# *Analysis of Radar Cross Section and Wave Drag Reduction of Fighter Aircraft*

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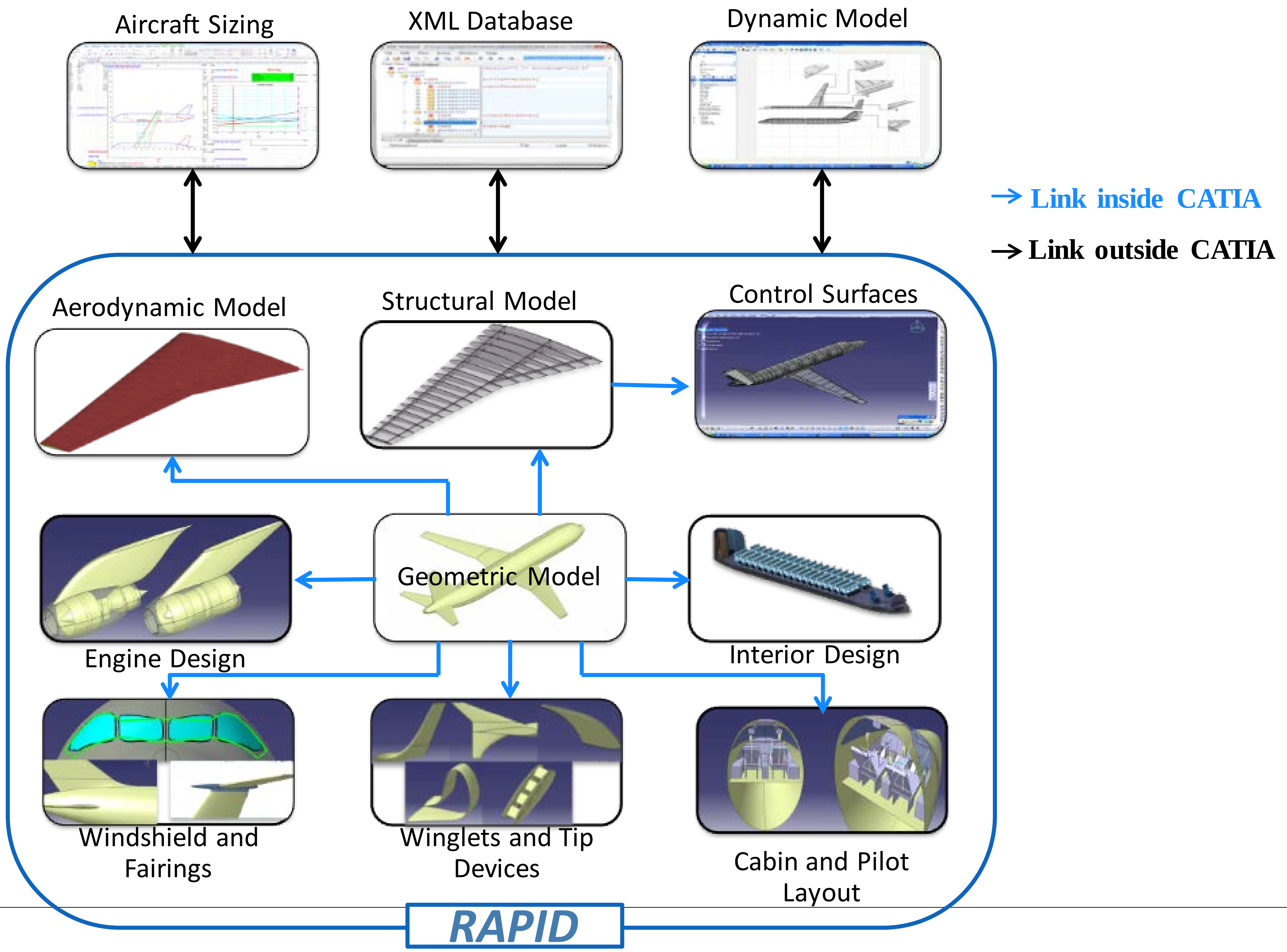
ENGENHARIA AERONÁUTICA

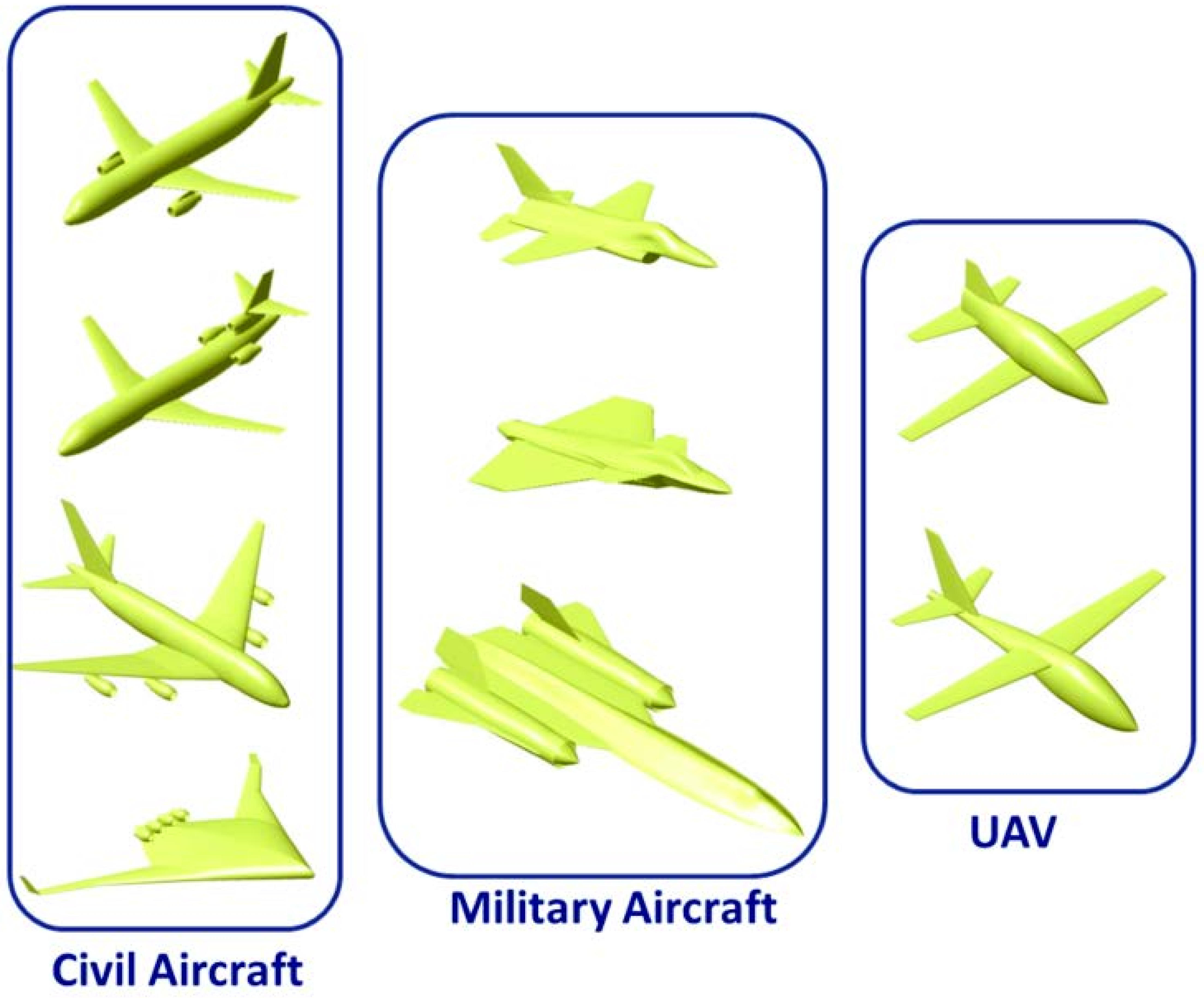
# Agenda

- Introduction
- Objectives
- Assumtions
- SOM - POFACETS
- Results
- Conclusions
- Future work

# Knowledge-Based Geometry Design



# Knowledge-Based Geometry Design



# Introduction

- Following the current trend of the military aircraft for stealth design and application, to demonstrate the importance of the equilibrium between low RCS and best aerodynamics.

- During of any preliminary design phase of an aircraft it is necessary the information about of shapes for low radar detection and what parameters are compatible with the structural and aerodynamic requirements.

