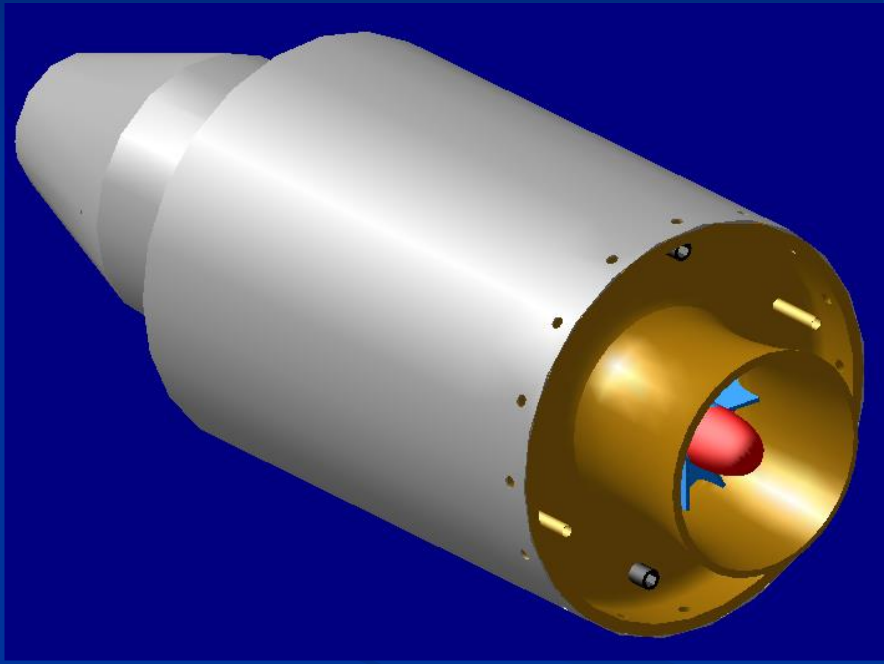
CS-TRAER Microjet Engine

Design of the small jet engine



by:

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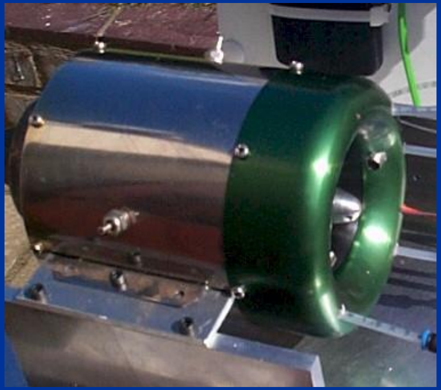
In the framework of the final project of the aerospace engineering faculty

Supervised by:
Assoc.Prof. Yeshayahou Levy

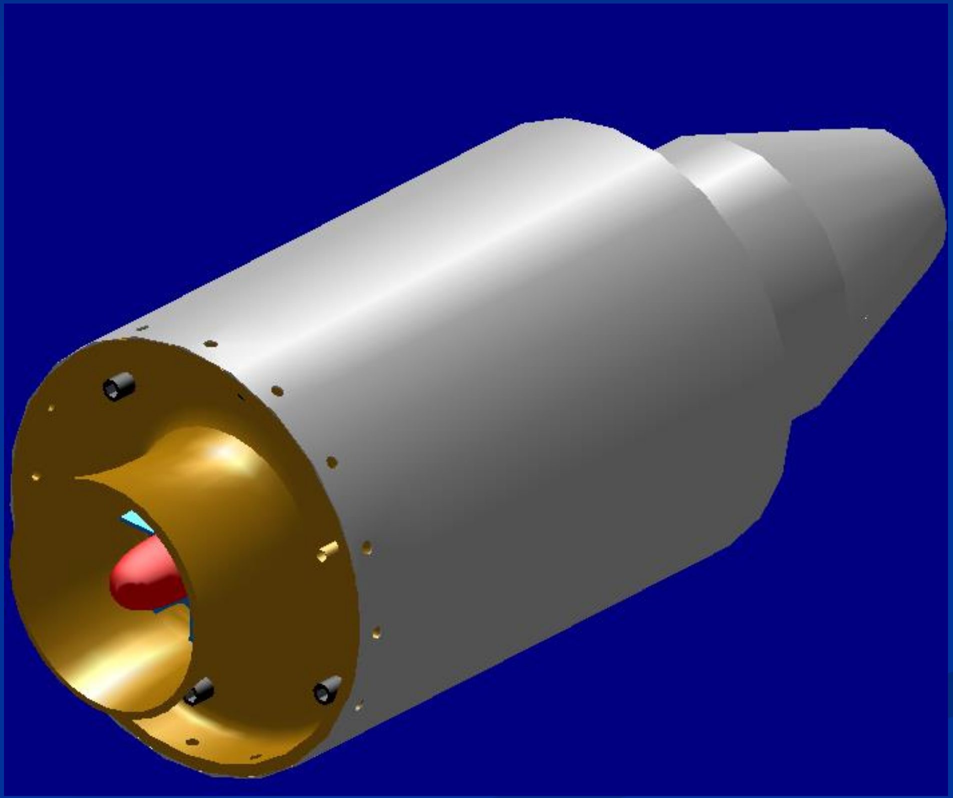
Similar Design:

	Wren MW-54 (UK)	Phoenix MK4 (UK)	Olympus
Thrust [Nt]	54	110	190
RPM	160,000	115,000	115000
Weight [kg]	0.8	2.1	2.4
Diameter [mm]	88	110	130
Length [mm]	150	270	270



