Multi-disciplinary Design Optimization (MDO) of Airborne Radome with Evolutionary Algorithms

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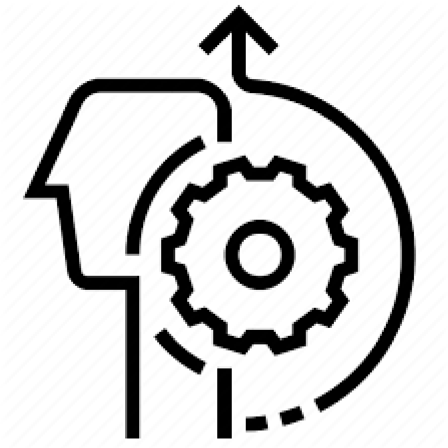
Topics

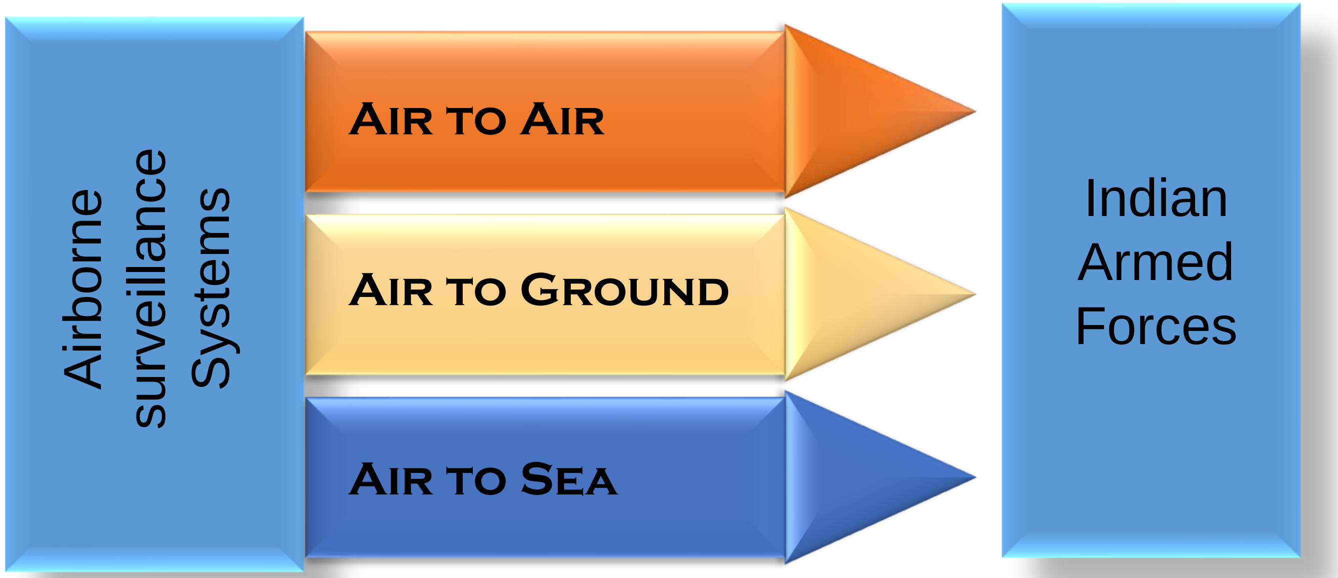
- Introduction
- Problem statement
- MDO architecture and analyses
- Results
- Discussion
- Future



MDO of Airborne Radome with Evolutionary Algorithms

Introduction

- Centre for Airborne Systems (CABS) is under DRDO, Ministry of Defence
- Airborne Surveillance Systems and Flight Test Research

