

### Uandha F. Barbosa, João Paulo M. C. Costa, <u>Raghu Chaitanya Munjulury</u>\*, Alvaro Martins Abdalla,

# USP, São Carlos, Brazil \* Linköping University, SE-58183, Linköping, Sweden Fluid and Mechatronic Systems

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





São Carlos School of Engineering ENGENHARIA **University of São Paulo** Brazil



## Agenda

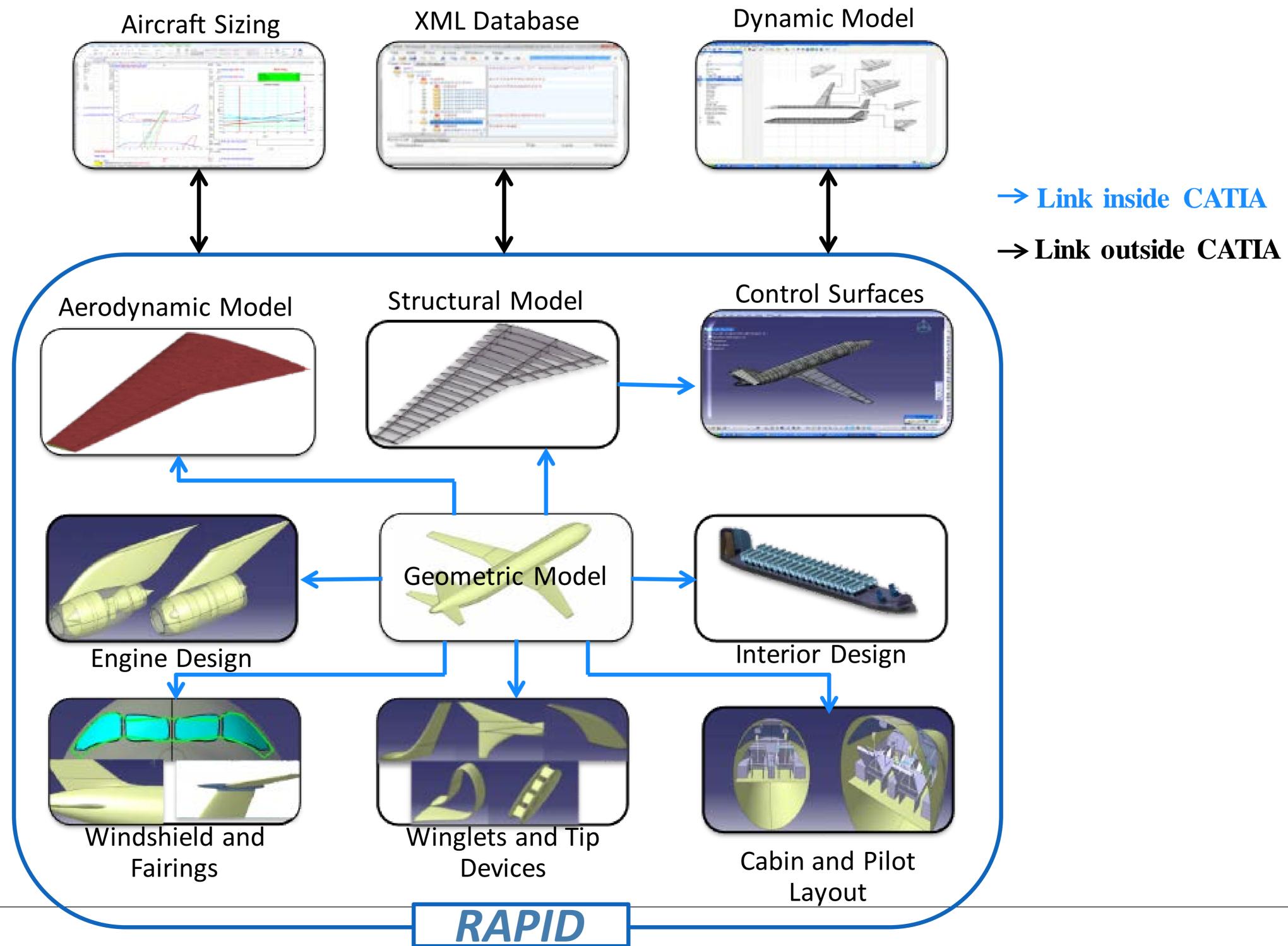
- Introduction
- Objectives
- Assumations
- SOM POFACETS
- **Results**
- Conclusions
- Future work





