SENSOR MODEL DESIGN FOR AIRCRAFT CONCEPT DEVELOPMENT

Carina Marcus, Saab Aeronautics

- Aircraft concept design
- Operational analysis
- Sensor modeling, radar example
  - Technical properties
  - Operational aspects

AIRCRAFT CONCEPT DESIGN

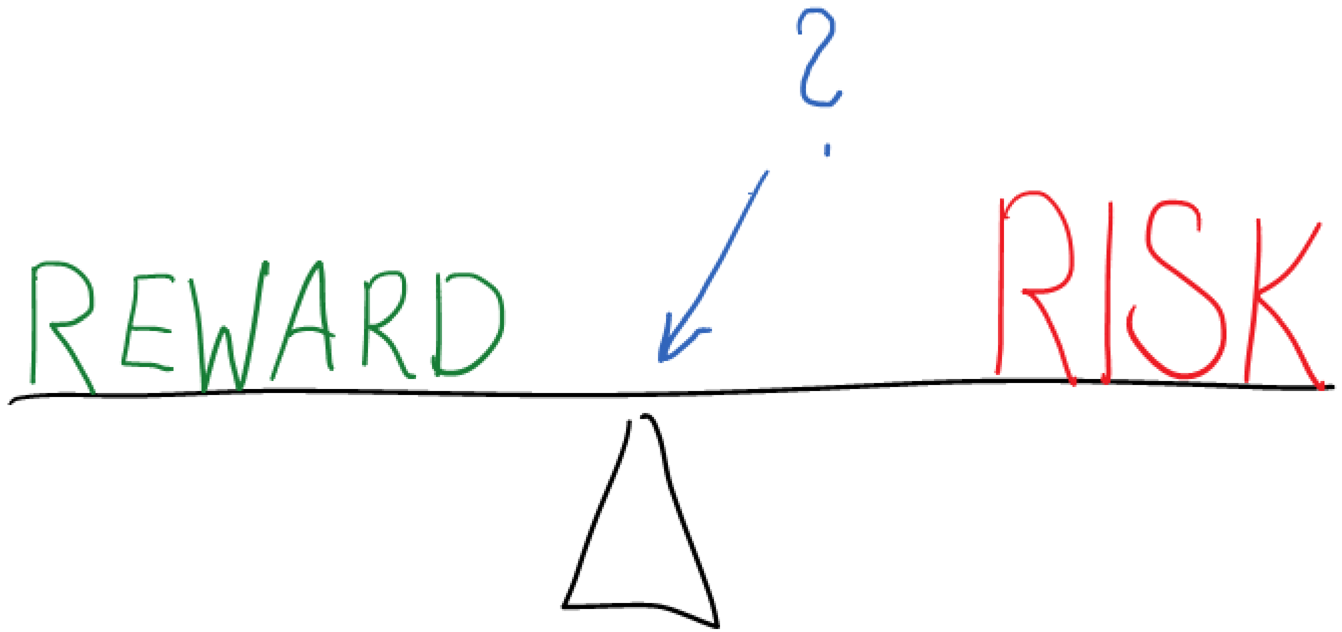
- The art of getting it all together
- Aircraft and subsystems
  - Fuselage
  - Propulsion
  - Sensors
  - …
- Usefulness varies with context - scenario
  - Design aircraft that are useful in some span of scenarios
  - Fit operational paradigms

SENSORS ON AIRCRAFT

- The benefits
  - Obtain data
  - Situation awareness
  - Option awareness
- The cost
  - Detection risk
    - Increased signature
    - Active emissions
  - Mass
  - Volume
  - Power
  - Cooling
- The sensing alternatives
  - Communication
  - Networking
  - Collaborative sensing
  - Data enhancement/refinement/

OPERATIONAL ANALYSIS POINT OF VIEW

- If there is an object Y with some characteristics at a position, can sensor X detect it?
- Does the detection process induce danger of detection?



MODELING GOAL

- Transfer the key properties of a detailed model to an easy-to-use model
- Sufficiently detailed, must encompass the gist of the sensor
- Transparent
- Well-behaved and bounded

QUESTIONS IN A TACTICAL SITUATION

- What does sensor X see?
  - Sensor properties
  - Wave propagation
  - Target properties

- The detection chain
  - Detection
  - Classification
  - Identification

- What does it take to progress from detection to at least classification?

