An Introduction to RF and IR Stealth Technology

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Talk I Outline (Today)

- History of stealth and status
- Aircraft combat survivability
  survivability and susceptibility
  radar and IR system fundamentals
  anti stealth and future weapon system
- Modeling and simulation of RF and IR stealth
  ECM and trade-off
- Stealth discipline in aircraft design
- RF stealth concepts
  EM scattering mechanism and RCS
  RCS prediction method and measurement
  RAM
  RCS reduction and RAS
- IR stealth concepts
- Summary

Talk II Outline (June 22, 2006)

- Basic EM theory
- Role of CEM (computational electromagnetics)
  - aircraft design
  - RAM development
- RCS prediction method
  - component buildup method
  - high-frequency approximation
  - moment method and fast solvers, FEM, and hybrid method
  - time-domain FVM
  - limitation, optimization, and current status of CEM research
- RAM
  - principle, design parameters, software
- IR signature assessment
  - prediction code
- Measurement and validation
- Summary

Definition of Stealth

- **Definition of stealth**

  The act of moving, proceeding, or acting in a ***covert*** way

  The ability to ***blend*** in with the background

  Reducing the aircraft signatures and observables, thus providing the aircraft with the capability of evading the enemy's air defence

- **Aircraft signatures**

  Active

  radar : airframe, engine inlet, weapons, radome, canopy

  Passive

  infrared : engine casing, airframe, exhaust plume, sun glint

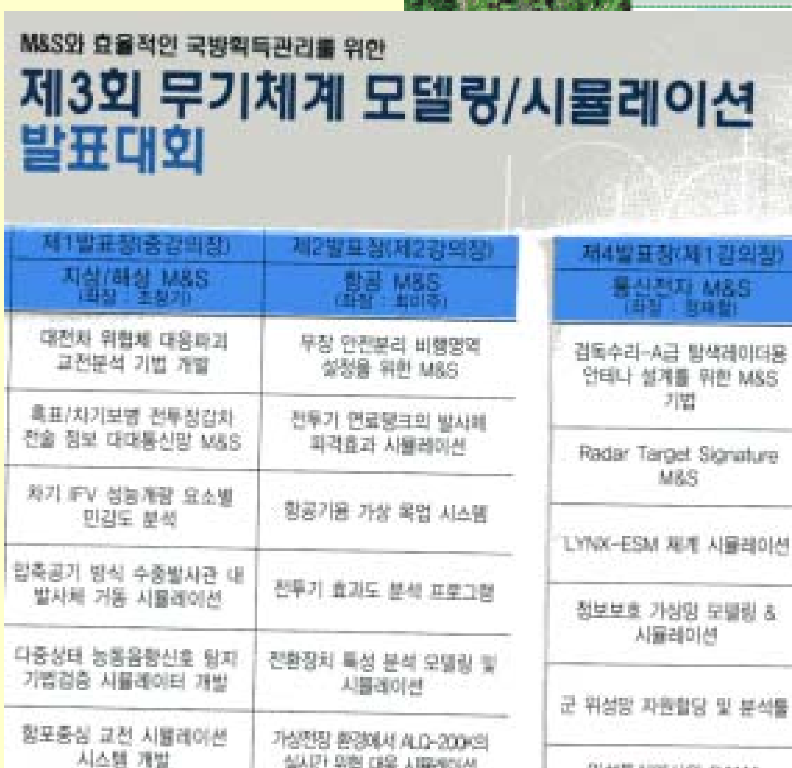
  acoustic : engine parts, engine exhaust, airframe

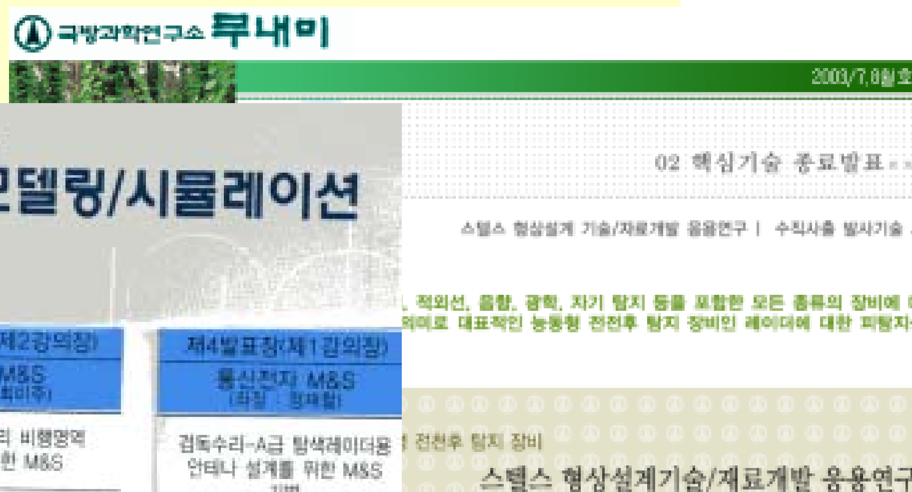
  visual : airframe, engine exhaust and glow, canopy glint