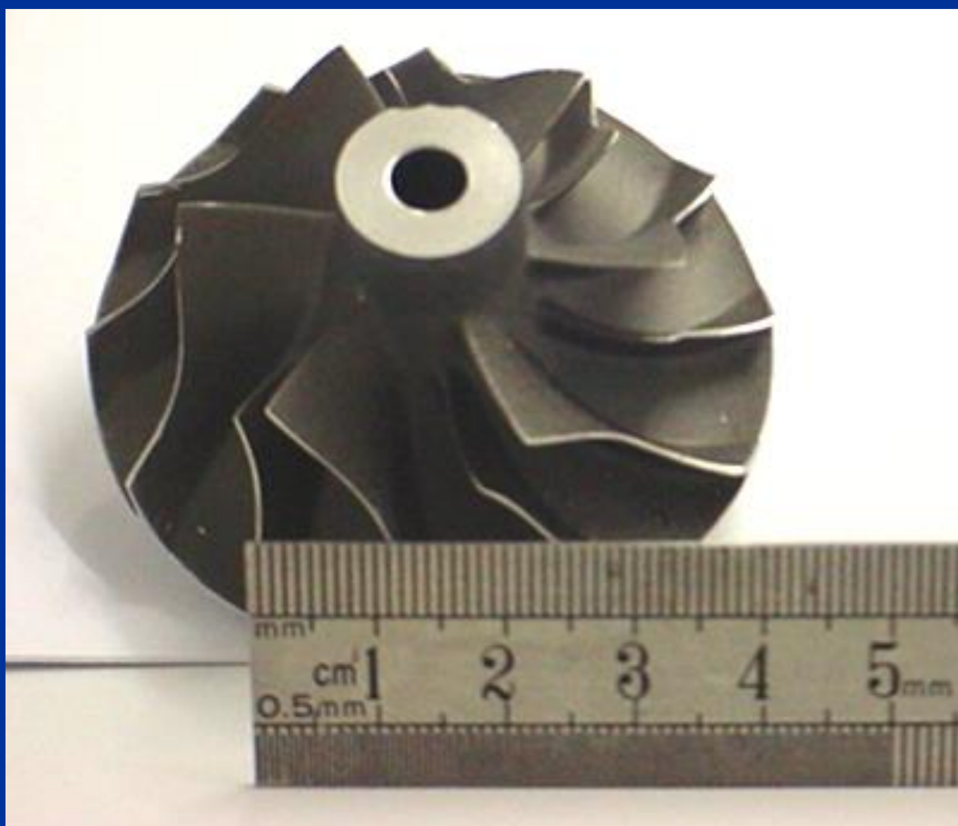
CS - TRAER

	CS-TRAER (Israel)
Thrust [Nt]	95
RPM	140,000
Weight [kg]	1.4
Diameter [mm]	100
Length [mm]	250



Single Stage Centrifugal Compressor

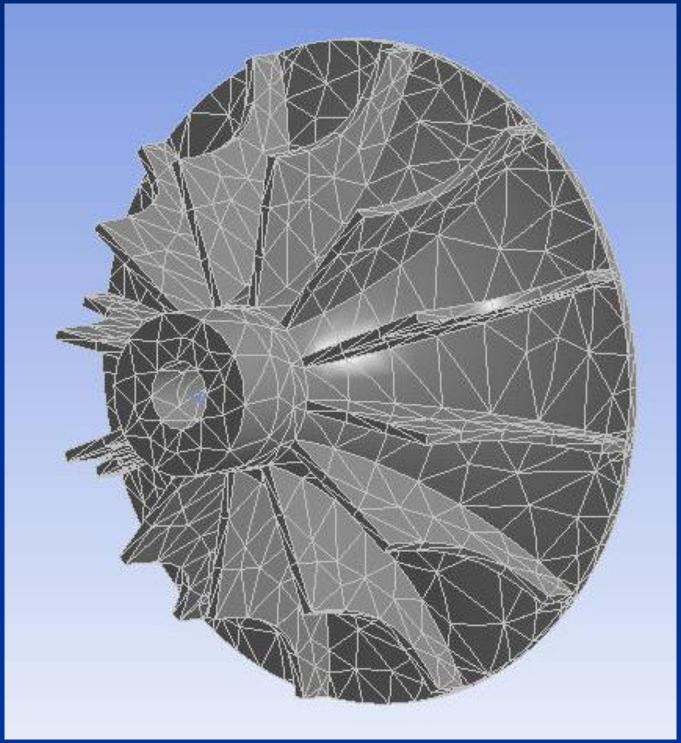
- Impeller - Turbonetics T3 – 50
- Stator - calculated and designed



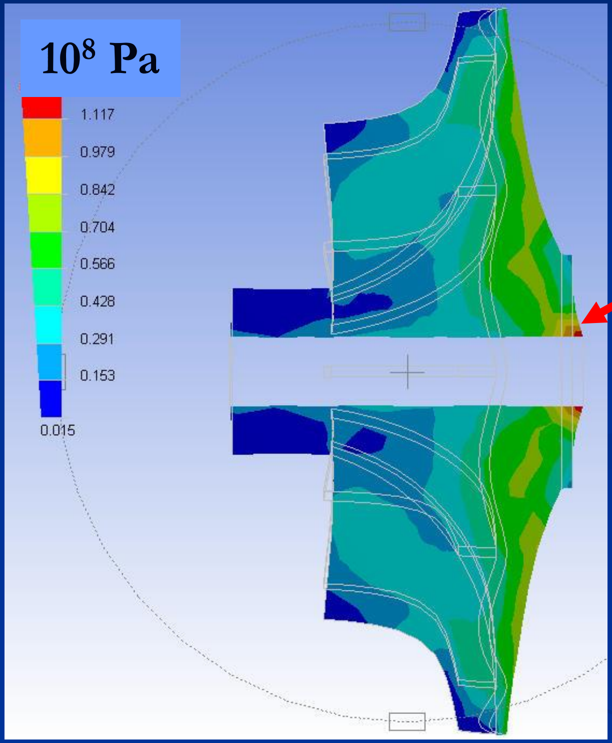
- Al-7075-T6

Compressor (cont.)

- **Finite Element analysis was performed on the impeller:**



FE mesh
30000 elements approximately



$$\sigma_y = 5 \cdot 10^8\, Pa$$

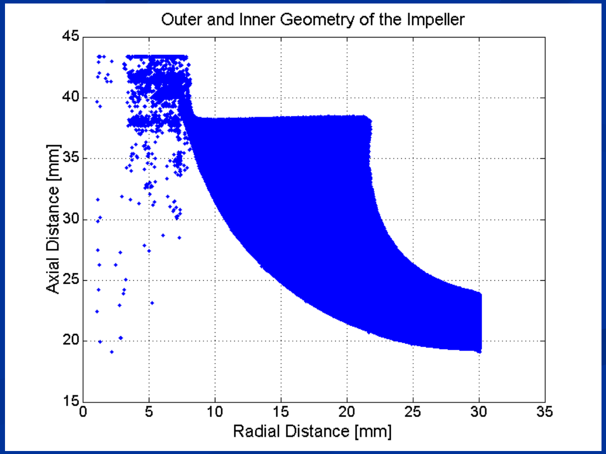
$$\sigma_{max} < \sigma_y$$

Stress distribution on the deformed shape.
(Deformation multiplied by 1000)

