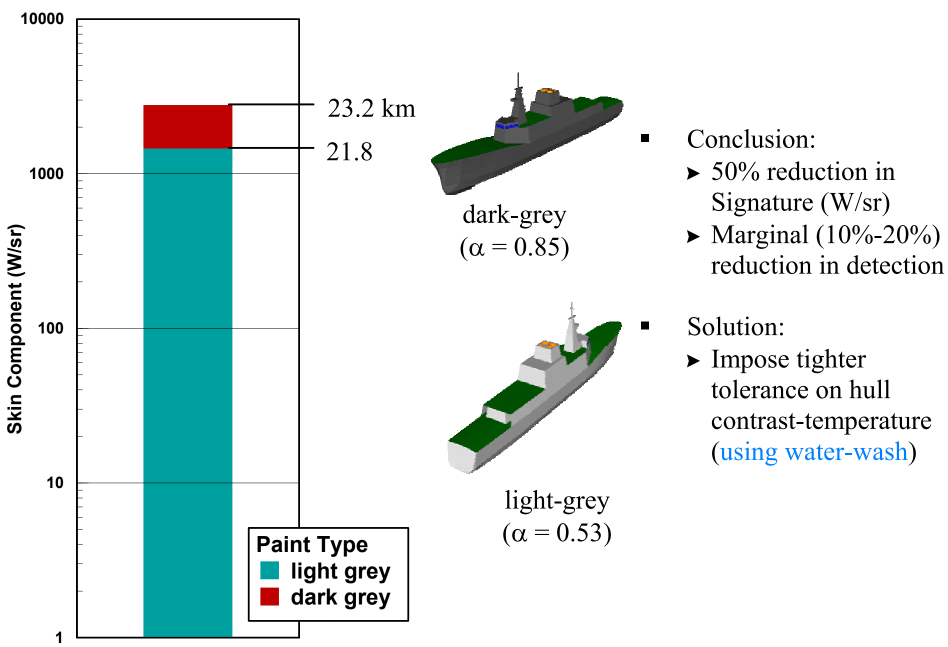



Figure 10 Effect of Paint on Daytime Skin Signature

**INTEGRATED SUPPRESSION**

Figure 11 shows the combination of engine exhaust and skin IR suppression schemes, for the four levels of suppression available. This single graph gives a good summary of the benefits from the various levels. Figure 12 shows the relative cost of the systems. This cost and benefit summary is ultimately used to select the IR suppression approach for the ship and this will determine the details of the IR specification.