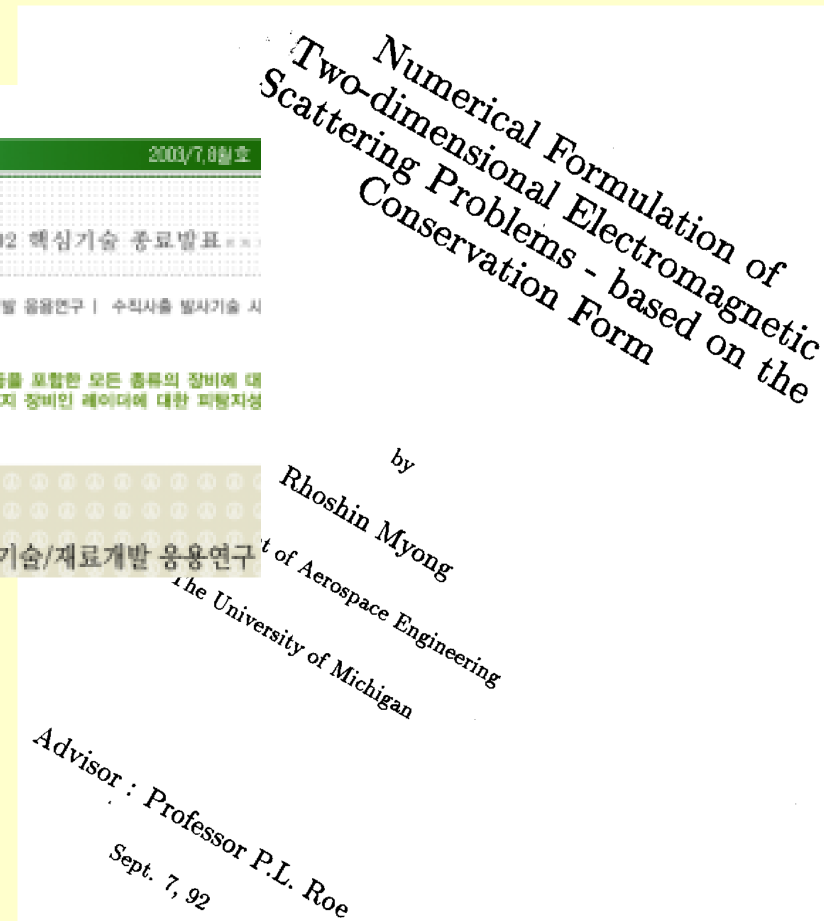
  misc. : navigation radar, communication, coutermeasures

Present Status (Domestic)

- **Domestic activities**
  ADD (1999-2002), navy application, universities







Present Status (Foreign: JSF)

Joint Strike Fighter's stealthy treatment

- No sheet material,minimal use of RAM
- Minimal use of tape, robotic application
- Minimal use of "butter"—short cure materials form in-place gaskets
- CAD/CAM tools and modern manufacturing

Maintain high level of tolerances

Joint Strike Fighter's stealthy design

- RF signature control to minimize susceptibility
- EO/IR technology to maximize survivability
- Covert lighting technology to minimize susceptibility to optical/night vision systems
- Control of electronic and acoustic emissions

Present Status (Foreign: Saab's Filur UAV)

- **Technology gap : "**It's been a quarter of a century since we developed the ***B-2***, and the basic tenets of how U.S. goes about designing a LO airplane have been ***known for at least 20 years***. But when you look at foreign systems designed to stealth principles, ***they're still not even remotely close to what we did***. … So, the U.S. still needs to ***protect those things that really make a difference***," A. F. Myers, Northrop then-vice president, 2006

- **Driving factors**

  Effectiveness : precision weapon

  Technology : modeling, RAM, avionics, navigation

  Diverse applications : sea, land

Saab has started flight testing of the demonstrator for its Filur—Flying Low-Observable Unmanned Research effort.

The 10-min. inaugural mission took

place at the flight test center at Vidsel, Sweden, on Oct. 10, but wasn't disclosed until last week. A follow-on test series is slated for next year.

The Swedish government is funding Filur mainly for Saab to explore radar cross-section and infrared signature reduction. Filur itself is not intended to become an operational system, although lessons would be applied to other projects and could benefit the European Neuron unmanned combat air vehicle demonstrator program in which Sweden hopes to participate.

The government recently completed a review of Neuron, after an earlier intergovernmental dispute held up funding for Saab to become involved. Sweden's defense procurement agency has determined that while there may be alternatives to Neuron, they will be more costly and undermine Sweden's international credibility as a partner, given the country's commitment to the program, says Saab Deputy CEO Ingemar Andersson.