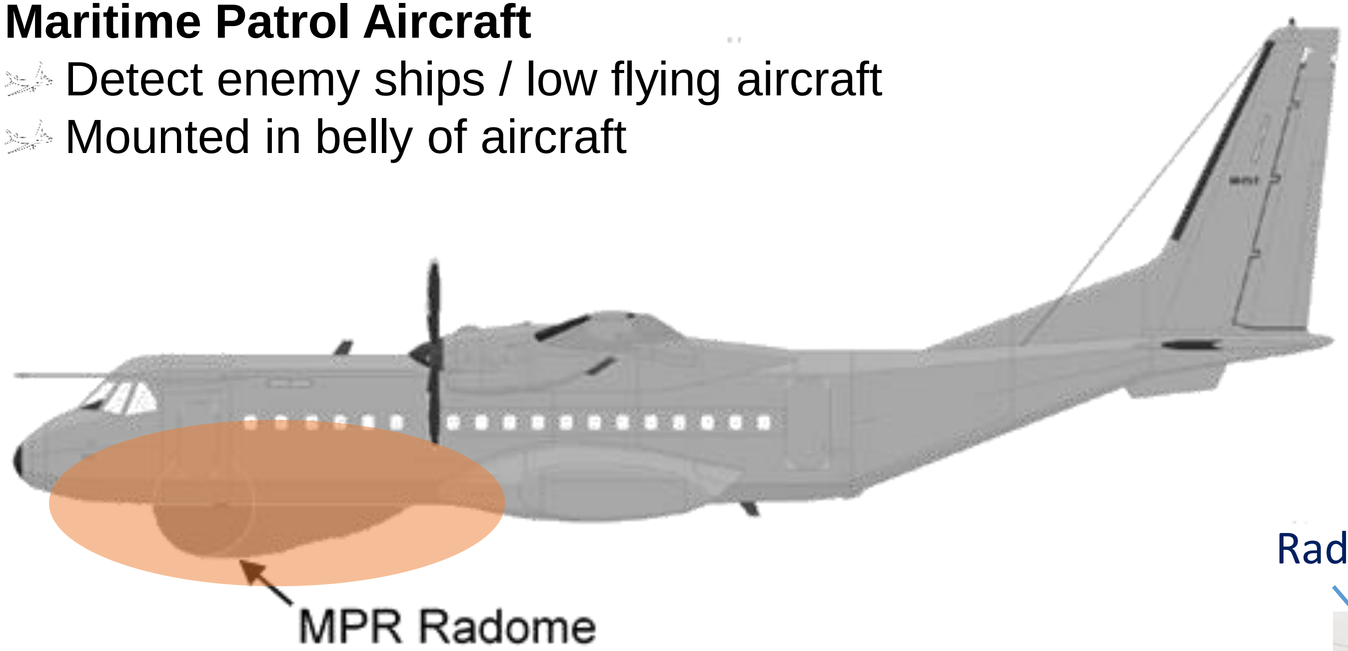


- All these systems are multidisciplinary in nature
  - Aerodynamics, Structures, Electromagnetics,… – integrated approach
  - MDA & O is very much essential

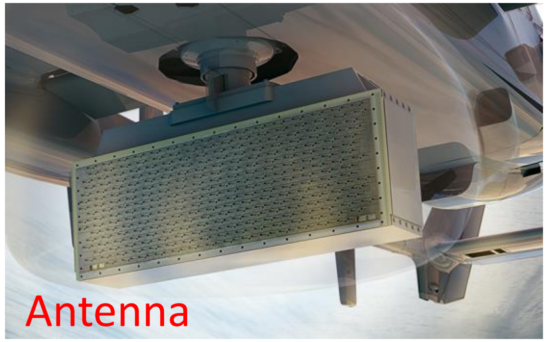
MDO of Airborne Radome with Evolutionary Algorithms

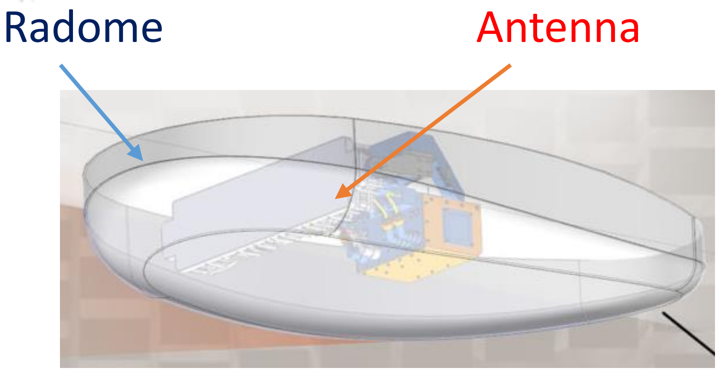
Introduction

Maritime Patrol Aircraft
- Detect enemy ships / low flying aircraft
- Mounted in belly of aircraft