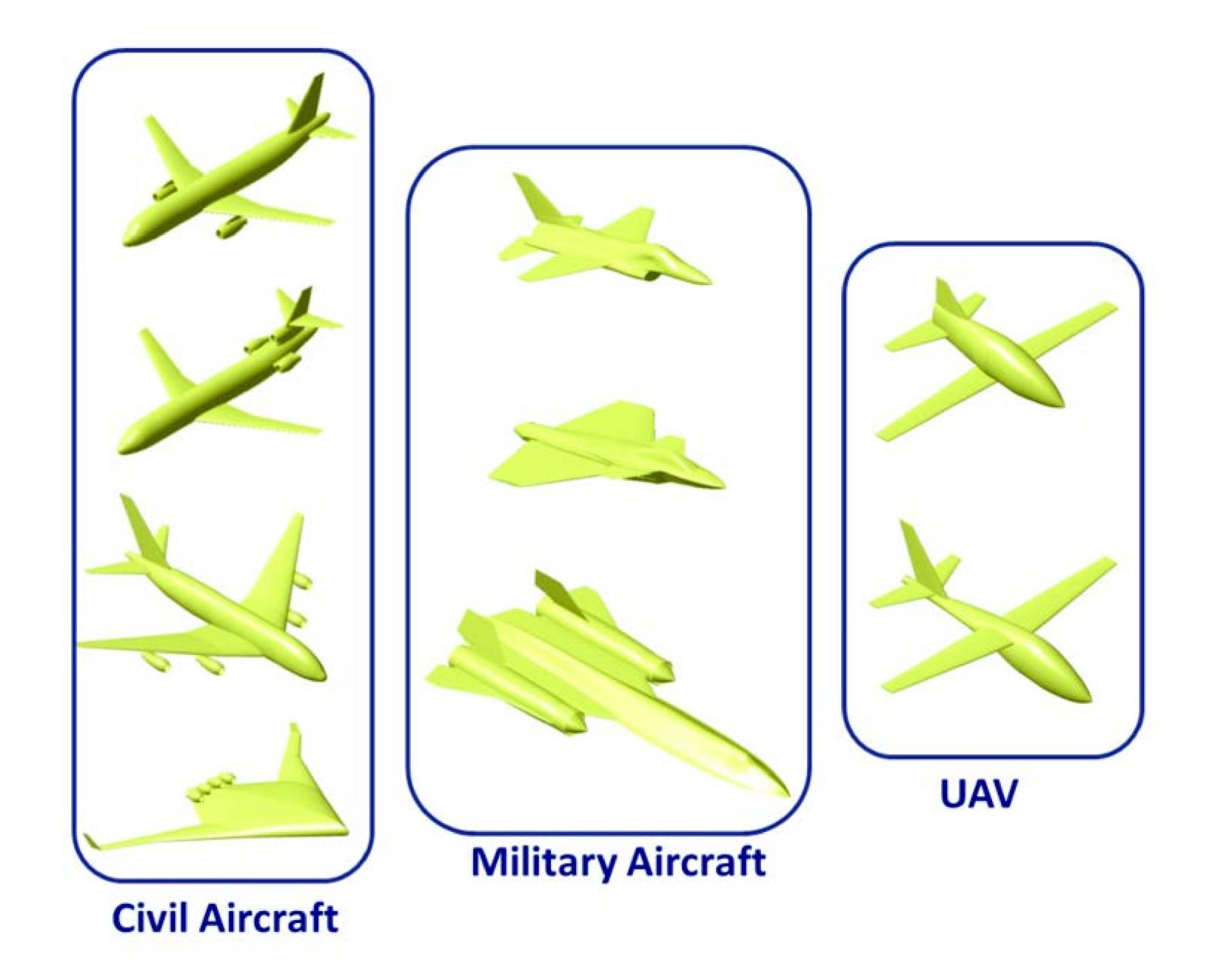
## Knowledge-Based Geometry Design





## 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

- concepts



### • To study stealth- aerodynamics analysis of supersonic aircraft

• 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

Span 1   Leading Edge Sweep Angle 2   Engine Numbers 3   Root Chord 3   Wing Area 3   Canard Area 3			
Leading Edge Sweep Angle Engine Numbers Root Chord ( Wing Area 3 Canard Area 3	Length	1	5
AngleEngine NumbersRoot ChordWing AreaCanard Area	Span	1	0
Root Chord ( Wing Area 3 Canard Area 3		Sweep	5
Wing Area 3 Canard Area 3	Engine Nun	ıbers	
Canard Area 3	Root Cho	rd (	6,
	Wing Are	ea 3.	5,
Total Vertical 5	Canard A	rea 3	) _
Stabilizers (VT) Area			5,0

### **Basic parameters of the conceptual models.**

Tail and intake size changes during the analyses.

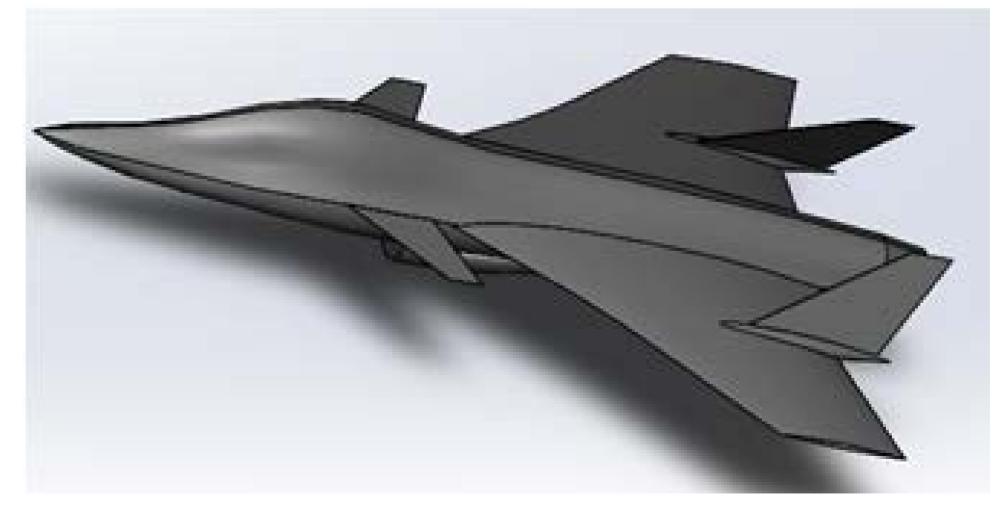


### Size

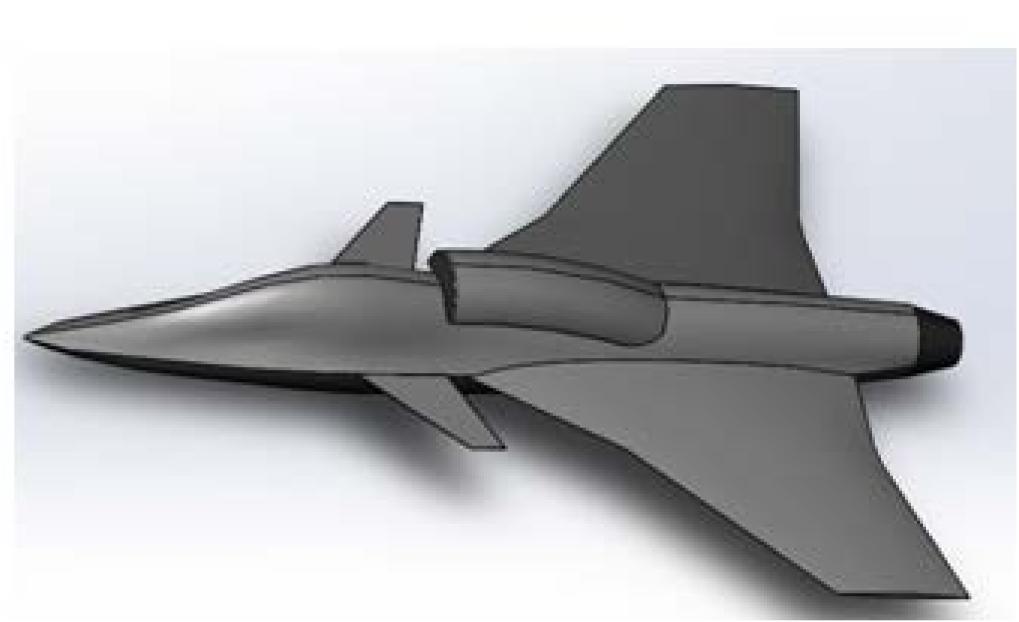
- 5,80 [m]
- 0,04 [m]
- 58,04°

- ,76 [m]
- 5,12 [m<sup>2</sup>]
- ,35 [m<sup>2</sup>]
- ,60 [m²]

### **Model Ventral Intake with V-Tail**



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







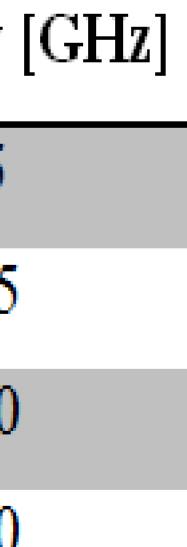
### Assumptions - Radar Cross Section

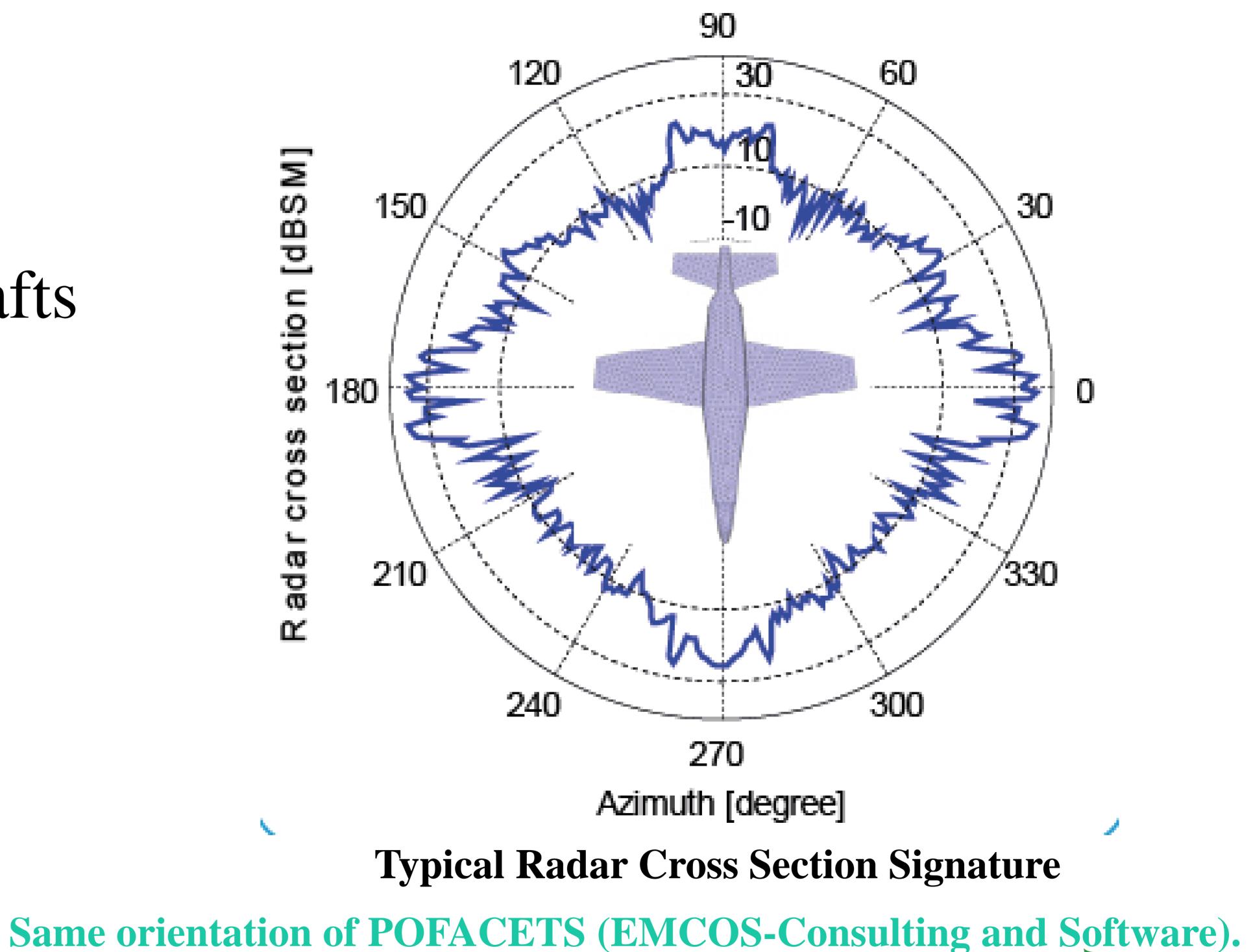
### •Monostatic Radars; •RCS considering only cases in high frequencies. (wavelengths size $\sim$ aircrafts size)