Saab executives hope the report will spur the government to finally commit the necessary funding for participation in Neuron, potentially before year-end. France's Dassault has the largest industrial stake, with Saab and Italy's Alenia Aeronautic at the next highest level.

Aircraft Combat Survivability (ACS)

- It is about the **effectiveness** of military aircraft contending with an enemy.
- **ACS**: The capability of an aircraft to ***avoid (susceptibility)*** or ***withstand (vulnerability)*** a ***man-made*** hostile environment (enemy air defenses or terrorist weapons).

  Survivability = 1 – Susceptibility x Vulnerability
- **Assessment**:

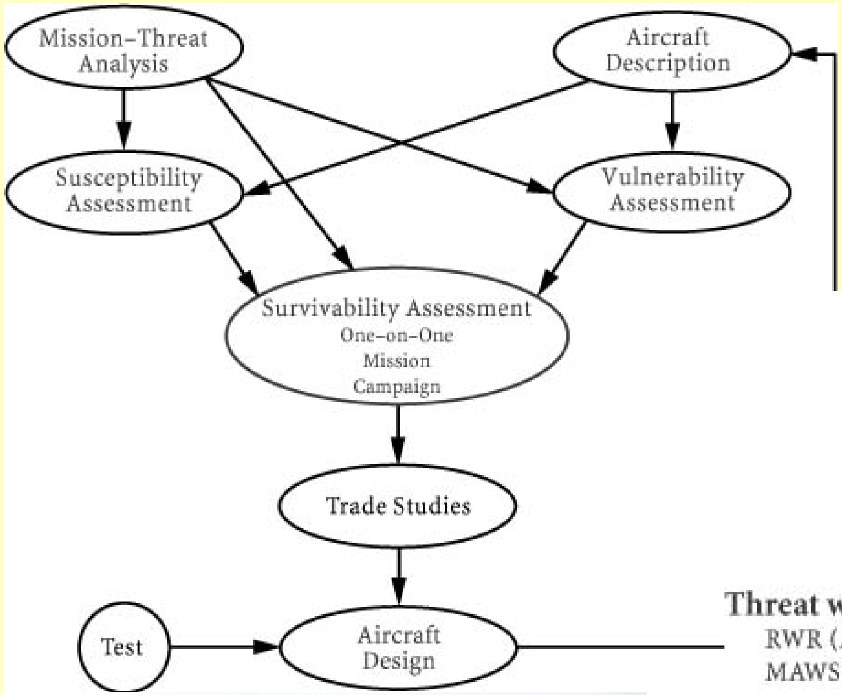
  1) establishing the requirements for survivability,

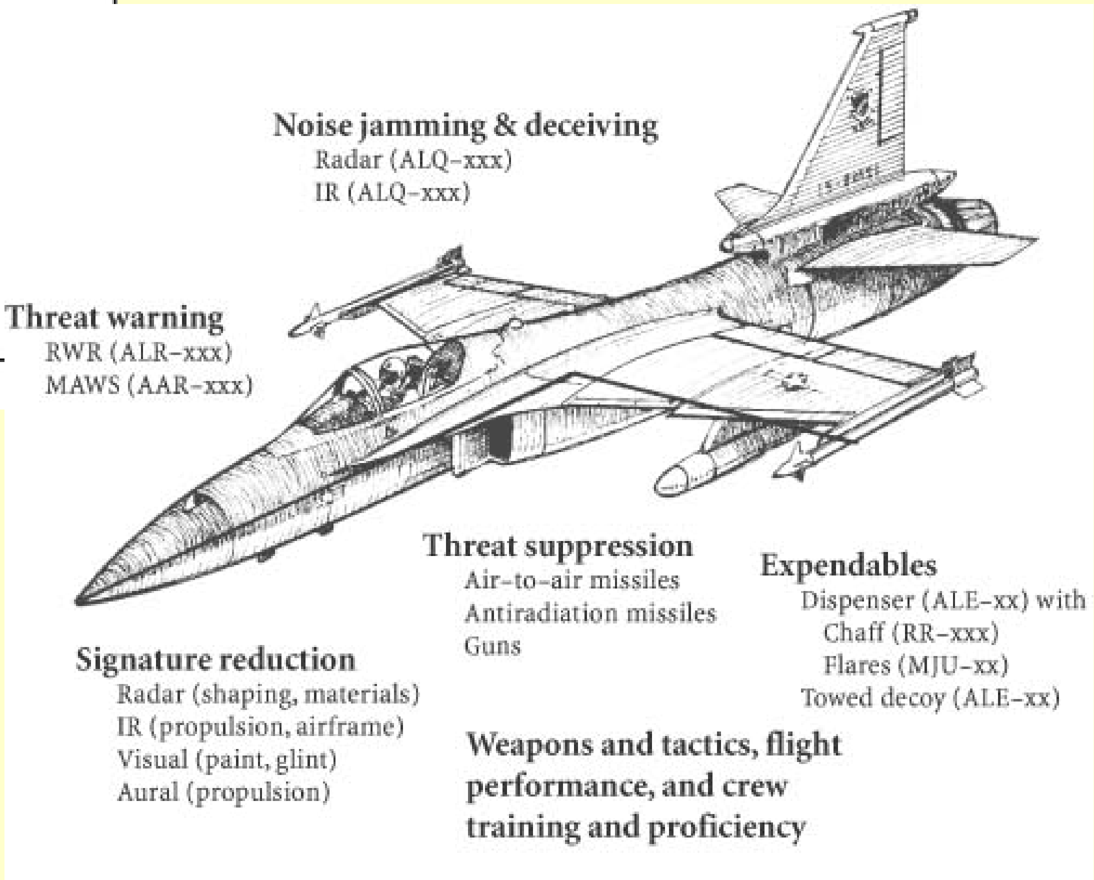
  2) selecting and designing the specific survivability enhancement features that will meet the requirements,