# Objectives

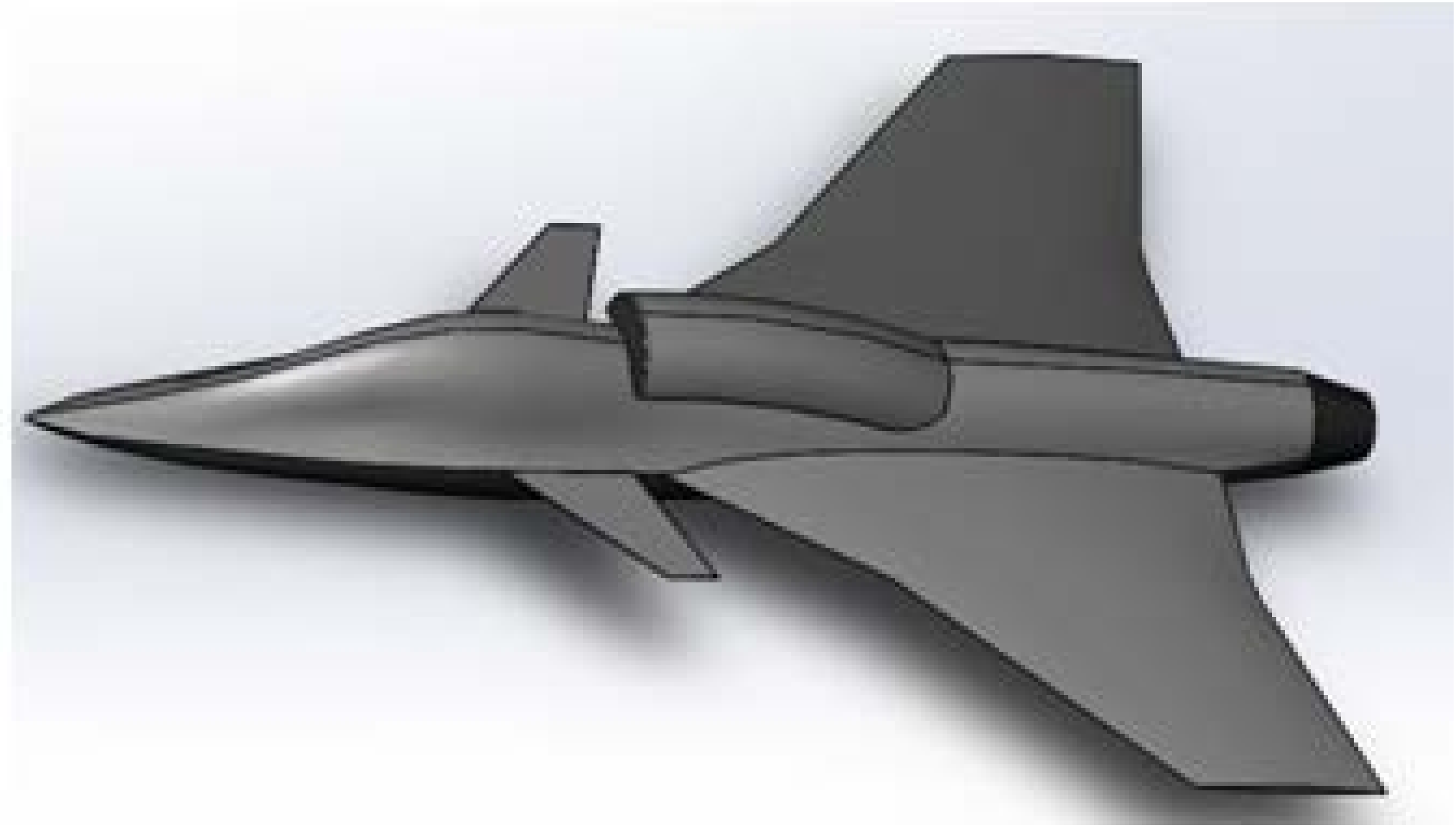
- To study stealth- aerodynamics analysis of supersonic aircraft concepts
- Design and develop 3-D computer-aided (CAD) models
- Estimation of Wave drag coefficient for each model
- RCS signature estimation based on physical optics (PO) method
- Comparison and summery of the concepts.

# Assumptions - Aerodynamics

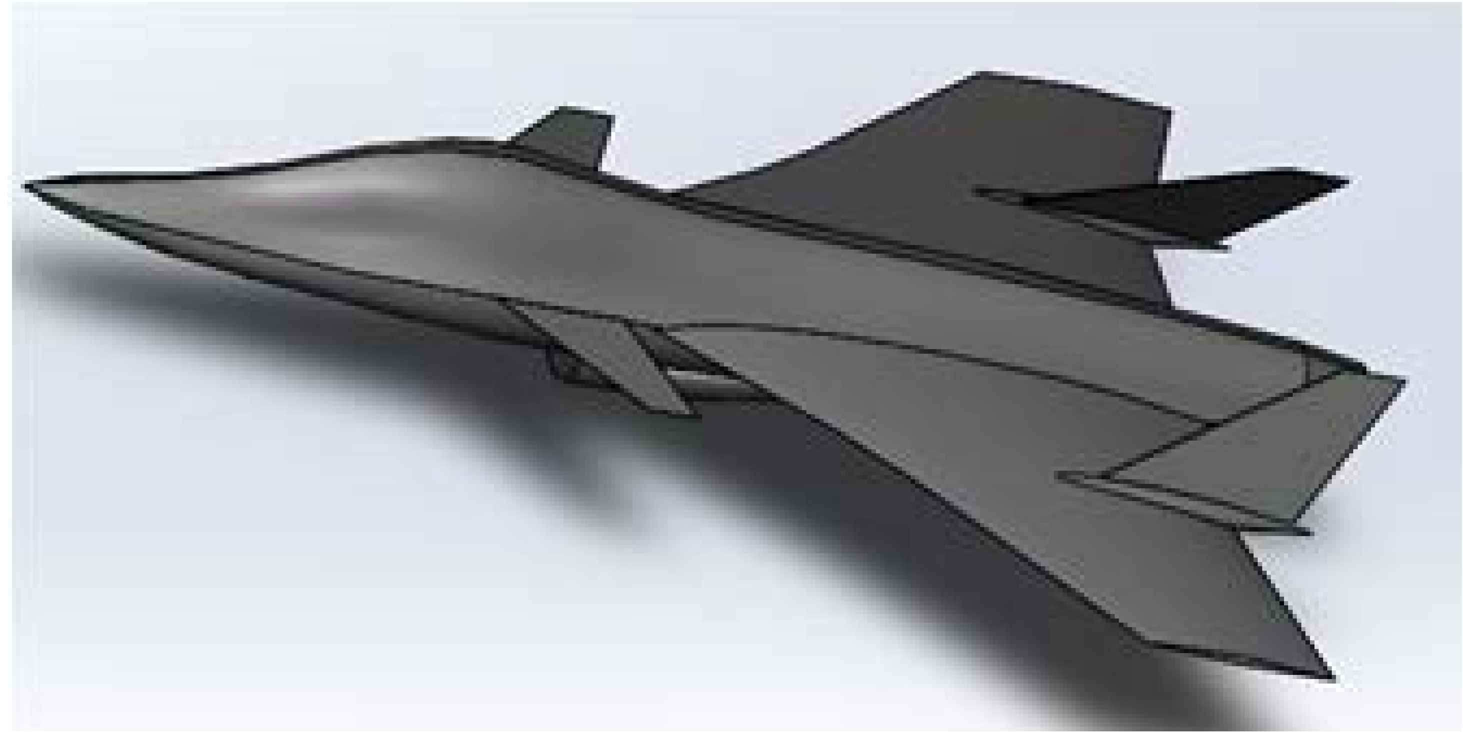
| Parameter | Size |
|---|---|
| Length | 15,80 [m] |
| Span | 10,04 [m] |
| Leading Edge Sweep Angle | 58,04° |
| Engine Numbers | 1 |
| Root Chord | 6,76 [m] |
| Wing Area | 35,12 [m²] |
| Canard Area | 3,35 [m²] |
| Total Vertical Stabilizers (VT) Area | 5,60 [m²] |