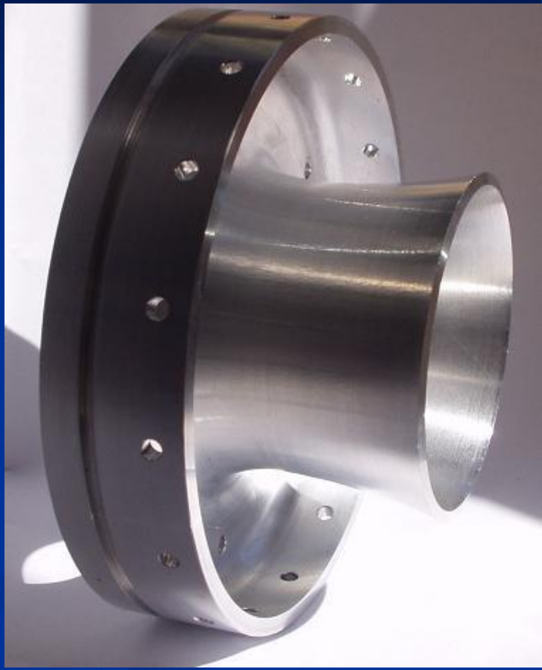
Inlet

- Designed for compatibility to the mass flow and compressor geometry

3D Scanning of the impeller



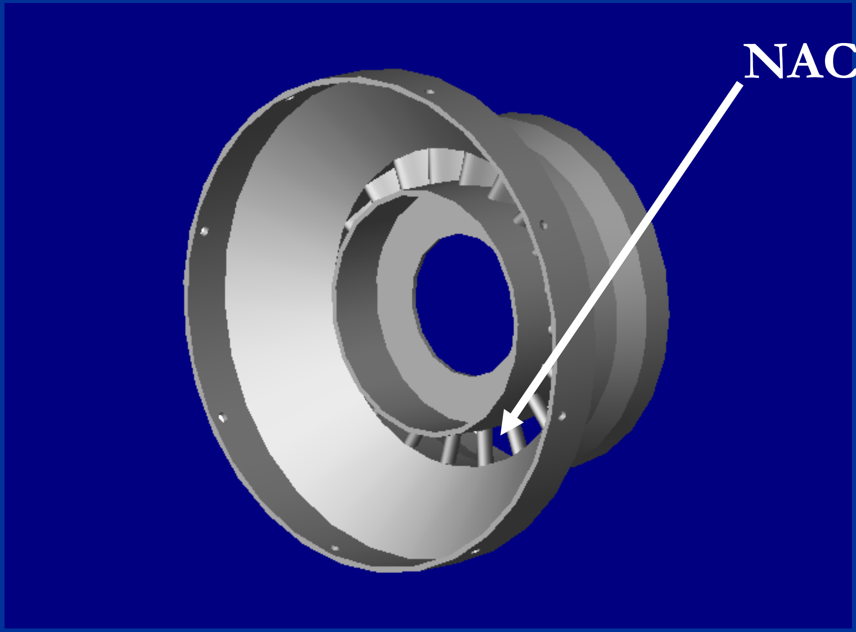
Received geometry



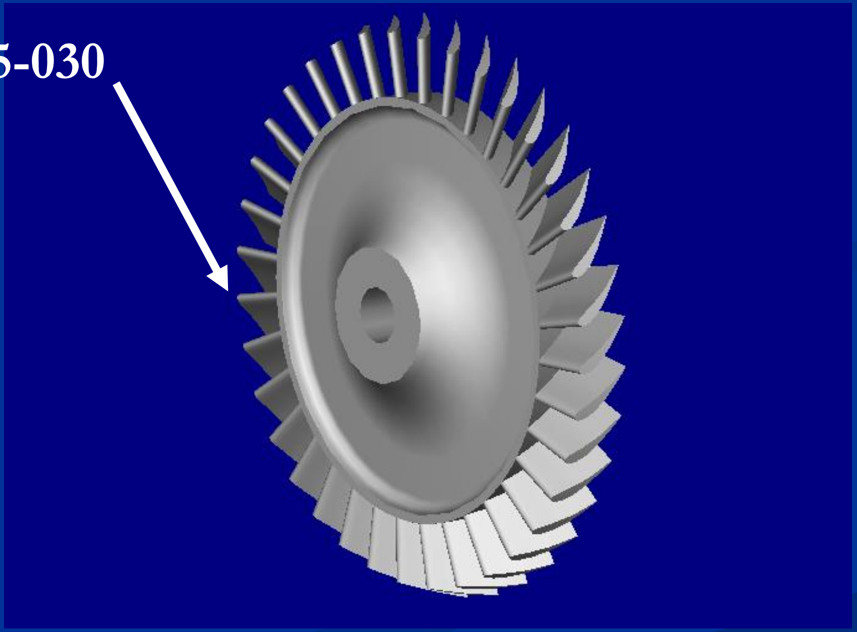
Finished part

Single Stage Axial Turbine

- Stator and Rotor – calculated for design and off-design points, for 0.5 reaction degree stage.