  3) supporting the evaluation that the final product meets the requirements, and

  4) providing survivability and vulnerability data to mission and campaign models.
- The U. S. military basic survivability requirements given in MIL-HDBK-2069

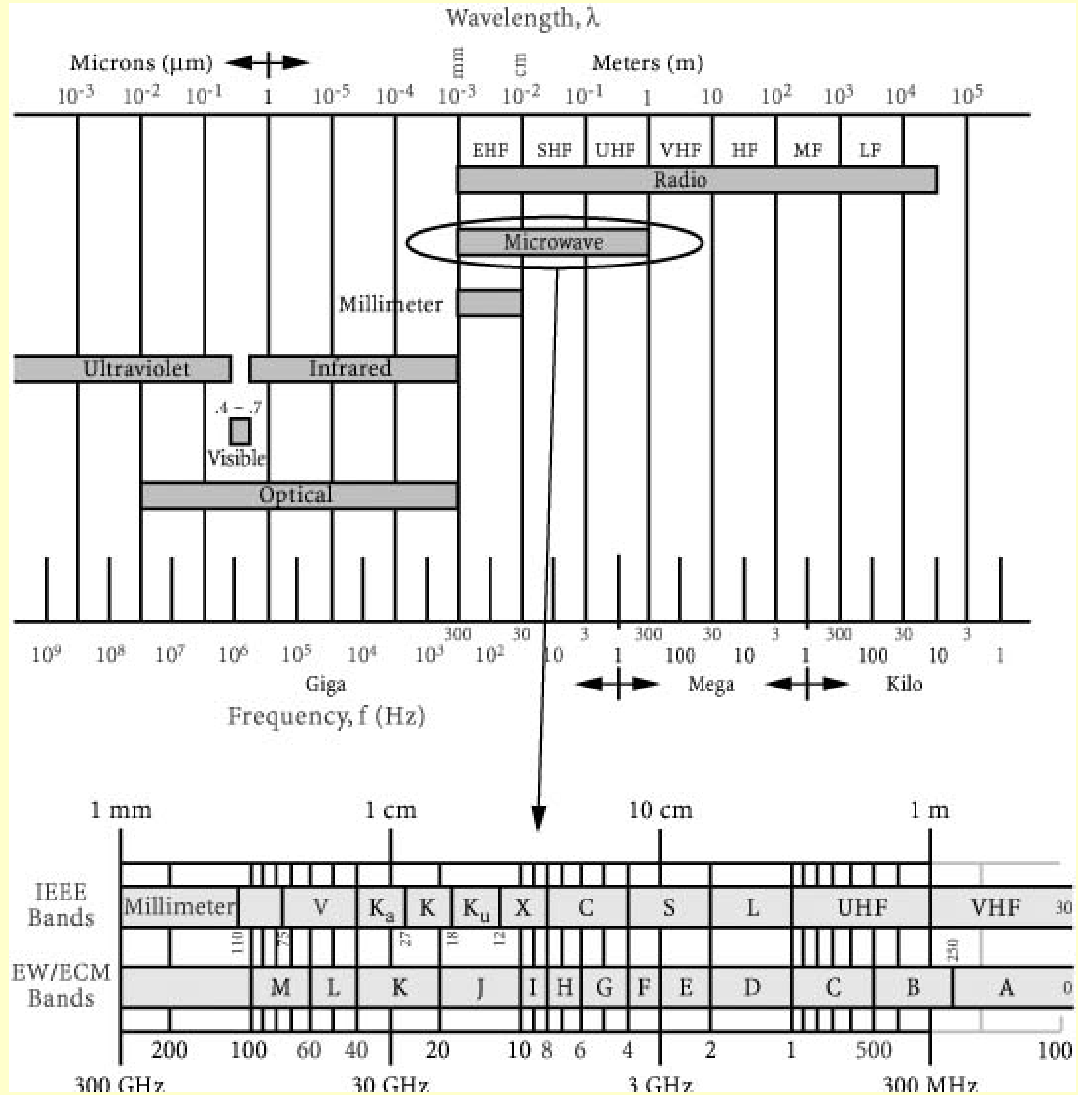
Flow of Assessment and Susceptibility Reduction Concepts