**Basic parameters of the conceptual models.**

**Model Dorsal Intake with Tail-Less .**



**Model Ventral Intake with V-Tail**



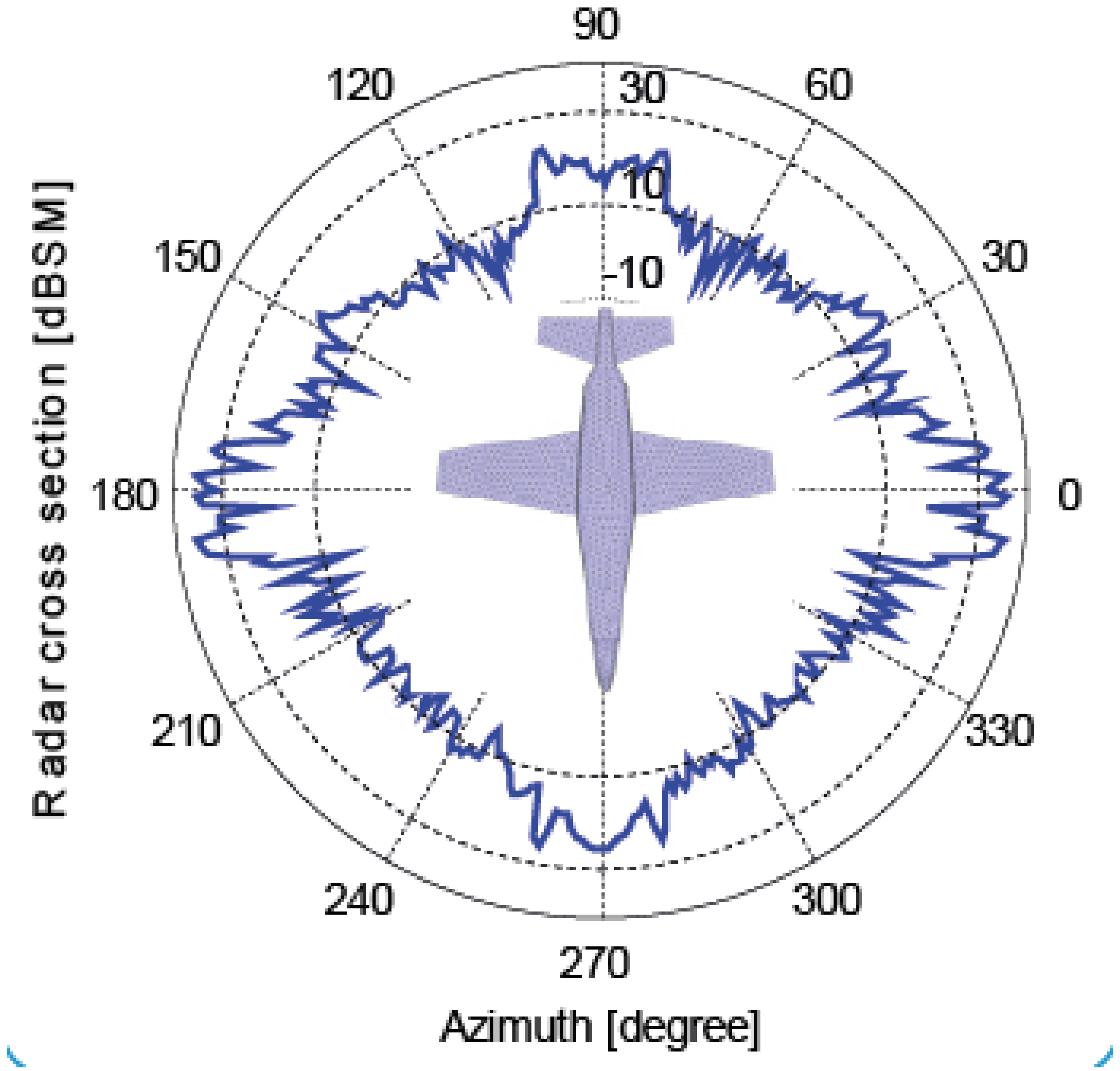
Tail and intake size changes during the analyses.

# Assumptions - Radar Cross Section

•Monostatic Radars;
•RCS considering only cases in high frequencies. (wavelengths size ~ aircrafts size)

| Band | Frequency [GHz] |
|---|---|
| S | 3,65 |
| X | 10,55 |
| Ku | 14,20 |
| K | 15,40 |

**Radars Bands for RCS simulation.**




**Typical Radar Cross Section Signature**

**Same orientation of POFACETS (EMCOS-Consulting and Software).**

# Methodology

**CAD Design**

- Fuselage, intake and canard were parameterized in VBA script ; while wings and vertical stabilizer were standardized.

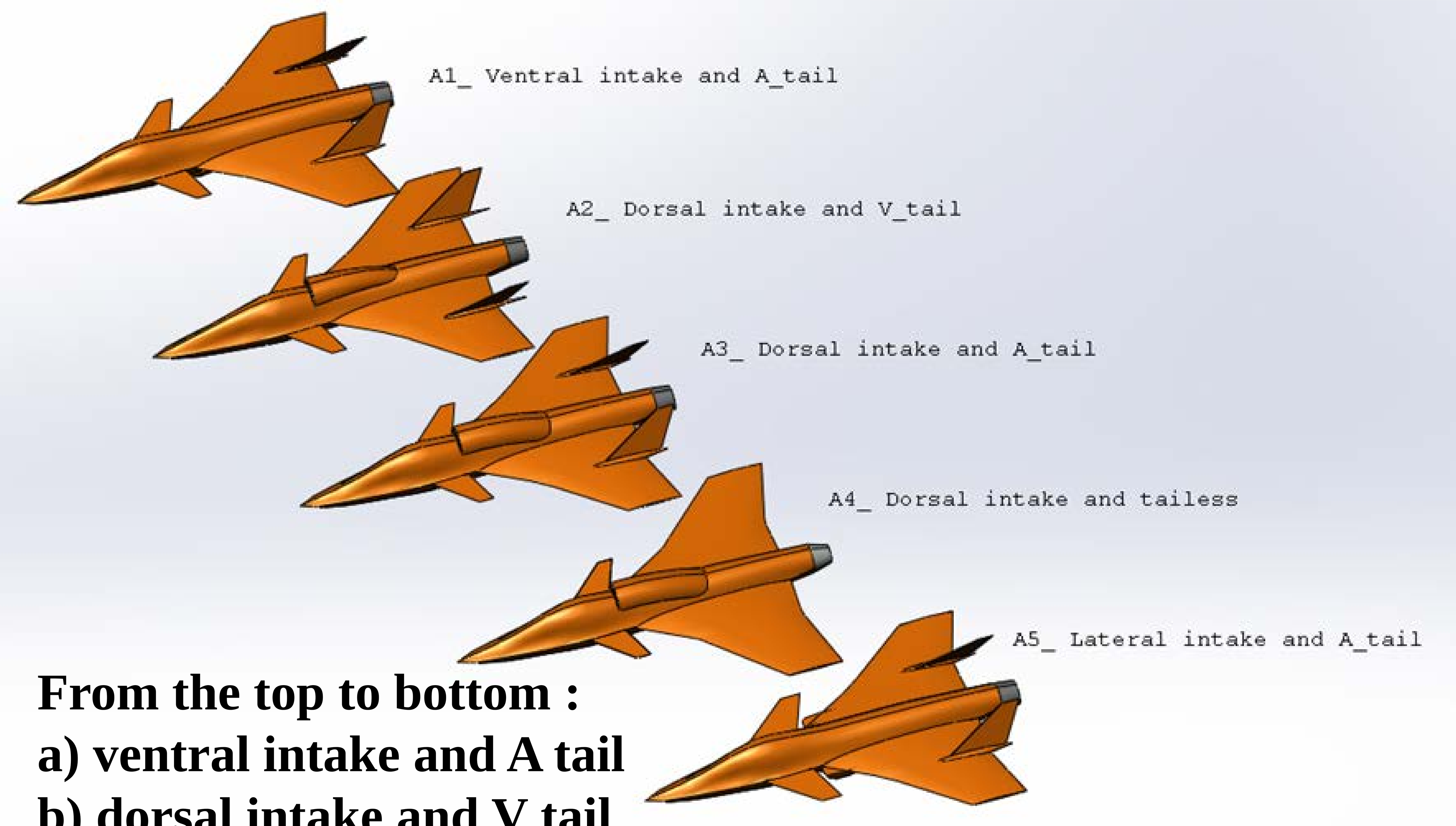
**Aerodynamic Analysis**

- Fifteen different sketches were made for these 3-D single-engine aircrafts
- Three concepts with lower wave drag coefficients obtained from SOM Program and OPEN VSP.