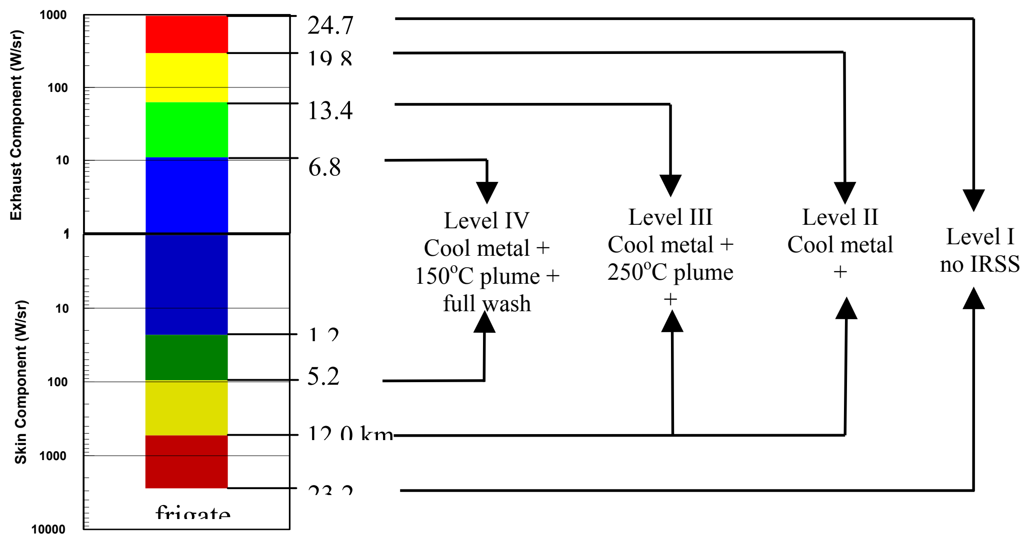



Figure 11 The Four IR Signature Suppression Levels

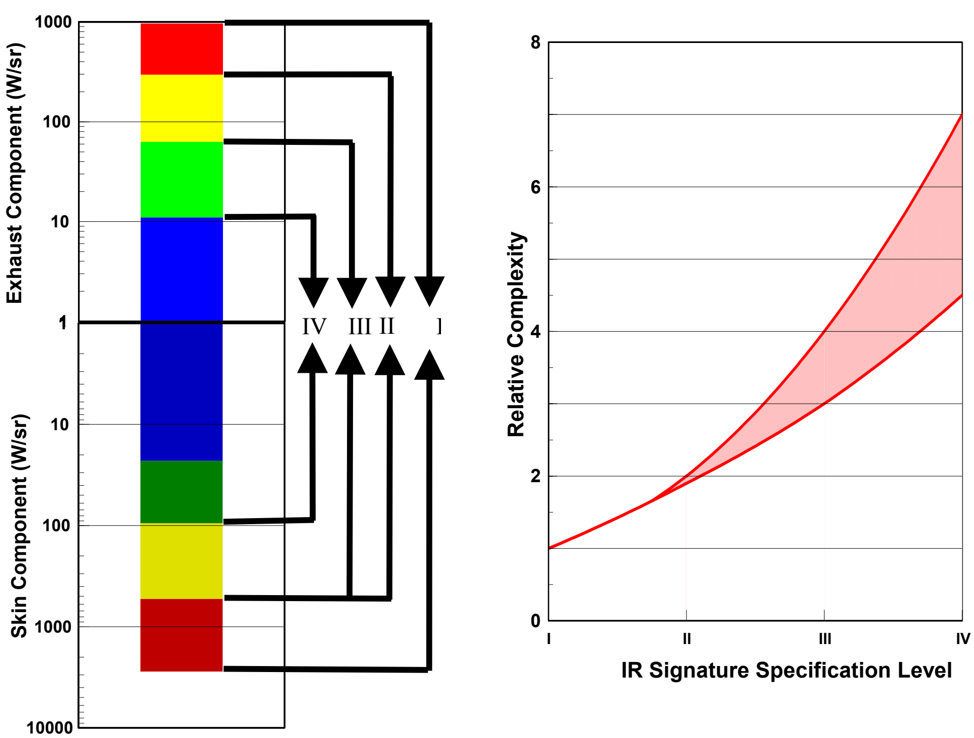



Figure 12 Summary

## OVERALL IR SPECIFICATION

Once the desired level of suppression has been selected it is necessary to define the specification in a contract document. As noted earlier this can be done in two ways:

i) hardware specification to give a desired signature level
ii) signature level specified to give desired susceptibility

The first way is preferred because with this approach the hardware needed to limit the IR signature and meet the ship susceptibility requirements will be achieved and this is the easiest way to manage the signature. However, the ship will also be made up from subsystems that are mounted on the ship and the IR signature of these subsystems must also be managed as part of the integrated approach. For this reason the hardware specification must also include limitations applied to these devices. This is best done by limiting the surface temperatures of any deck mounted hardware. If this surface temperature limit cannot be met then it will be necessary to apply surface treatments to the equipment such as insulating blankets.

## CONCLUSIONS

This paper has presented an integrated approach to selecting an IR specification for a military platform. A generic Frigate was used as a sample platform but the same approach can be used for land and air vehicles.

The process begins with a baseline analysis of the platform to determine the unsuppressed condition. Then four levels of suppression are applied and the benefits are quantified. From this a cost benefit analysis can be done to determine the final level of suppression needed.

The specification can then be written in terms of the IR signature desired or it can be written in terms of the hardware needed to meet the desired signature levels. Finally the specification must contain a means of verifying that the goals have been achieved.

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