S.P.EYE

Special
Purpose
EYE

Critical Design Review

The Team

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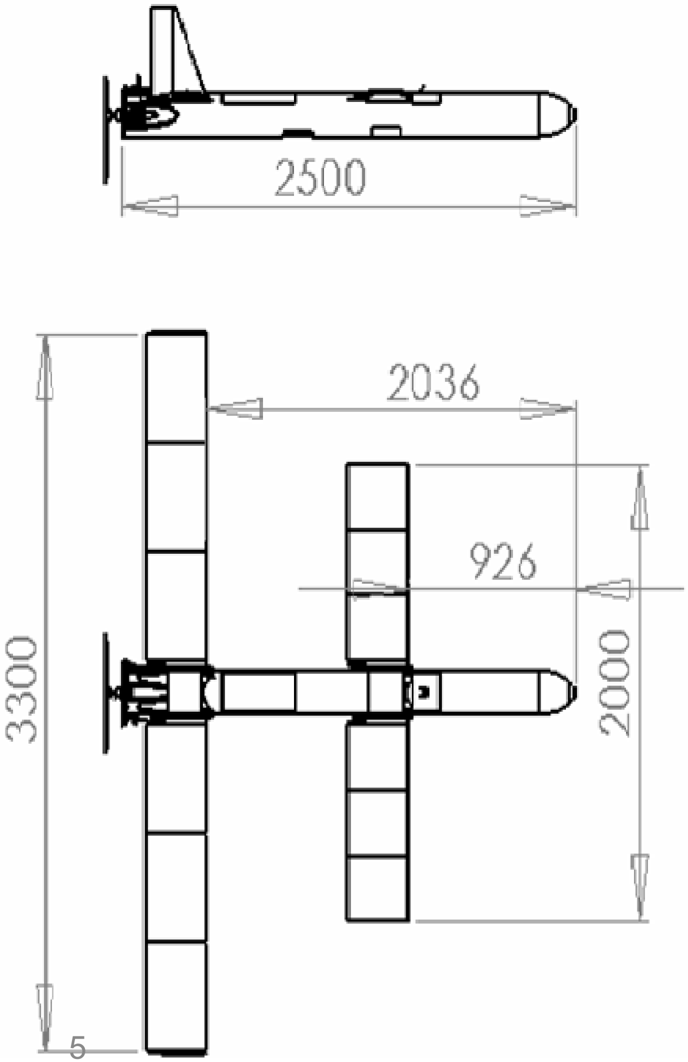
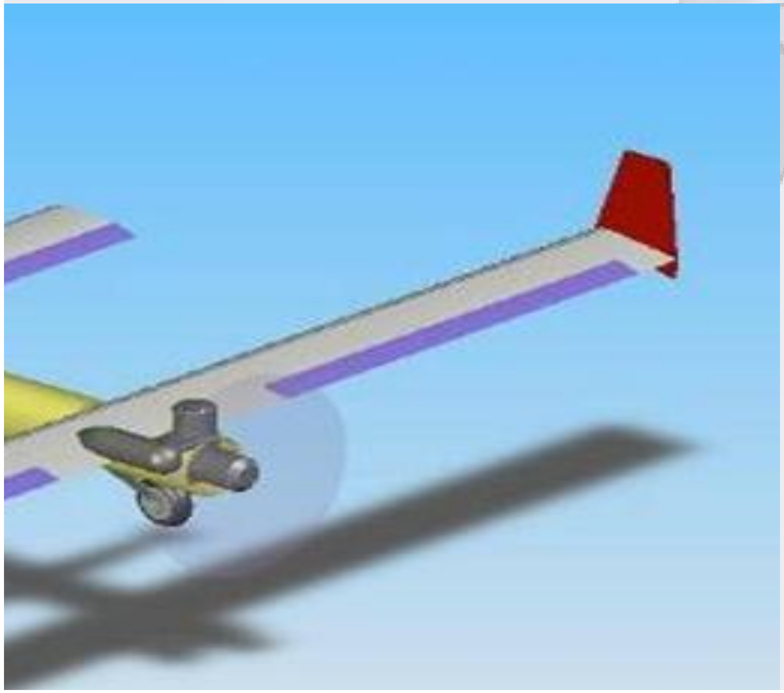
Contents

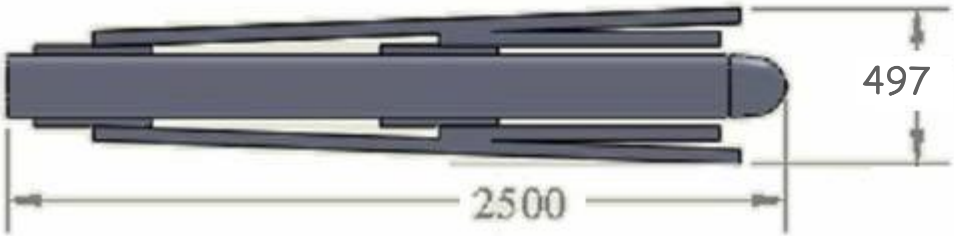
Introduction

- S.P. EYE: air born, air released UAV
- General concept: UAV performing the observation missions
- The main purpose: Enlarge the existing aircraft surveillance range
- The principal requirements:
  - two UAV-s in 'gondola'
  - min. extra range –100 nm per each UAV
  - real time air-borne mission control

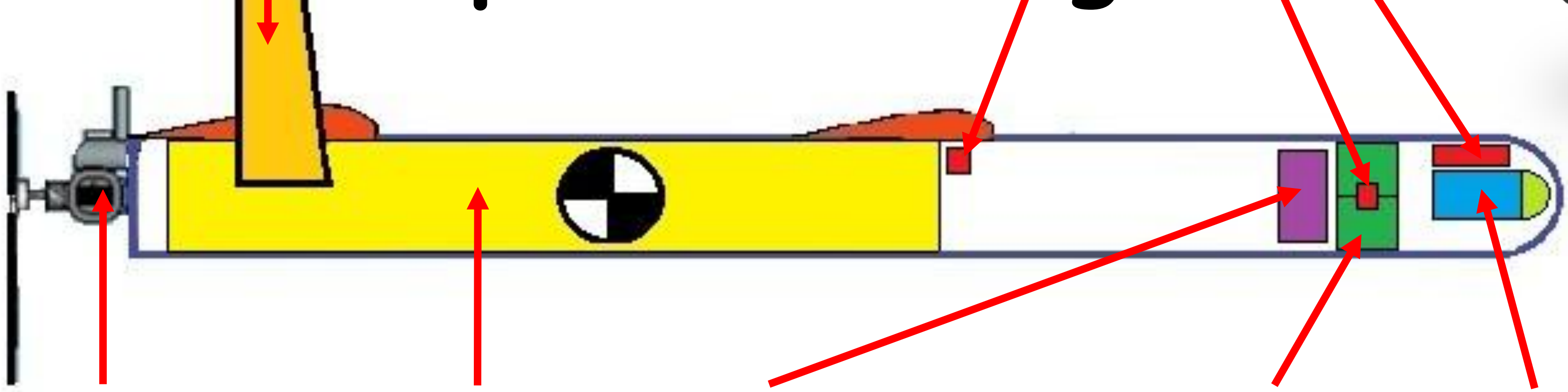
MONGuard:







UAV Component Configuration:



- The Camera was placed in the front of the vehicle to ensure

prevent

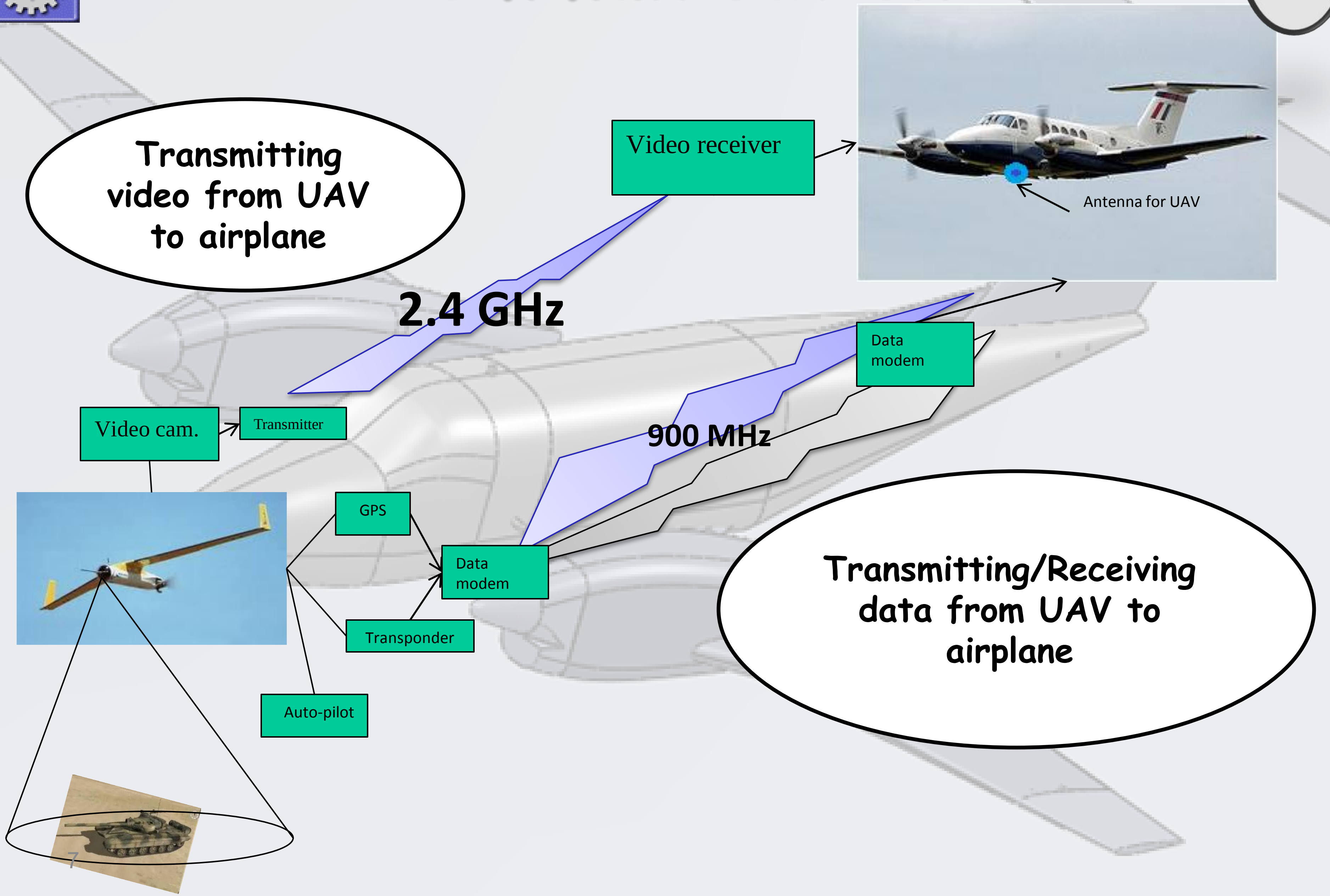
alance

The new configuration has the same center of gravity

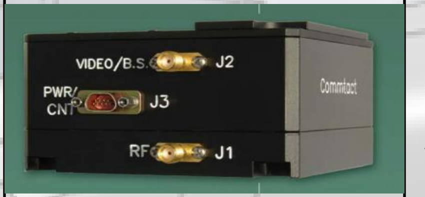
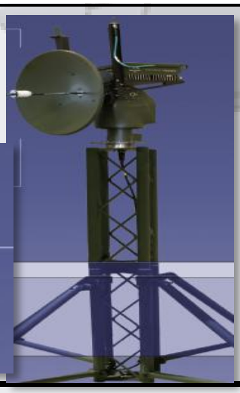
Hence we don't need to make a new control system.

- Self-destruct Mechanisms: 1 placed near the camera, 2 placed on the transmitter and receiver and 3 was placed for balance and will detonate towards the fuel tank.
- Fuel Tank changed due to the rest of the configuration.

Communication



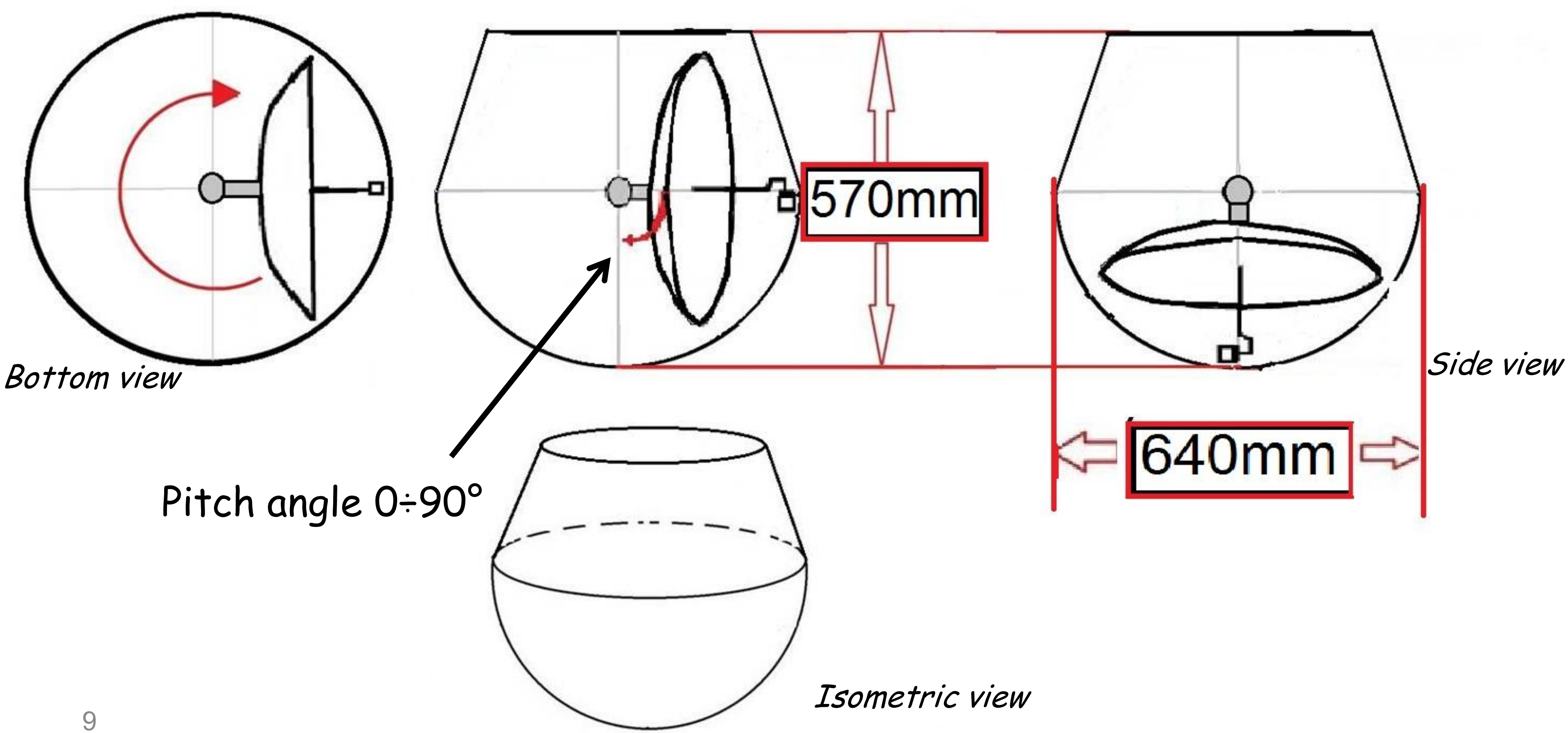
Communication components:

Component	picture	details
UAV transmitter: COMMTAC CTX-Series		**Analog video (PAL, NTSC), audio, data** **Output power: 200mW-15W** **Bandwidth: 16Mhz, Frequency band: L, S, C, X, Ku** **Range: ~150Km. Weight: 420gr**
UAV receiver: **COMMTAC CRX-Series**		**Analog video (PAL, NTSC), audio, data** **Bandwidth: 16Mhz** **Frequency band: L,S,C** **Weight: 370gr**
Omni-directional antenna: **OMA-P2S102**		**Frequency: 902-928Mhz, 2200-2500Mhz** **Height: 250 mm** **Weight: 0.14 kg**
Airplane Transmitter/Receiver	 	**System capabilities** • Available in different frequency bands • Long range — up to 250 Km (LOS) • Extended range beyond LOS via relay • Downlink data consist of compressed video, telemetry and other data protocols (up to 20M bite/sec). • Full duplex command uplink and video & telemetry downlink • Video format – PAL/NTSC

Required antenna dimensions

The requirement of 360° azimuth forms axi symmetrical body

Height = 570 mm
Diameter = 640 mm



Payload

The EO payload best suited to SP-EYE purpose is:
MicroPop

Micro POP IAI	Day Night	Wide angle 2-4X electronic	Better than 150 μ rad	Azimuth ±170 Elevation: -90 +20	15-17 W	1.2kg	D104mm H180mm

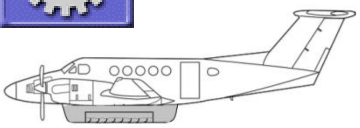
- **Pros:**

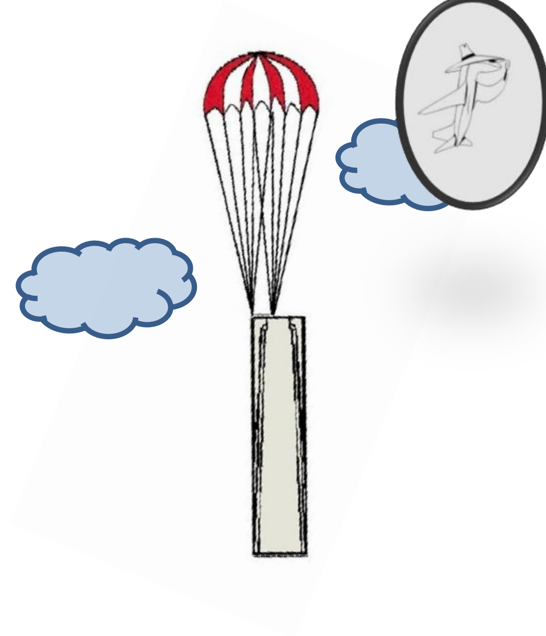
- excellent onboard stabilization
-1 sensor, refittable for day/night use
-small dimensions
-low price (estimation)
-made in Israel

- **Cons:**

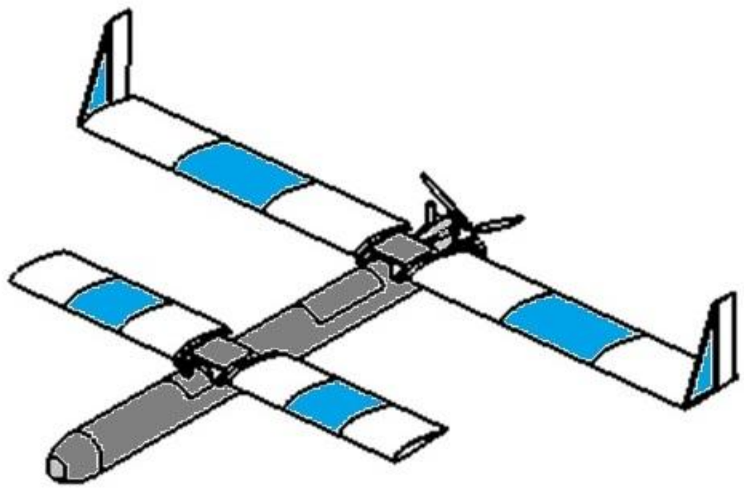
-heaviest among the light-weight EO turrets
-mediocre optics