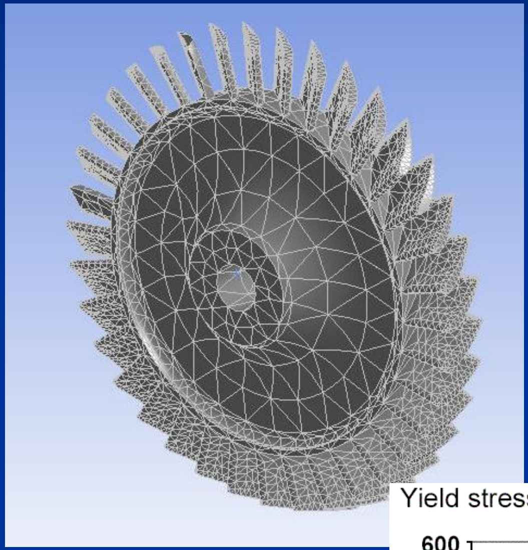
Casting only

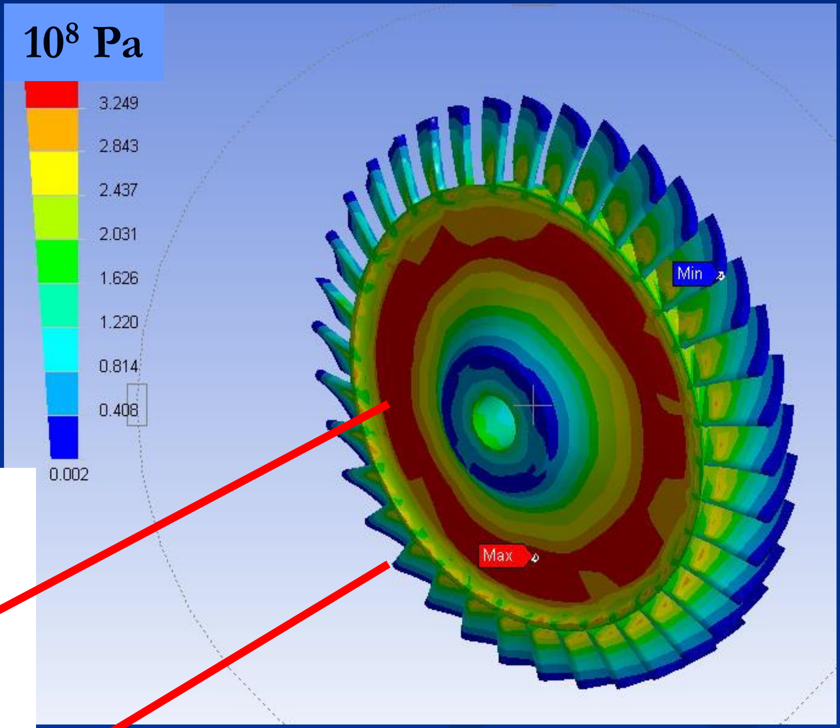


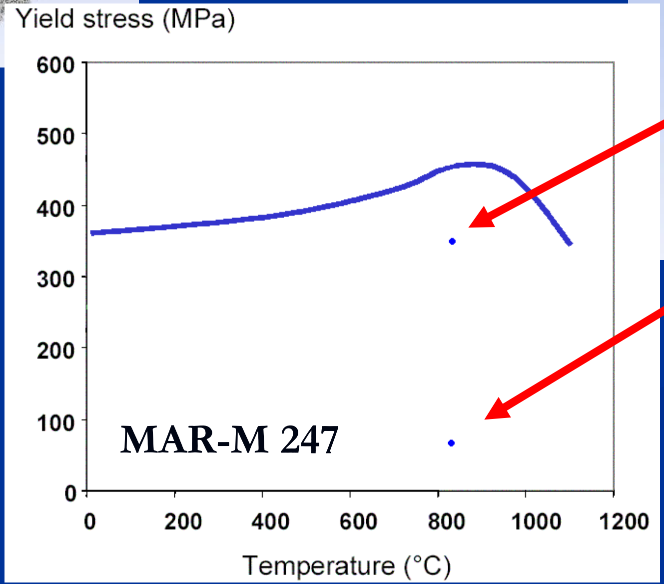
Casting or milling

Turbine (cont.)

- FE analysis was performed on the turbine wheel:







Stress distribution on the deformed shape.
(Deformation multiplied by 1000)

Shaft

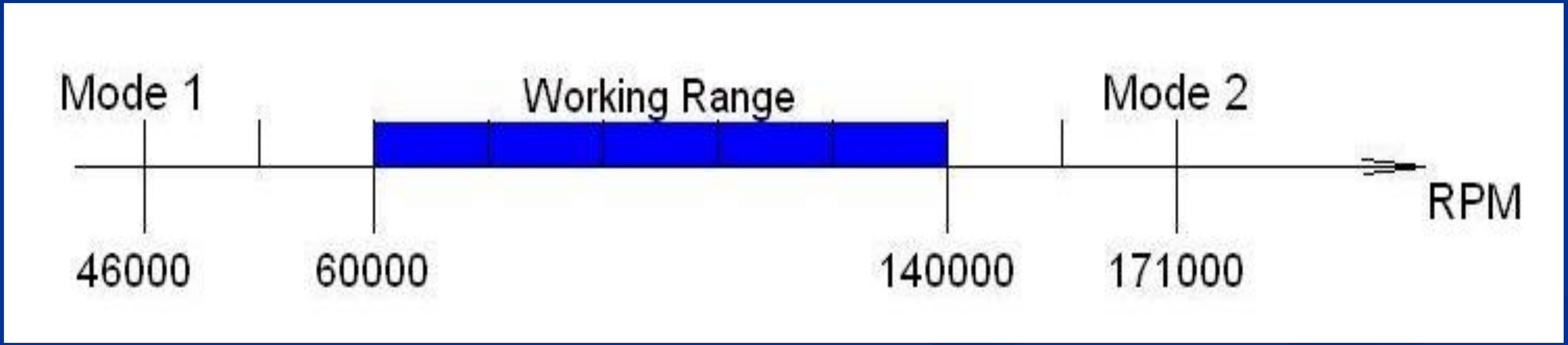
- Calculating with reference to Critical Revolution problem for the whole range of working frequencies

- Iterative Finite Element analysis of the shaft (12000 elements approximately)

- Combining FE & CAD allowed receiving final working geometry

Shaft (cont.)

- Working frequency region of the engine:

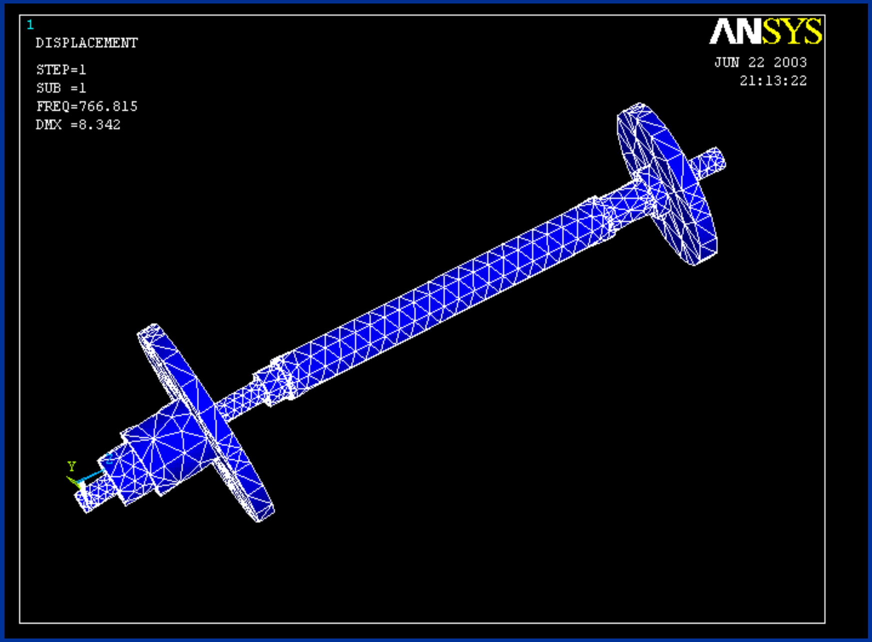


- The working range has a safe margin from the mode frequencies:
  - 25 per cent margin above
  - 30 per cent margin below

  the working range.