EXTENDED DESIGN VIEW

Hardware changes

- Need for longer detection ranges, ability to detect smaller targets
- Increased gain – larger antenna – larger aircraft – signature and scenario implications
- Increased power – equipment change – mass, volume – operational capability

Software changes

- Signal processing improvements – no physical impact

TECHNICAL ASPECTS

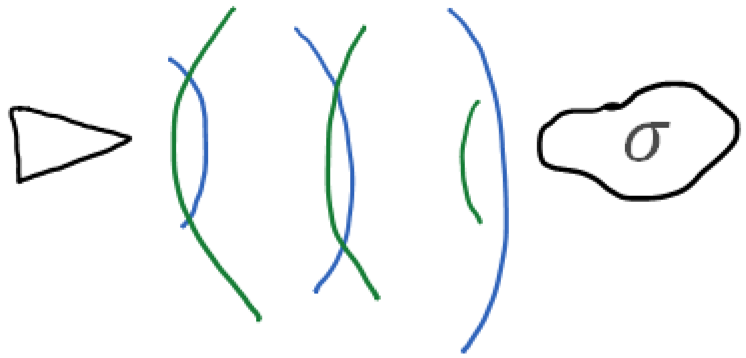
RADAR

- Signal

$$P_{rx} = \frac{P_{tx}G_{tx}}{4\pi R^2}\sigma\frac{1}{4\pi R^2}\frac{G_{rx}\lambda^2}{4\pi}$$

- Noise

$$N = N_f k_B T B$$



- Signal-to-Noise ratio

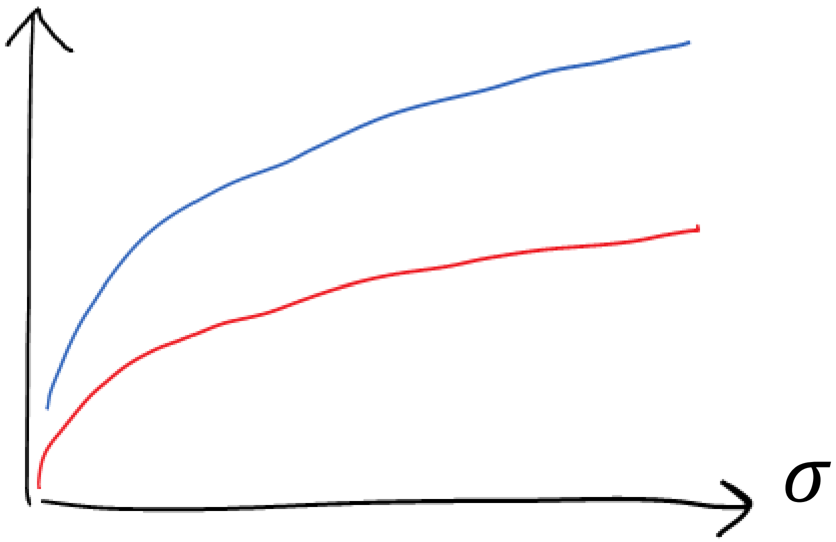
$$SNR = \frac{P_{rx}}{N}$$

RADAR EQUATION

- Lump several parameters into one
- Problems arise as the lumped K does not show what is going on
- Limitations which improves the model:
  - Max/min range
  - Minimum signature at some range(s)

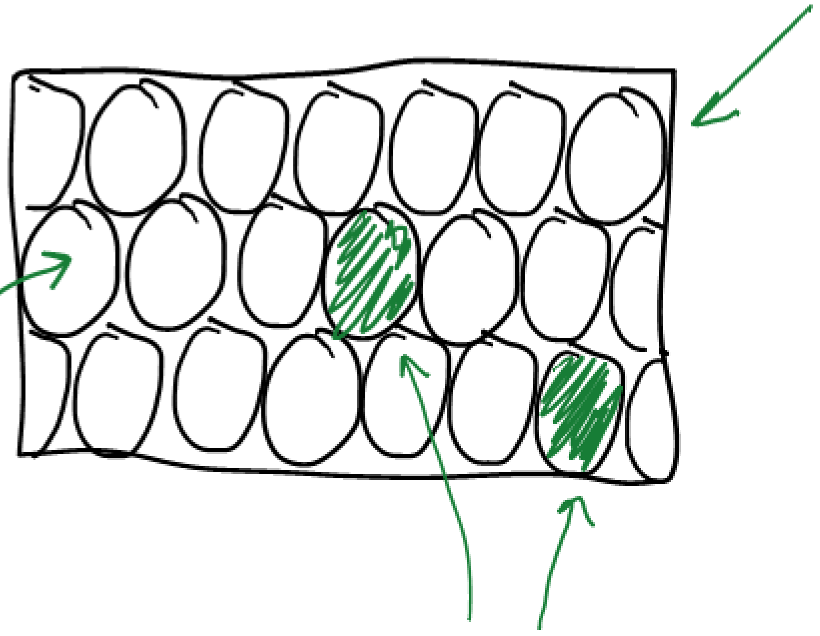
$$R = \sqrt[4]{\frac{P_{tx}\, G_{rx}\, G_{tx}\, \lambda^2 \sigma}{(4\pi)^3 SNR\, N_f\, k_B\, T\, B\, L}}$$