Design point: Aircraft flying at 0.4 Mach (137m/s) airspeed and 2438m (8000ft) altitude





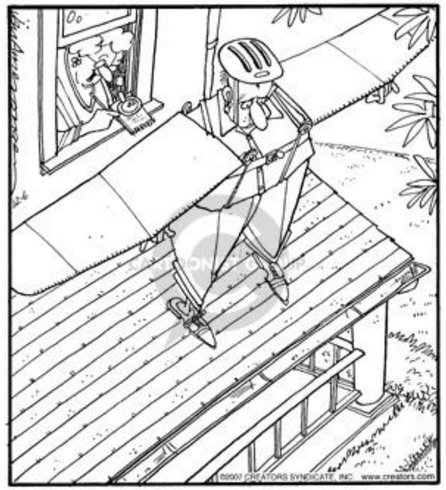
Antenna cover = Radome (RAdar DOME)

Radome : EM transparent, Polymer Composite, Aerodynamically streamlined

* All figures are illustrative

Problem statement

- To optimise airborne radome with respect to aerodynamic, structural and electromagnetic design aspects using Multidisciplinary Design Optimization (MDO) principles
- Process
  - Modeling disciplinary aspects of radome for numerical simulation
  - Integrate disciplinary analyses on a software framework capturing the inter-disciplinary interactions
  - Carry out Multidisciplinary Design Optimization (MDO) involving three disciplines i.e., aerodynamics, structure and electromagnetics
  - Study the trend of disciplinary objectives with respect to each other
  - Establish Pareto optimality for three objectives



"Thumbs up, Arthur, our glide calculations still check out!"

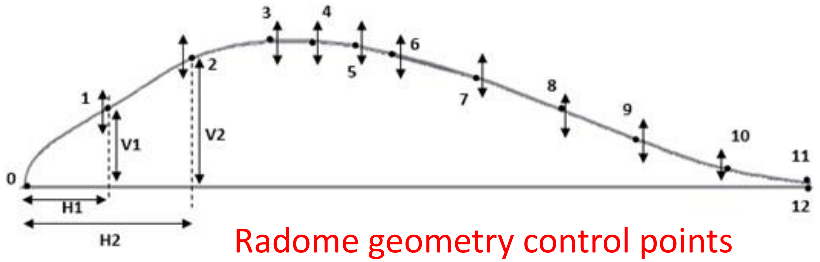
Problem statement

Design Variables

Points 1 to 10: x and y coordinates (20)
Point 11 : y value (1)
Point 12 : x value (also radome length)

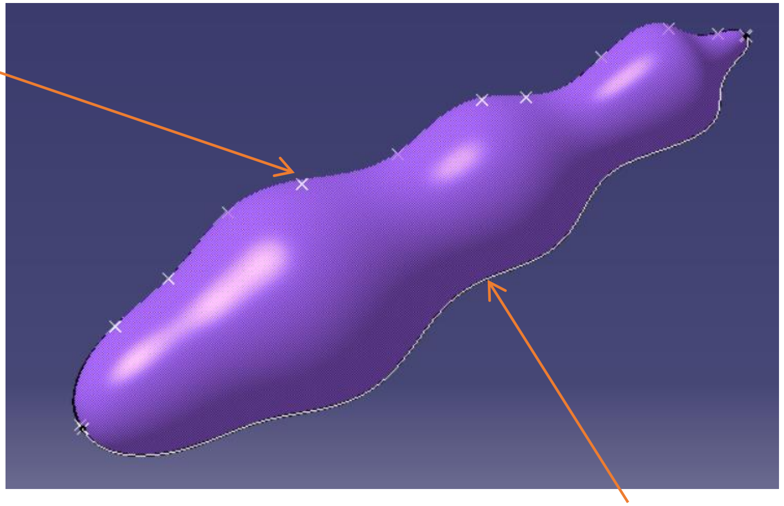
Layers in outer skin (1)
Layers in inner skin (1)
Thickness of core (1)