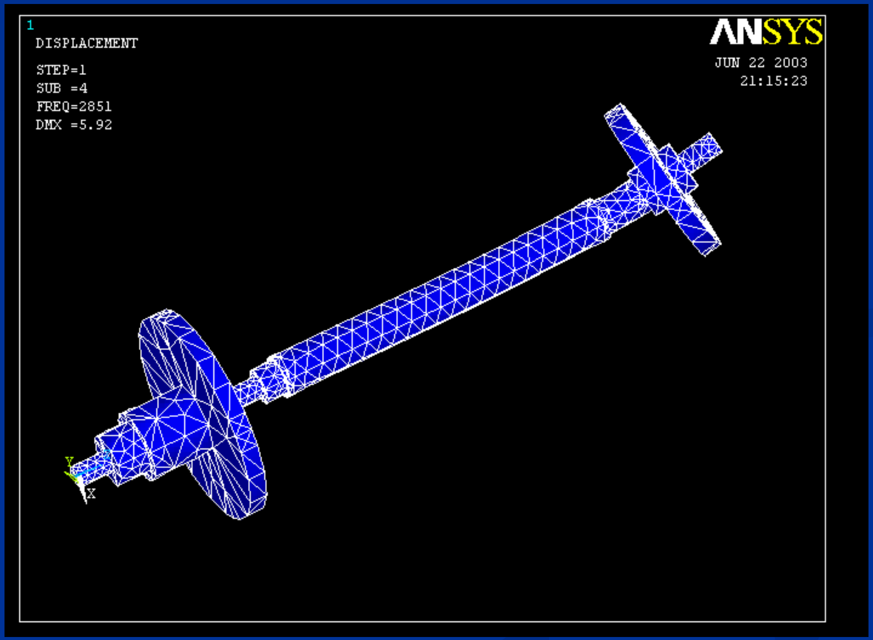
Shaft

- Mode Representation:



Mode 1

46000 RPM



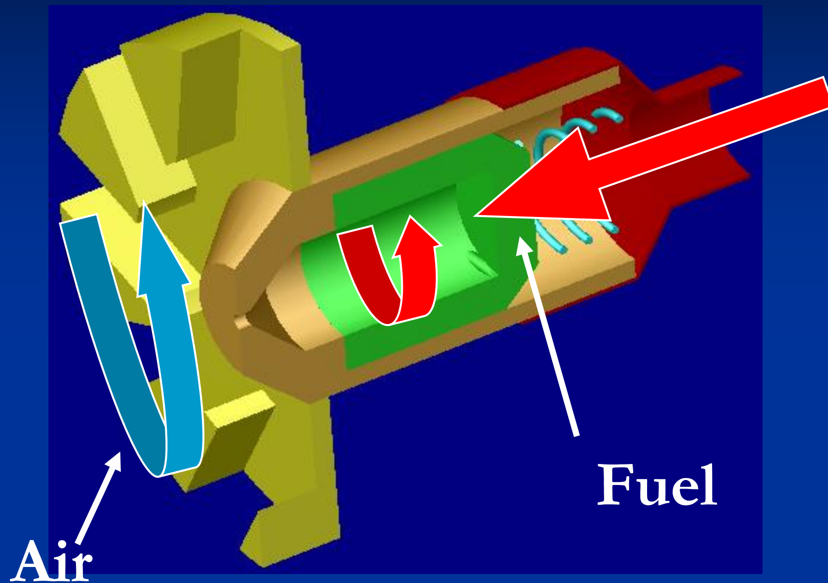
Mode 2

171000 RPM

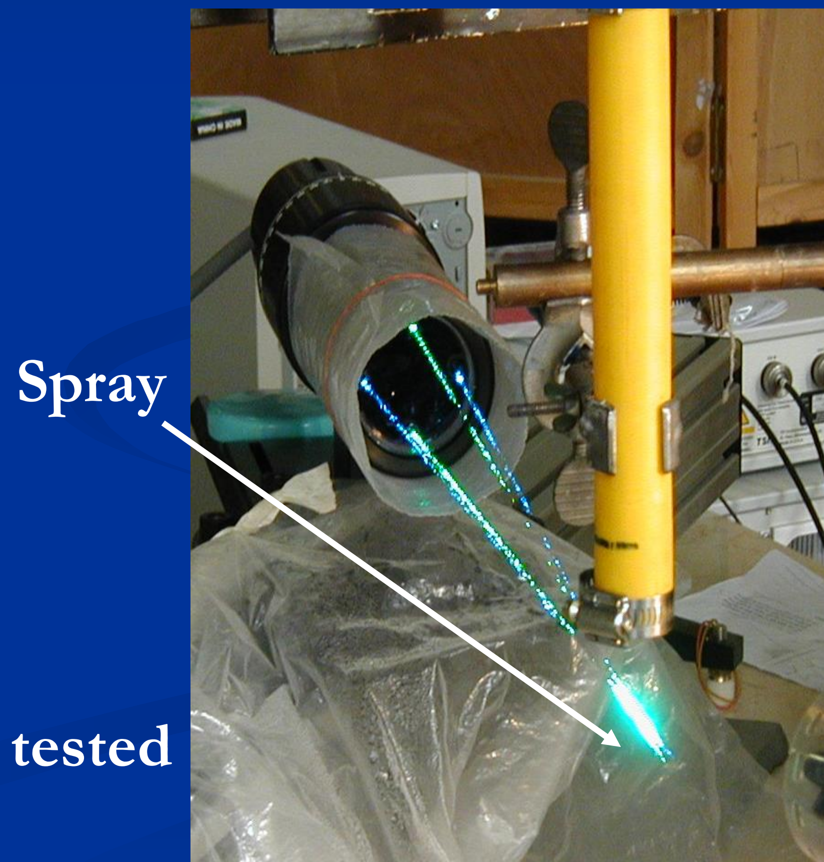
Combustion Chamber – Fuel System

- Preliminary calculations of annular combustion chamber
- Construction and testing different air-blast swirl atomizer experimental models
- Construction and testing a 1:6 model of the combustion chamber