$$R = K\sqrt[4]{\sigma}$$



RADAR

- Search pattern
  - Technology
  - Tactical needs



RADAR EQUATION

- When searching, the radar needs to spread the attention over an angular sector
- Increase range:
  - More power
  - Increase antenna size
  - Reduce noise factor
  - Reduce losses
  - Improve signal processing
  - Lengthen dwell time, t_d
- All the measures above have limitations

$$R = \sqrt[4]{\frac{P_{avg}\, G_{rx} G_{tx}\, \lambda^2 \sigma}{(4\pi)^3 SNR\, N_f k_B\, T_0 L / t_d}}$$

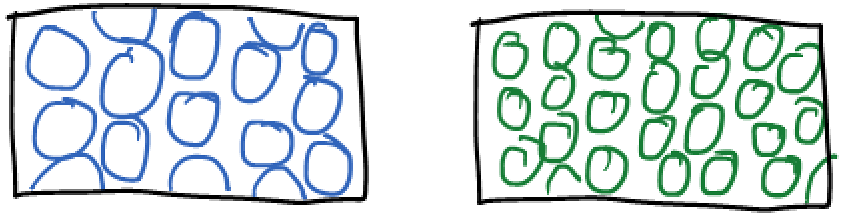
$$t_d = t_\Omega \frac{\Omega_b(\theta, \phi)}{\Omega}$$

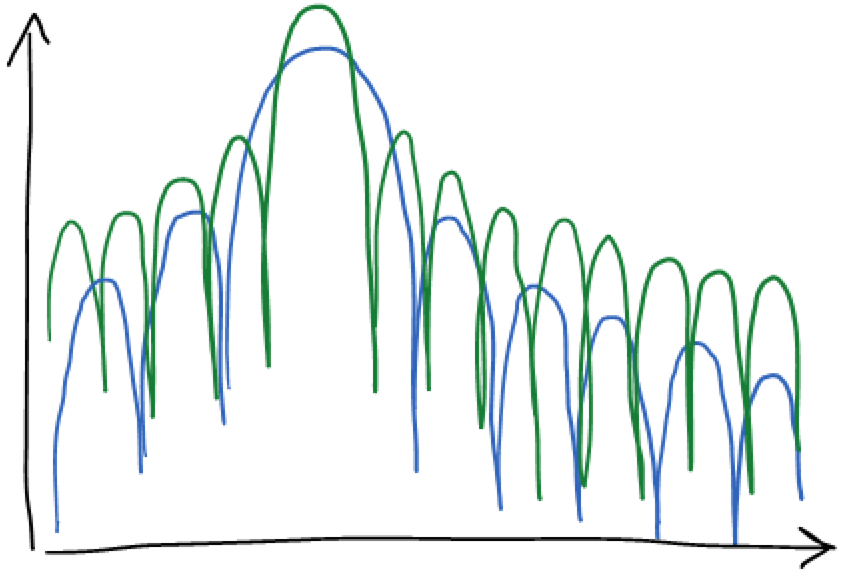
EXAMPLE: INCREASE THE ANTENNA SIZE

- Larger antenna - same output power
  - Increased gain
  - Narrowing of lobes
- More narrow beam
  - Lengthen the total scan time

    OR
  - Shorten the dwell time

$$R = \sqrt[4]{\frac{P_{avg}\, G_{rx} G_{tx}\, \lambda^2 \sigma}{(4\pi)^3 SNR\, k_B\, T_0 L / t_d}}$$





OPERATIONAL ASPECTS

RISK AWARENESS

- Transmissions can be detected – risk assessment
- Transmit tactics
- Antenna size, sidelobe levels
- Replace sensor use with communication?

EXTERNAL FACTORS

Target characteristics

- Signature
- Flight dynamics

Atmosphere

- Attenuation

Background

- Clutter

CONCLUDING REMARKS

- Use sensibly detailed models
- Verify the fidelity of the models
- Test the models thoroughly in simple tactical situations
- Maintain an even level of detail for all models in the simulation