Radar System Fundamentals

- **Radar (Radio Detection And Ranging):**
  transmitter, antennas, and receiver
  monostatic, bistatic, and
  multistatic radars
- **Band: 100 MHz ~ 20 GHz**
  surveillance and detection
  (VHF, UHF, S),
  SAM (C, X), onboard (K)



IR Fundamentals

- **Infrared radiation**

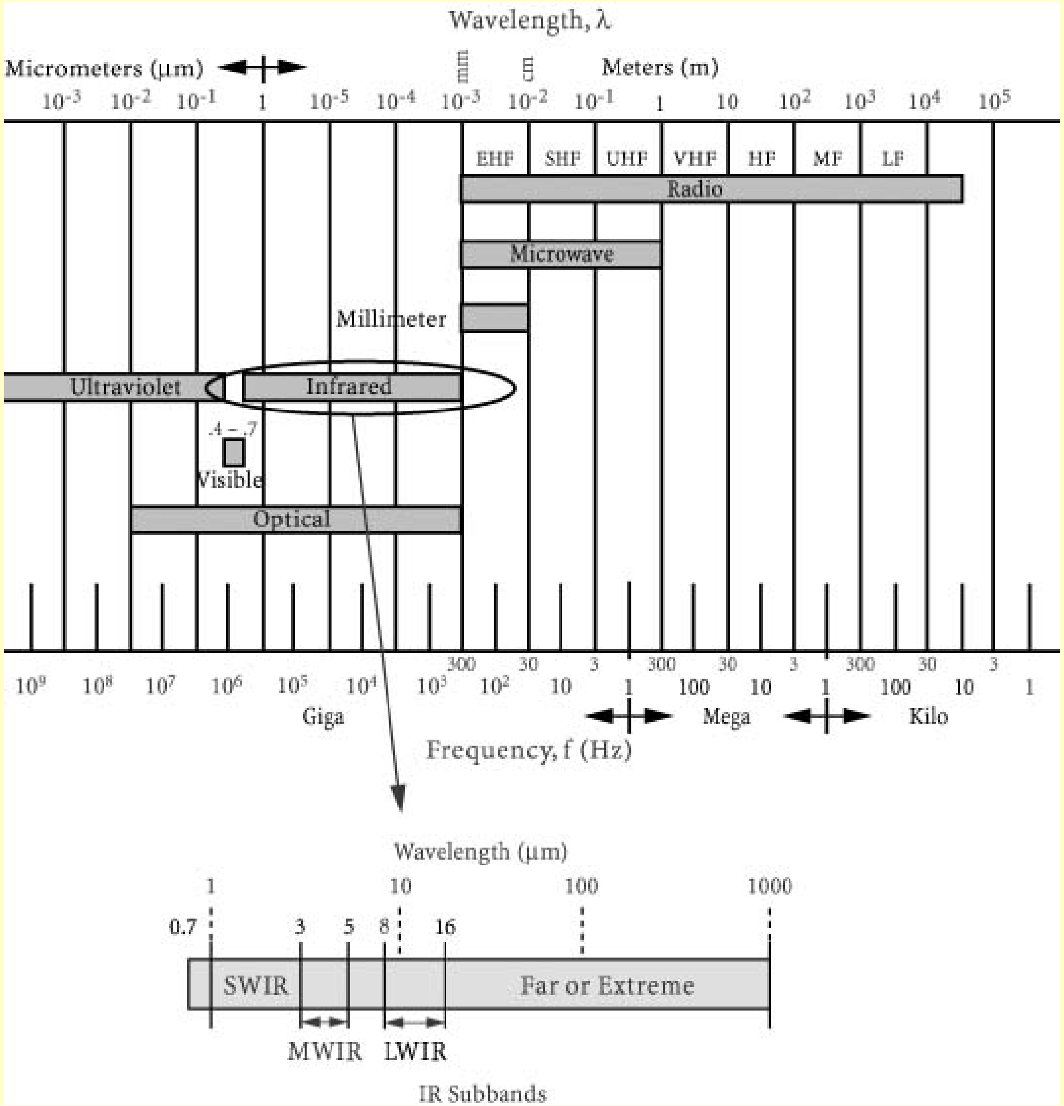
  seeker dome, optical components,

  and detector (thermal or photon)