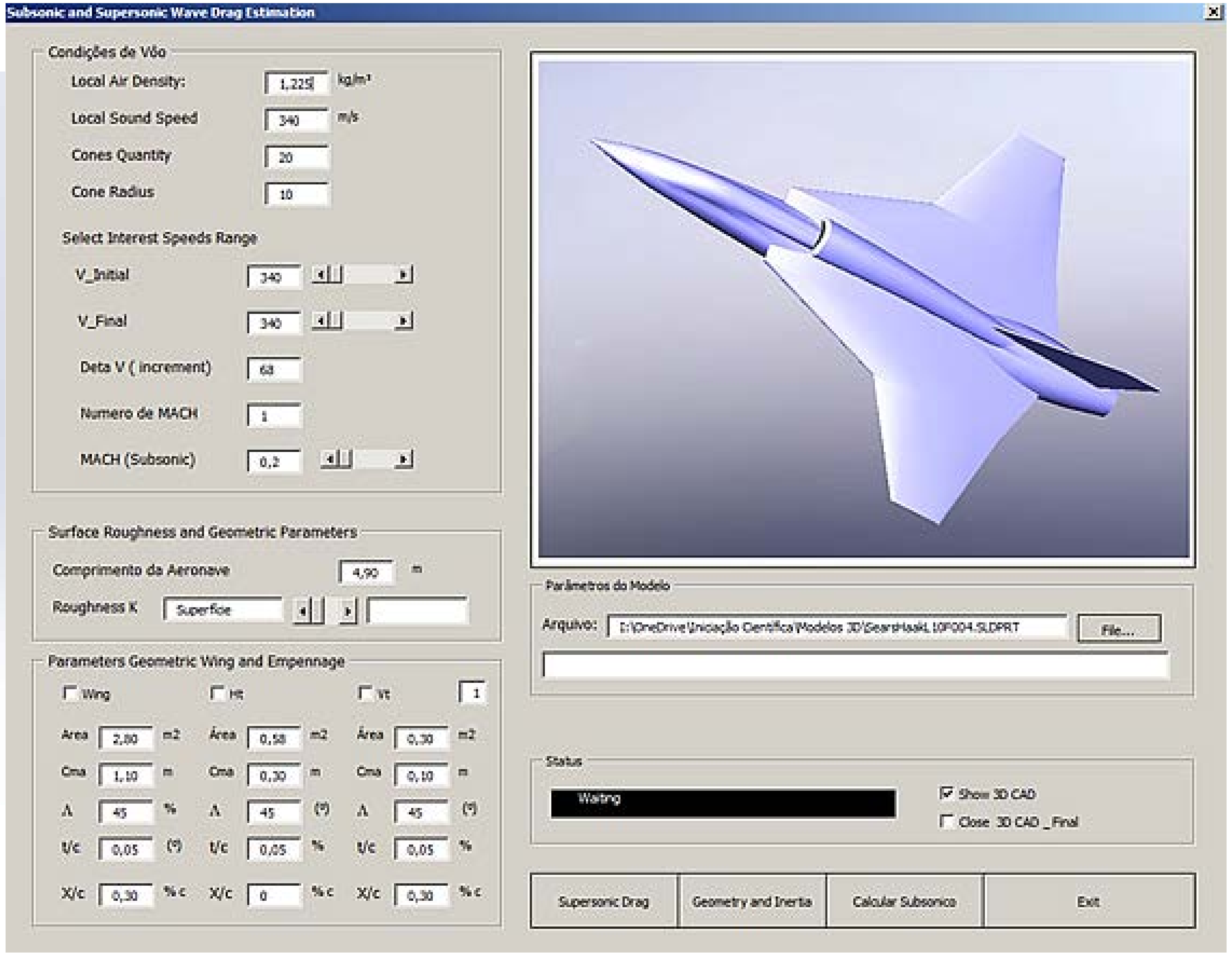
**RCS Analysis**

- Surface´s model is discretized into triangular facets elements
- Imported into POFACETS for RCS simulation.

# SOM – Sonic Optimization Module




**From the top to bottom :**
**a) ventral intake and A tail**
**b) dorsal intake and V tail**
**c) dorsal intake and A tail**
**d) dorsal intake**
**e) lateral intake and A tail.**




**Subsonic and Supersonic Estimation program - SOM**

# SOM – Sonic Optimization Module

$$C_{WD} = \frac{E_{WD}}{S_{ref}}\left[1 - 0.396(M-1.2)^2 \left(1 - \frac{\Pi\Lambda_{LE-deg}^{0.77}}{100}\right)\right]\frac{D}{q}_{Sears-Haack}$$

$\Lambda_{LE-deg}$ = *Leading edge sweep angle*
$E_{WD}$ = *Empirical wave drag efficiency*
$M$ = *Mach number*

$$\frac{D}{q}_{Sears-Haack} = \frac{9\pi}{2}\left(\frac{A_{max}}{l}\right)^2$$

$$V_{body} = \int_0^1 A_{cross-section}(y)dy$$

$$V_{body} = \pi(l-2r)r^2 + \frac{4\pi r^3}{3}$$

$$A(x) = \frac{V_{tot}}{l}\left[1 - \left(\frac{x}{l/2}\right)^2\right]^{2/3}$$

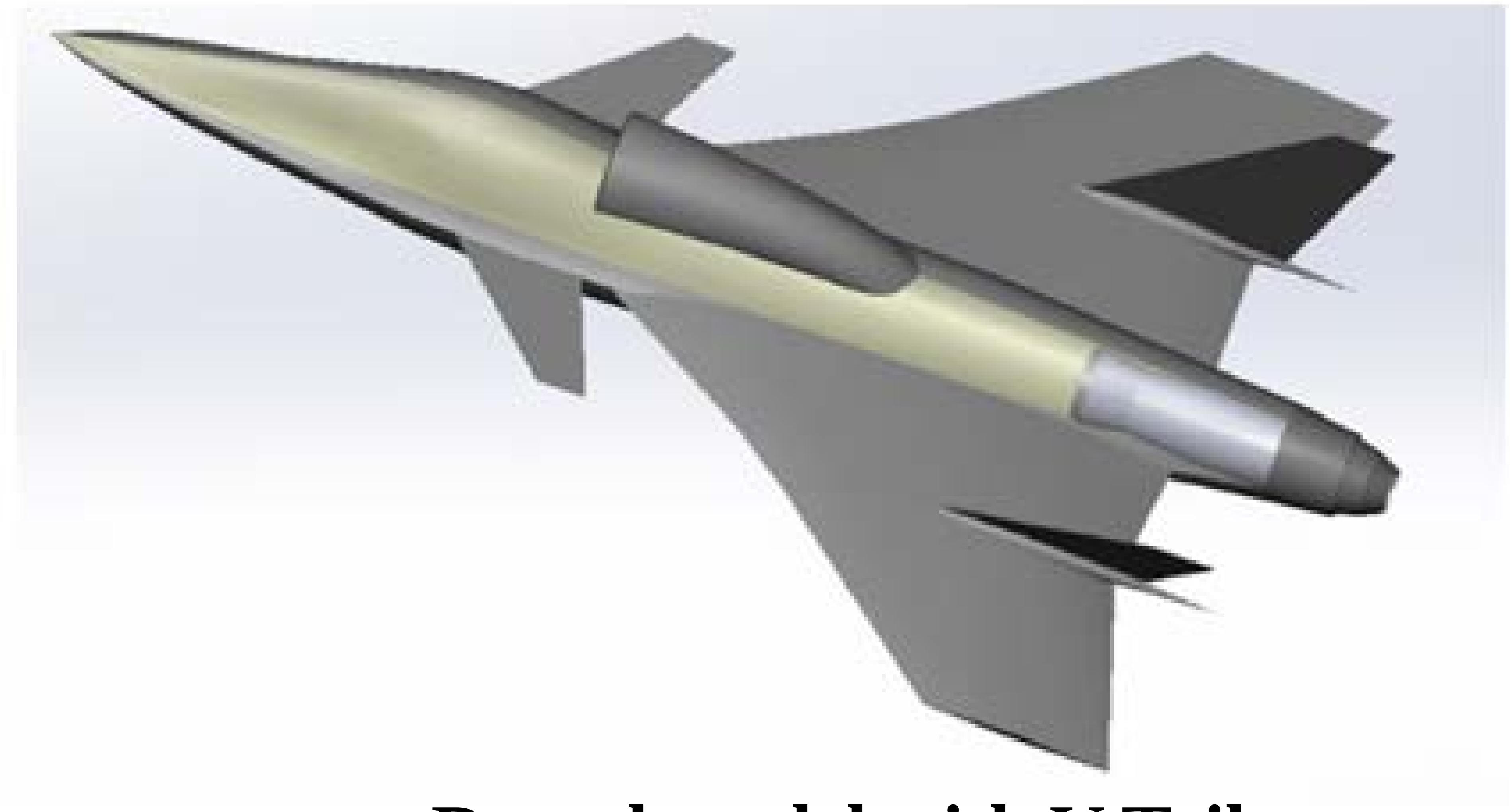
$$D_{M\to 1} = -\frac{\rho V^2}{4\pi}\int_{-x_0}^{+x_0}\int_{-x_0}^{+x_0} S''(x)S''(x1)\log|x - x1|\,dxdx1$$

# Results - Aerodynamic

- The dorsal intake with V tail model (M_VT) had minimum wave drag coefficients based (considering the mean wave drag coefficient for all the 5 Mach numbers).