Total = 25

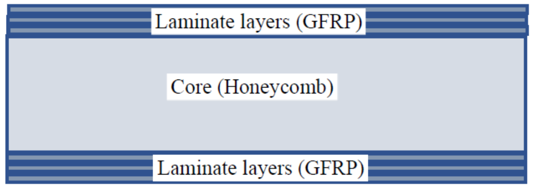


Radome geometry control points

Points



Spline



Radome Cross section (A-Sandwich)

Problem statement

DESIGN CONSTRAINTS

Strength constraint (Tsai Wu index)

$$F_1\sigma_1 + F_2\sigma_2 + +2F_{12}\sigma_1\sigma_2 + F_{11}{\sigma^2}_1 + F_{22}{\sigma^2}_2 + F_6\tau_{12} + F_{66}{\sigma^2}_6 < 1.0$$

Antenna size : 0.5m x 0.25m

Geometry constraint

For distance 0.5m to 1.0m (H_i) from leading edge; the height of radome (V_i) should be less than or equal to 0.25m (to accommodate antenna)

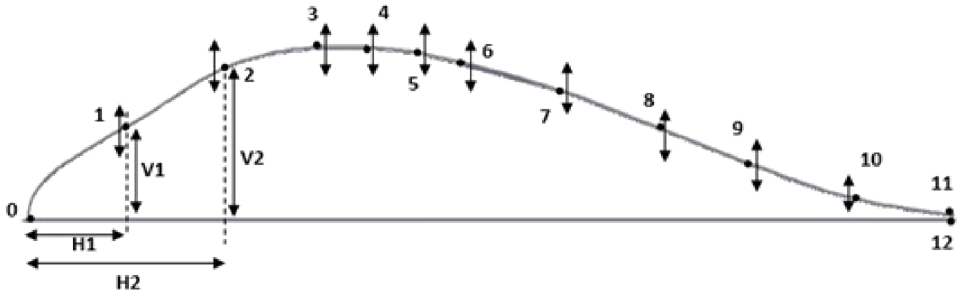
DESIGN OBJECTIVES

Drag force (*J₁*)

$$D = \frac{1}{2} C_D \rho v^2 S$$

Radome weight (*J₂*)