- **Wavelength: 0.7 ~ 1000 micron**

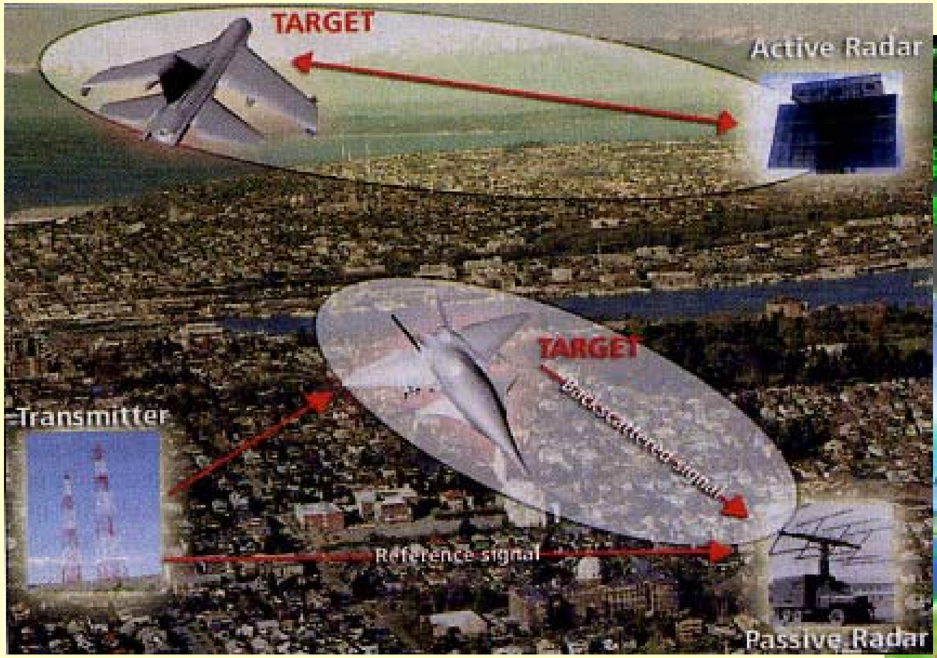
  continuum radiator (solid; grey bodies)

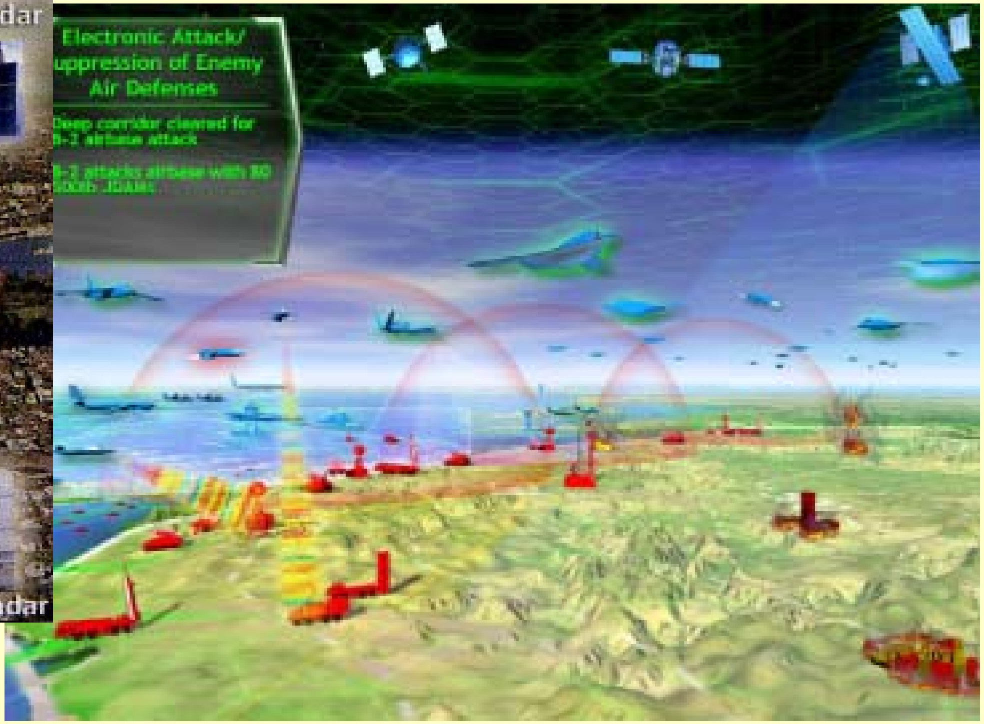
  line radiator (gas): water vapor (1.4, 1.9, 2.7, 3.2, 5.5, 7.5 micron), carbon dioxide (2.7, 4.3, 14, 16 micron)