Release mechanism, concept



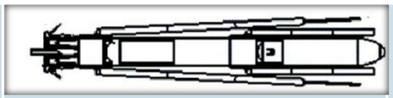
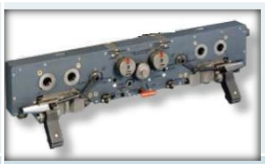
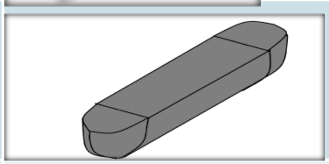


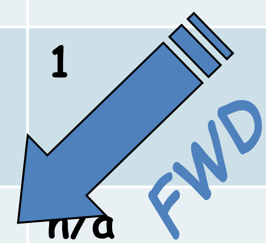
Wings unfolding, beginning of the mission



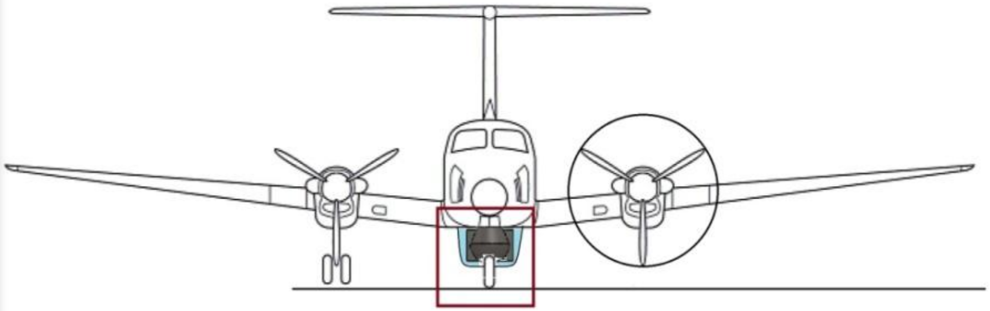
'Gondola': chosen sizing & calculating

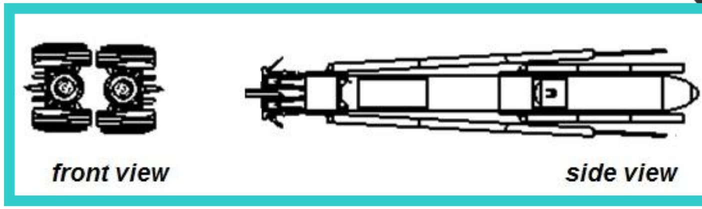
Chosen 'gondola' layout

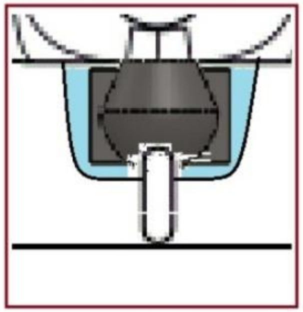
Name	Picture	Weight ,kg	Dimensions L, w, h mmxmmxmm	Quantity
UAV (folded)		50	2500x377x497	2
Antenna		30	640x640x570	2
Protective Shell		20	2500x395x560	2
BRU-46		20	711x51x152	2
"Gondola" shell		65	3900x820x600	1
Doors opening mechanism and wiring	 	~20	n/a	n/a
Total		~ 390		

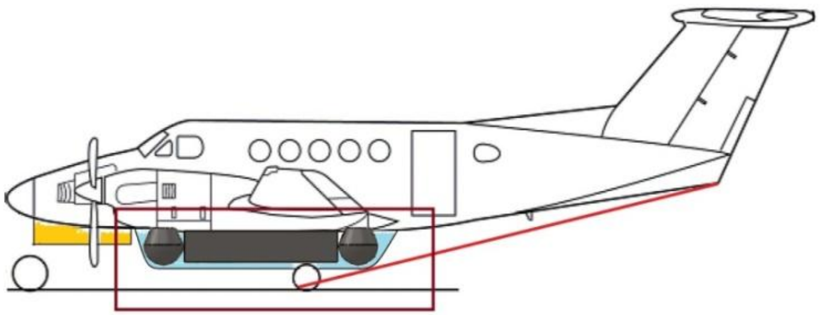


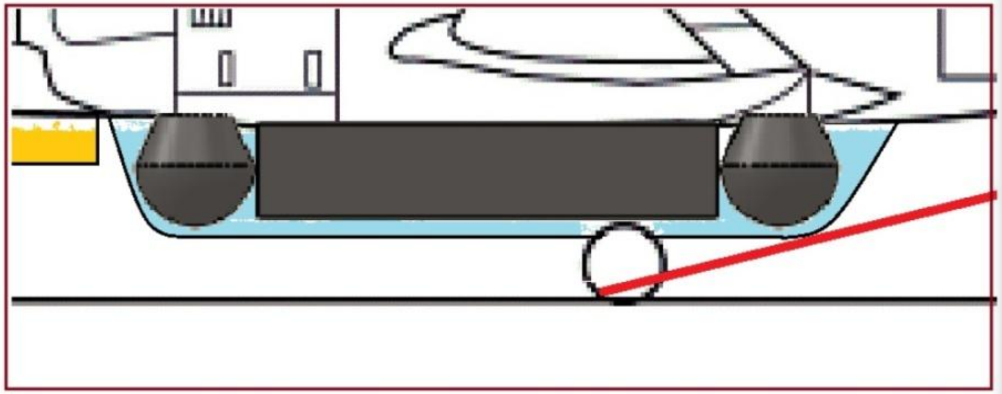
Chosen geometric configuration









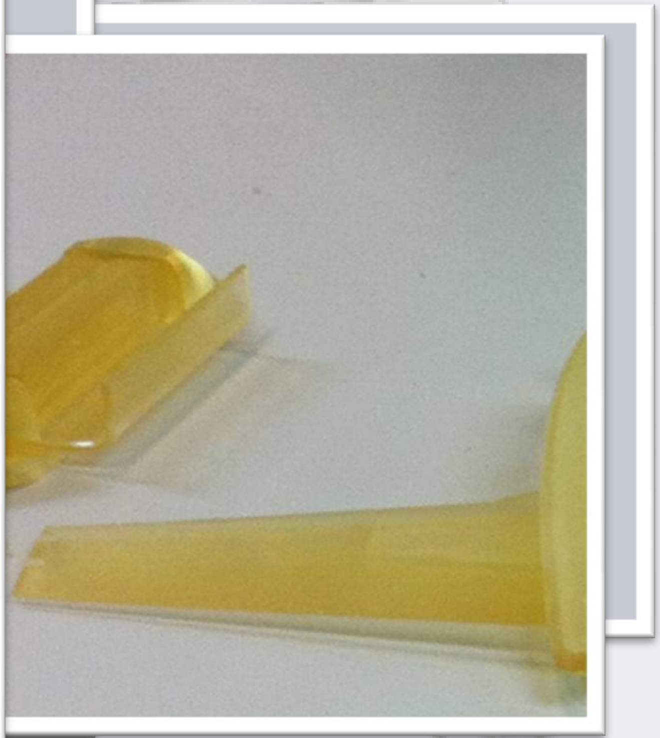


This configuration is optimal.

Foregoing calculations will be based on it.

Wind tunnel model

- CAD model
- Wind tunnel model design
- Model printing by rapid prototype (RP)
- Assembly

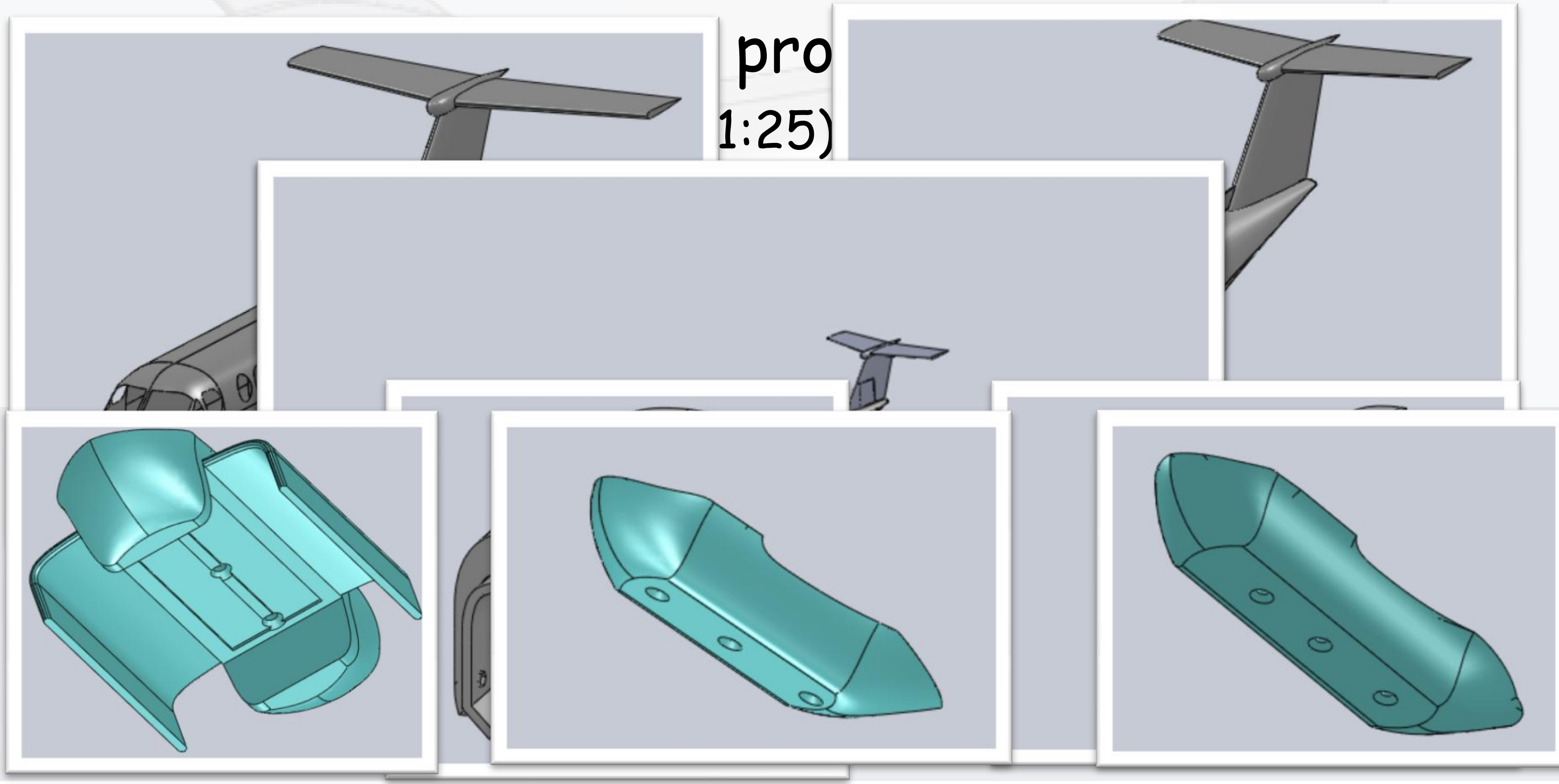


CAD model

- General surface geometry (Parasolid) was received. Surfaces were translated to solid bodies(Sisyphean toil)

pro

1:25)



RP printing

Technion RP printer was used

"Rapid Prototyping" is a fast method for producing high-resolution 3D printing using 3D computer graphics.

The printer reads STL files and creates the part, layer by layer using polymeric material.

Advantages

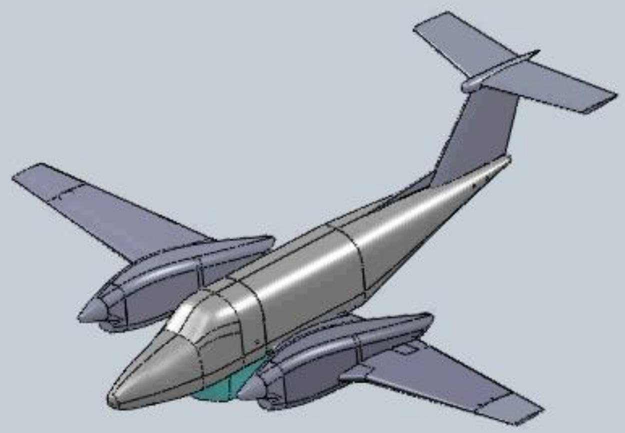
- Easy to manufacture.
- Faster & lower cost compared with Aluminum CNC

Disadvantages

- Material deforms over time
- Weak material
- Part size limit
- Large tolerances

Assembly

Engine



Assembly

Multiple problems occurred during the assembly process.
Main reasons:

- RP printer inaccuracy
- tolerances

Abrasive paper and time solved them

Parts & Weights

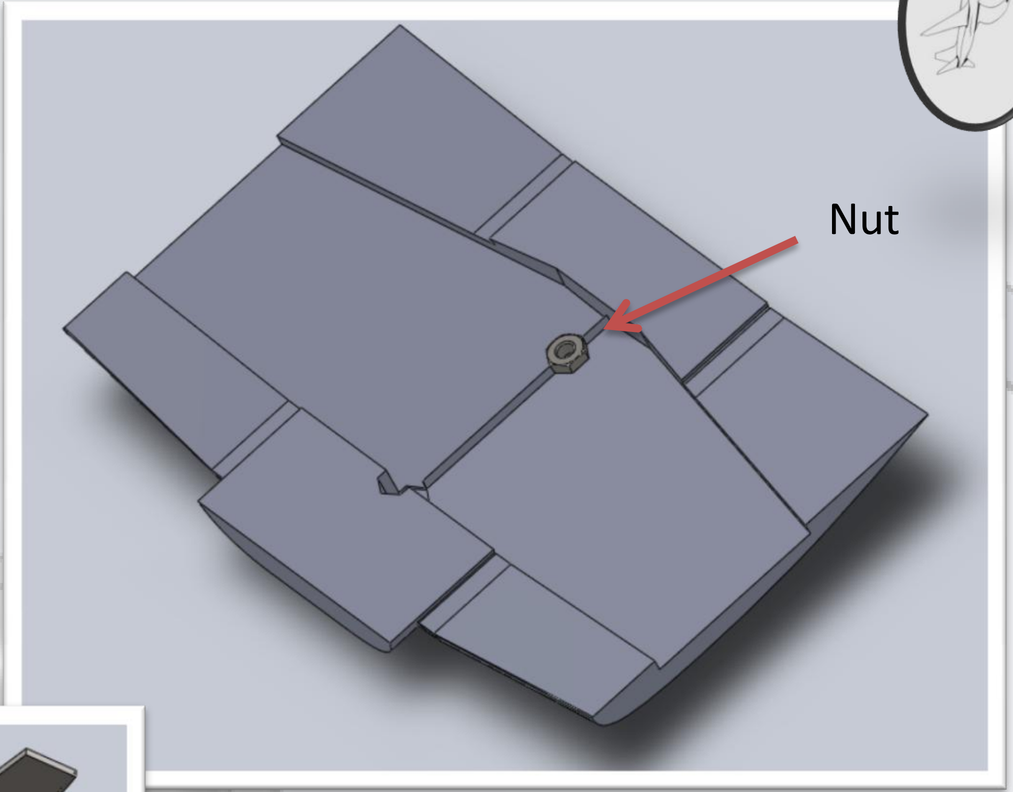
#	Model part	Weight [gram]
1	Nose	263.8
2	Central upper	418.8
3	Central lower	77.2
4	Back	391.1
5	Right wing	222.3
6	Left wing	224.8
7	Right wing tip	7.7
8	Left wing tip	7.5
9	Right engine top	22.2
10	Left engine top	22.4

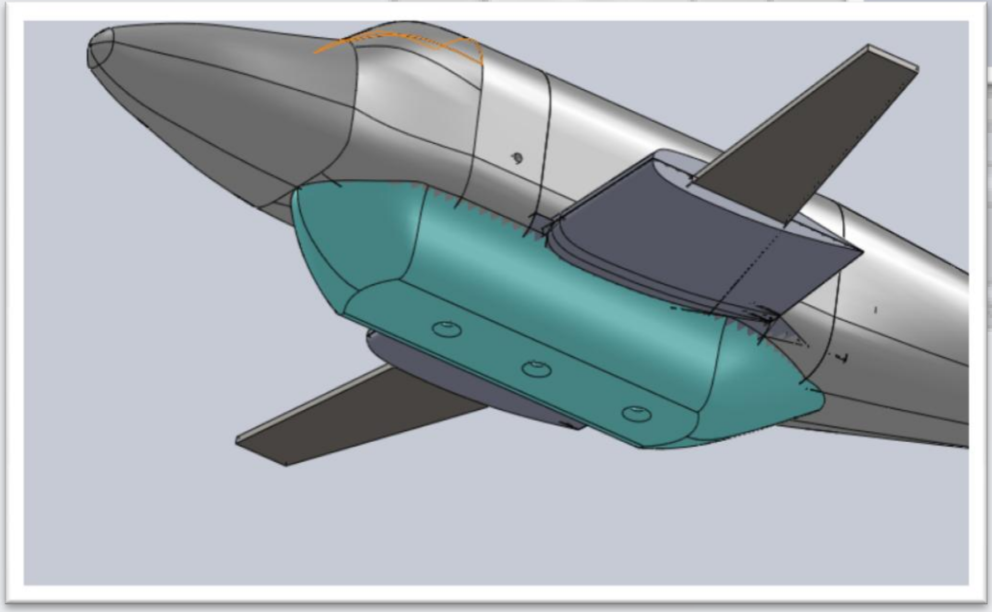
#	Model part	Weight[gram]
11	T-tail	89.3
12	Tail fin	0.8
13	Long open gondola	145.8
14	Long close gondola	241.5
15	Short close gondola	187.8
16	UAV X 2	80.2
17	Right wing reinforcement	317.2
18	Left wing reinforcement	
19	Bolt X 4 + balance sleeve	
20	Tail reinforcement	2.5

Configuration	Total weight, [gram]
Long close gondola	1865.5
Short close gondola	1825.3
Long open gondola equipped with UAV X 2	1915.6

Assembly

Gondolas and other parts were connected with bolts and nuts. Nuts were glued to the plastic.