$$W = SA_R * [(N_L * T_L * \rho_L) + (T_c * \rho_c)]$$

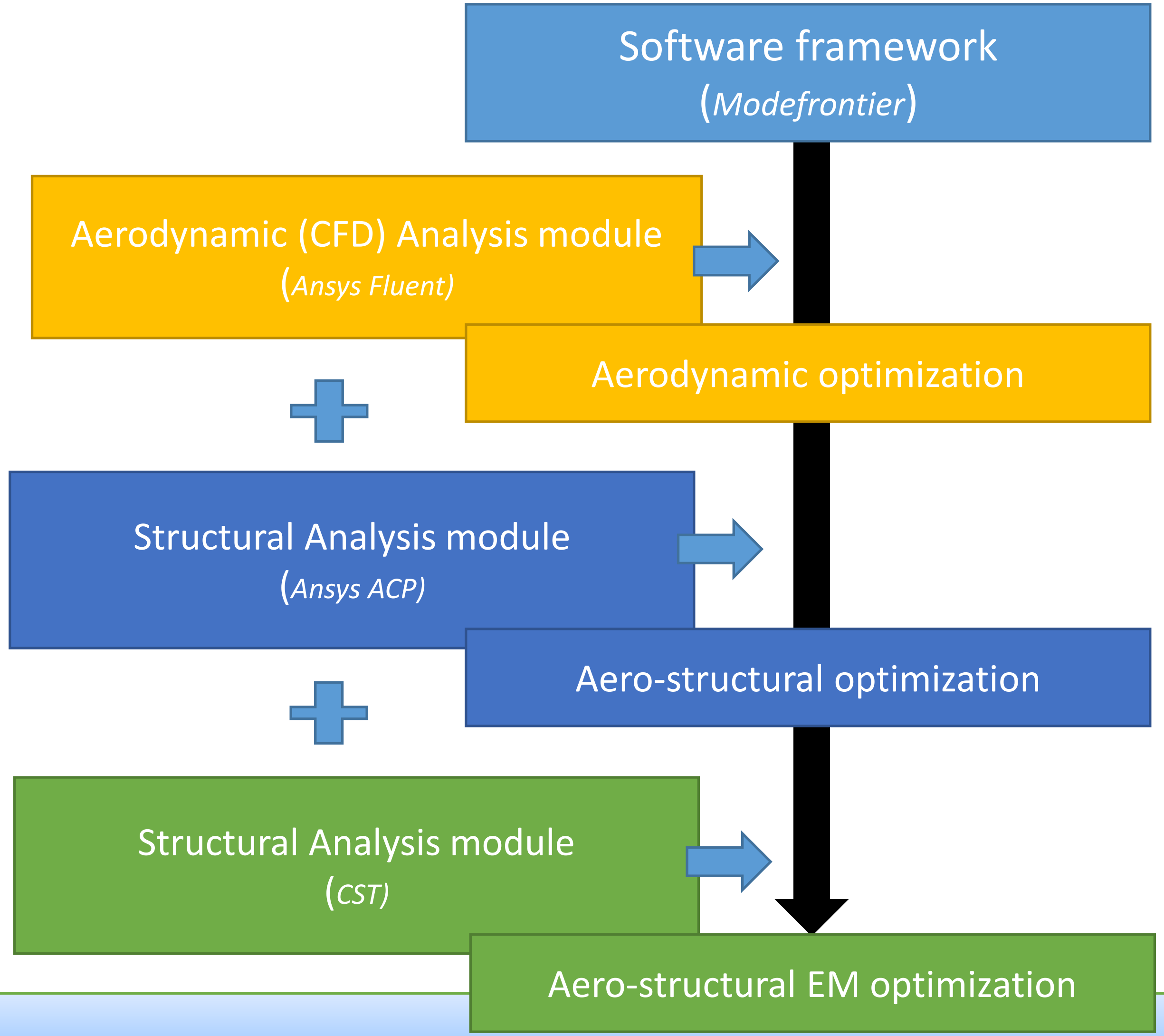


Sidelobe loss (*J₃*)

E = (Sidelobe level without radome - Sidelobe level with radome)

MDO of Airborne Radome with Evolutionary Algorithms

MDO architecture and analyses



Objective : Drag

Objectives : Drag, weight

Objectives : Drag, weight, sidelobe loss

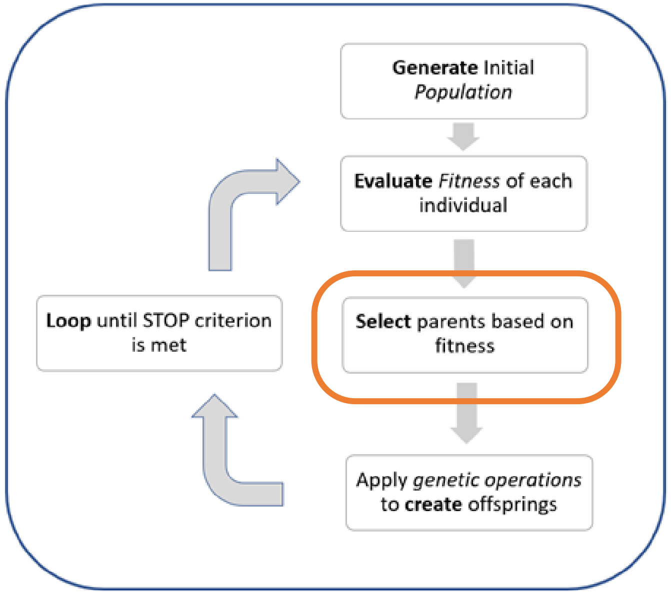
MDO architecture and analyses

- GA is the chosen evolutionary algorithm

Three algorithms used

- **Non Sorting Genetic Algorithm II (NSGA II)***
  - **Deb et al (2002)**
- **Multi Objective Genetic Algorithm II (MOGA II)****
  - **Rigoni and Poles (2005)**
- **PilOPT**
  - **Proprietary algorithm - *modefrontier***