Fuel System

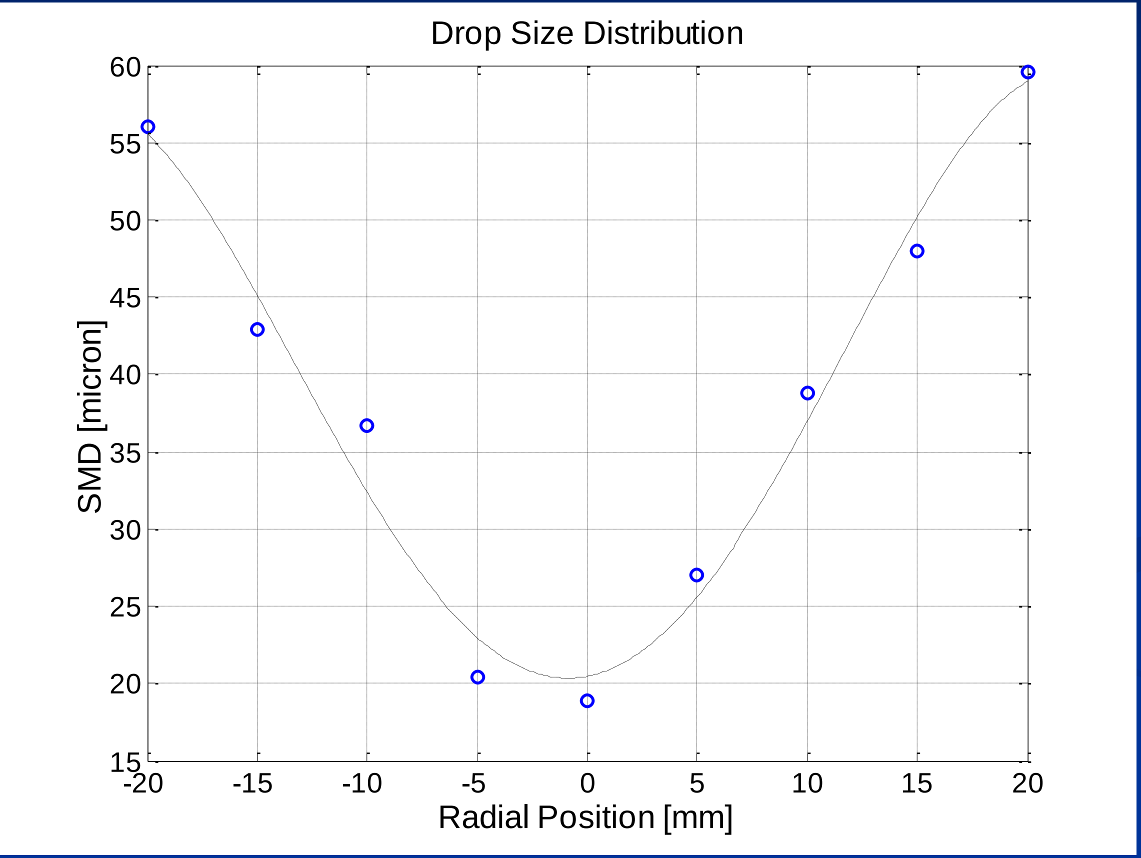


Phase Doppler Anemometry Measurement System



Two different types of swirlers were tested – co-rotating and counter-rotating.

Fuel System (cont.)