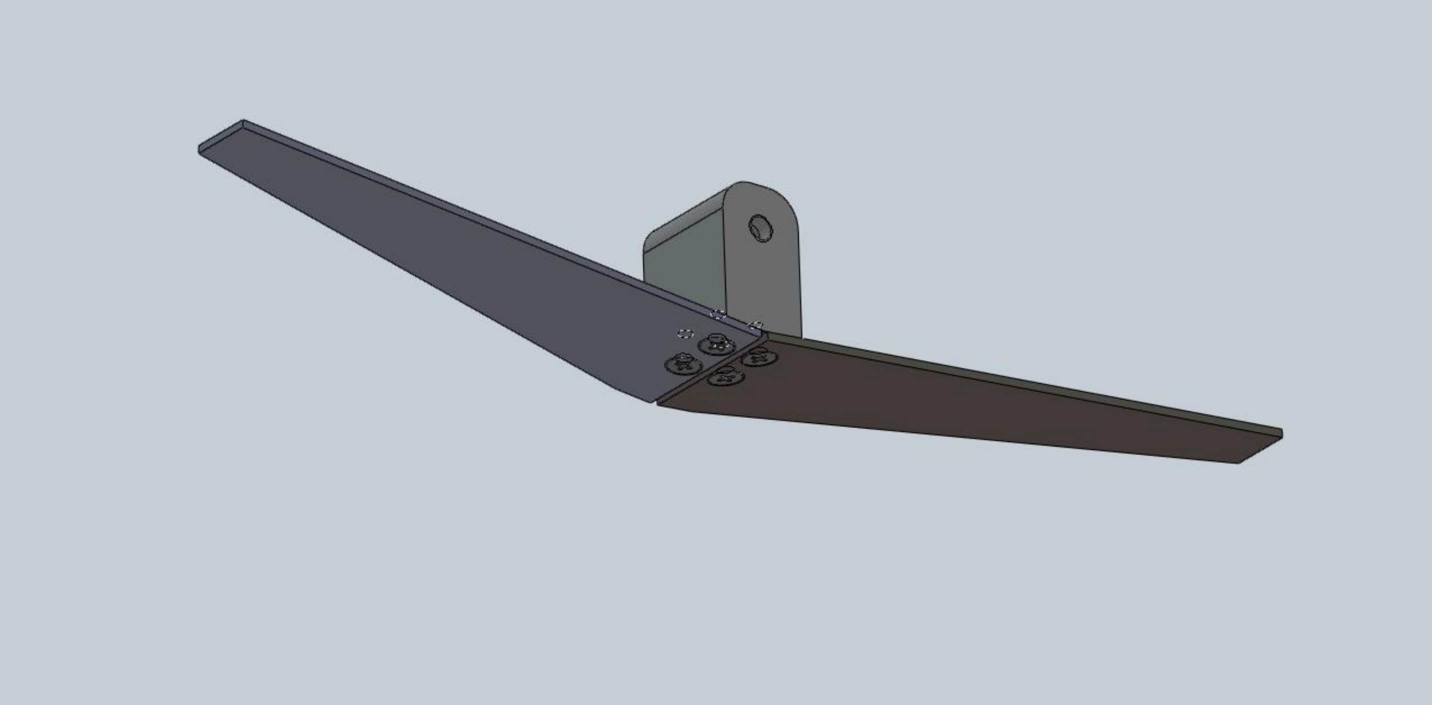




Balance connector assembly

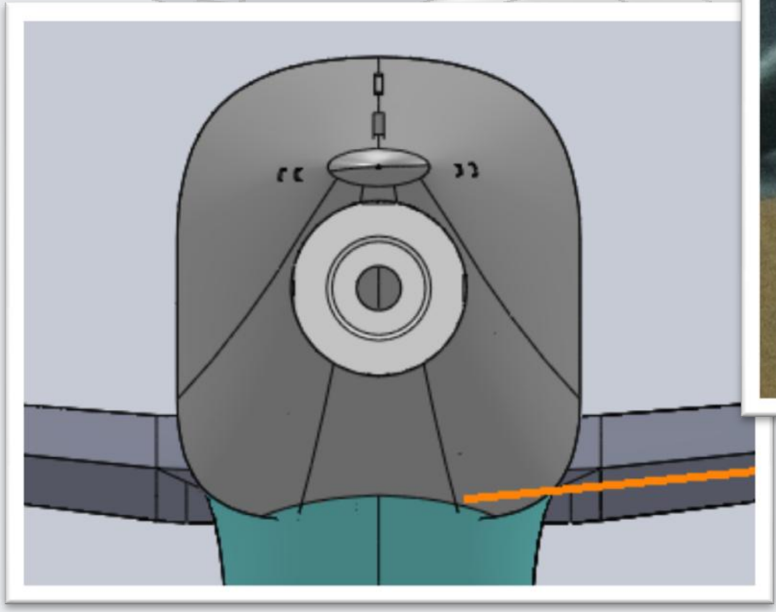
- It was decided to connect the balance connector and wing reinforcement.

- Usually axisymmetric balance connector is used. It was decided to design original connector to accomplish this task.



Balance connector assembly

The back of the model is holed to install a balance.
The hole diameter was chosen to enable possible balance displacements.



Wind tunnel test and result analysis

Purpose

Gondola influences on the flow and aerodynamic constants:

- Drag
- Roll
- Yaw
- Pitch
- Side force
- Lift

Test procedure:

All the tests were held with the original plane, long and short gondola

- Alpha-sweep
- Beta-sweep
- Beta-sweep with roll angle
- Smoke and tuft tests

Some predictions before the flight

Coefficients:

Drag,	$C_D : +5\%$
Lifting slope,	$C_{L\alpha} : No\,change$
Pitch moment,	$C_{M_0} : -1.3 \cdot * 10^{-3} - absolute\,value$
Pitching slope,	$C_{M\alpha} : No\,change$
Windcock,	$C_{N\beta} : 6\%$
Roll,	$C_{L\beta} : -9\%$
Side force,	$C_{Y\beta} : -3\%$

Based on plane's and gondola's geometric properties only.

Test governing constants:

Original plane:

V=150 m/s (300 knots)

Mac=1.7 m

Re=16 million

Model:

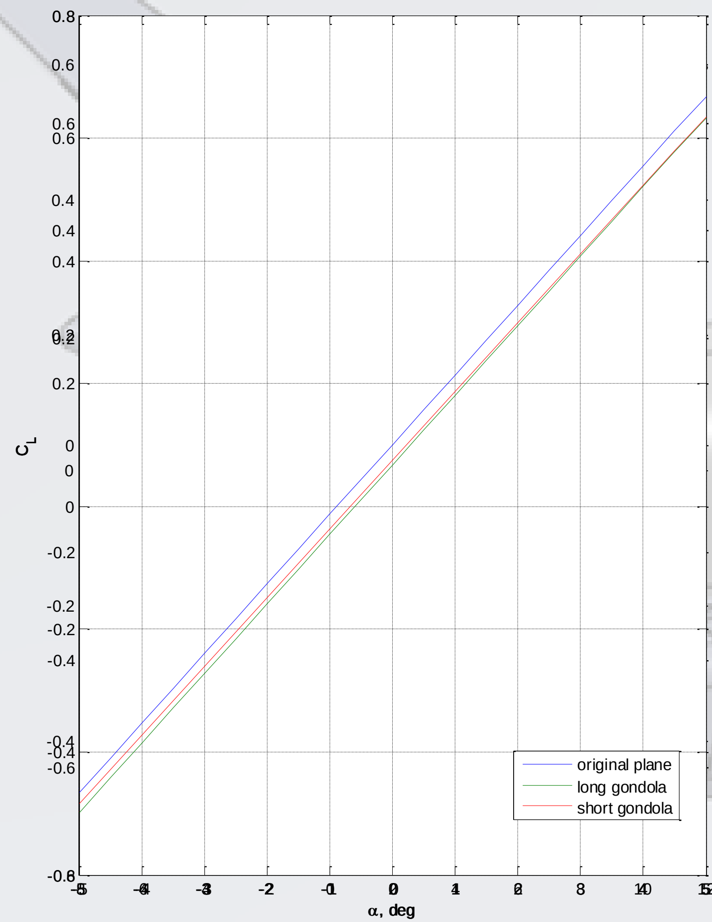
V=30 m/s (60 knots)

Mac=0.068 m

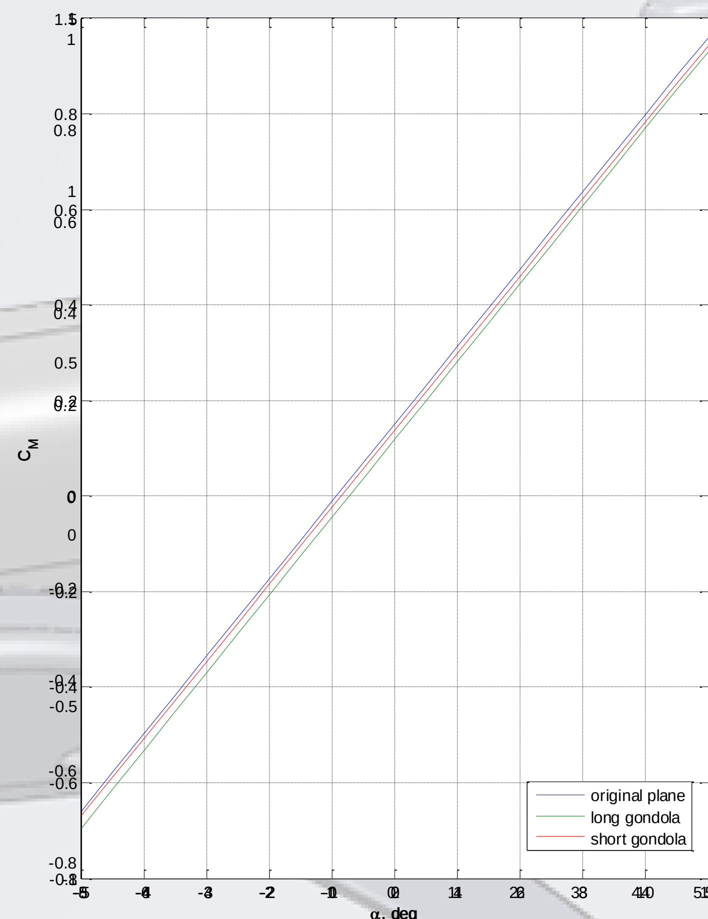
Re=130,000

Video

Tests results : Longitudinal



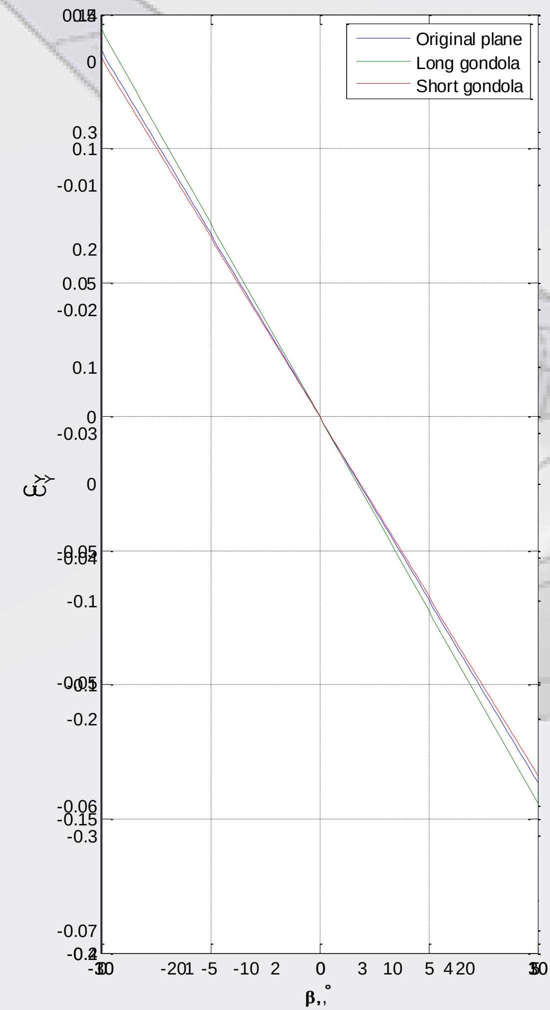
$$\Delta C_L = -0.0002\alpha - 0.033$$



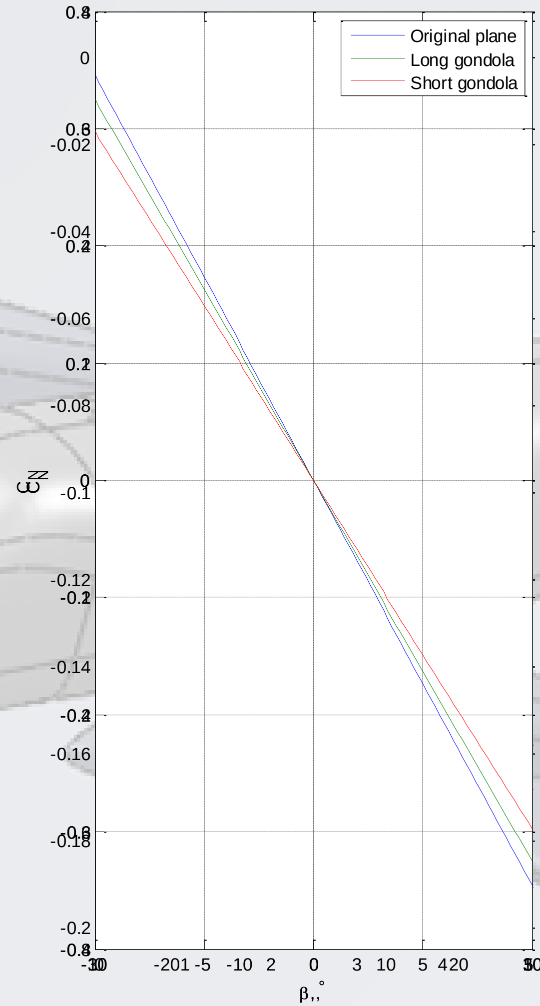
$$\Delta C_M = 0.0008\alpha - 0.0323$$

expected: $\Delta C_{Mo} = -0.0013$

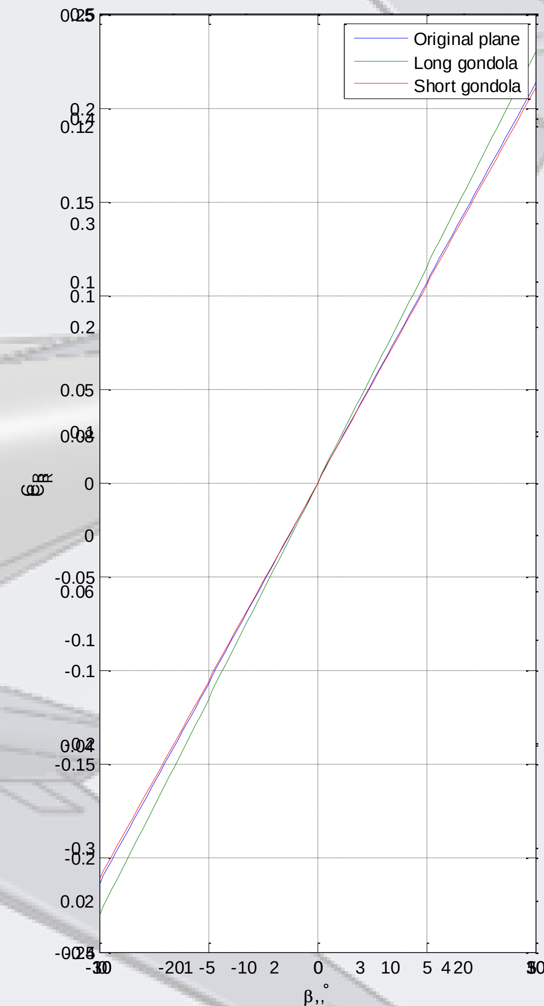
Test results: Lateral



$\Delta C_{Y\beta} = -7\cdot 10^{-4} \approx -3.5\%$



$\Delta C_{N\beta} = 0.0021 \approx 6\%$



$\Delta C_{R\beta} = 0.0019 \approx 8.8\%$

expected: $\Delta C_{Y\beta} = -3\%$

$\Delta C_{N\beta} = 6\%$

$\Delta C_{R\beta} = -9\%$

Tests result: Drag

$$\Delta C_{D,Long\,G} = 0.0104\ (28.5\%)$$

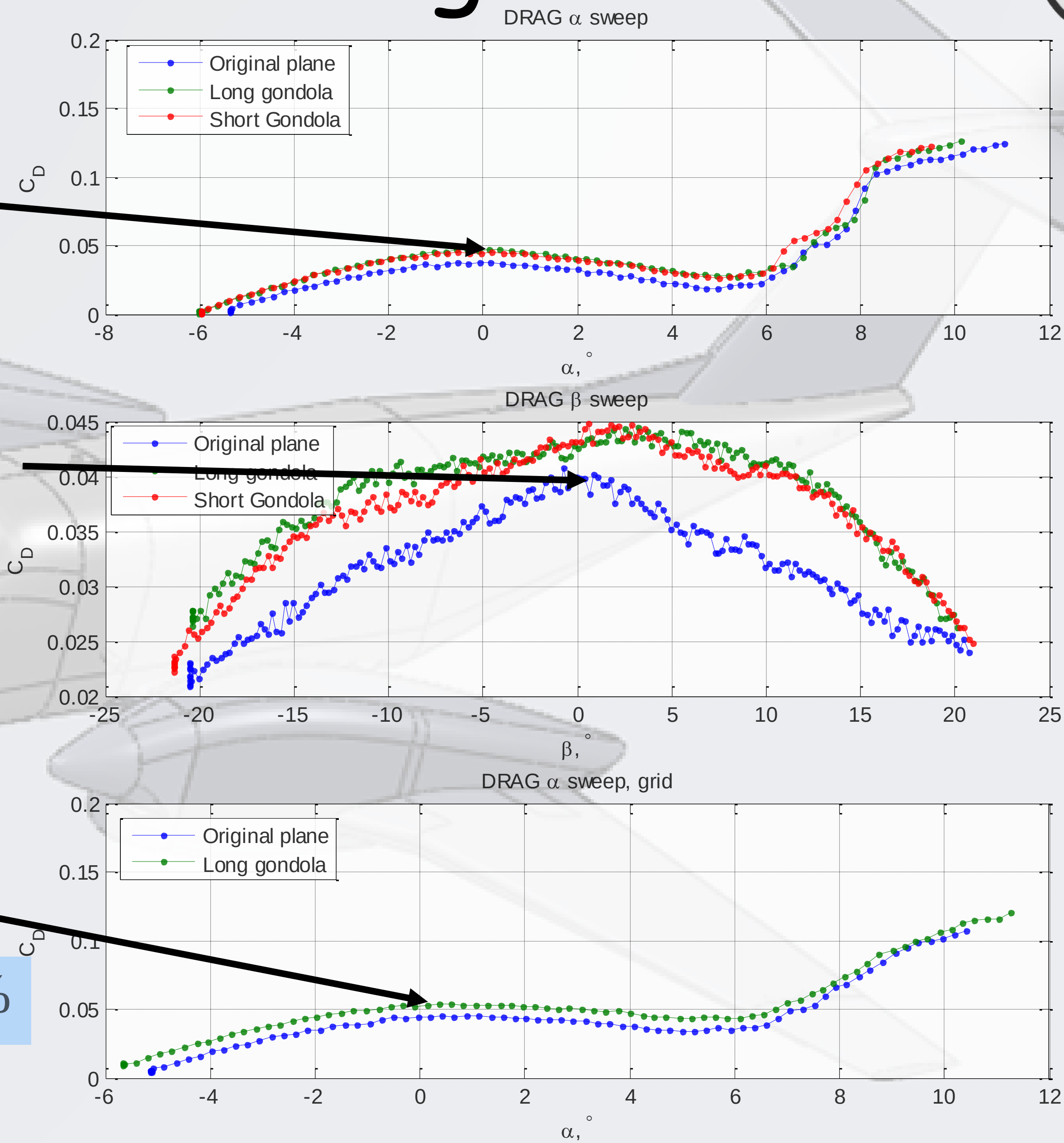
$$\Delta C_{D,Short\,G} = 0.0083\ (22.6\%)$$