Genetic Algorithm

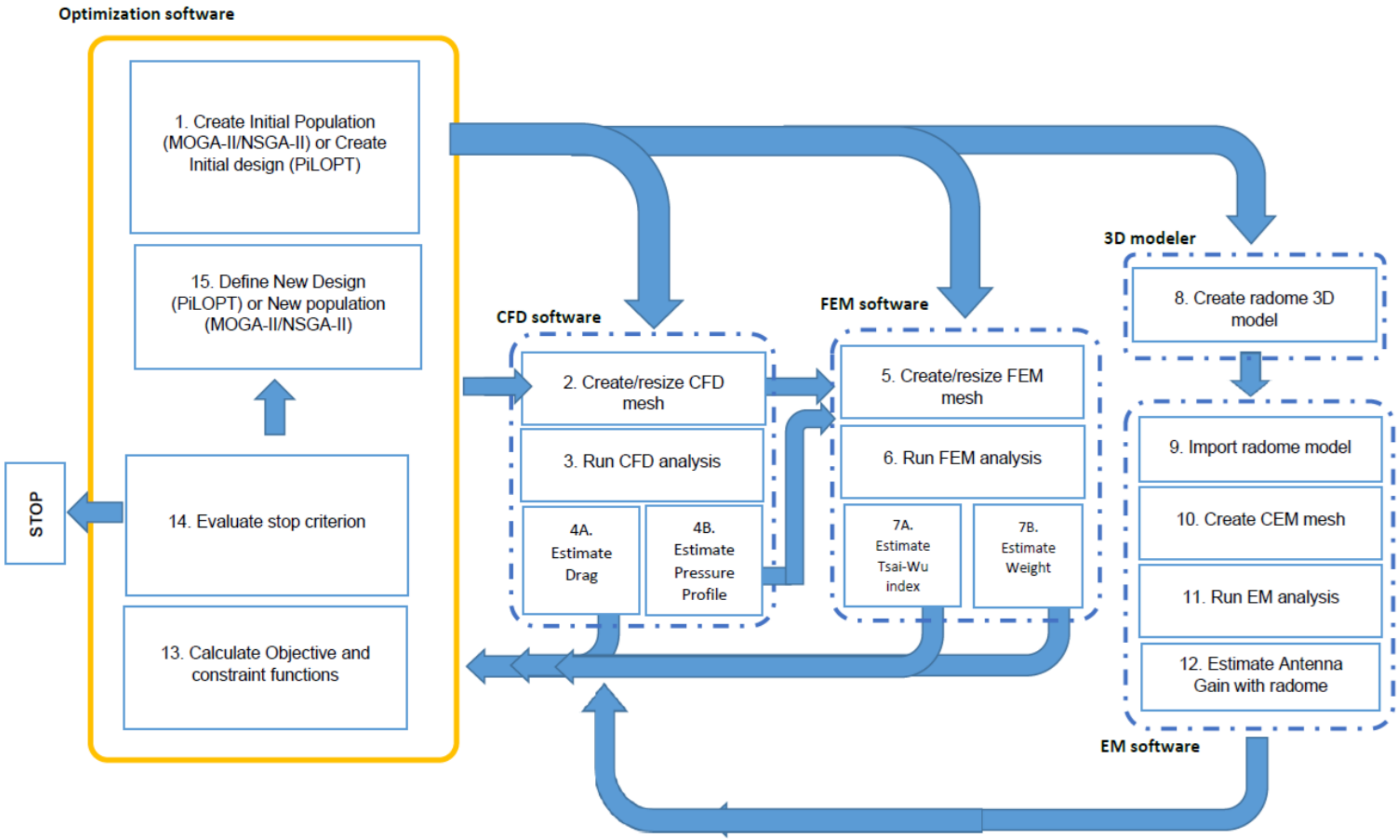


*Deb, K, Amrit Pratap, Sameer Agarwal, and T Meyarivan. 2002. "A Fast and Elitist Multiobjective Genetic Algorithm NSGA-II." *IEEE Transactions on Evolutionary Algorithms* 6 (2): 182-197.