Band	Frequency
S	3,65
Χ	10,55
Ku	14,20
K	15,40

**Radars Bands for RCS simulation**.









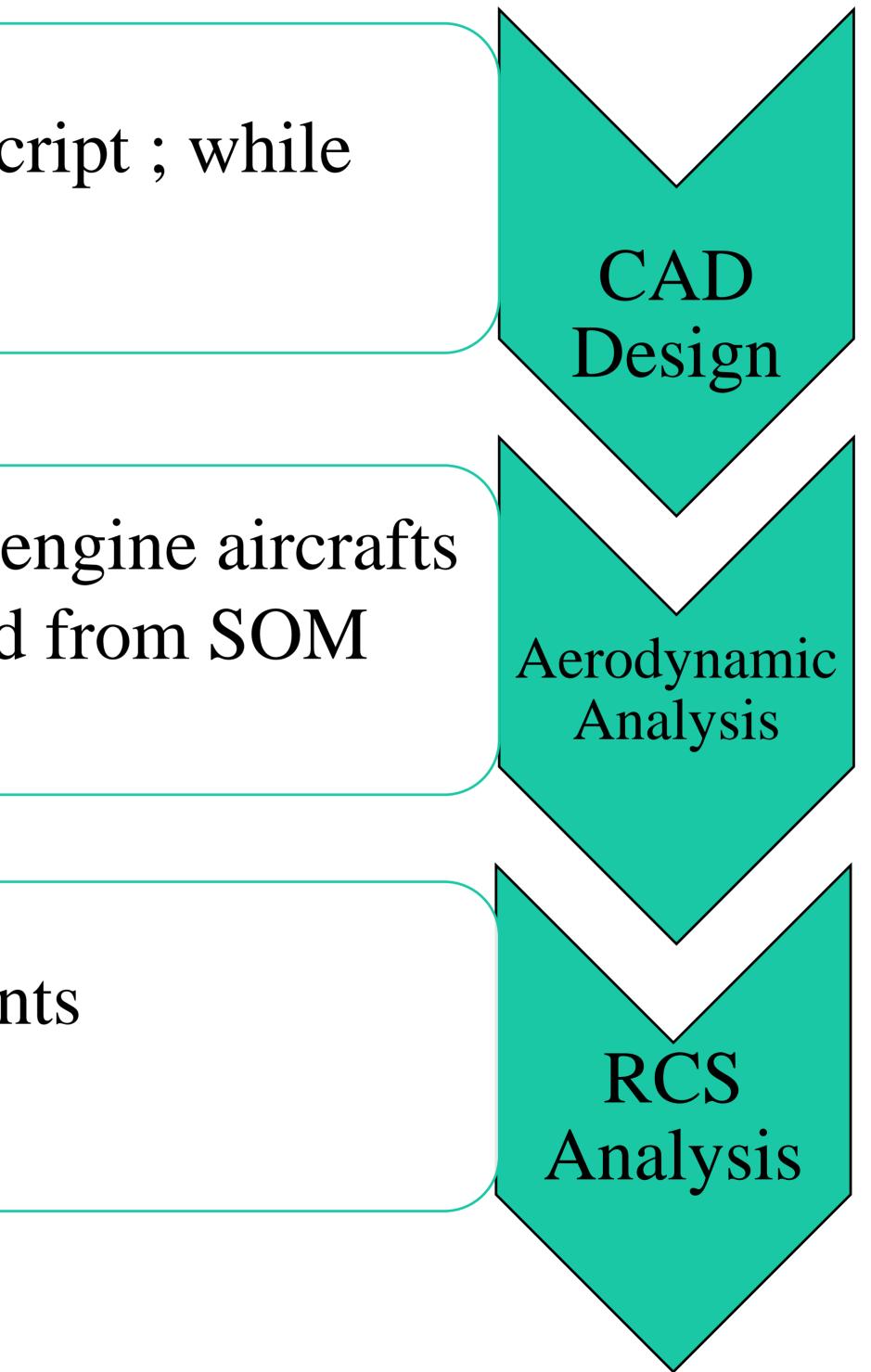
## Methodology

•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.

•Surface's model is discretized into triangular facets elements •Imported into POFACETS for RCS simulation.

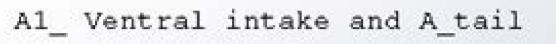


### •Fuselage, intake and canard were parameterized in VBA script ; while wings and vertical stabilizer were standardized.





## SOM – Sonic Optimization Module



A2\_ Dorsal intake and V

A3\_ Dorsal int

A4\_ D

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.

### LINKÖPING UNIVERSITY

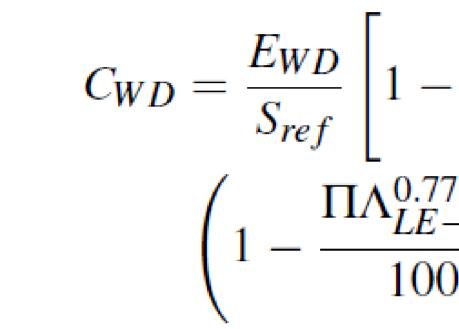
	Condições de Võo
	Local Air Density: 1,225 kg/m <sup>2</sup>
	Local Sound Speed 340 m/s
	Cone Radius 10
	Select Interest Speeds Range
1	V_Initial J40 III D
	V_Final 340 41 340
and theil	Deta V ( increment) 63
and A_tail	
	Numero de MACH 1
	MACH (Subsonic) 0,2 4 >
al intake and tailess	
	Surface Roughness and Geometric Parameters
	Comprimento da Aeronave 4,90 <sup>m</sup> Parâmetros do Modelo
at DE Tetravel inteles and D teil	Roughness K Superfice
A5_ Lateral intake and A_tail	Arquivo: L:\OneDrive Unicação Cientifica\Wodelos 3D/SearsHaakLt0r004.SLDPRT File.
H	Parameters Geometric Wing and Empennage
7	Film Film
	Area 2,00 m2 Área 0,58 m2 Área 0,30 m2
	Cria 1,10 m Cria 0,30 m Cria 0,10 m Status
	Weitrop
	Ve 0.05 (9) Ve 0.05 % Ve 0.05 %
	X/C 0.30 % C X/C 0 % C X/C 0.30 % C Supersonic Drag Geometry and Inertia Calcular Subsonico Exit