$$\Delta C_{D,Long\,G} = 0.0032\ (8.0\%)$$

$$\Delta C_{D,Short\,G} = 0.0040\ (10.2\%)$$

$$\Delta C_{D,Long\,G} = 0.0086\ (19.5\%)$$

expected: $\Delta C_{D,Long\,G} = 5\%$

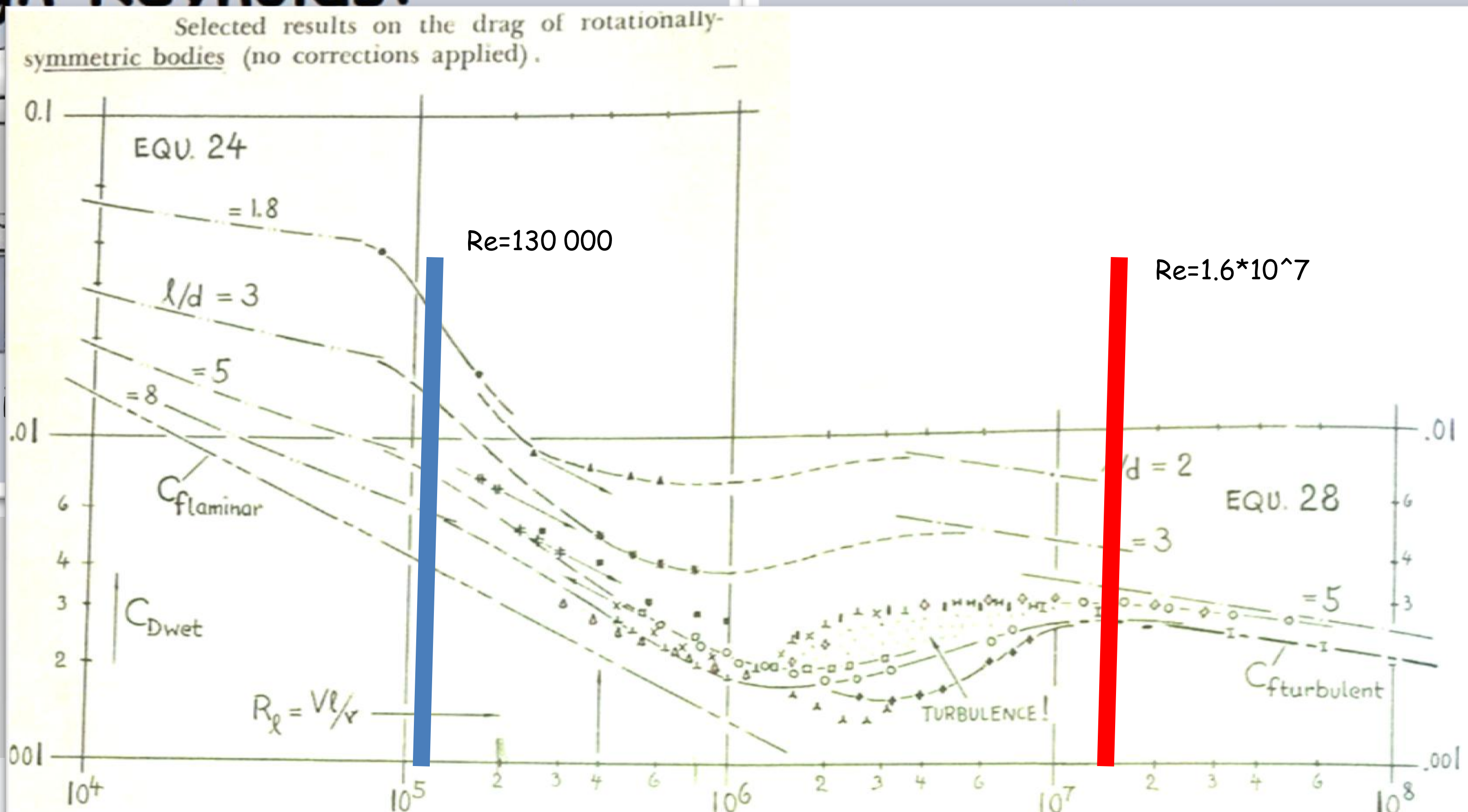


Reason for inappropriate results
Stream Separation

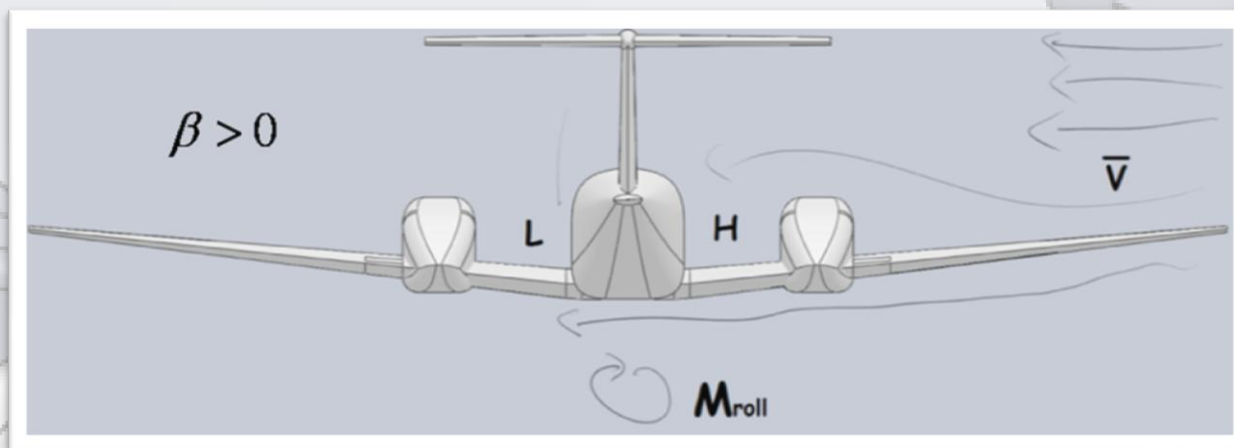
FWD

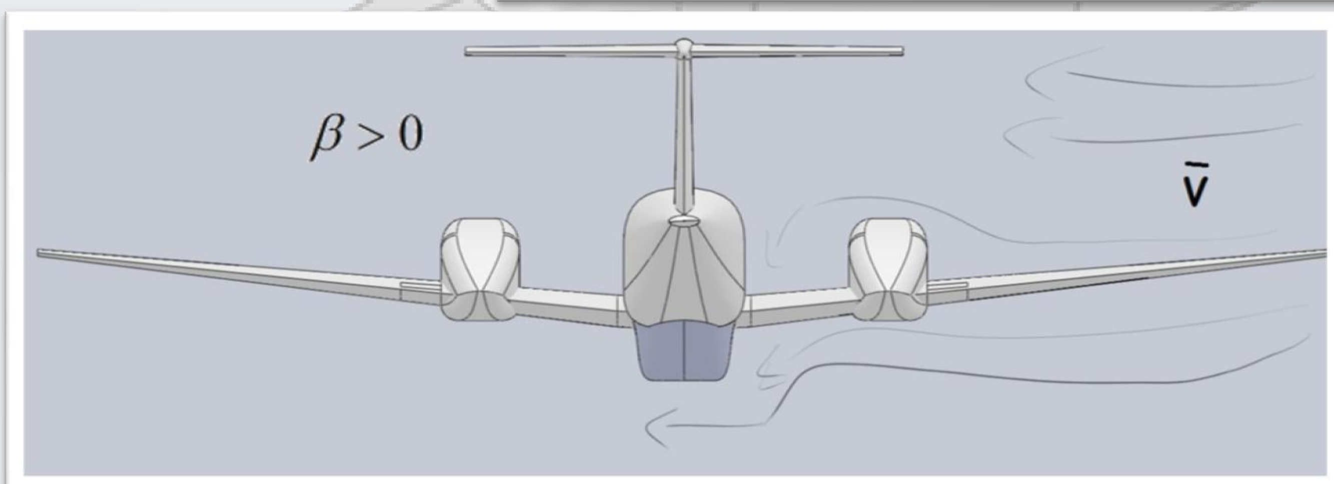
High Reynolds:

Critical Reynolds :



Reason for inappropriate results
“Gondola” position





Compensating windcock effect

- It is necessary to compensate the windcock effect produced by the gondola without harming the roll.

$$A_{fin} = f(C_{l_{fin}}, X_{fin}, AR_{fin}, \eta_{tail})$$

$$if: X_{fin} = X_{tail} \Rightarrow A_{fin} = 0.06...0.1 m^2$$

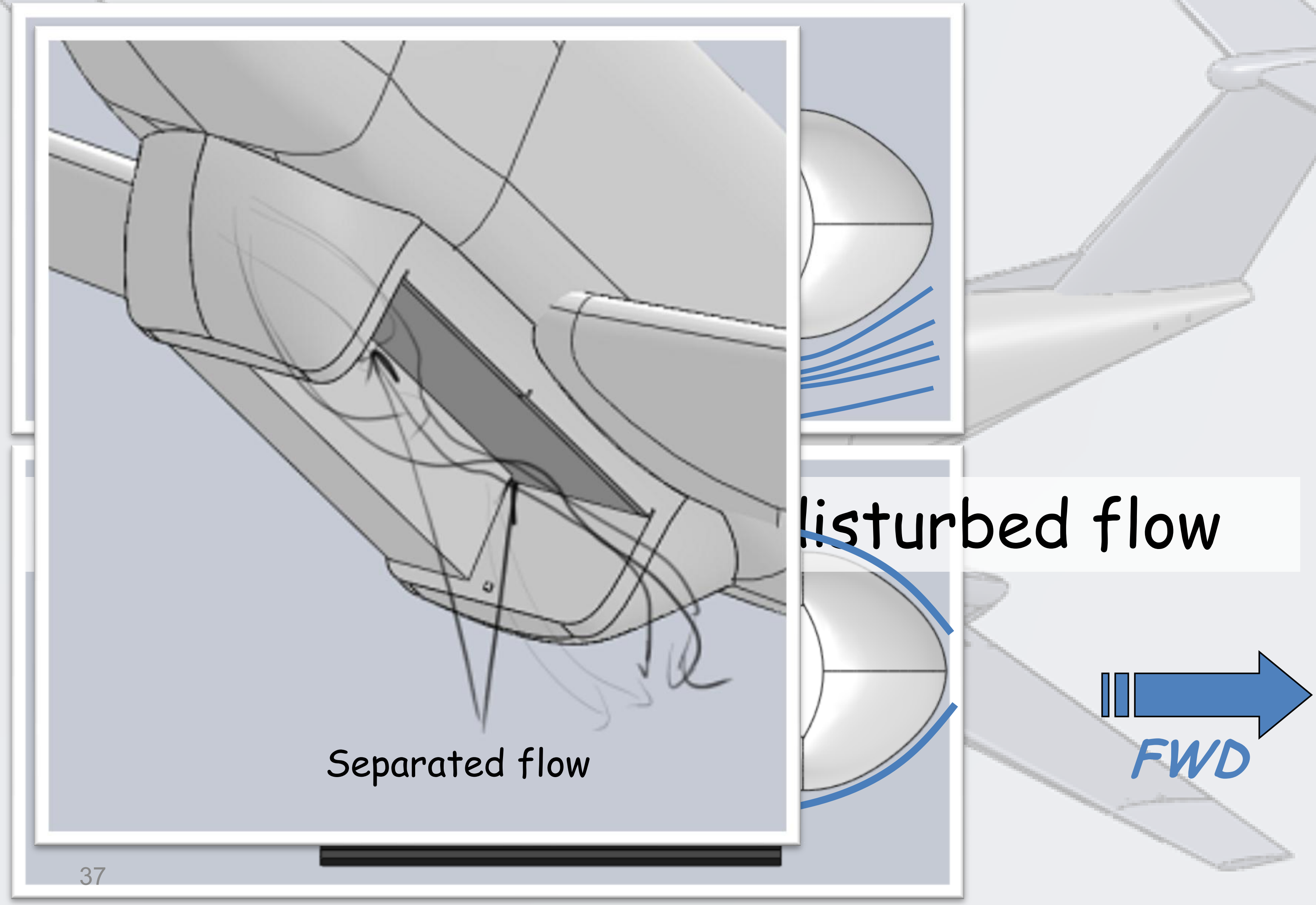
$$Z_{fin} - Z_{cg} \approx 0$$

$$X_{fin} \approx X_{tail}$$

$$A_{fin} \approx 0.5 m^2$$

Tuft/Smoke experiment

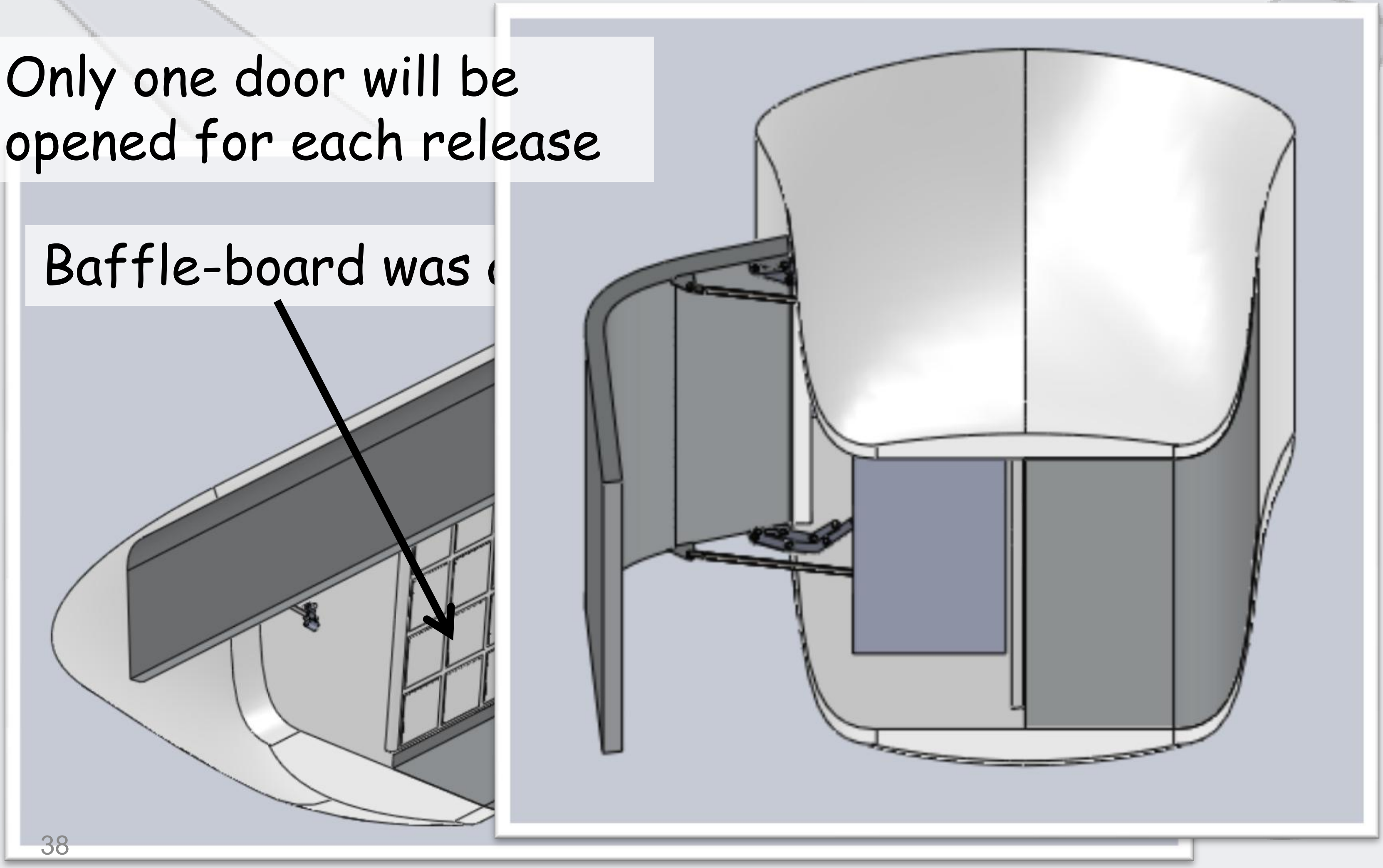
Flow inside the "Gondola"



Flow inside the "Gondola"