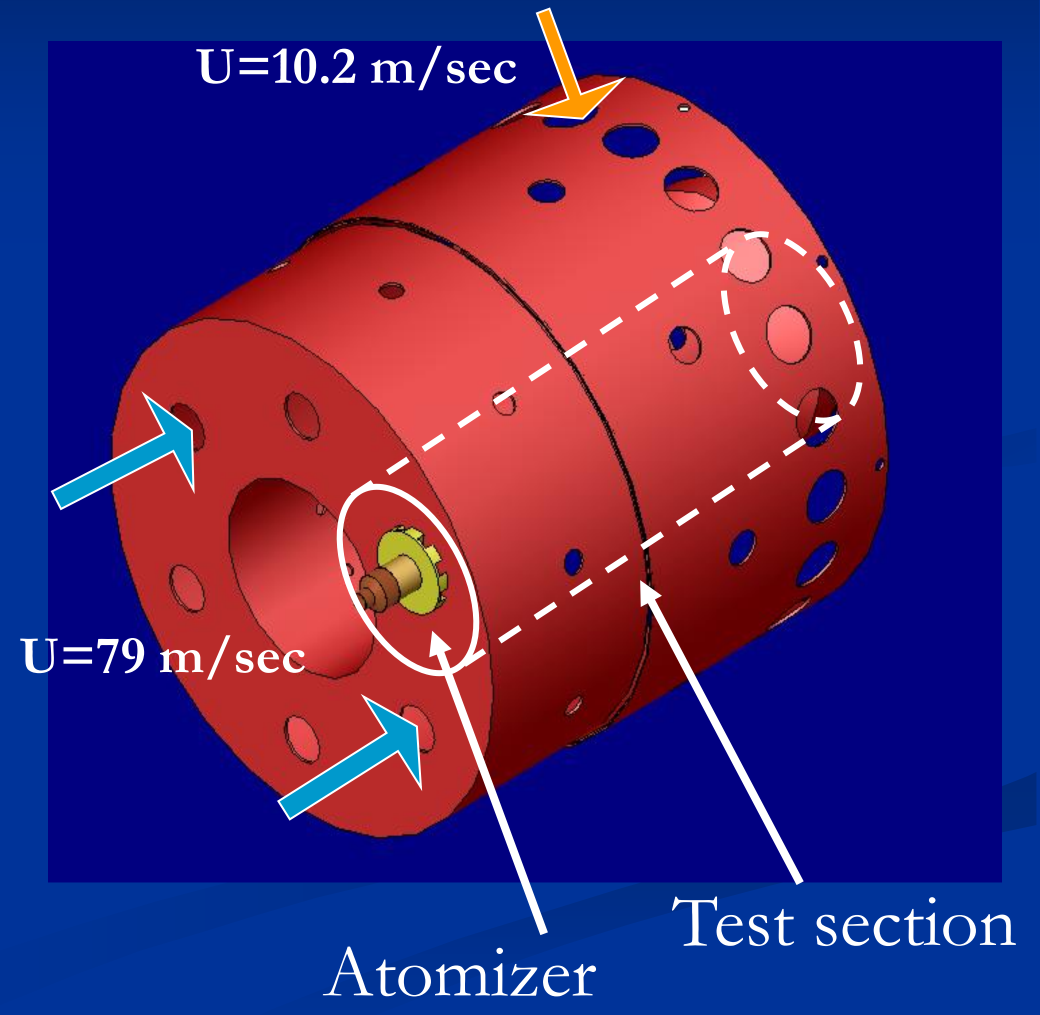


$$SMD = \frac{\sum_{i=1}^{n} d_i^3}{\sum_{i=1}^{n} d_i^2}$$

The system has a 7% possible uncertainty in determining drop size

Combustion Chamber

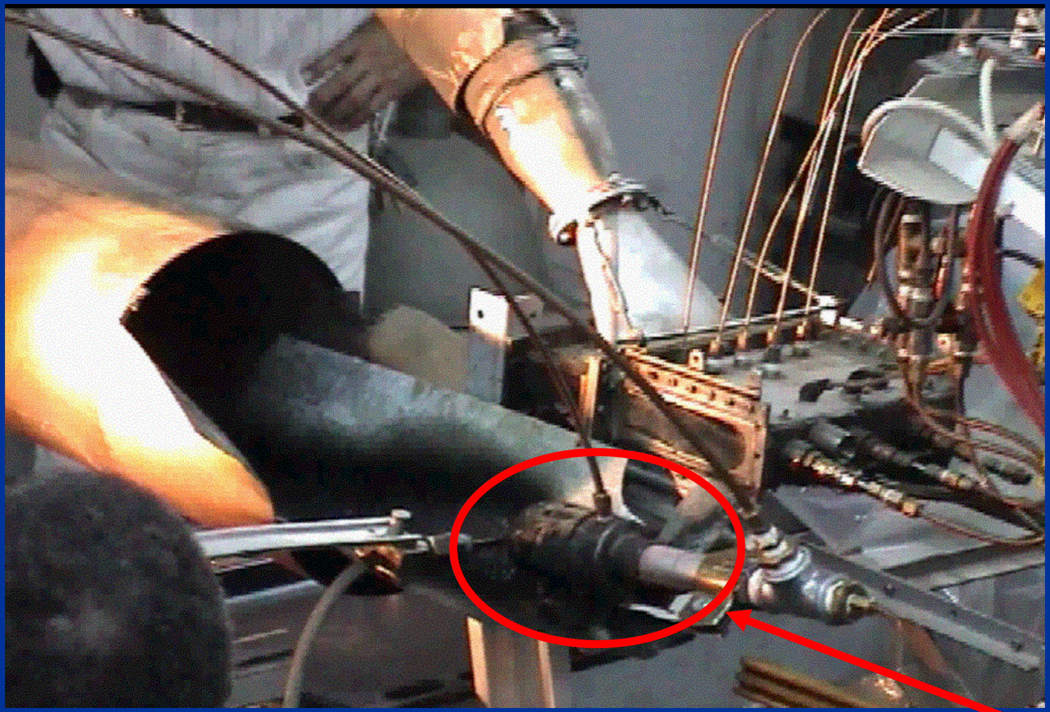
- Selection of combustion chamber geometrical design – Annular Straight Through Flow
- Converging into quantity and size of the hole pattern.



- Material – Inconell-713

Combustion Chamber (cont.)

- **Performing a burning test for the primary zone, including swirler.**



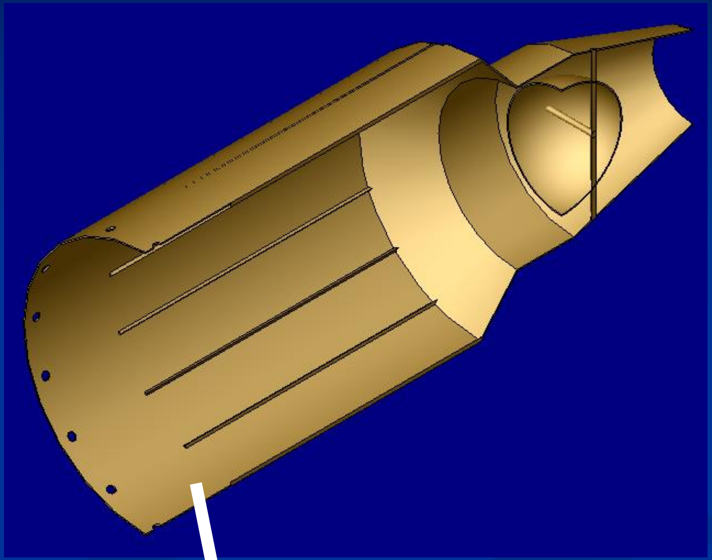
The experiment is here

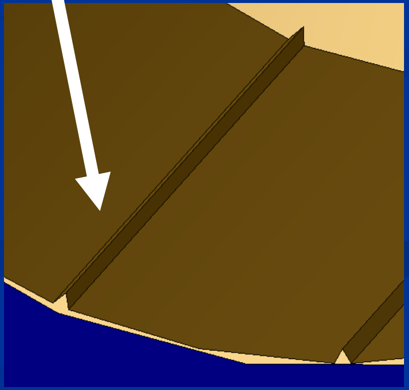
The tested model

Outer Casing – Nozzle

- Outer casing and nozzle designed as one integrated part as shown:

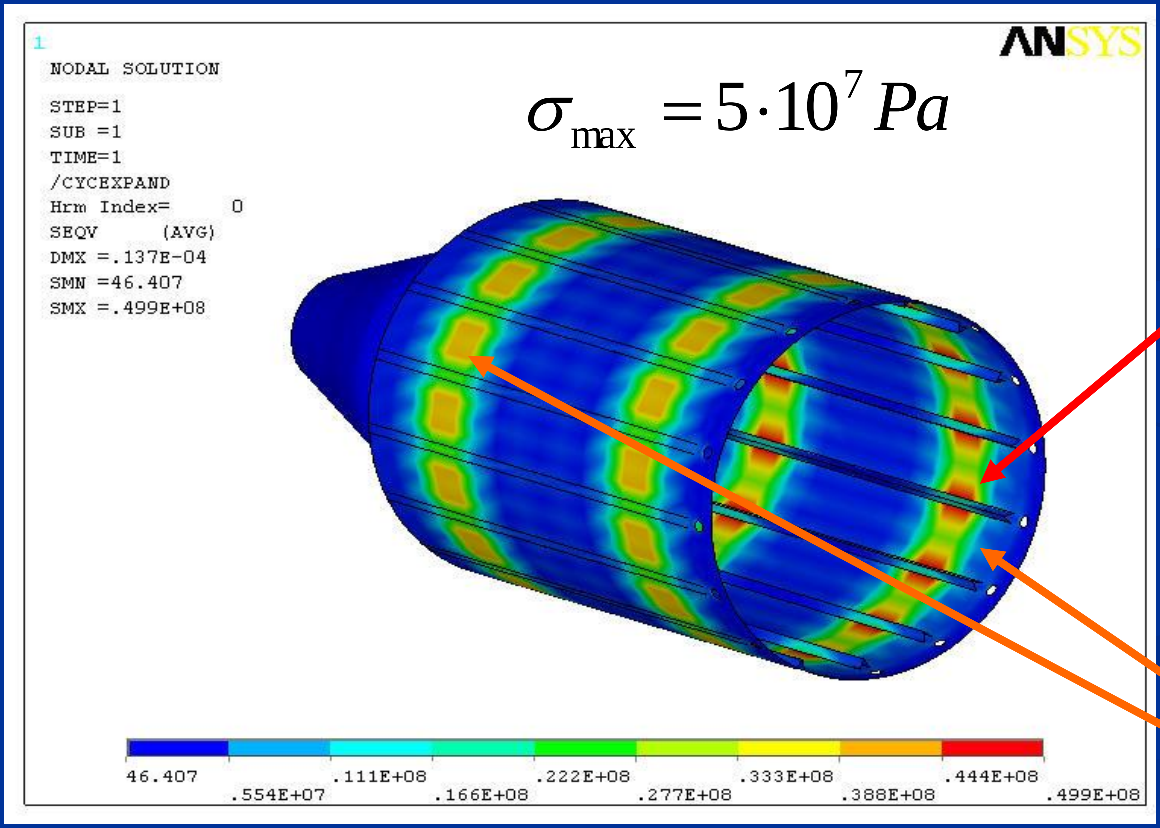
- Outer casing was strengthened by 16 spars in order to achieve required bending strength.