Anti Stealth and Future Technology

- Bistatic radar and radar net
- Multirole electronically scanned radar (200 mile, X-band)
- UWB (ultra-wide band) pulse radar: effective in RAM and ECM
- Passive radar
- Multi-spectral IR detector
- Direct (high power microwave) weapon system : striking communication networks, need of optical communication





RCS Characteristics and Scattering Mechanisms

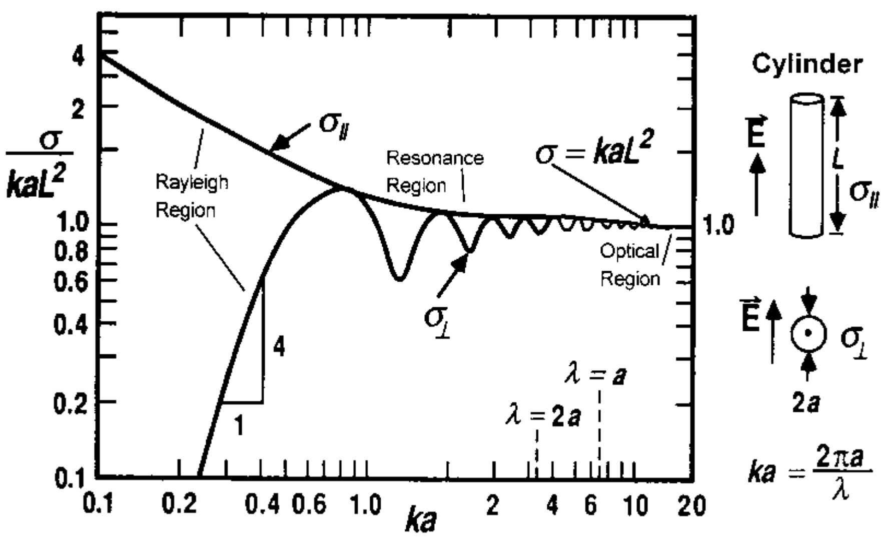


Figure RCS of a cylinder relative to wavelength

RCS : frequency, polarization, incident angle, observing angle, geometry, material properties

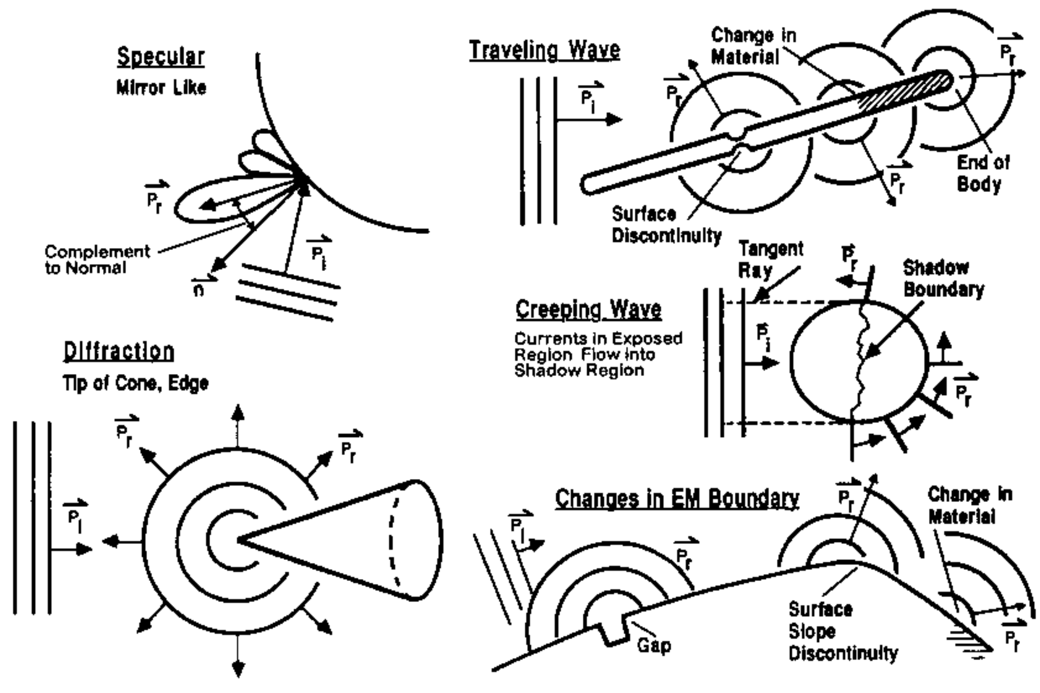


Figure Sources of electromagnetic scattering

Radar Absorbing Materials (RAM)