### **Subsonic and Supersonic Estimation program - SOM**





## SOM – Sonic Optimization Module



M = Mach number

D

*q* Sears-Haa

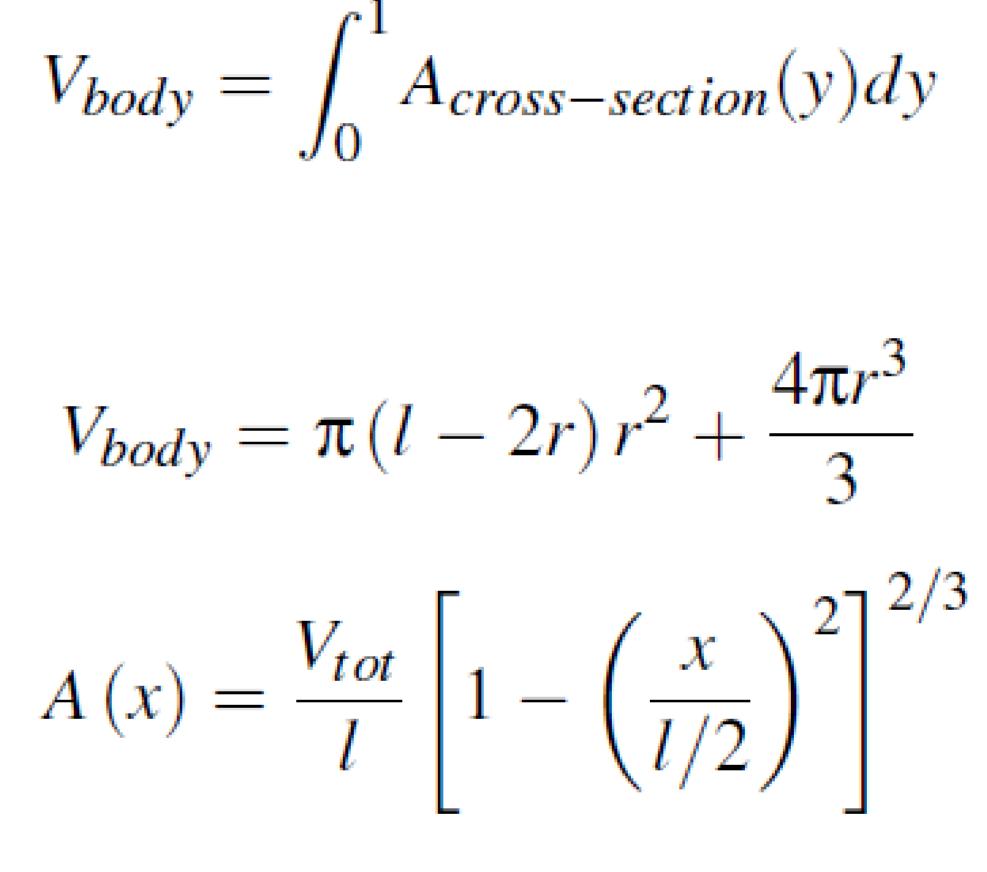


$$\frac{1 - 0.396(M - 1.2)^2}{\frac{\Lambda_{LE}^{0.77}}{100}} \left[ \frac{D}{q} \right] \frac{D}{q} Sears-Haack}$$

 $\Lambda_{LE-deg} = Leading \ edge \ sweep \ angle$ *E*<sub>WD</sub> = *Empirical wave drag efficiency* 

$$=\frac{9\pi}{2}\left(\frac{A_{max}}{l}\right)^2$$

 $D_{M \to 1} = -\frac{\rho V}{4-\rho}$ 

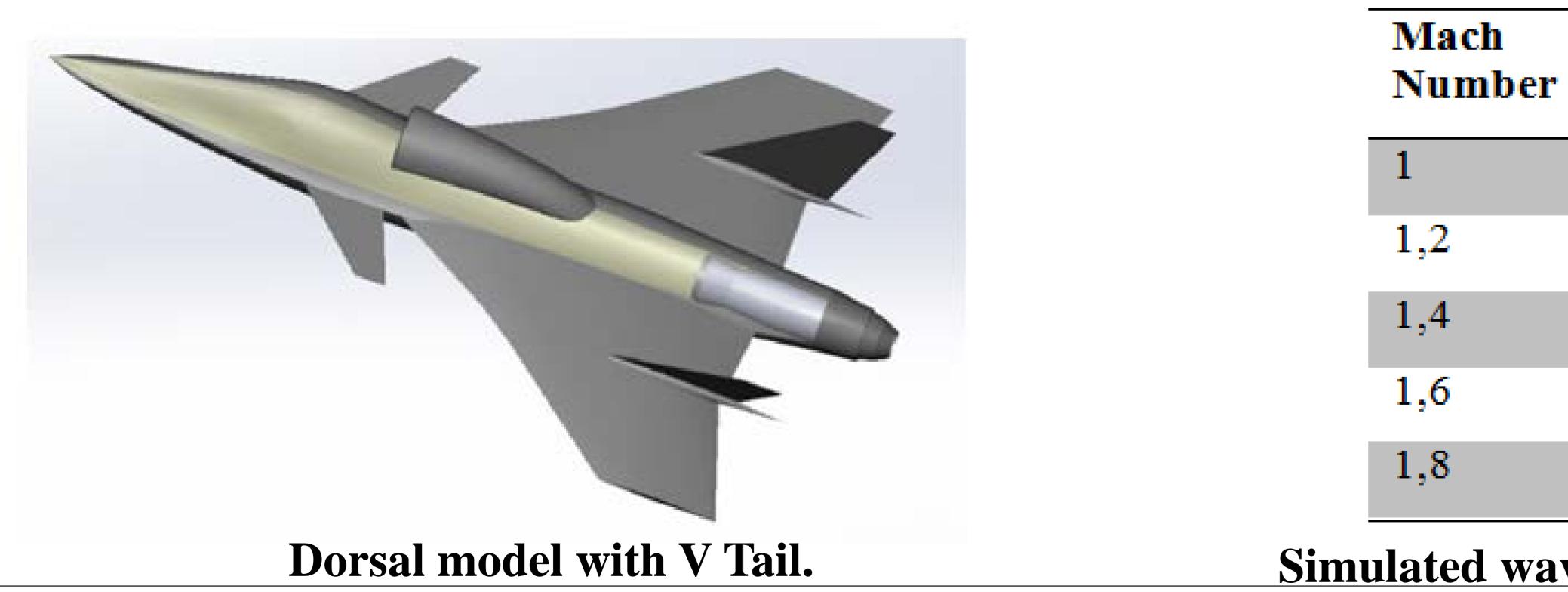


$$\frac{\sqrt{2}}{\pi} \int_{-x_0}^{+x_0} \int_{-x_0}^{+x_0} S''(x) S''(x1) \log |x| - x1| dx dx$$



## Results - Aerodynamic

The dorsal intake with V tail model (M\_VT) had numbers).





Model Dorsal Intake with V Tail (M\_VT). Model Ventral Intake (M\_I).