**wave drag coefficients with OPEN VSP.**

| Mach Number | M_VT | M_I | M_TL |
|---|---|---|---|
| 1 | 0,065 | 0,088 | 0,066 |
| 1,2 | 0,059 | 0,064 | 0,062 |
| 1,4 | 0,052 | 0,053 | 0,046 |
| 1,6 | 0,044 | 0,046 | 0,042 |
| 1,8 | 0,035 | 0,037 | 0,038 |



**Dorsal model with V Tail.**

| Mach Number | M_VT | M_I | M_TL |
|---|---|---|---|
| 1 | 0,065 | 0,088 | 0,066 |
| 1,2 | 0,059 | 0,064 | 0,062 |
| 1,4 | 0,052 | 0,053 | 0,046 |
| 1,6 | 0,044 | 0,046 | 0,042 |
| 1,8 | 0,035 | 0,037 | 0,038 |

**Simulated wave drag coefficients with SOM Program.**

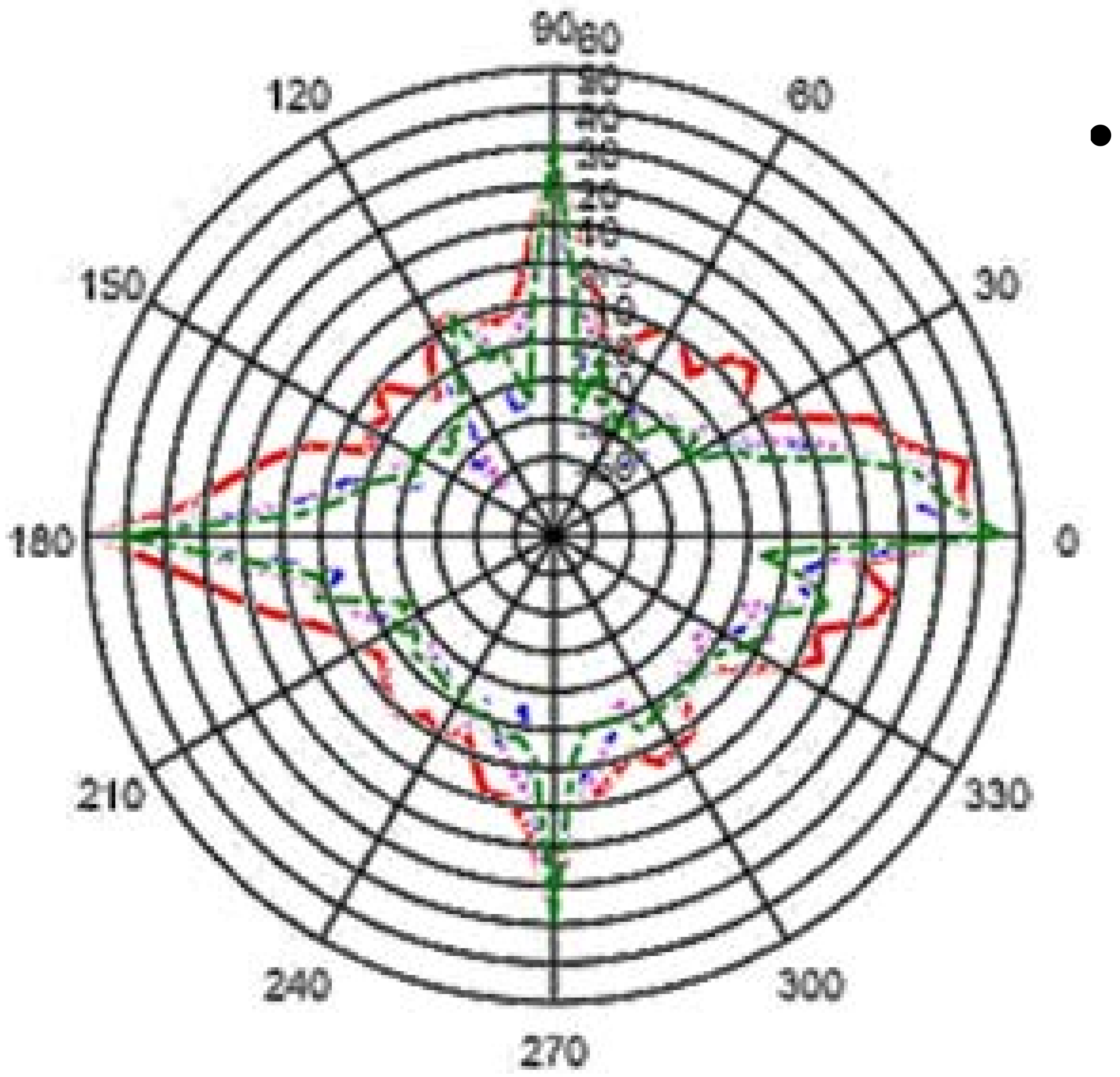


**Model Ventral Intake (M_I).** **Model Dorsal Intake with V Tail (M_VT).**

**Model Dorsal Intake with Tail-Less (M_TL).**

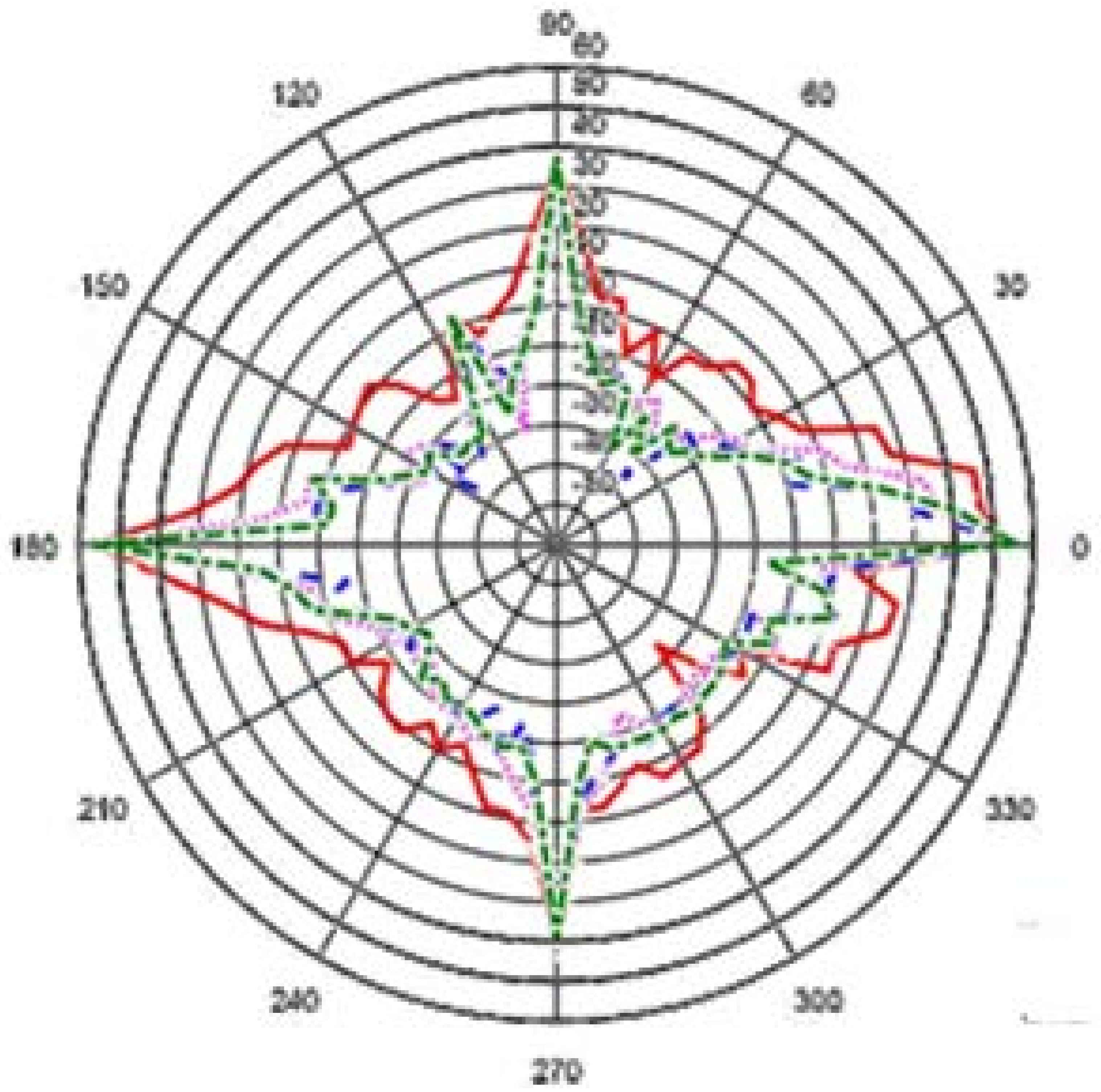
# Results - RCS

- The green line is closer to the center of the graphic = minimum signature is represented by this frequency
- The frequency 15,40 GHz.