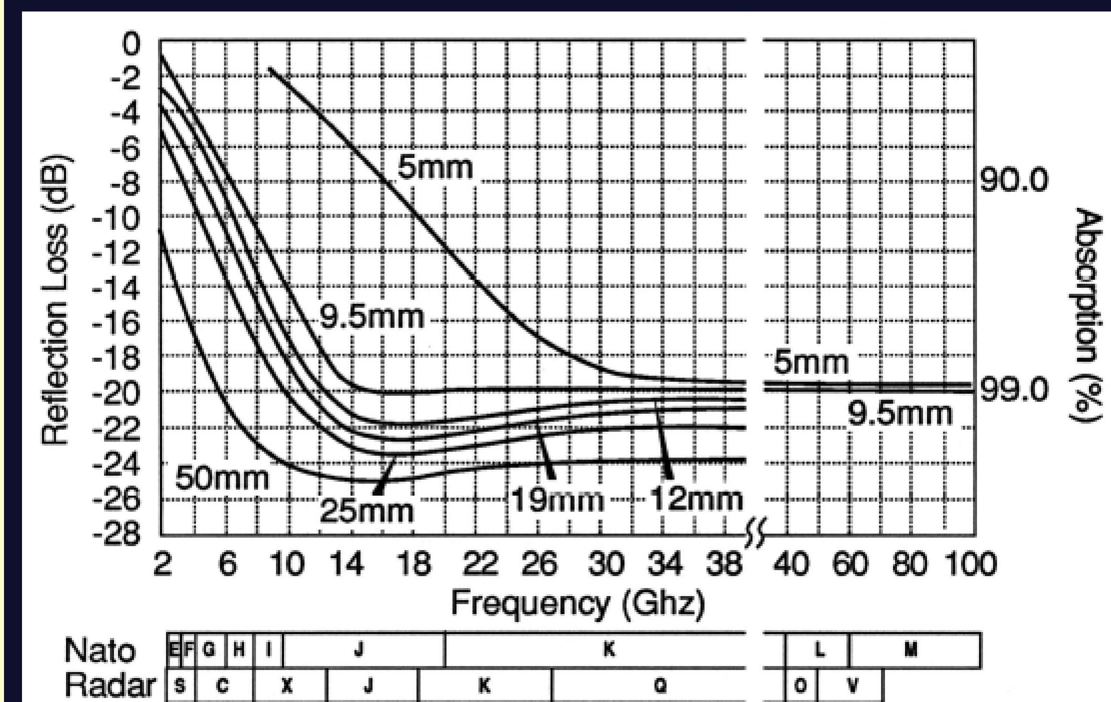
- **Broadband (attenuating) RAM**

  Small change in impedance

  Absorbing lossy layered material (impedance, freq., thickness, angle of incidence)

- **Resonant (interference) RAM**

Broadband Foam Absorbers Performance Curves



Summary of Graded Deposit Absorbers		
From the Design Parameters (wish-list)		
Frequency	=	Good
Reflection Loss	=	Good
Polarisation (x2)	=	Good
Angle of incidence	=	Good
Weight	=	Low
Thickness	=	Medium
Mechanical	=	Fragile
Environment	=	Benign

RCS Reduction Concepts

- **Shaping: Reducing the scattering of incident wave back, effective against monostatic radars**

  Adapting a compact, smooth blend external geometry (flying wing-body concept)

  Adapting a faceted configuration (but, aerodynamics penalty)

  Buried engines located over the upper surfaces, a screen placed over the air intake, appropriate shaping of the intake lips and inlet ducts

  Eliminating cockpit transparencies

  Clean external geometry without protuberances (weapons) and gaps

  Highly swept leading edges with rounded wing tips

  Avoid flat and re-entrant surfaces, having a V-shaped tail

  Use of composites that have impedance comparable to that of air

  Design any internal structure reducing reflections in a given direction

  Special treatment of radome

- **RAM: Attenuating and interference, 20 dB reduction over 2-18 GHz band (optical regime), not effective against UWB radar**

IR Signature Reduction

- **Concepts**

  Reduce the temperature of the hot parts and the exhaust

  Reduce the surface emissivity of the hot parts

  Reduce or mask the observable surface radiating area

- **Techniques**

Propulsion source:

engine with available coolant air source

cooled shields or turn that block the view from an IR observer

coating with IR absorbent materials

reducing the gas temperature near the exhaust system by using a cooler surrounding airstream or by putting the plume in a cross flow or by using two-dimensional nozzle

Airframe source:

difficult in dealing with aerodynamic heating (M>2)

insulation or judicious placements of hot components

nearly flat transparent surface, IR absorbing paint for sun glint

optimised coating of different emissivity for localized bright spots (stagnation region like leading edges)

Summary

- **Stealth technology is**

  Evolving

  Multi-disciplinary, team-oriented

  Politics and money driving

- **In the stealth business, one needs to**

  Decide level of stealth considering factors ACS, cost, time, maintainability, and technology trend

  Develop core capability: S/W development branch of M/S, RCS and IR, H/W (RAM, test facility)

  Run the demonstration program in initial development