### minimum wave drag coefficients based (considering the mean wave drag coefficient for all the 5 Mach

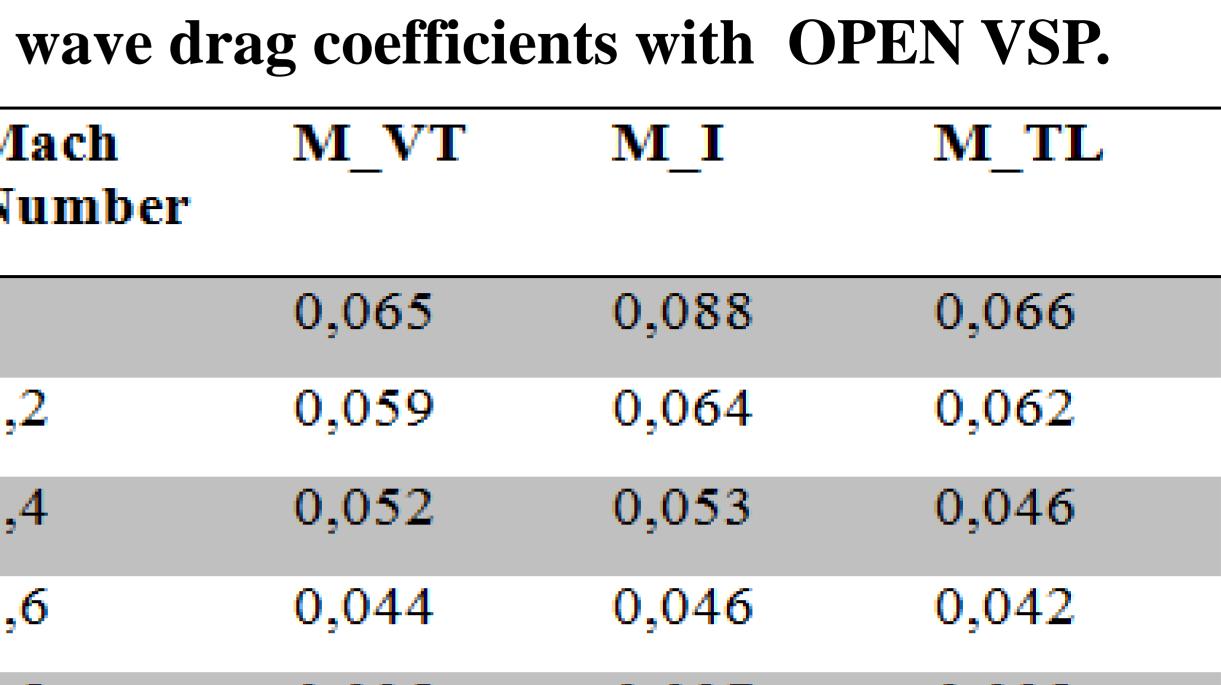
Model Dorsal Intake with Tail-Less (M\_TL).

	0		
Mach Number	M_VT	M_I	<b>M_T</b>
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

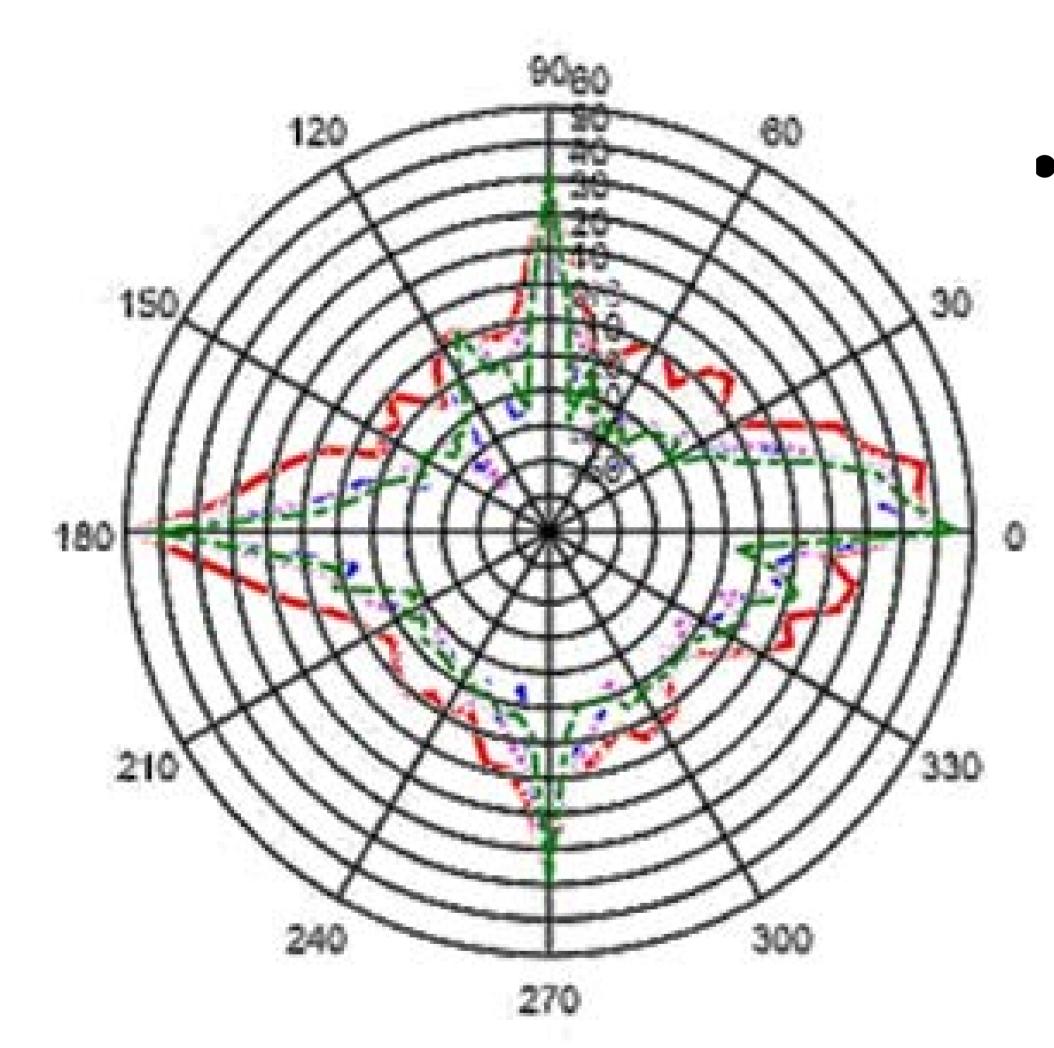
M_VT	M_I	M_TL
0,065	0,088	0,066
0,059	0,064	0,062
0,052	0,053	0,046
0,044	0,046	0,042
0,035	0,037	0,038