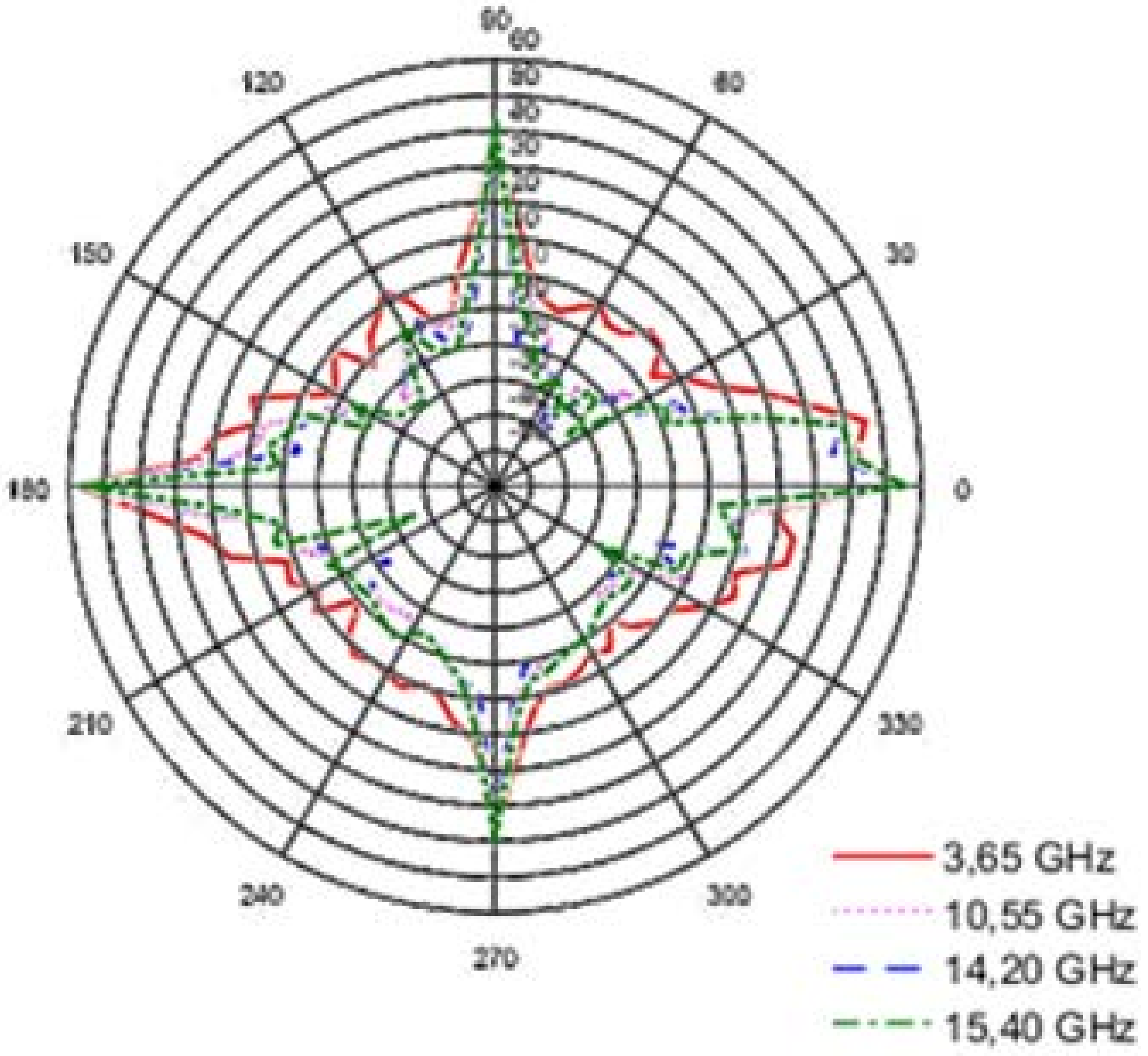

**Radar signature for M_VT aircraft model**

**Model Dorsal Intake with V Tail (M_VT).**




**Radar signature for M_TL aircraft model**

**Model Dorsal Intake with Tail-Less (M_TL).**

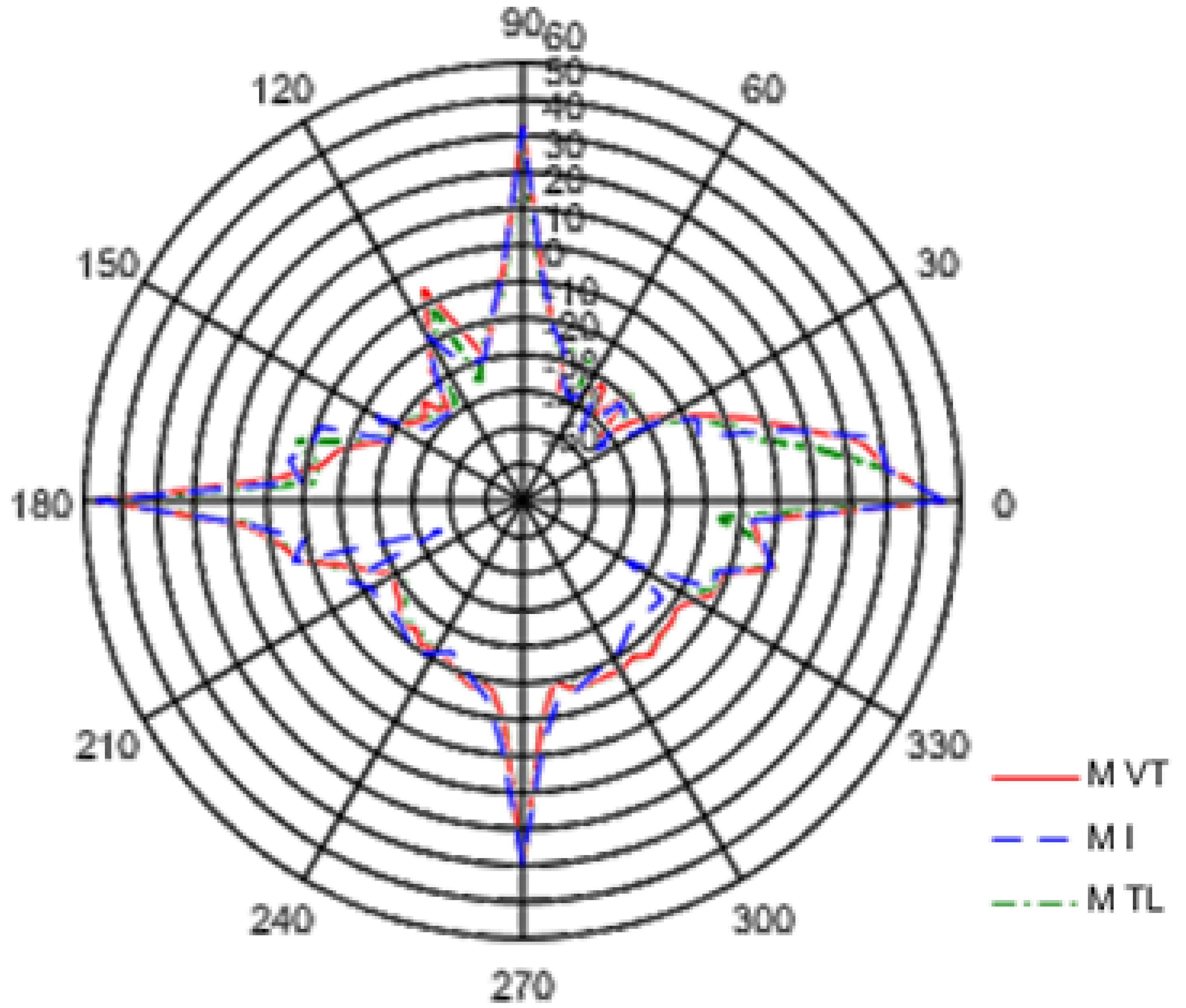



**Radar signature for M_I aircraft model**

**Model Ventral Intake (M_I).**

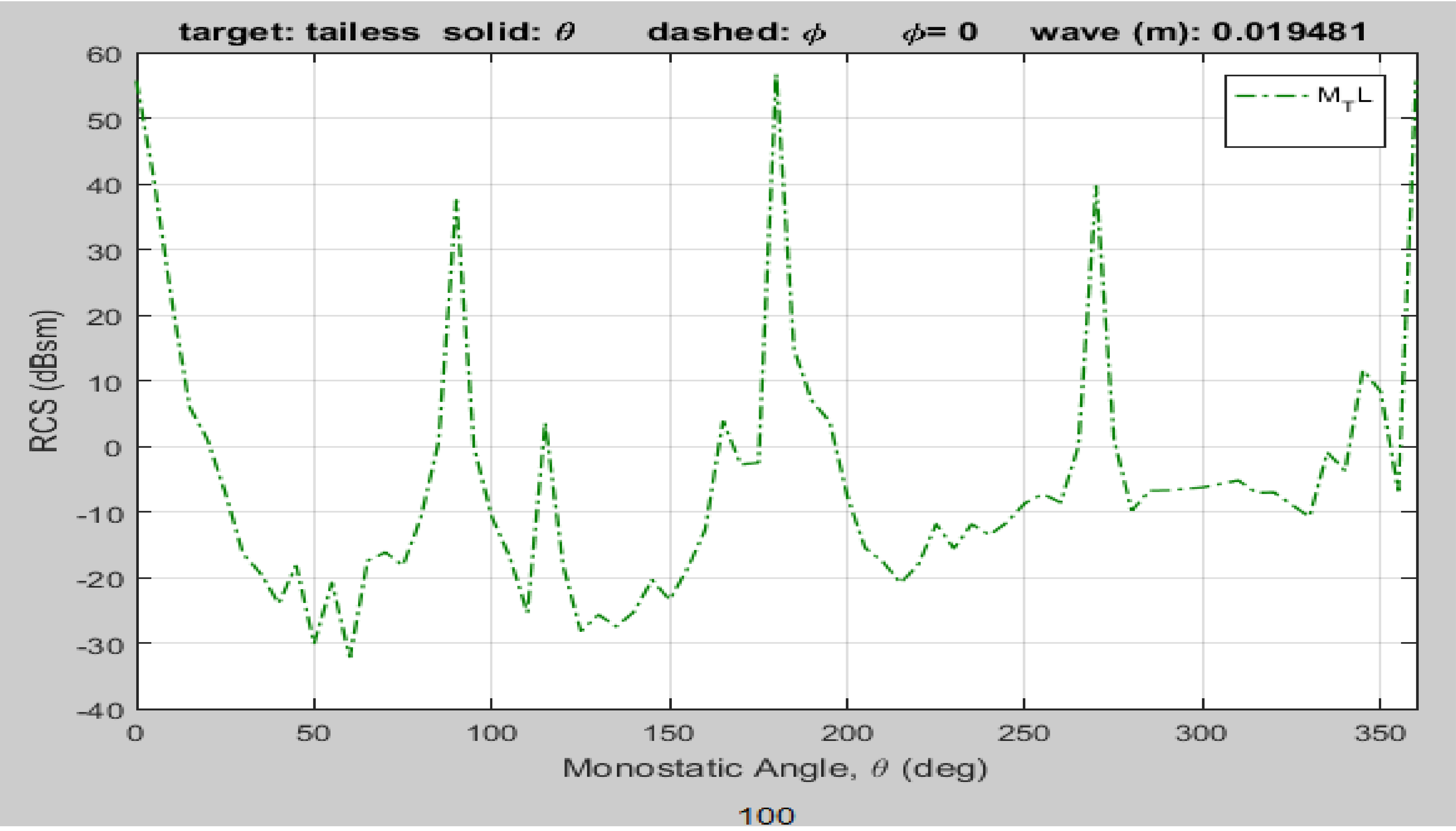
# Results - RCS

- Compare the three targets : (1) The aircraft's design