**Rigoni, E, and S Poles. 2005. "NBI and MOGA-II, two Complementary Algorithms for Multi-Objective Optimizations." *Dagstuhl Seminar Proceedings*

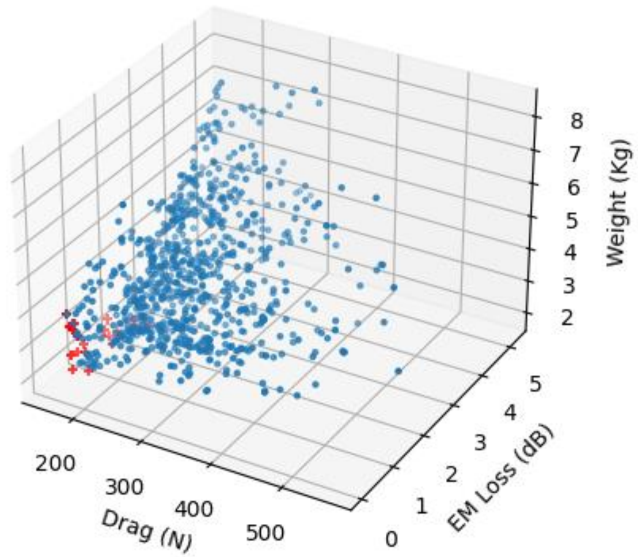
MDO of Airborne Radome with Evolutionary Algorithms