### Simulated wave drag coefficients with SOM Program.





### Results - RCS

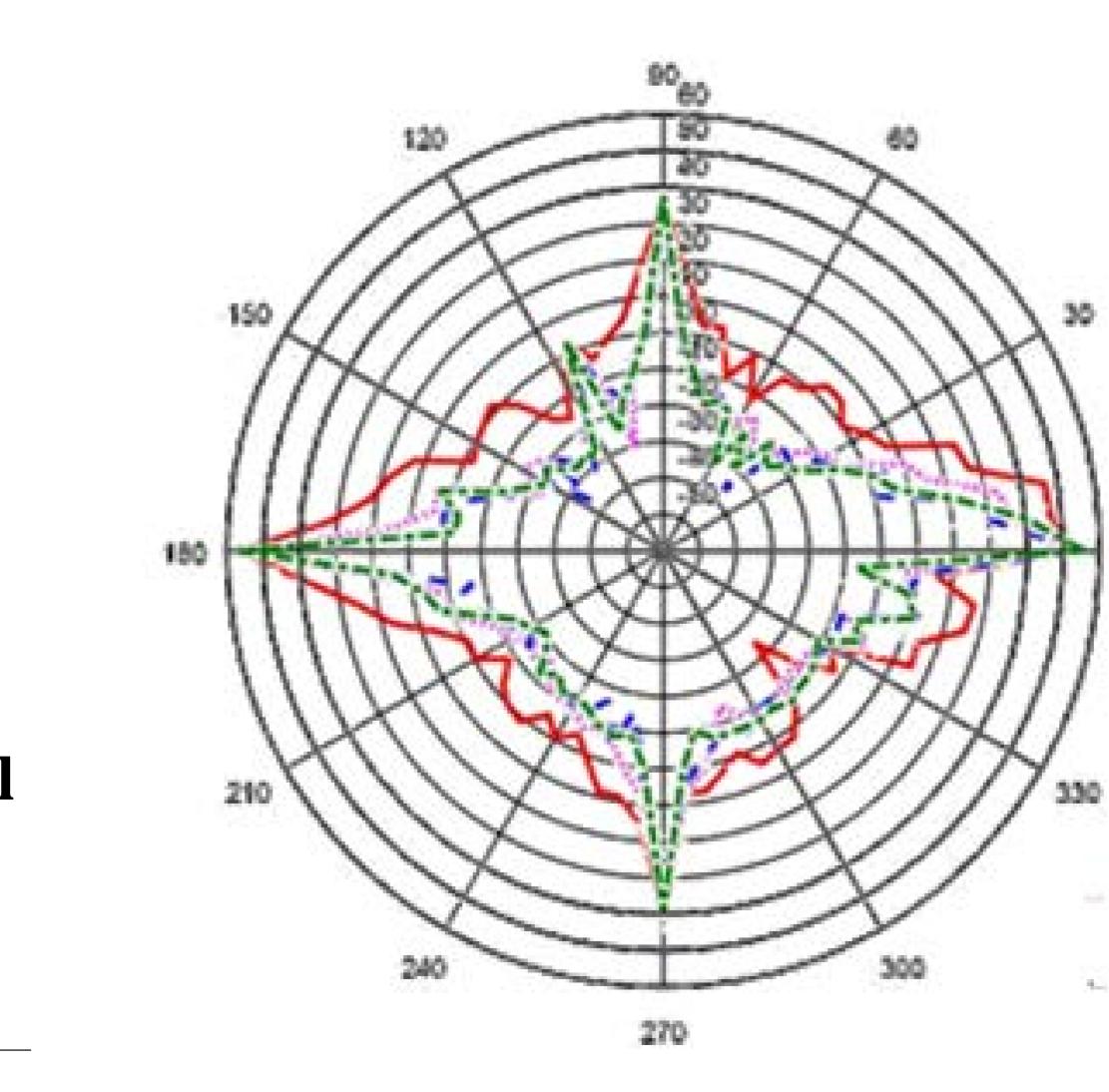


**Radar signature for M\_VT aircraft model** 

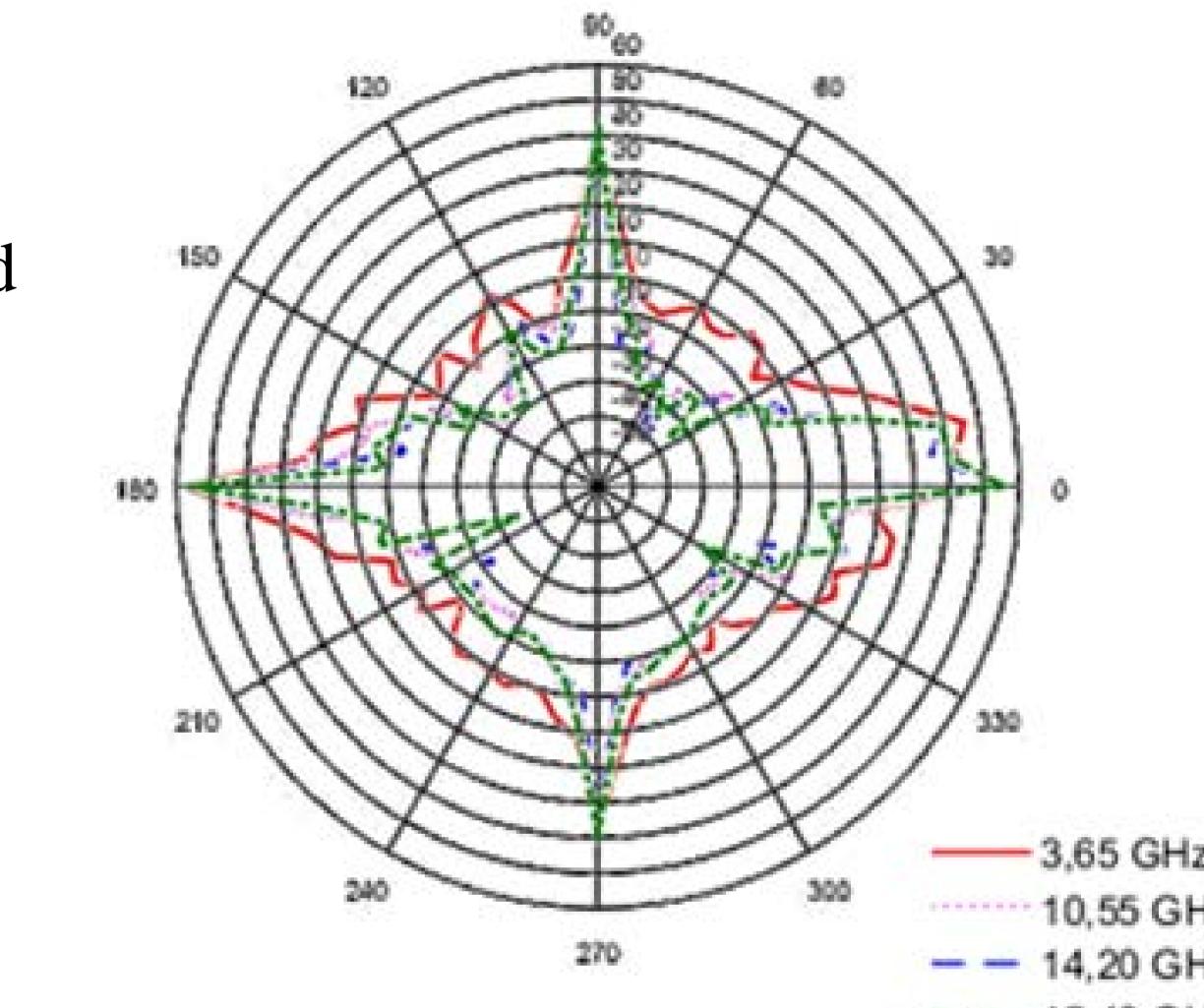
Model Dorsal Intake with V Tail (M\_VT).



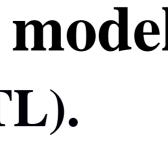
- The green line is closer to the center of the graphic = minimum signature is represented by this frequency
- The frequency 15,40 GHz.