have similar radar signature; (2) we can infer that the M_I model (blue line) is the one with low signature.
- Comparing the results of the Table (points every 5°) with measured areas, the ventral intake with vertical (M_I) stabilizer has better signature.

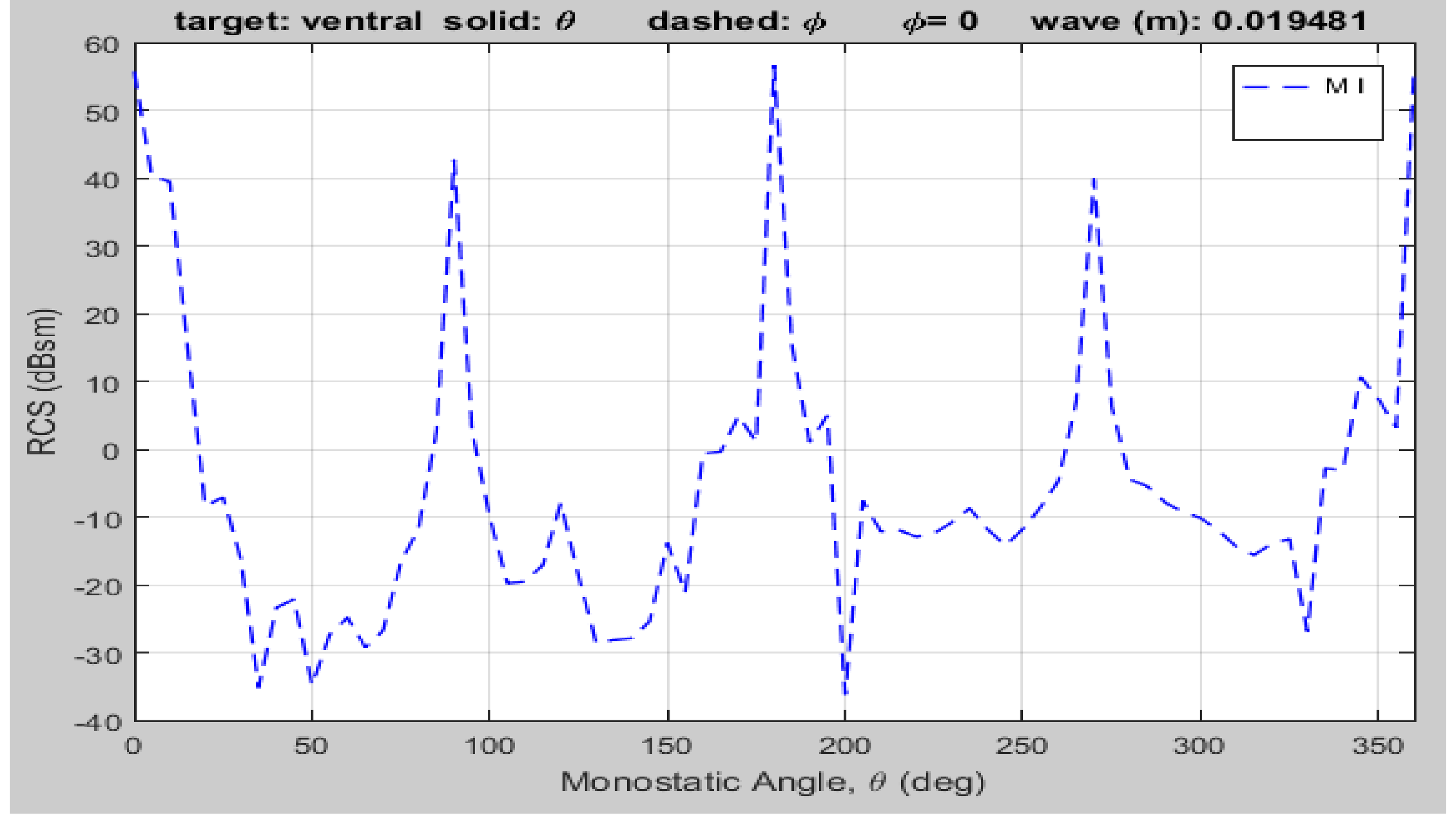



**Radar signature for the M_VT, M_I and M_TL aircrafts designs**

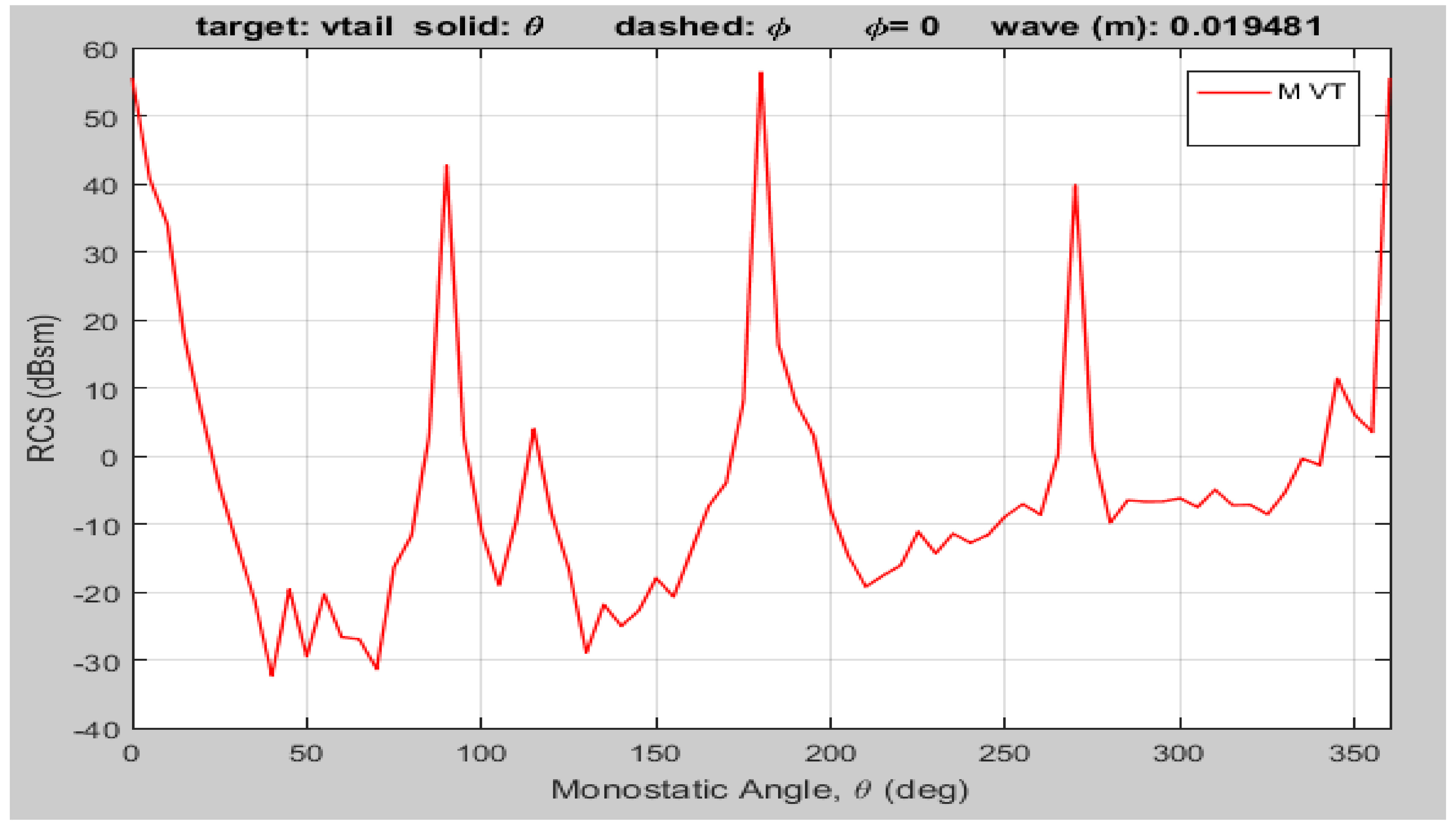
**Model Dorsal Intake with V Tail (M_VT).**