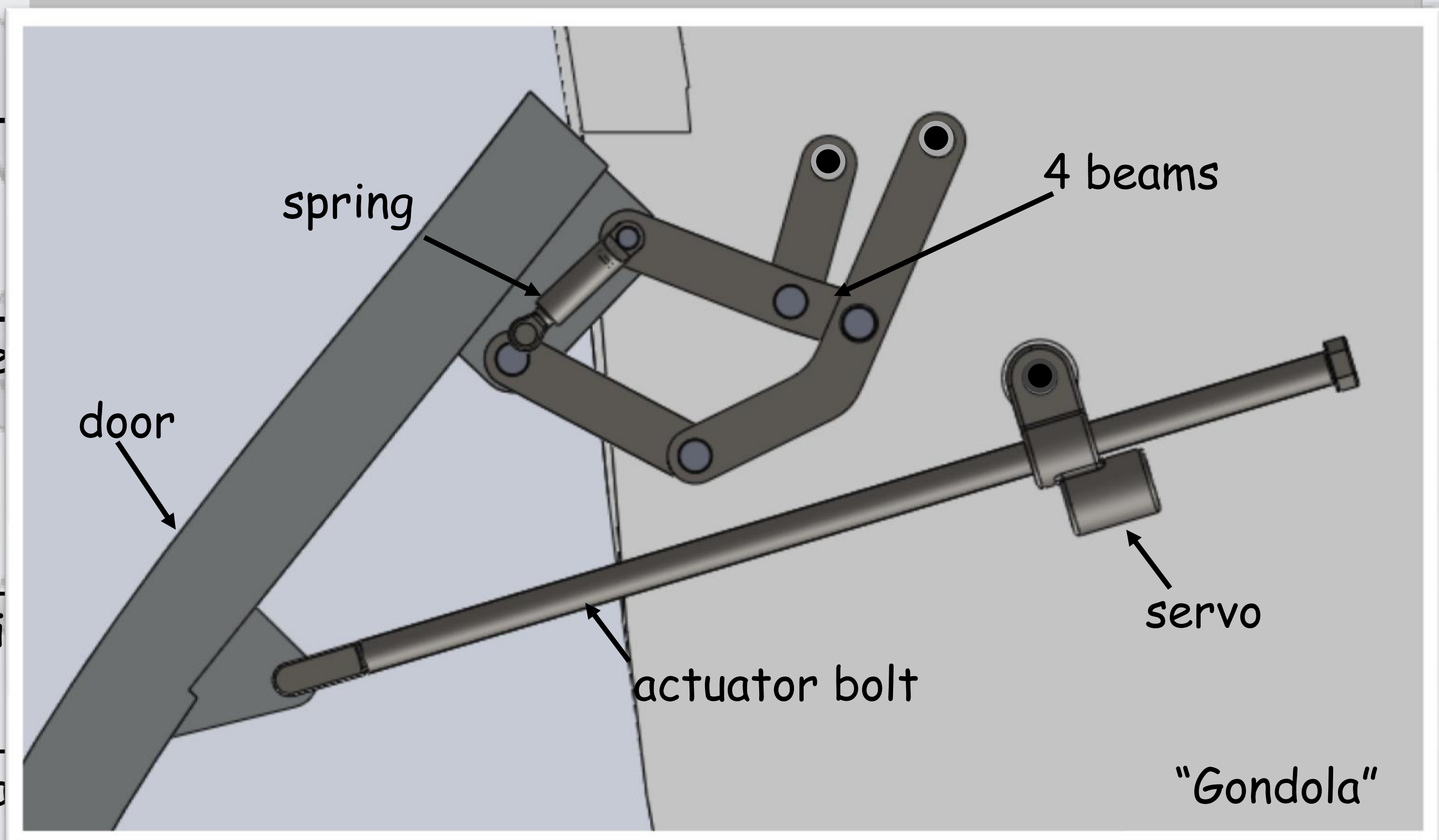
Problem solution

Only one door will be opened for each release



Door Opening Mechanism

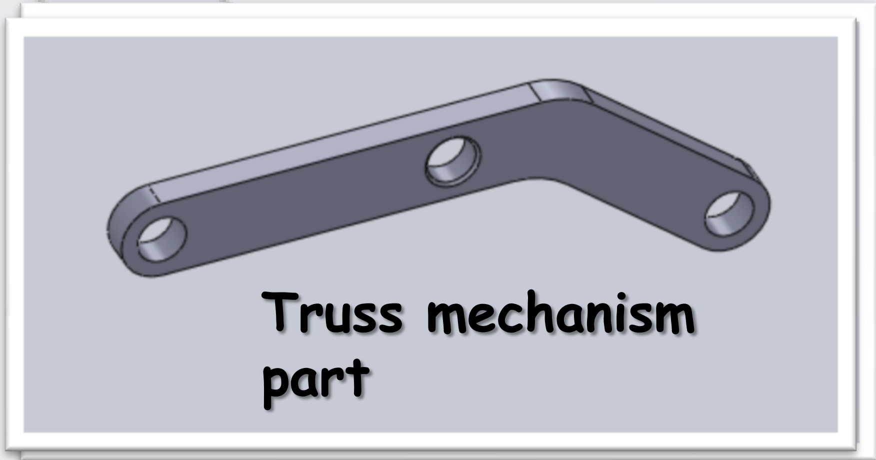
Door Opening Mechanism

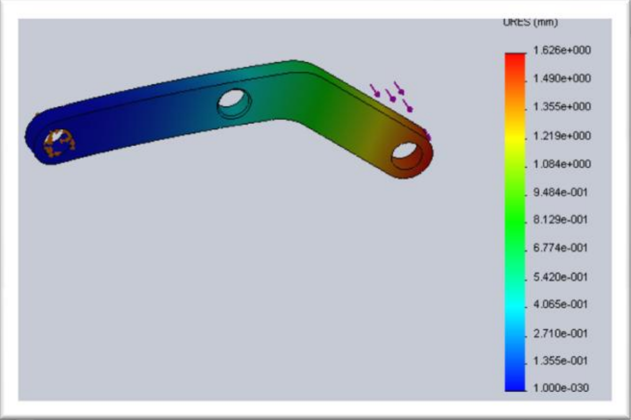


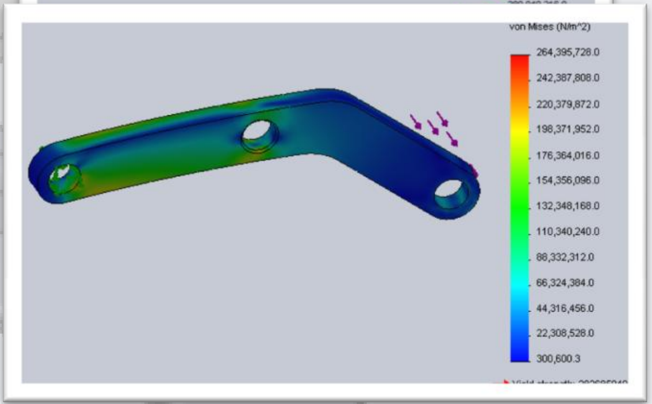
				sole
Picture				
Complexi				gh
Stable sta				s
Reliability	high	high	average	average

Mass of one truss mechanism +actuator ~3 kg → Total mass ~ 12kg < 20 kg expected

Stress analysis







- All the loads were based on dynamic pressure analysis and wing loading of original plane.
- The actuator bolt receives only the axial stress.
- Thus, the truss mechanism must take all the bending stress.

"Gondola" Stress Analysis

Stress calculations are based on wing loads and rudder loads

King Air wing load:

Max takeoff weight: ~6800 kg

Wing Area ~ 28.2m2

Wing load = $$\frac{6800*9.81}{28.2} = 2300[Pa]$$

Gondola design will be based on pressure(stress side load) of 3000[Pa]

"Gondola" structure design

Suggested materials for use:

- Aluminum 2024
- Composite material(sandwich) – Fiberglass and Nomex
- Strengthened Aluminum 2024 with support beams

“Gondola” Structure Design

- The initial comparison is done between the simple aluminum plate and the other “contesters”
- The lighter material capable of taking the load will be “the winner”
- Material cost is not taken in consideration

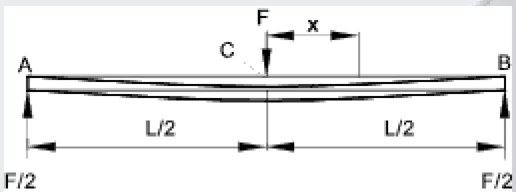
Gondola's material

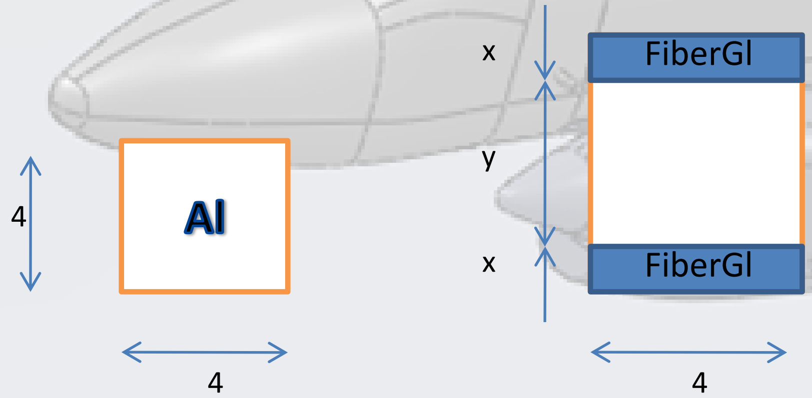
	Aluminum	Composite	
		FiberGl	Nomex
Young Modulus E [GPa]	70	72	17
Density[g*m-3]	2.7	2.5	0.1

Gondola's material

Deflection Formula:

$$y_c = \frac{FL^3}{48EI}$$





Gondola's material

- Calculations show that using composite materials where Fiberglass has thickness of 1mm and Nomex thickness of 8 mm will be equivalent to aluminum with thickness of 4mm

- Taking density in consideration, composite material use will save 20% in weight for the overall skin.

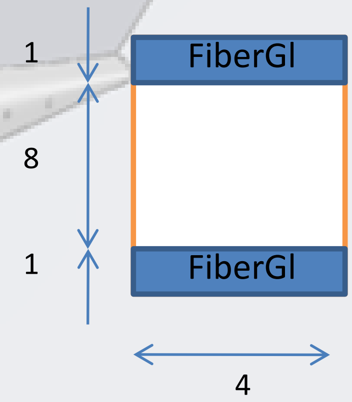
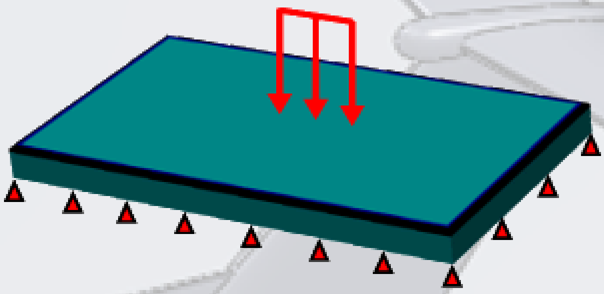


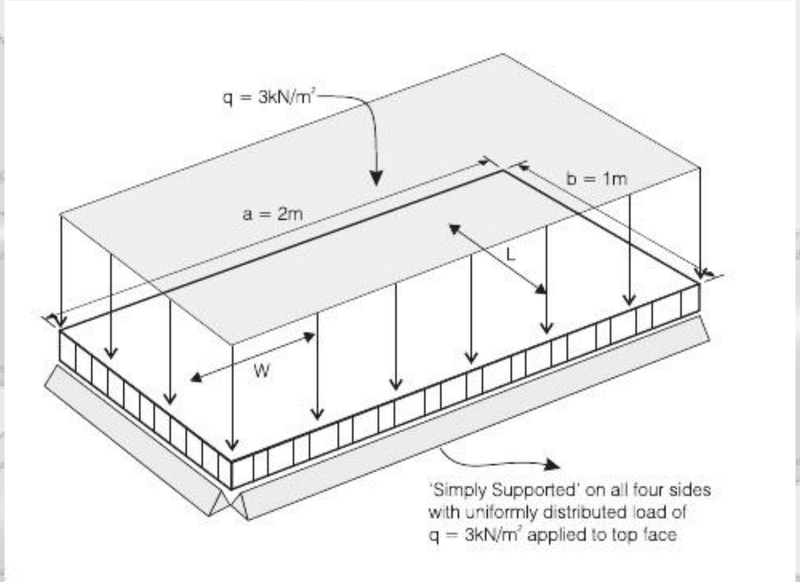
Plate calculations

- Simple aluminum plate



- Leading Formula: $\delta = \dfrac{C_1 q X^4}{E t^3}$
- Plate thickness of $t = 6$ mm will be sufficient to support the pressure.

Plate calculations



Where final width of the sandwich is 7mm

Plate calculations

The leading formulas:

$$V = \frac{\pi^2 E t_f h}{2b^2 G_W \lambda}$$

$$V = \frac{\pi^2 (70 \times 10^9)(0.5 \times 10^{-3})(25.9 \times 10^{-3})}{(2)(1^2)(220 \times 10^6)(1 - 0.33^2)} = 0.023$$

Deflection

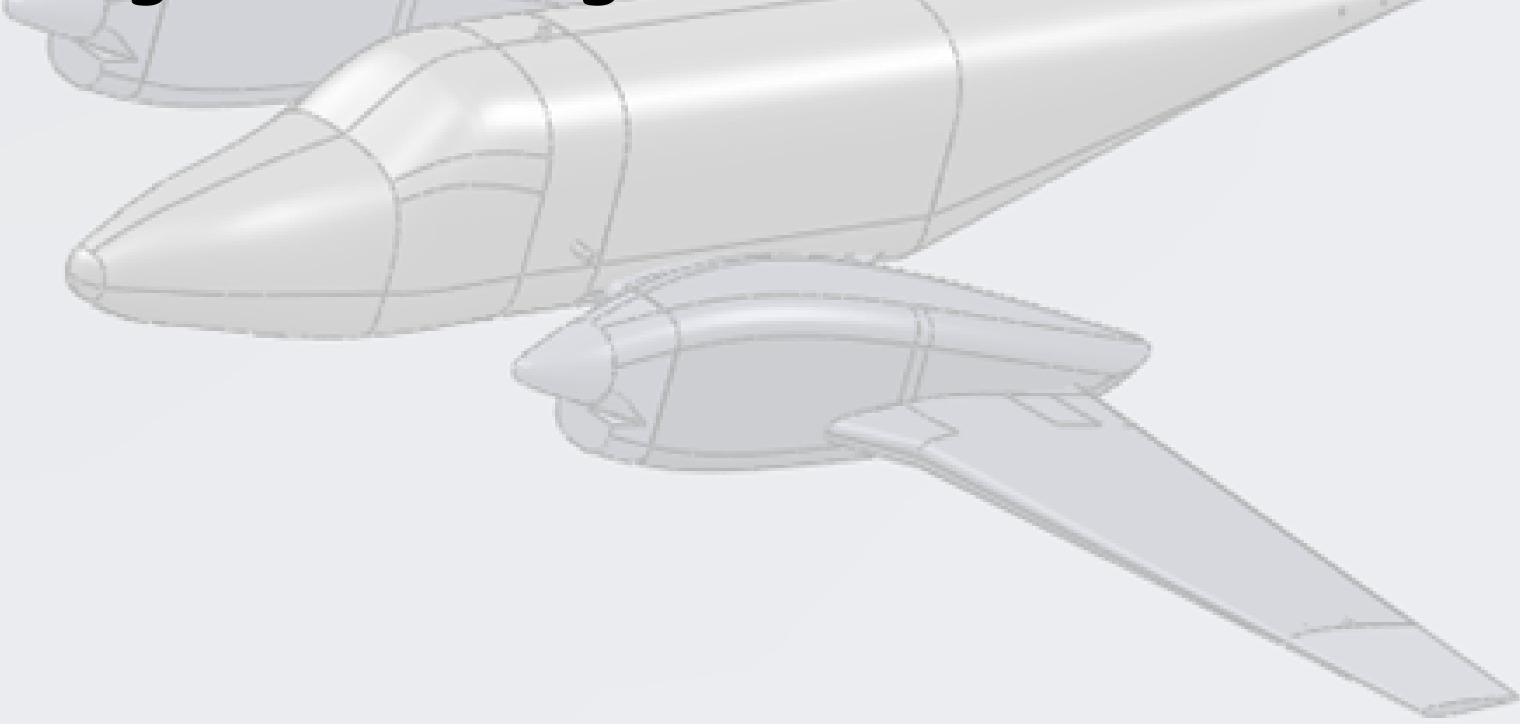
$$\delta = \frac{2K_1 q b^4 \lambda}{E_f t_f h^2}$$

$$\delta = \frac{(2)(0.0107)(3 \times 10^3)(1^4)(1 - 0.33^2)}{(70 \times 10^9)(0.5 \times 10^{-3})(25.9 \times 10^{-3})^2}$$

$$\delta = 0.0024\text{m} = 2.4\text{mm}$$

Aluminum-Complex Material comparison 3D case

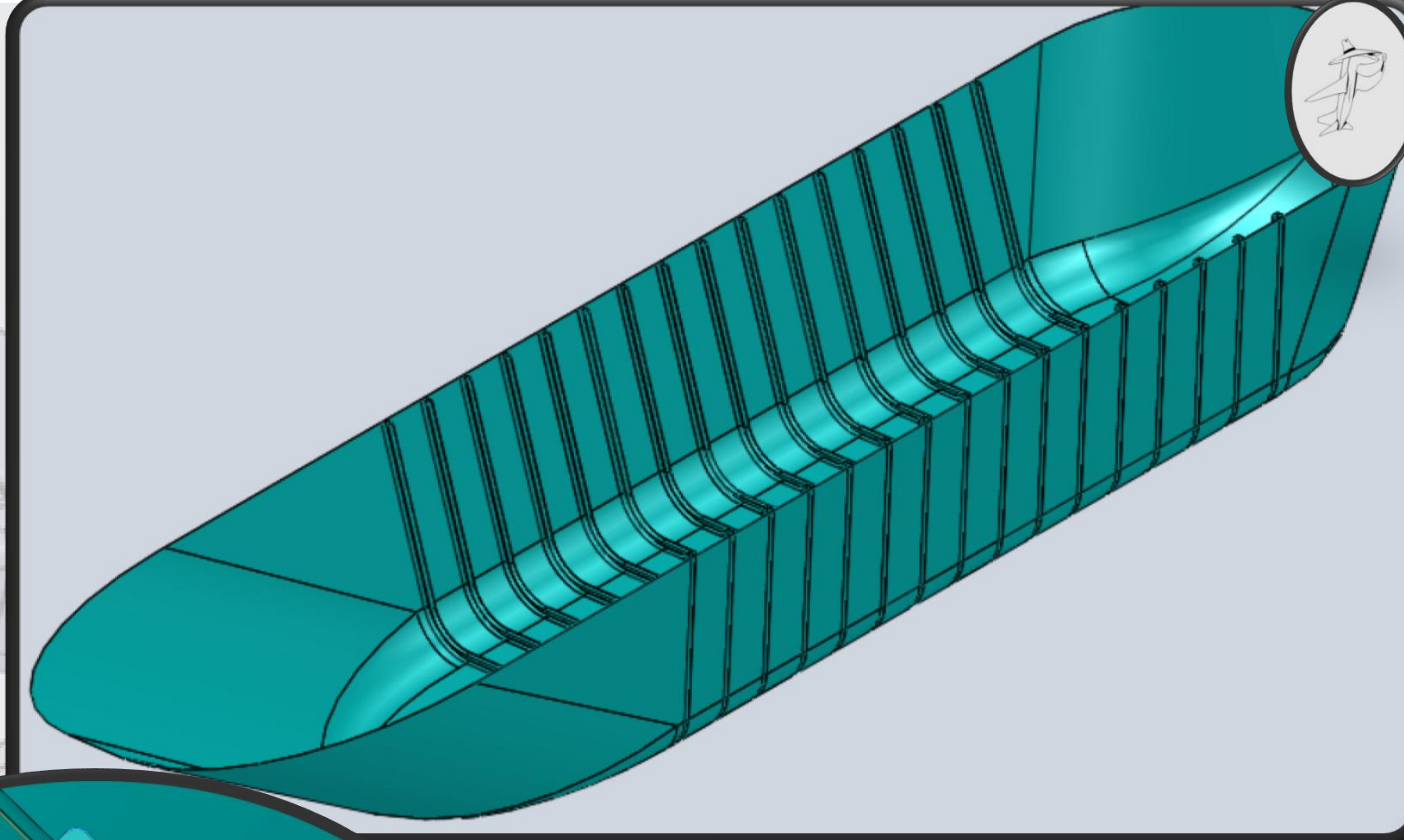
- Under external load of 3000[Pa], Composite material will save aprox. 30% of gondola weight.