**Radar signature for M\_TL aircraft model Model Dorsal Intake with Tail-Less (M\_TL).** 



### **Radar signature for M\_I aircraft model** Model Ventral Intake (M\_I).



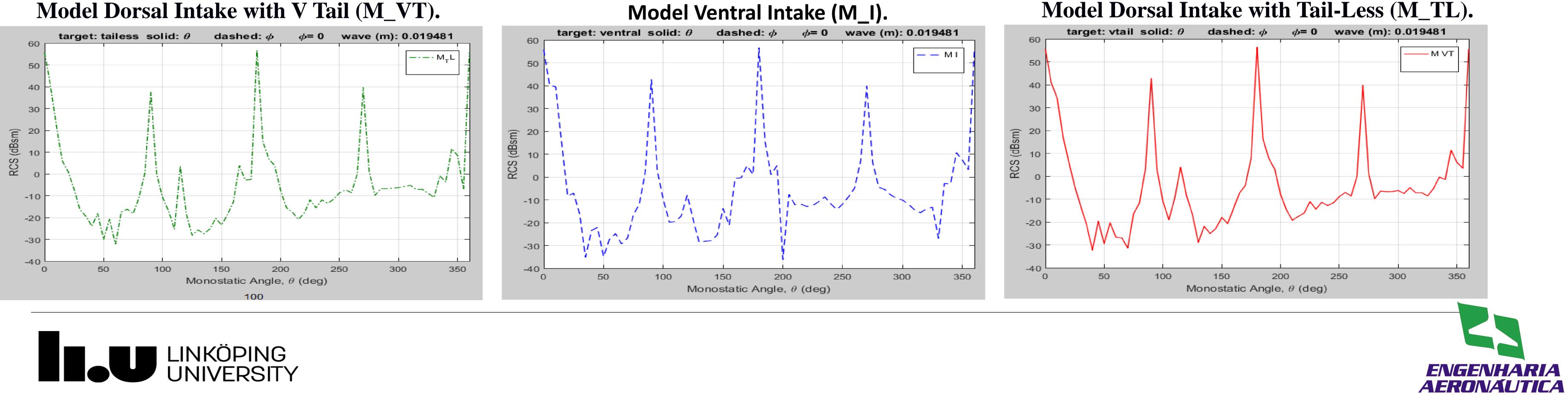
ai ta



	3	,6	50	эн	z
÷,	1	0,	55	GI	łz
•	1	4,	20	GI	Ηz
• •	1	5,	40	GI	Ηz

### Results - RCS

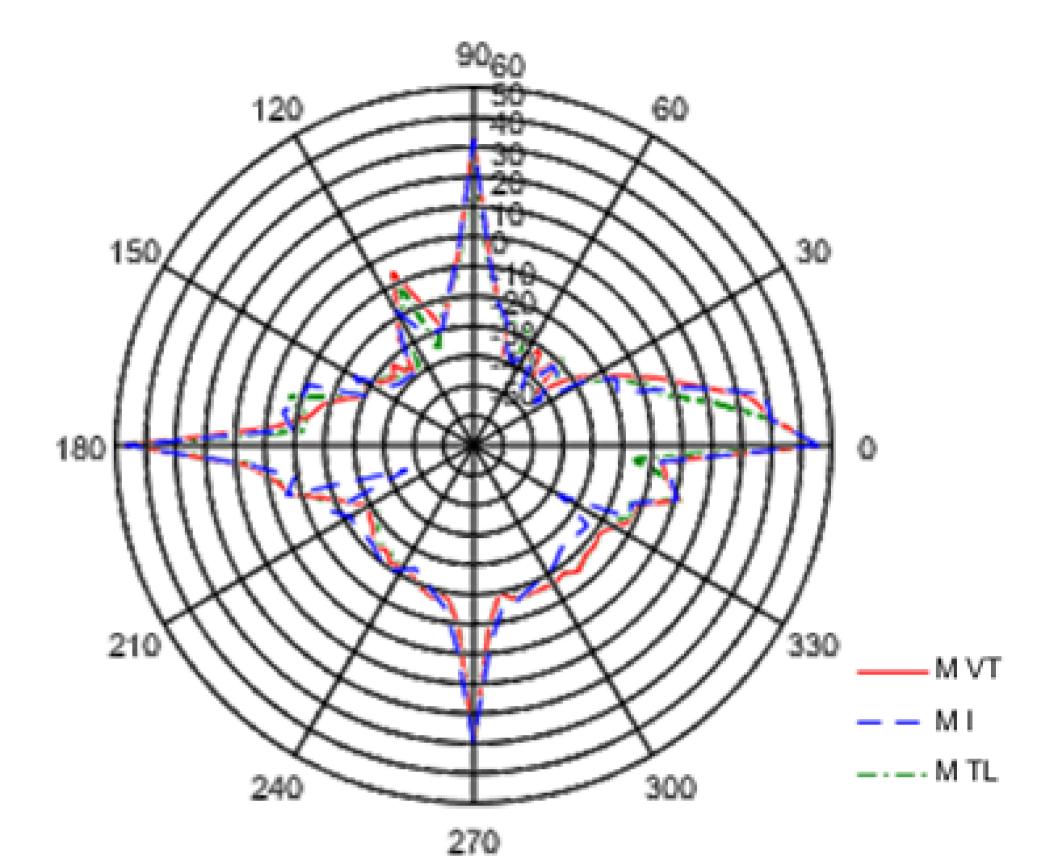
- (blue line) is the one with low signature.
- stabilizer has better signature.



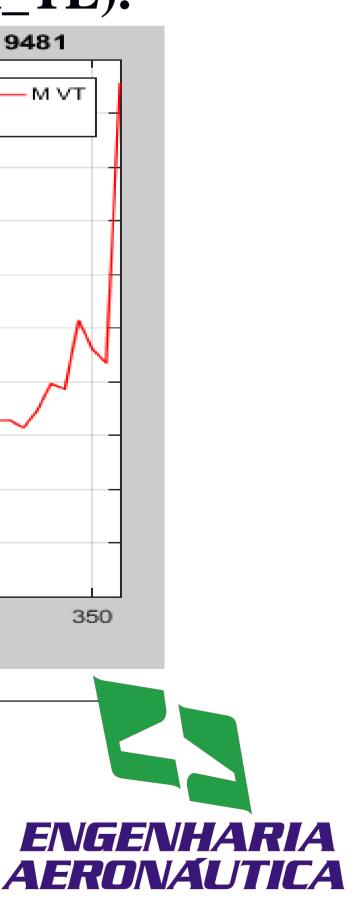


• Compare the three targets : (1) The aircraft's design have similar radar signature; (2) we can infer that the M\_I model

• Comparing the results of the Table (points every  $5^{\circ}$ ) with measured areas, the ventral intake with vertical (M\_I)



**Radar signature for the M\_VT, M\_I and** M\_TL aircrafts designs



## Conclusions

- obvious.



• 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 stealthaerodynamics 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



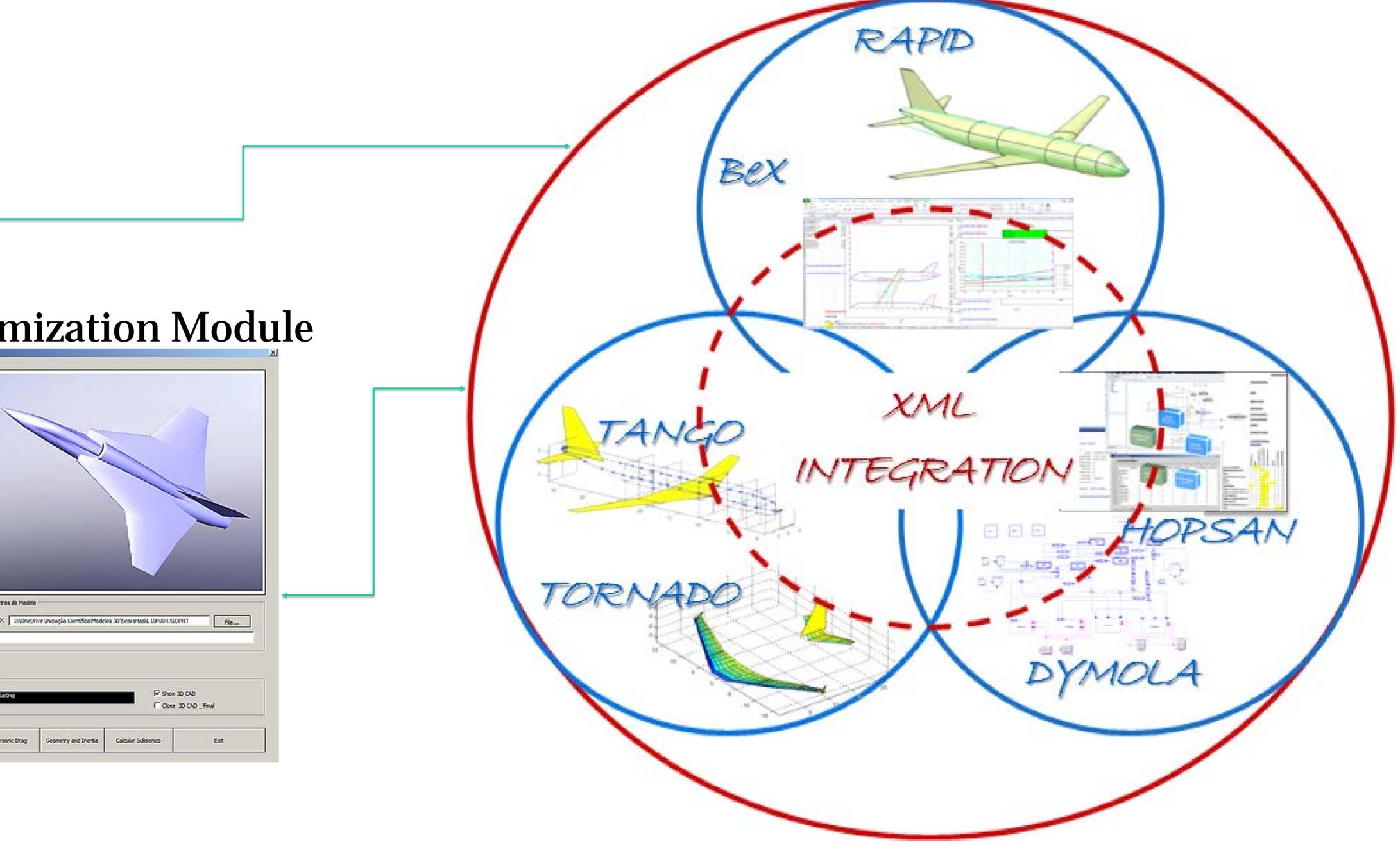
## Future Work- Collaboration with other tools