MDO architecture and analyses

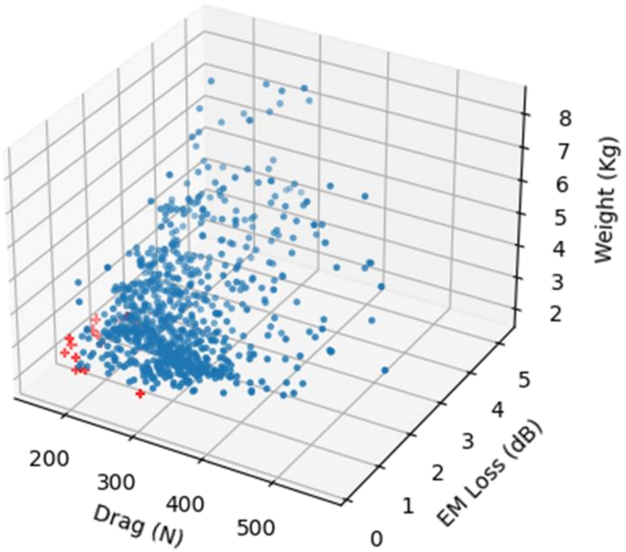


MDO of Airborne Radome with Evolutionary Algorithms

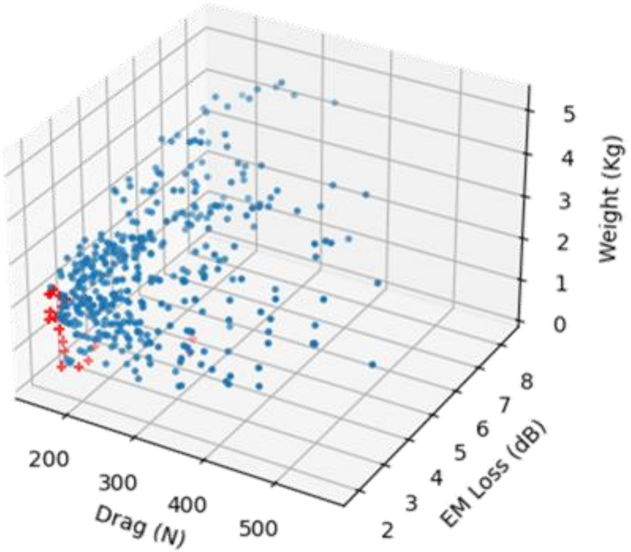
Results



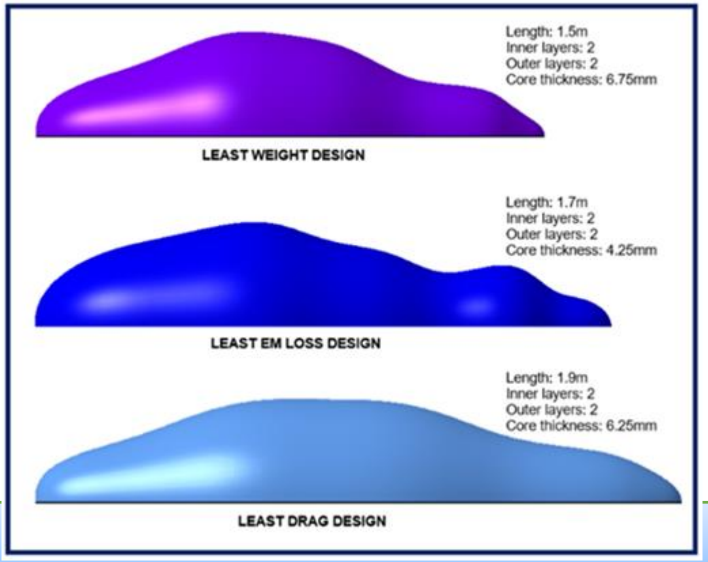
Non Sorting Genetic Algorithm II



Multi Objective Genetic Algorithm II



PilOPT algorithm



[2]Shankar, M. R.; Niranjanappa, A. C. Dattaguru, B. Aero-structural and Electromagnetic Design Optimization of Maritime Patrol Aircraft Radome Using Direct Search Algorithms, Defence Science Journal, Vol. 73(4), 394-401, doi:10.14429/dsj.73.17889

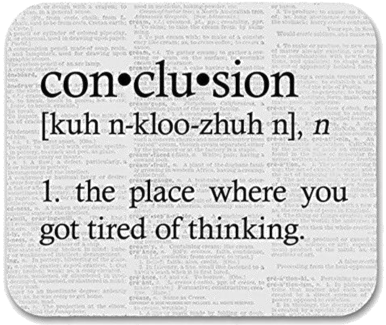
Discussions

- Initially behavior of aerodynamic and structural disciplines studied
  - Are in the expected line
  - Well defined 2D Pareto front established[1]
  - *Modefrontier* enables read-in /read out of communication and results thru well established routines
- Three disciplines of radome design[2] integrated and *MDO* carried out.
  - Arguably for the first time for radome.
  - CAD model is read thru CST and EM model created; thru routines from *Modefrontier*
- 3D Pareto optimality explored and achieved for first time
  - Large number of designs for decision maker to choose from
- Fully automated MDO process for radome design and optimization
  - Can be used for other external structures of aircraft as well

[1]Shankar, M. R.; Niranjanappa, A. C. & Dattaguru, B. Aerodynamic and Structural Optimization of Maritime Patrol Radar System Radome using Evolutionary Algorithms, Defence Science Journal, 71(4), 2021, 421-428, doi:10.14429/dsj.71.16249

[2]Shankar, M. R.; Niranjanappa, A. C. Dattaguru, B. Aero-structural and Electromagnetic Design Optimization of Maritime Patrol Aircraft Radome Using Direct Search Algorithms, Defence Science Journal, Vol. 73(4), 394-401, doi:10.14429/dsj.73.17889

Conclusions



- Two well-used GA techniques applied for MDO; both give similar results.
  - NSGA is able to find marginally more designs on *Pareto front* than MOGA
- *Modefrontier* proprietary code, PilOPT, also yields same results.
- Fully automated MDO process for radome design and optimization
  - Can be used for other external structures of aircraft as well

Future work

- These are starting points for an industrial solution
  - Deeper analyses of chosen designs (in Pareto front) required
- To include manufacturing and environmental aspects
  - Manufacturing tolerances affecting design output
  - Coatings and Paints play an important role in EM; they need to be modelled as well