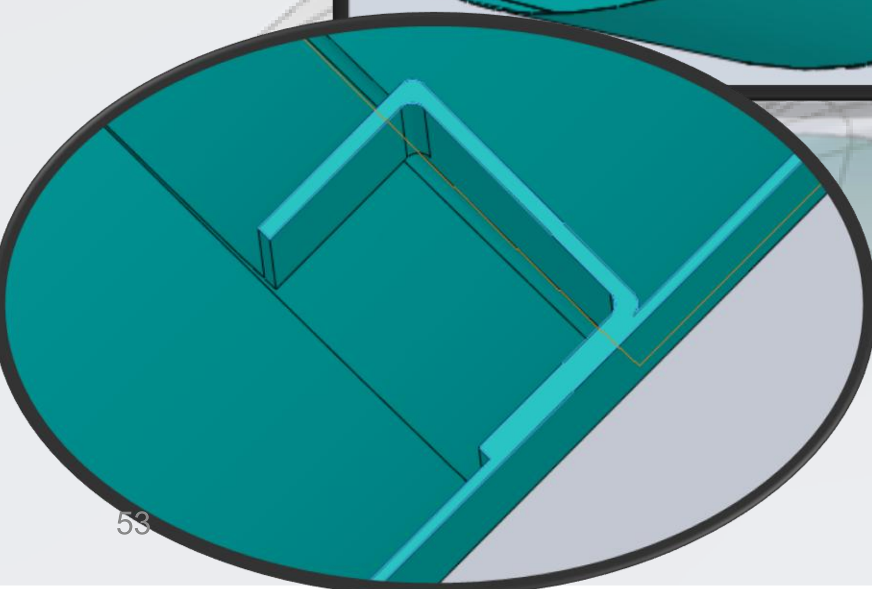


Aluminum – Reinforced Aluminum comparison

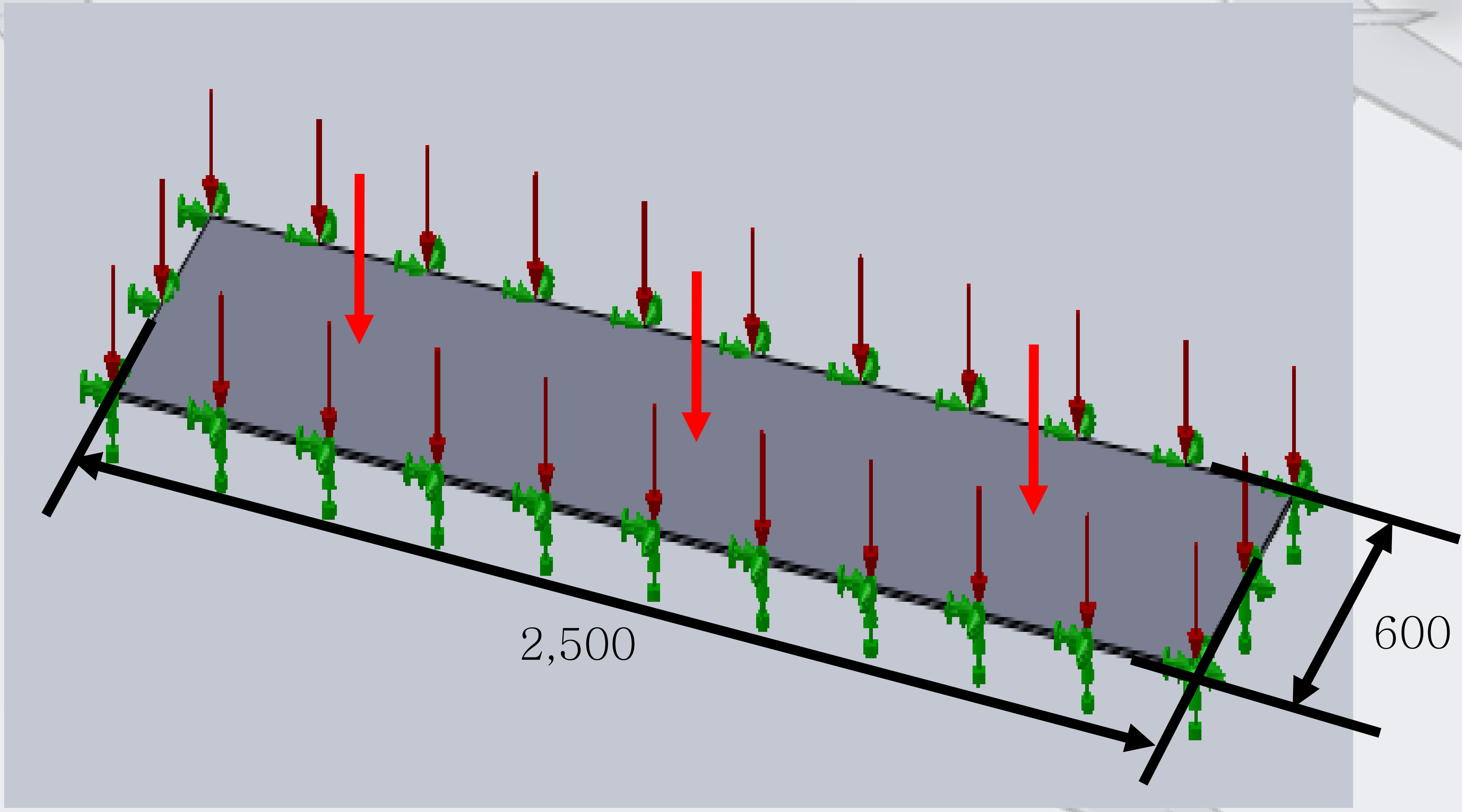
- Comparison between Aluminum sheet and Reinforced Aluminum sheet

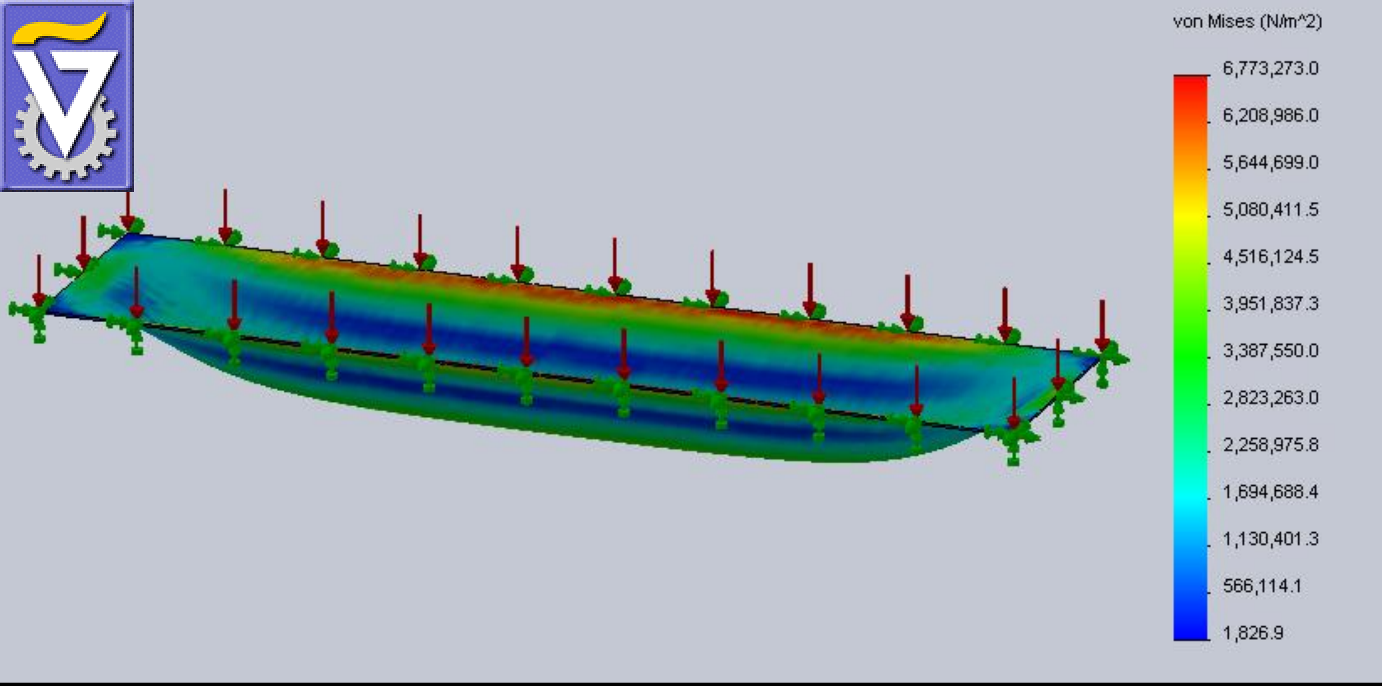
- Done using numerical methods.

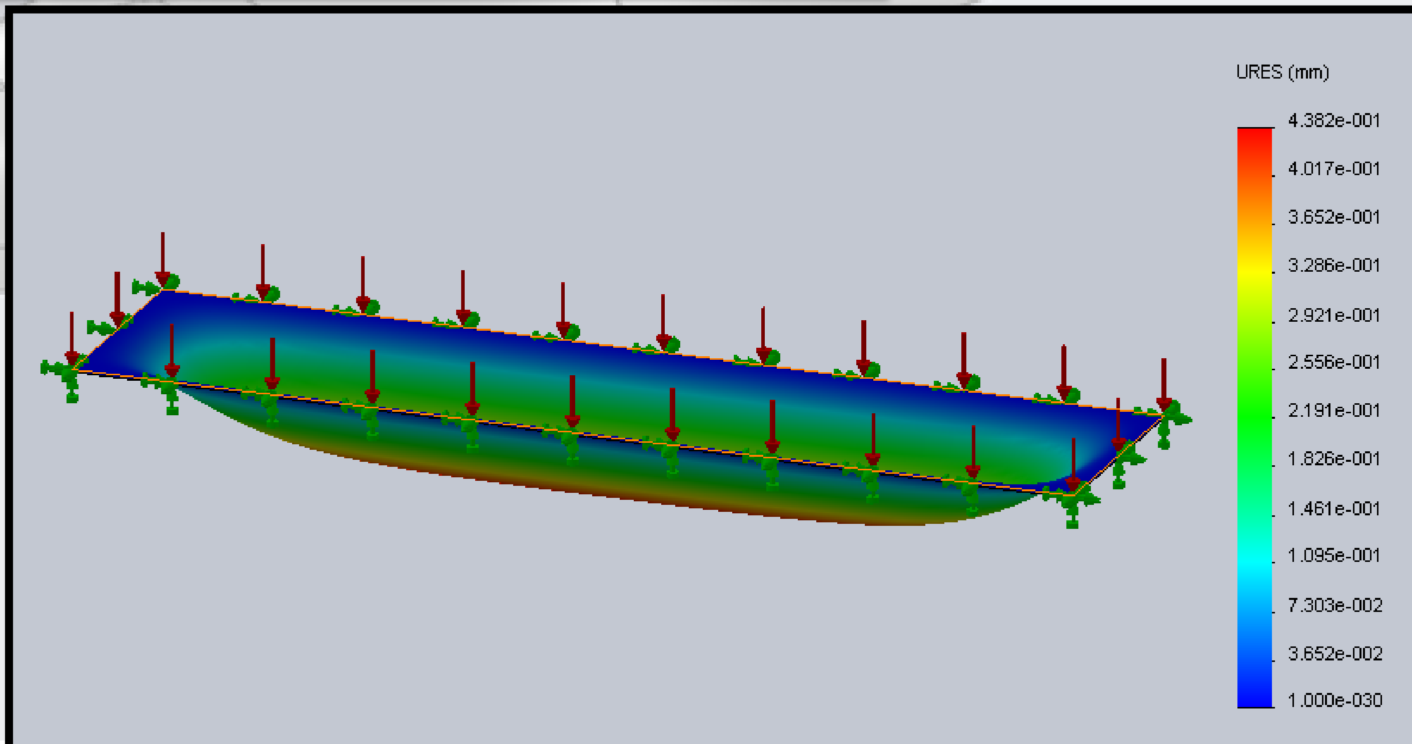




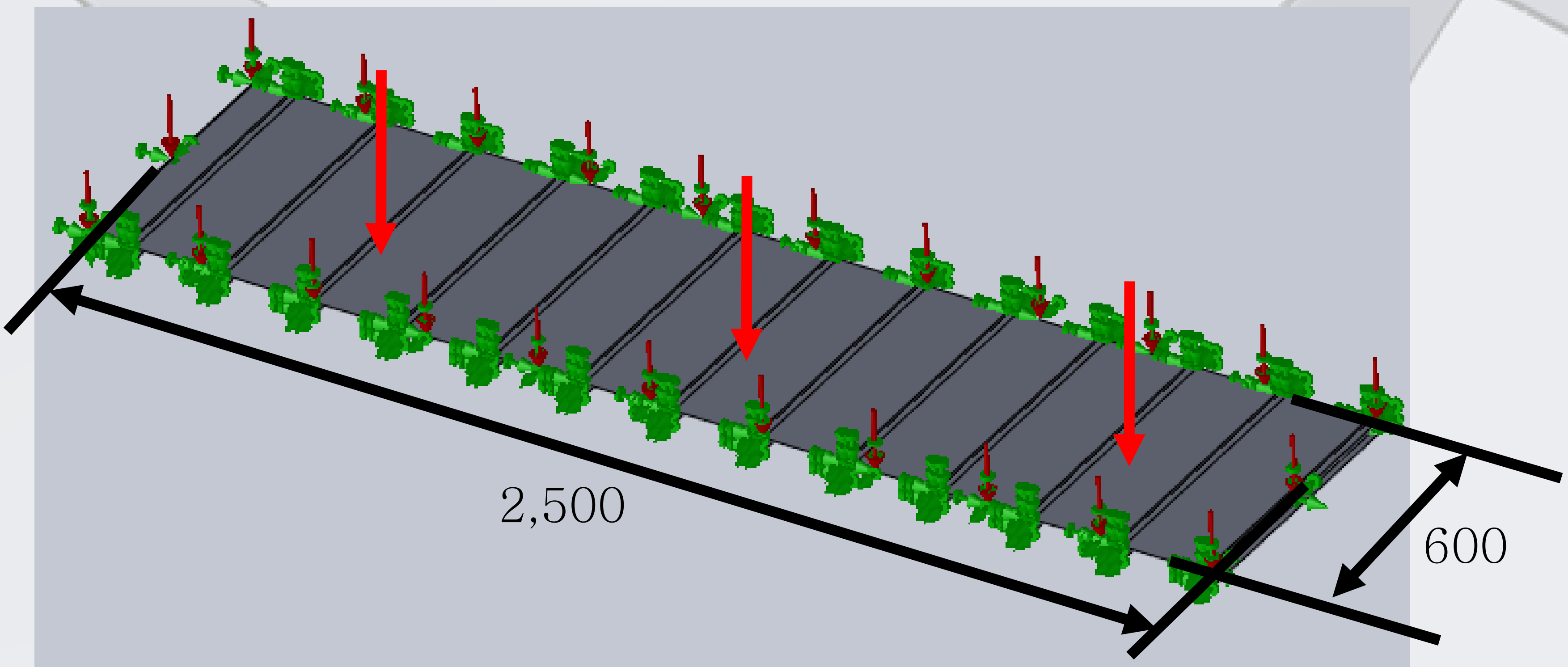
Simple aluminum plate 6mm thick

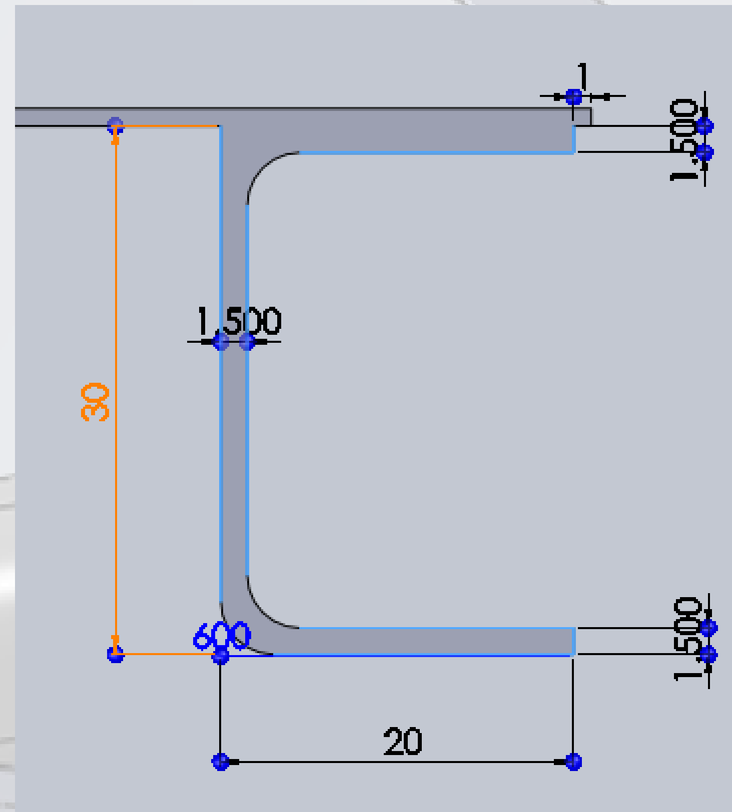


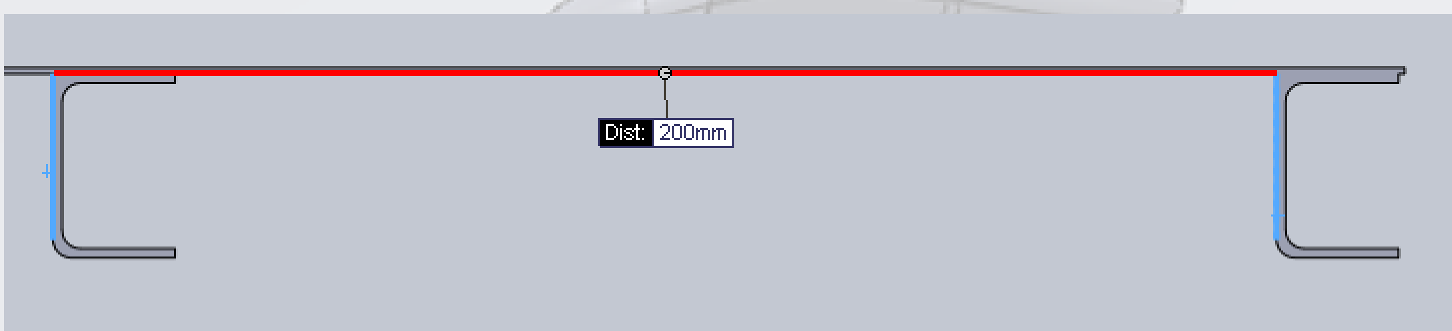

von Mises (N/m^2)
6,773,273.0
6,208,986.0
5,644,699.0
5,080,411.5
4,516,124.5
3,951,837.3
3,387,550.0
2,823,263.0
2,258,975.8
1,694,688.4
1,130,401.3
566,114.1
1,826.9