### POFACETS

### SOM – Sonic Optimization Module

Local Air Dens	ity:	1,2	25 ka	ha .			
Local Sound S	peed	34		\$			
Cones Quantit	Y	20	-				
Cone Radius		10	-				
Select Interest :	Speeds Ra	nge					
V_Initial		340	<u>ш</u>		ы		
V_Final		340	ш.		×		
Deta V ( incr	ement)	63	19				
Numero de N	ACH						
	anic)			2	эI		
MACH (Subs)	CONTRACTOR OF THE OWNER OWNER OWNER OWNER OWNER	1.11.2		1000			
MACH (Subs		0,2			-		-
MACH (Subs orface Roughnes omprimento da	ss and Geo	10	rameter				
rface Roughnes omprimento da	ss and Geo	metric Pa	rameter	4,90			
irface Roughne: omprimento da oughness K	ss and Geo Aeronave Superfice	metric Pa	rameter:	4,90			
rface Roughnes omprimento da oughness K rameters Geom	ss and Geo Aeronave Superfice	metric Pa	rameter:	4,90			
urface Roughnes omprimento da oughness K irameters Geom IT Wing	as and Geo Aeronave Superfice webric Wing	metric Pa and Emp	rometern 	s 4.00 ] [ ]			
urface Roughnes comprimento da oughness K irameters Georr IT Wing Area 2.00	ss and Geo Aeronave Superfice Setric Wing	metric Pa and Emp st	rometern ennage m2	8 4.90 ] [ ] [ ] W Area	] =	Sec.	
irface Roughnes omprimento da oughness K irameters Georr IT Wrg Area 2,00 Cma 1,10	ss and Geo Aeronave Superfice wetric Wing IT ( m2 Area	metric Pa and Emp st	rometern ennage m2	8 4.90 ] [ ] [ ] W Area	0.30	=2	
rface Roughnes omprimento da oughness K rameters Georr F Wing Area 2,00 Cma 1,10	ss and Geo Aeronave Superfice wetric Wing ΓΓι m2 Área m Crea % Λ	end Emp and Emp and Emp and Emp	rometer: ennage m2 m	5 4.90 ] [ [ ] m Årea Cma	0.30	=2	

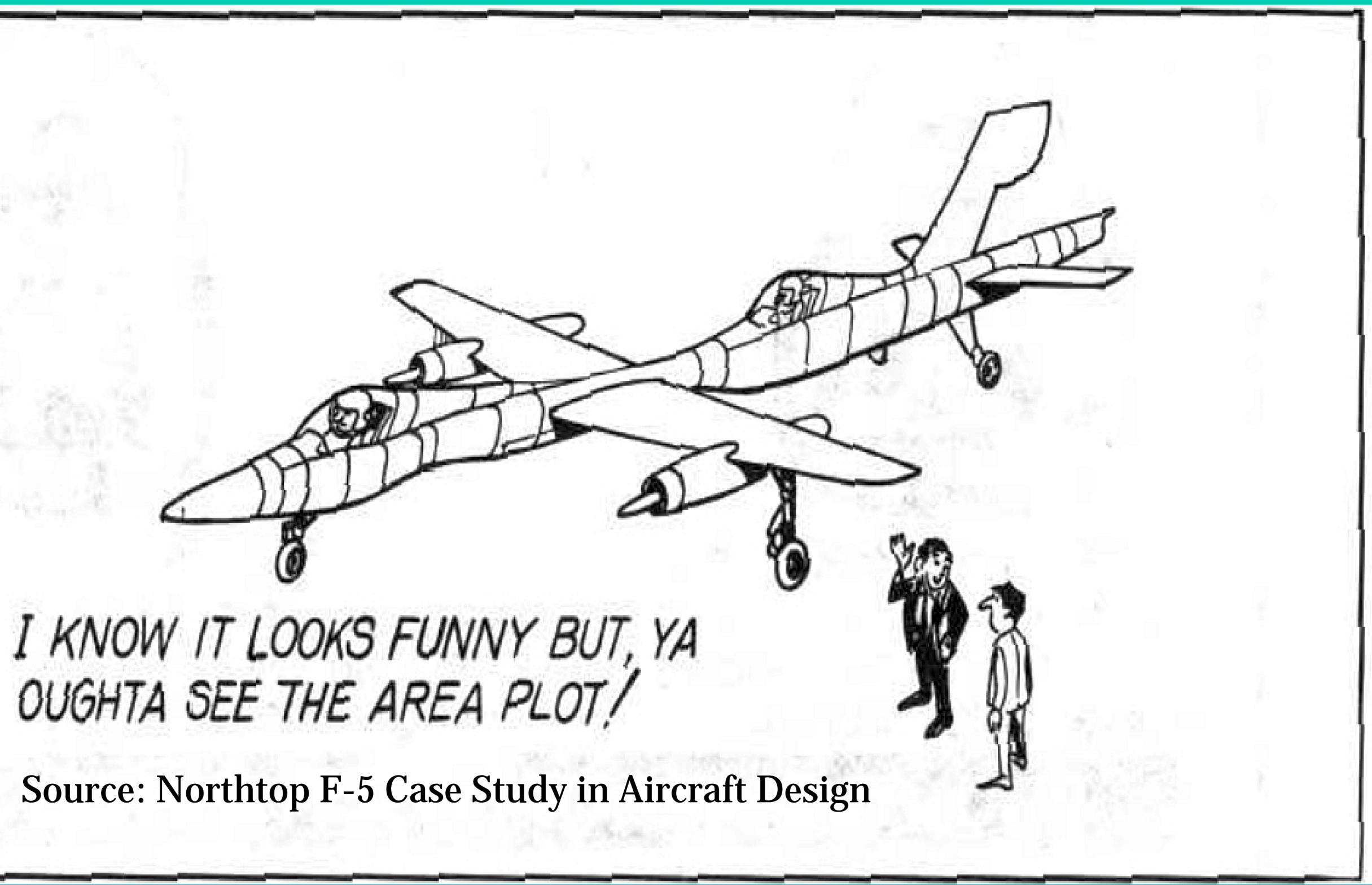






### 16

### LINKÖPING UNIVERSITY



### raghu.chaitanya@liu.se