**Model Ventral Intake (M_I).**




**Model Dorsal Intake with Tail-Less (M_TL).**



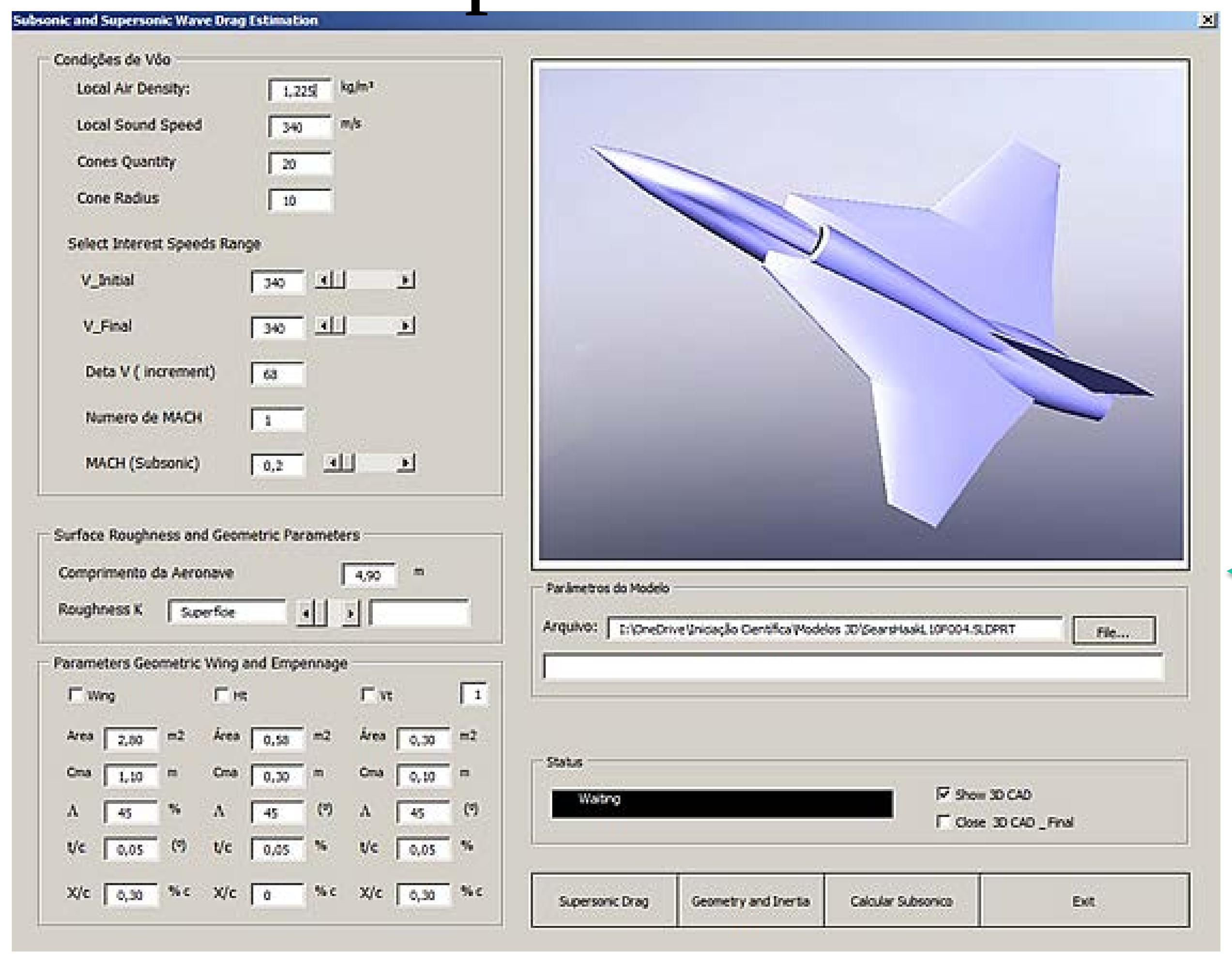
# Conclusions

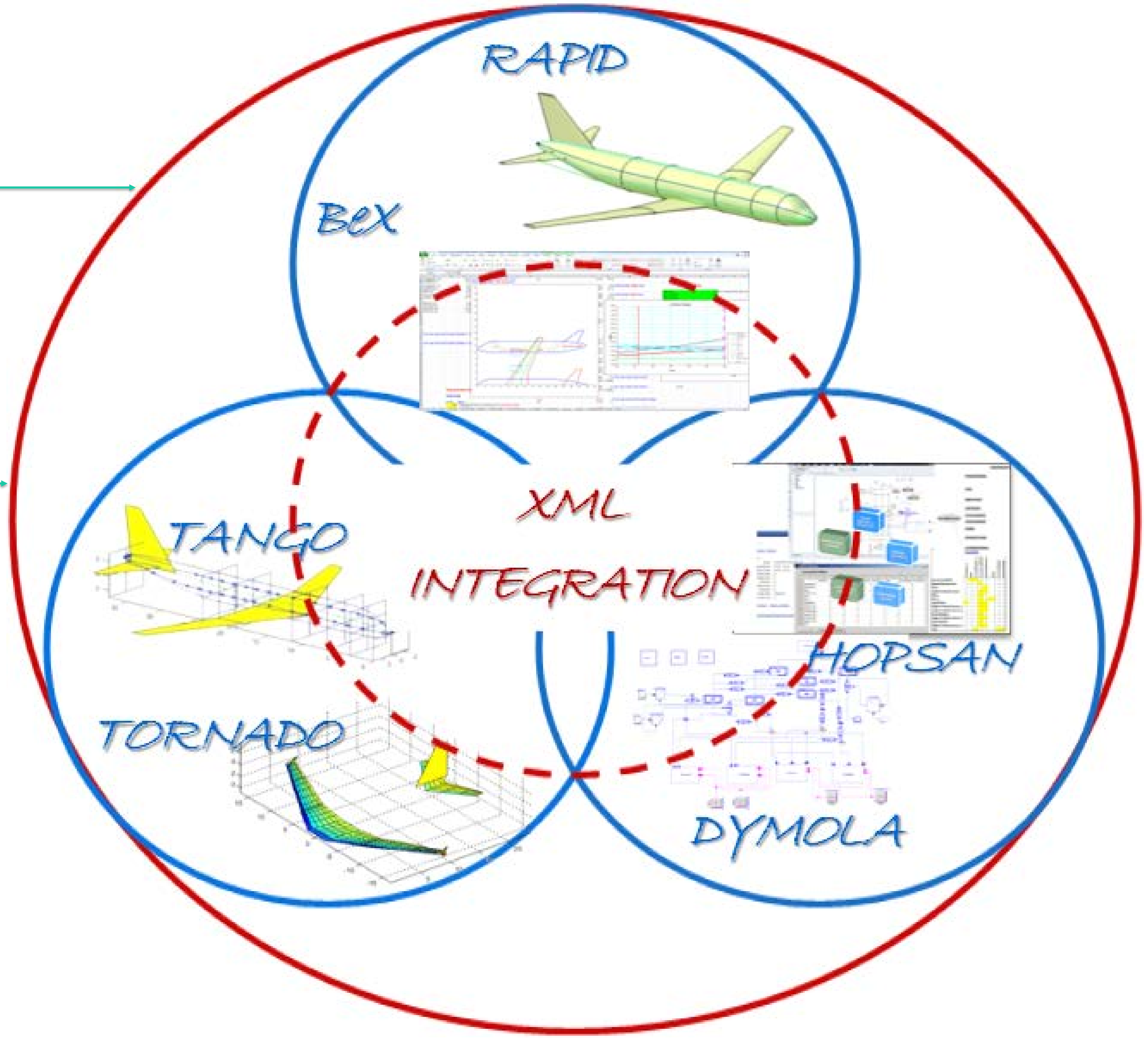
- The Radar Cross Section is the measure of targets' distance to radar. It is correlated with high frequencies and planform shaping
- The design rule for a stealth aircraft is an optimum equilibrium of stealth-aerodynamics characteristics. This study allows observing, in accordance with the literature, that the best design for stealth characteristics is not the best for the aerodynamics ones. The effort to study and develop optimization tools to enable reaching the best result as possible for both characteristics is fundamental since usually is not that intuitive and not that obvious.

# Future Work- Collaboration with other tools

POFACETS

SOM – Sonic Optimization Module





Source: Northtop F-5 Case Study in Aircraft Design

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