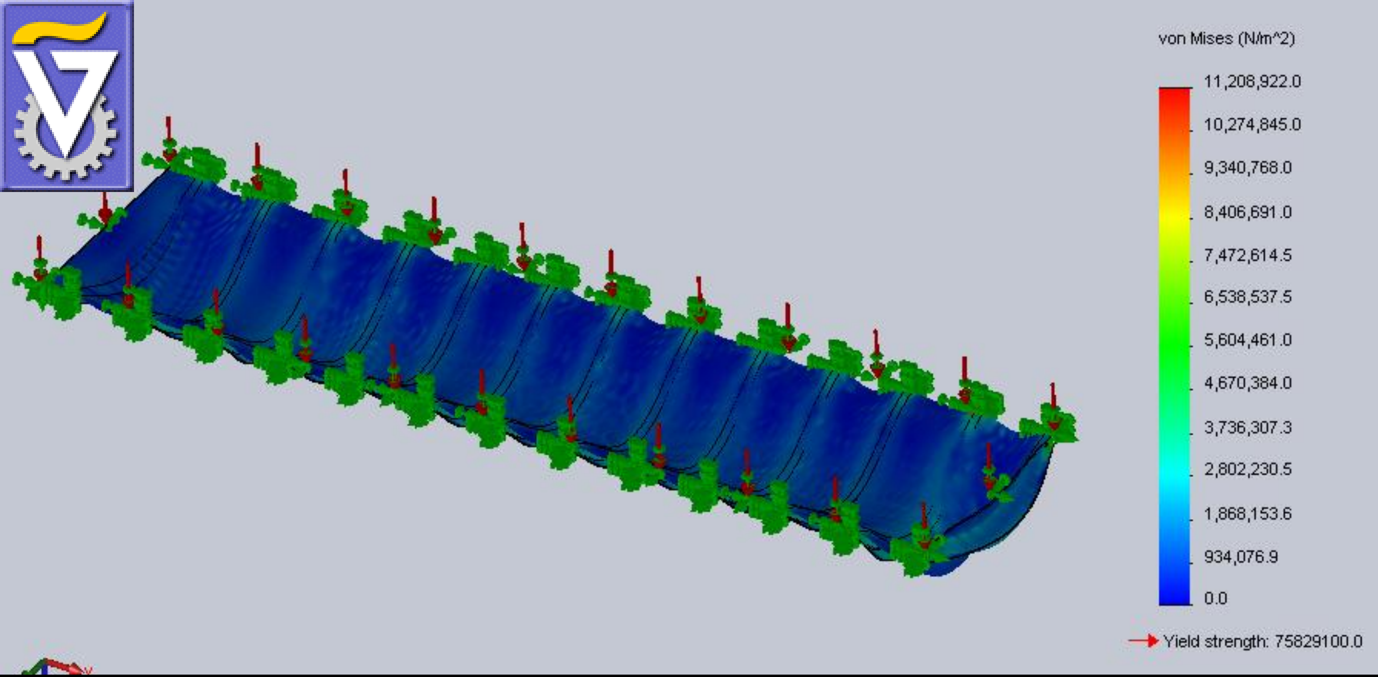

URES (mm)
4.382e-001
4.017e-001
3.652e-001
3.286e-001
2.921e-001
2.556e-001
2.191e-001
1.826e-001
1.461e-001
1.095e-001
7.303e-002
3.652e-002
1.000e-030

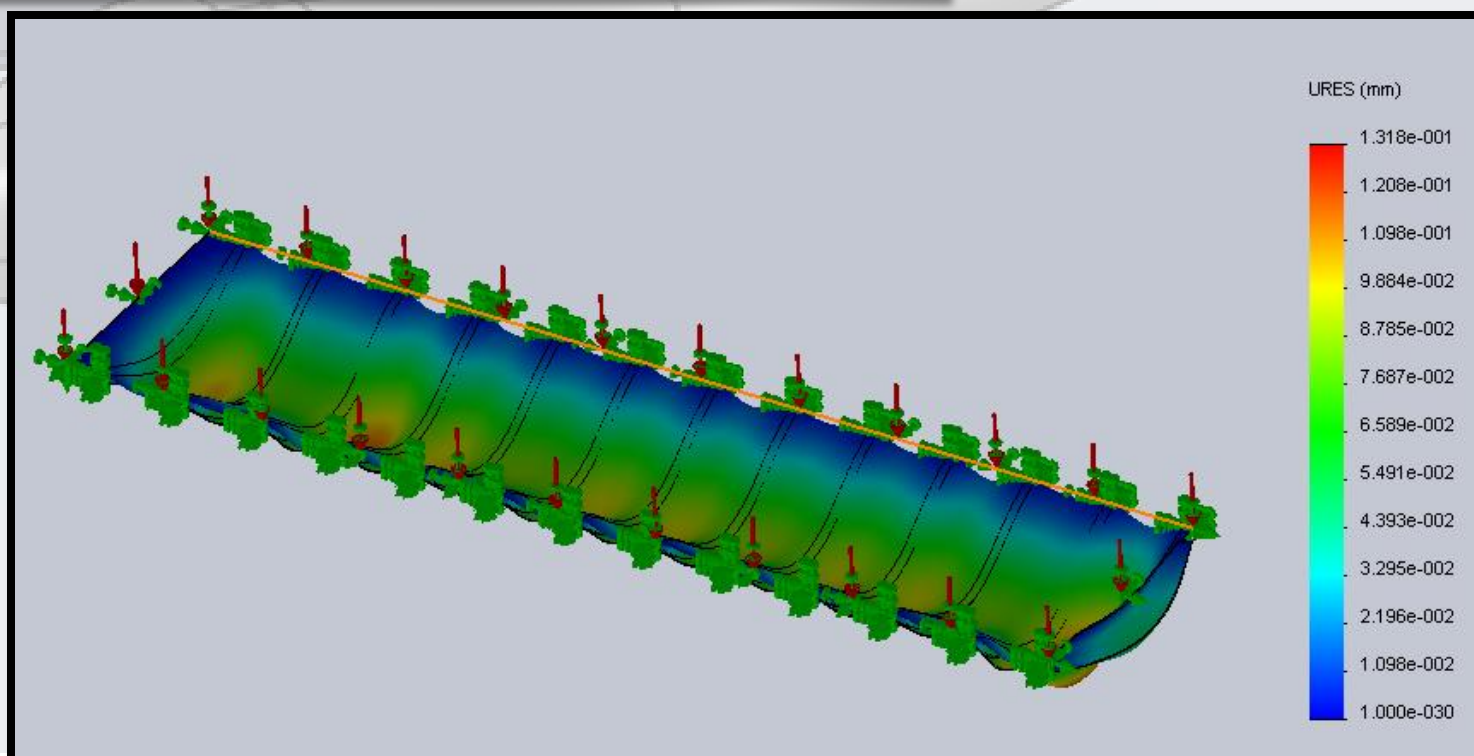
Aluminum plate, 1mm thick with strengthening C beams




1
1,500
1,500
30
600
1,500
20


Dist: 200mm


von Mises (N/m^2)
11,208,922.0
10,274,845.0
9,340,768.0
8,406,691.0
7,472,614.5
6,538,537.5
5,604,461.0
4,670,384.0
3,736,307.3
2,802,230.5
1,868,153.6
934,076.9
0.0
Yield strength: 75829100.0


URES (mm)
1.318e-001
1.208e-001
1.098e-001
9.884e-002
8.785e-002
7.687e-002
6.589e-002
5.491e-002
4.393e-002
3.295e-002
2.196e-002
1.098e-002
1.000e-030

Mass comparison

For the simple plate:

- Mass = 9000.00 grams

For the strengthened plate:

- Mass = 2301.37 grams

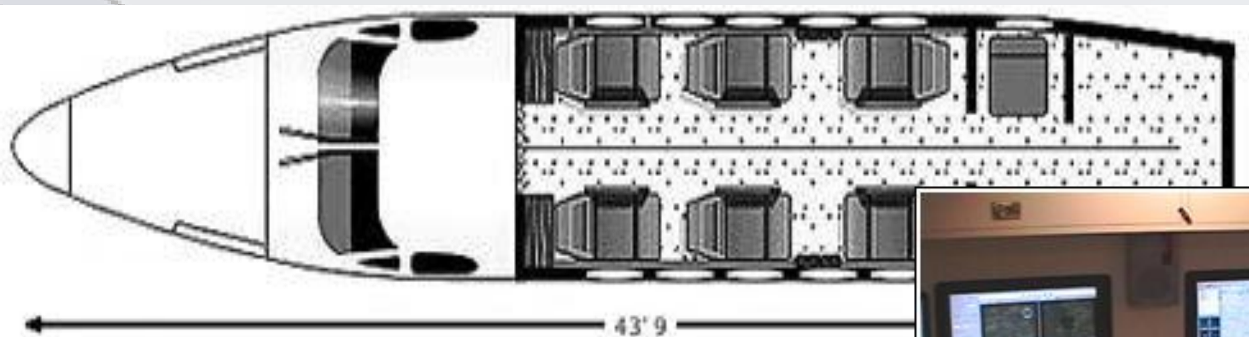
Conclusion - We get the same bending on the thin, strengthened plate as the simple 6mm plate but with 75% weight reduction (the strengthened bored is 25% the weight of the simple bored).

Conclusion

Structure:	Mass
Aluminum Plate	*
Reinforced Aluminum Plate	***
Composite material	**

Reinforced aluminum plate is the lightest material to stand the pressure.

Internal cabin layout



Ground control station

Main purposes: operation of the UAV by radio waves
•execution or high level flight control
•monitoring of the onboard systems and payload control

Includes: Ground Control Software multi-computer (mobile or built-in) setup

Main Concept: 'Point and fly' - it allows the operator to focus on the actual mission and is intuitive to handle.

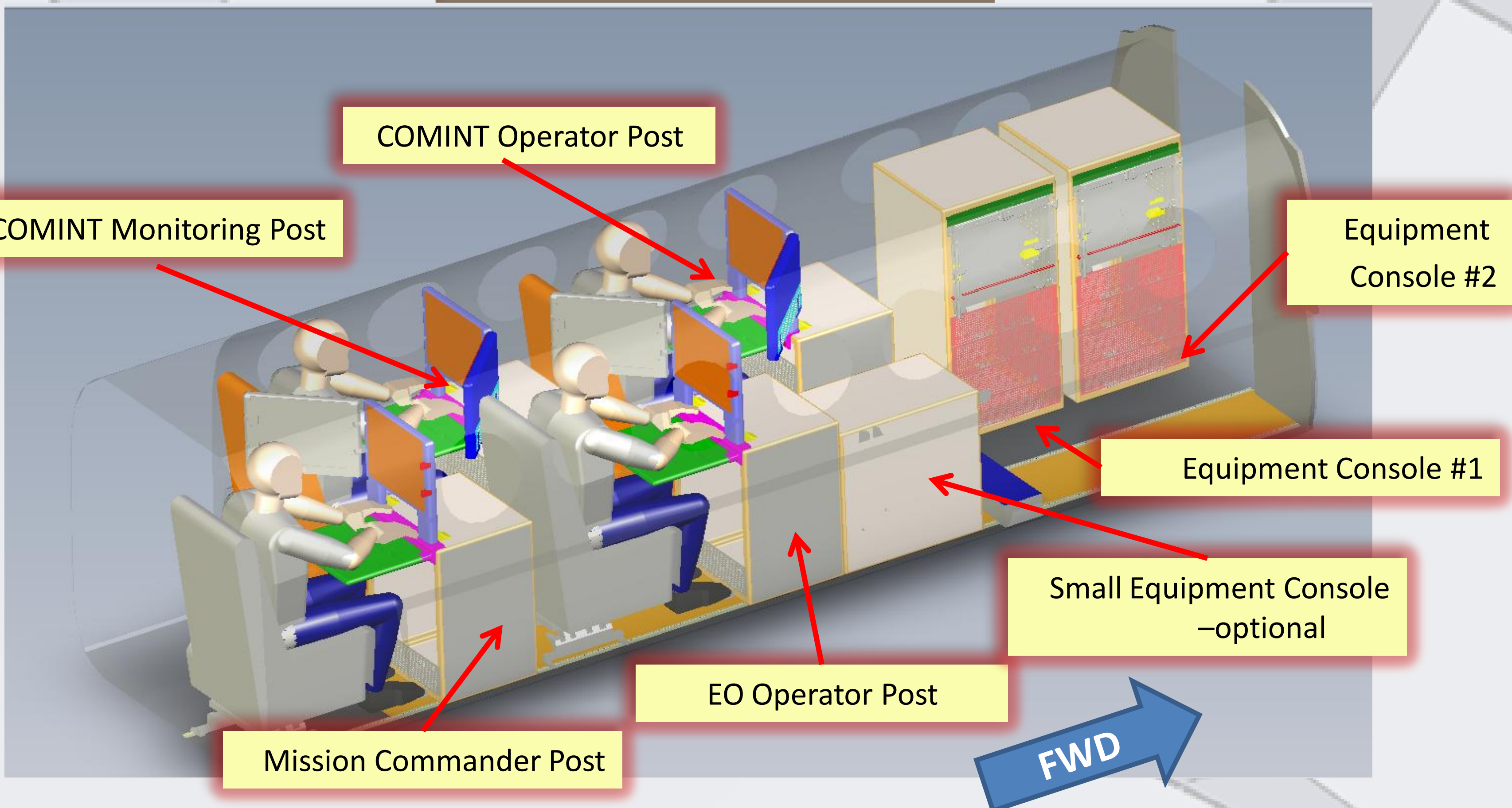
Ground Control Station

Need two operators:

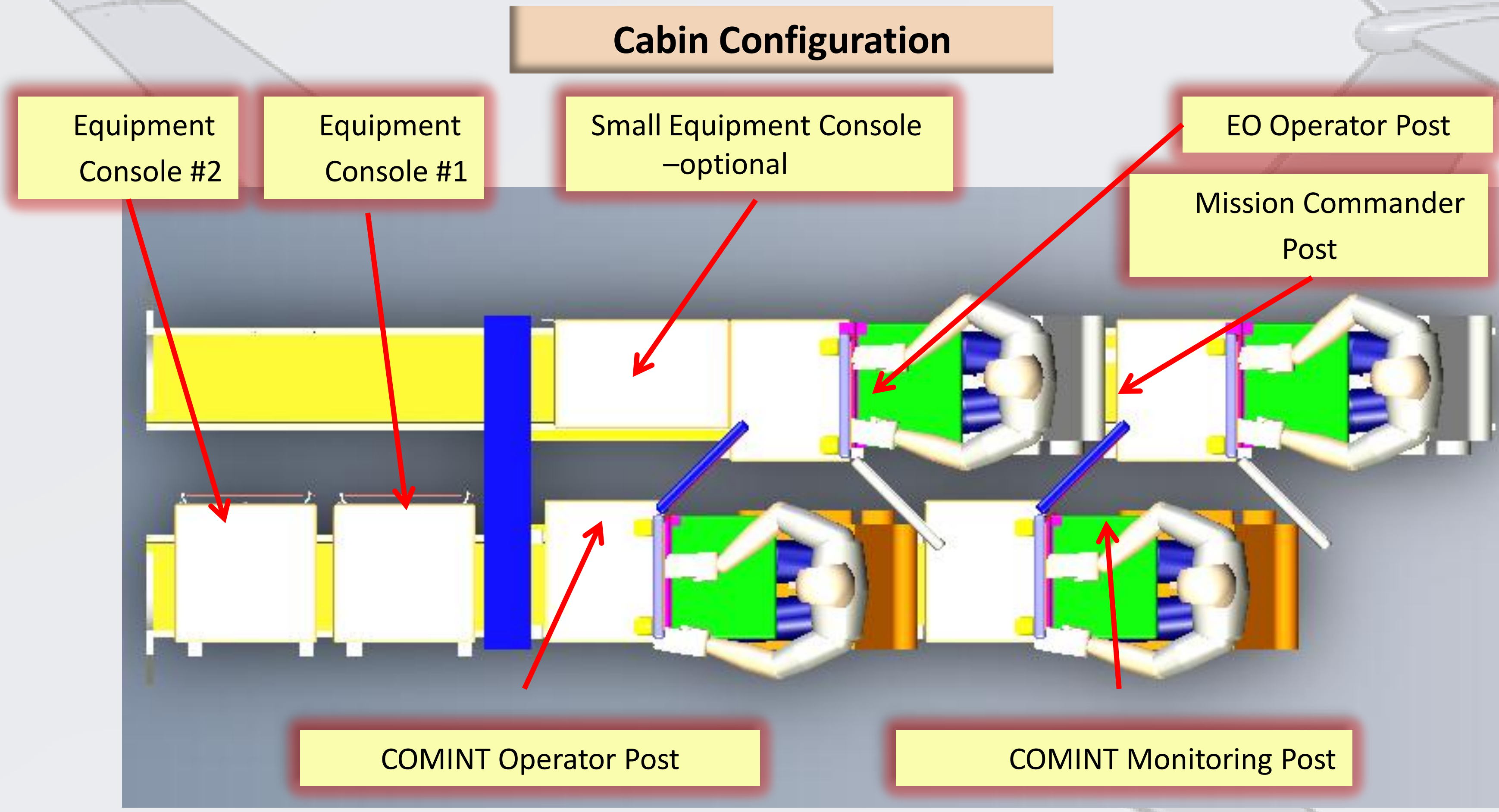
- **One operator controls the aircraft**
- **Another operator gathers the intelligence data**

Possible Cabin installation configuration
(Surveillance mission with no UAV)

Cabin Configuration



Cabin installation configuration
(Continue)

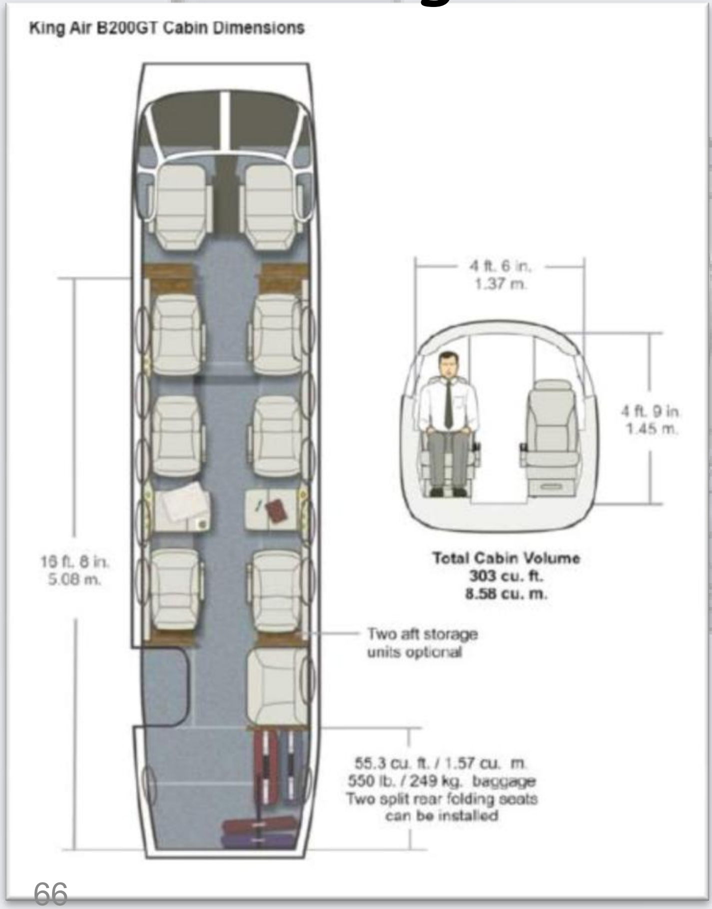


What do we have:

King Air B200 cabin dimensions:

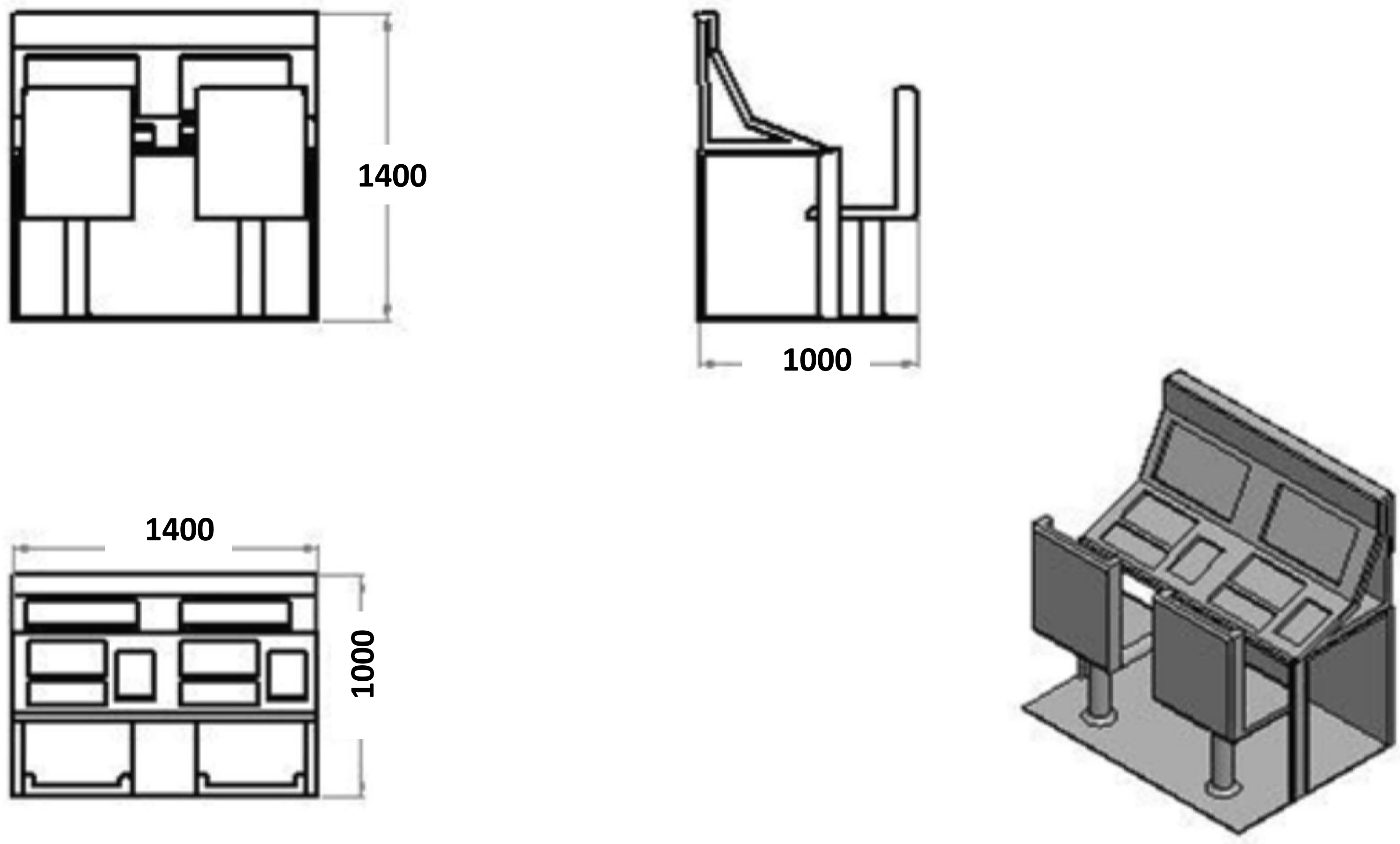
Max. Width: 1.4 m

Max. Length: 5 m

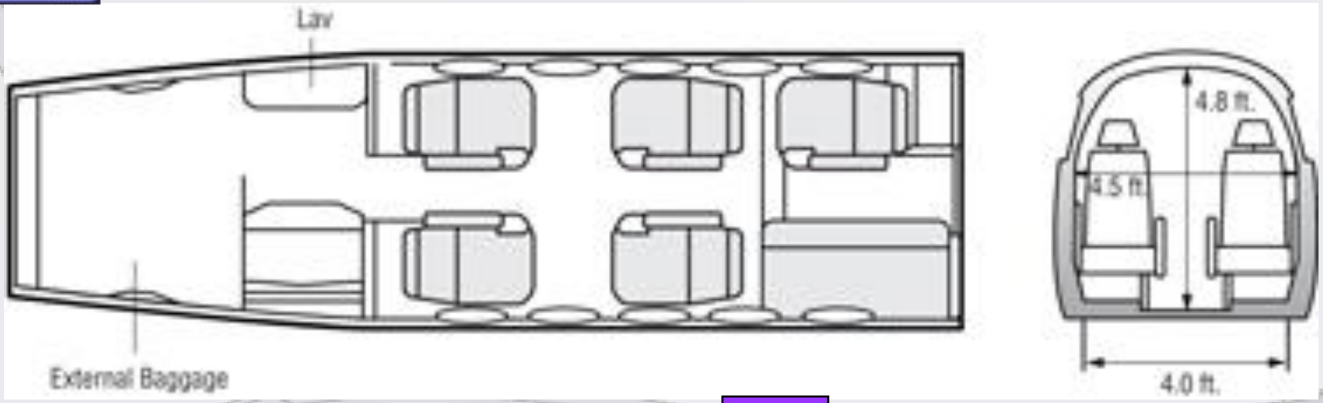


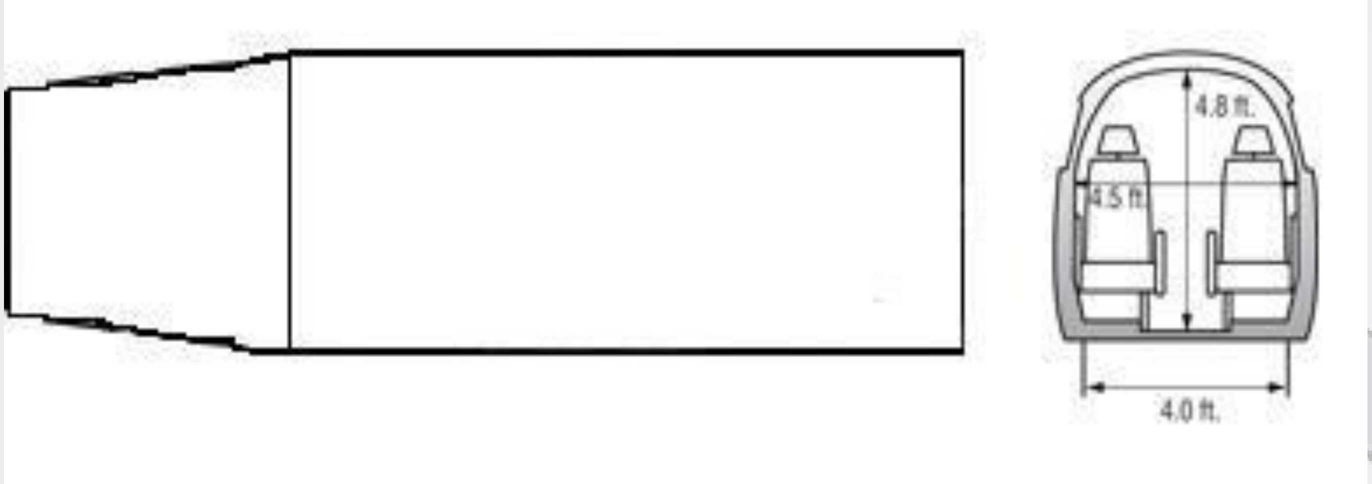
UAV- operating system:

Simplification of the UAV-control system:

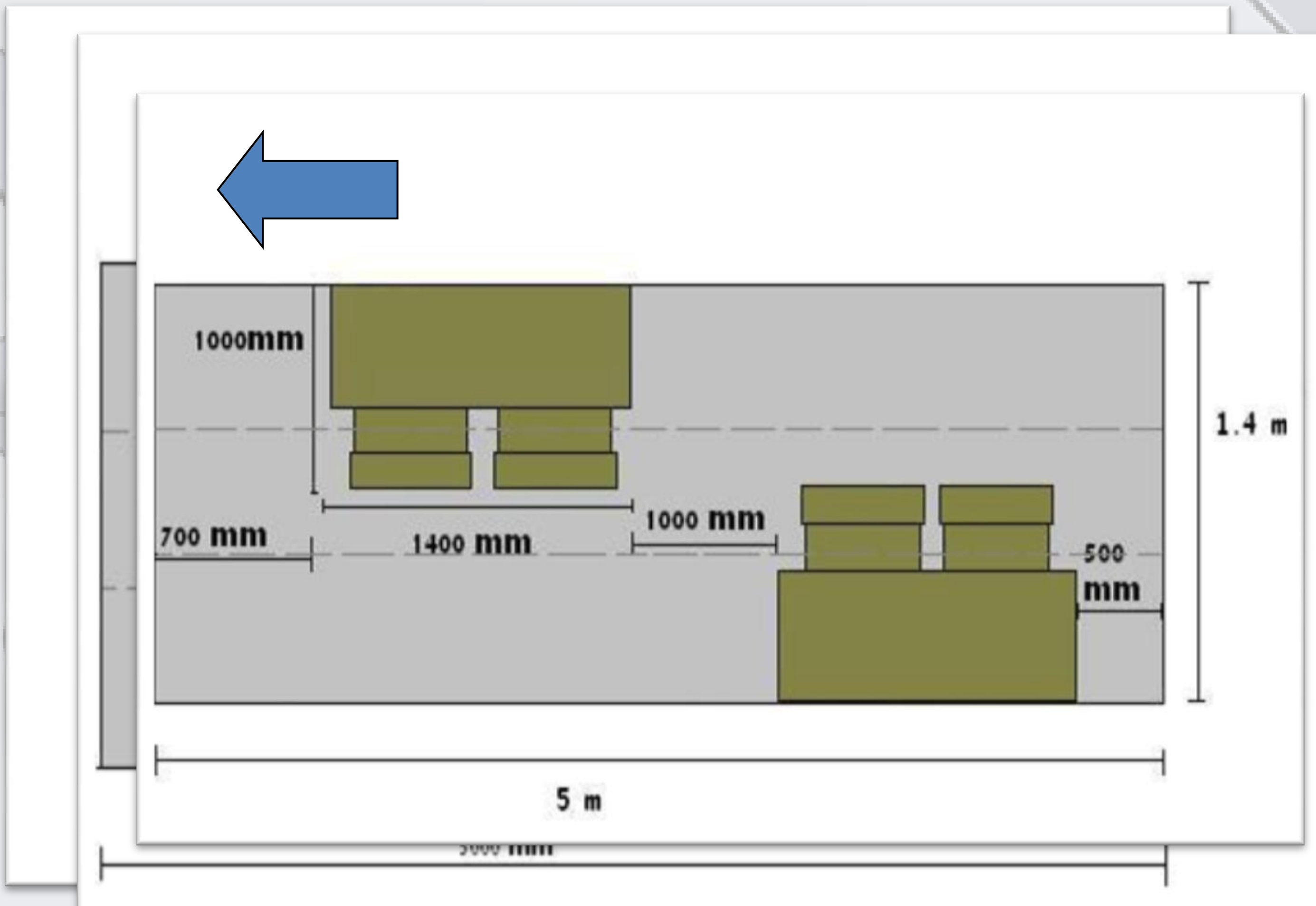


Simplification of the internal space:

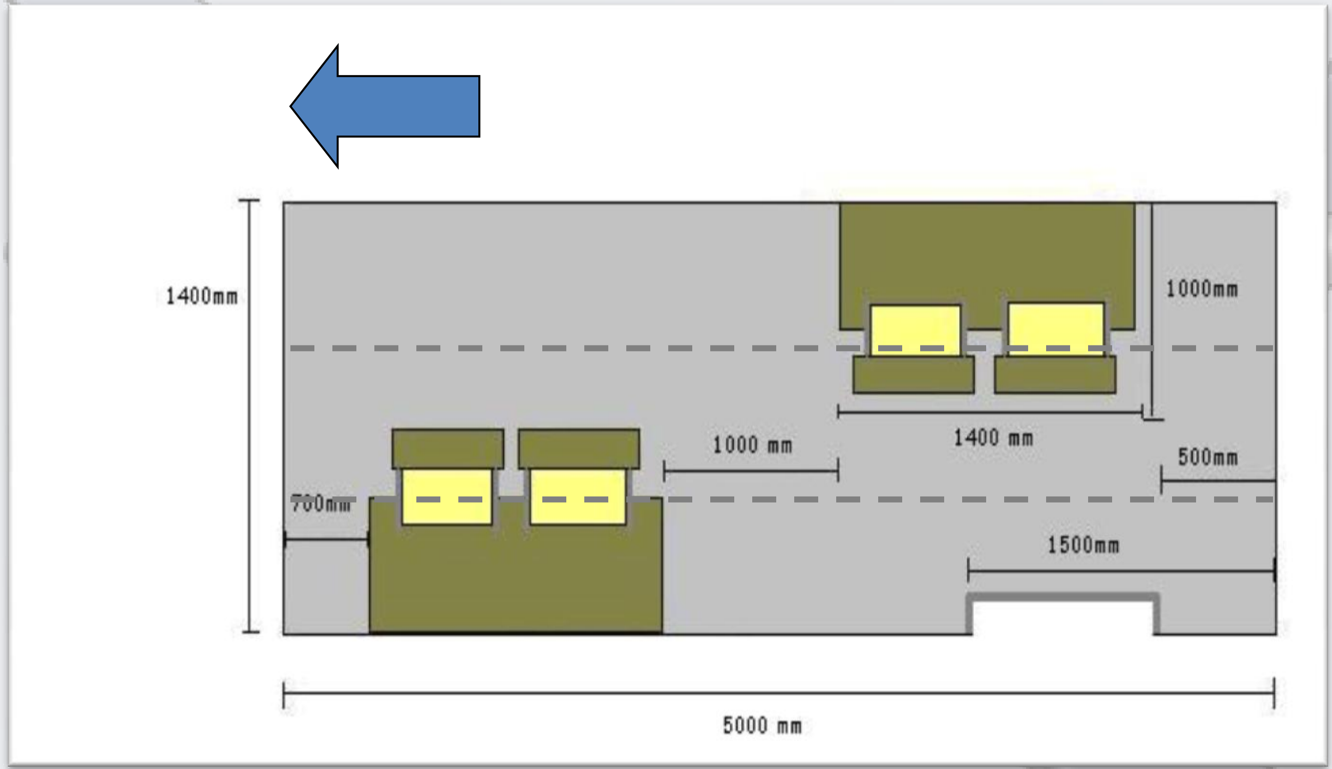




Possible layout #3:



THE CHOSEN LAYOUT:



Conclusions & Summary

The following were accomplished:

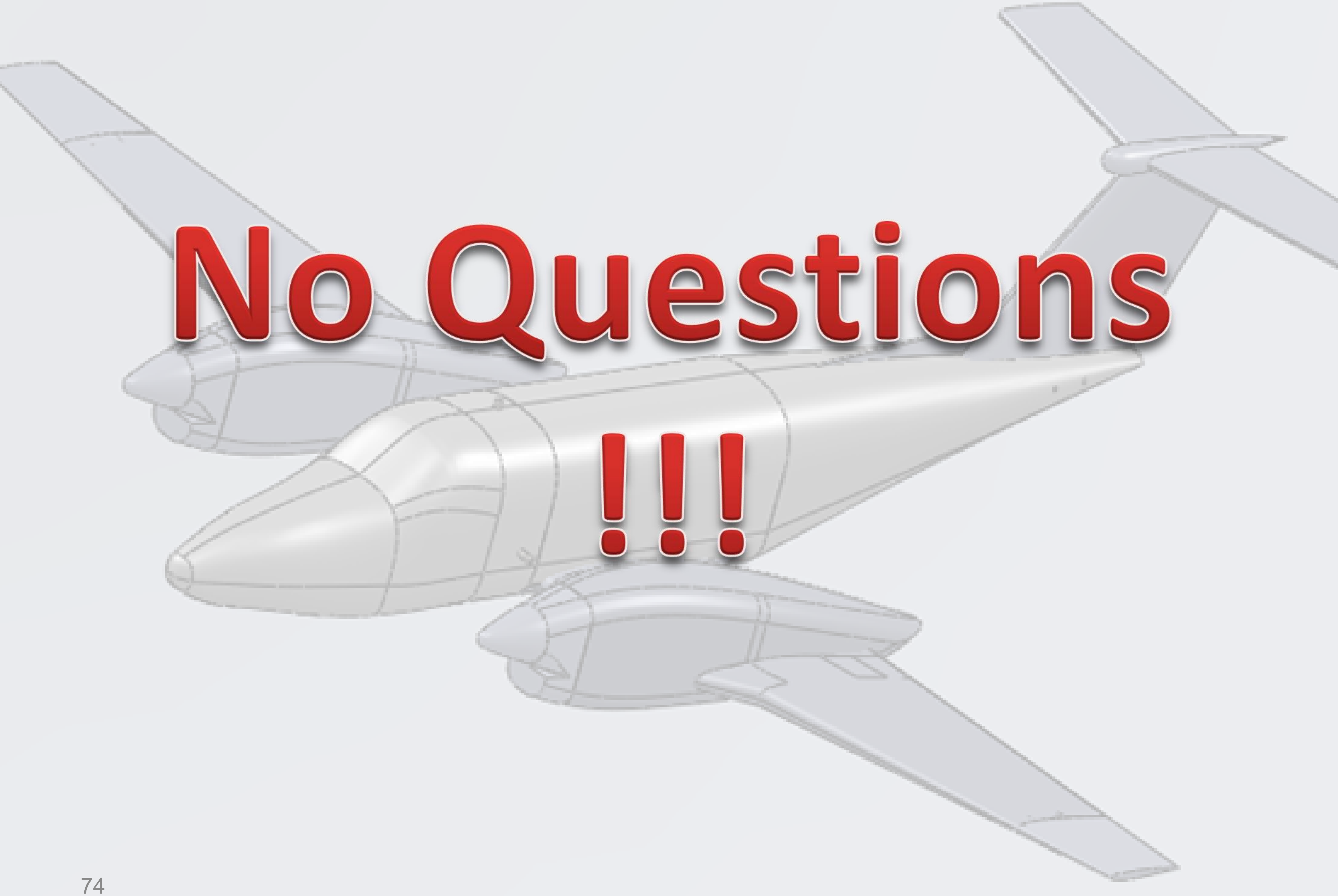
	'Gondola'	'MonGuard'	Wind tunnel model & tests
Configuration selection and detailed design	•doors opening mechanism •structure design	•internal layout •weight distribution	•model design and manufacturing •Tests
Detailed analysis	•load and stress		•Aerodynamics

Requirements VS Achievements:

- Enlarging the surveillance range – possible within 100 NM
- LOS communication – possible within Airborne Control Station
- 'Gondola' capability for carrying two UAVs – possible, including equipment for each mission
- EO Sensor of 1.5 kg – The 'MicroPop' EO sensor fulfills the requirement

Thanks:

- Prof. Gil Iosilevskii
- Prof. Gregory Kopp (University of Western Ontario)
- Dr. Jose Meyer
- Dr. Ehud Kroll
- Mr. Moti Ringel
- Mr. Marcel Leventer
- Mr. Prosper Shushan
- Mr. Tzvika Shakhar
- Our Supervisor Mr. Dror Artzi



No Questions

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