Outer Casing – Nozzle (cont.)

- FE analysis was performed on the spar configuration (30000 elements approximately)



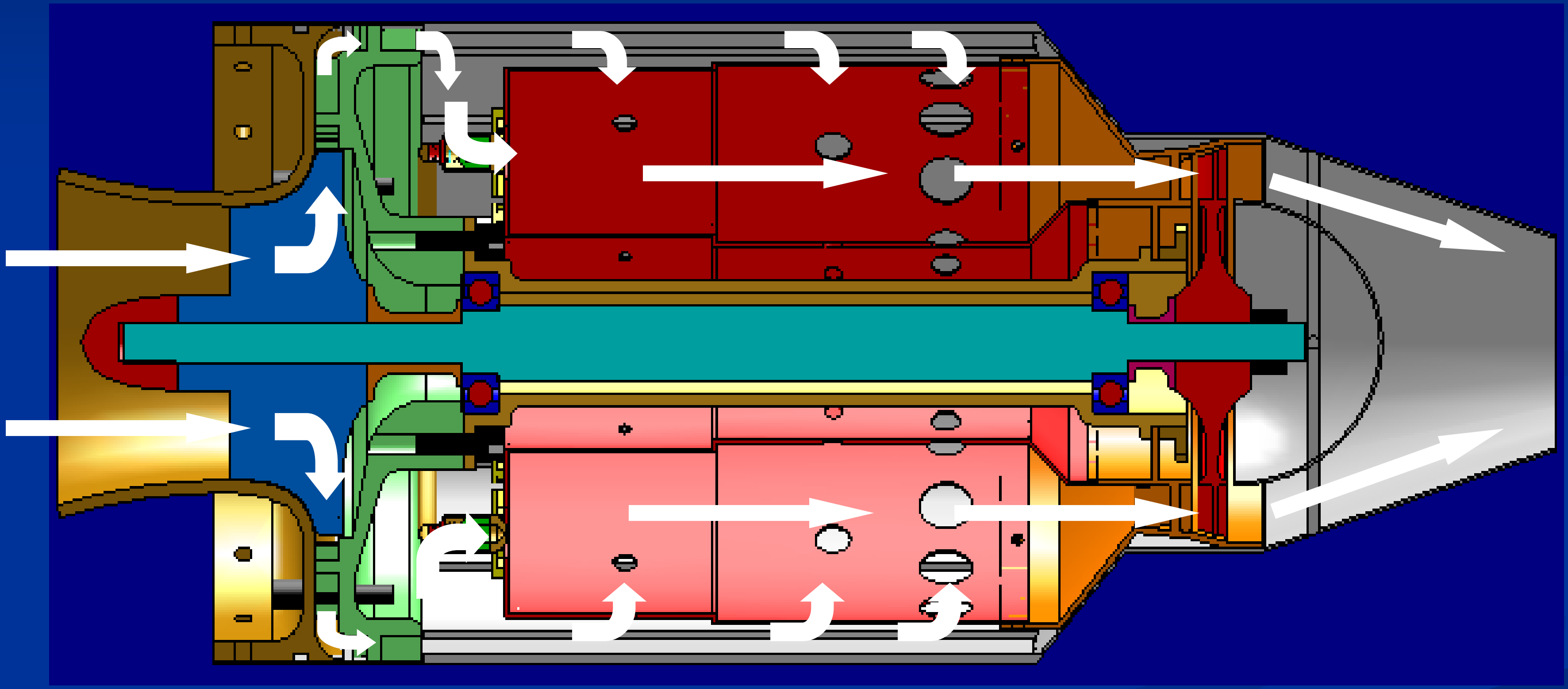
$$\sigma_{\max} = 5 \cdot 10^7\, Pa$$

$$\sigma_{yield} = 2.7 \cdot 10^8\, Pa$$

$$\sigma_{\max} < \sigma_{yield}$$

Effect of Holding Rings

Whole Engine Pictures



The air movement through the engine

Cost Estimation

The Part	Prototype Cost (US $)	Serial Production Cost (US $)
Intake	200	20
Impeller	46	46
Compressor Stator	770	77
Fuel System	220	100
Combustion Chamber	1200	200
Turbine Stator	4000	400
Turbine Rotor	4000	400
Casing and Nozzle	2000	200
Bearings (2 units)	105	105
Ignition System	100	100
Assembly & Balancing	800	100
Total	13400	1700

Summary

- The following engineering tools were used:
  - FE Analysis & CAD/CAM tools
  - Classical thermo and aerodynamics calculations
  - Generic combustion chamber calculations
  - Laser – Optic diagnostic system
  - A Lot Of Common Sense

- Approximately 90 % of calculations were completed
- About 40 % of parts were produced

Conclusions

- Jet Engine production is a field that require a lot of experience, but the first step was done
- Simple but innovative ignition/fuel supply system without the need for the preheat process
- Potential market for the product is wide

Acknowledgements :

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- Mr. Eli Cohen
- Mr. Yehoshua Niselevich
- Mr. Shoshan Prosper
- Mr. Dani Dudik

Questions???

CS-TRAER???

- C – Common
- S – Sense
- TR – Trial
- A – And
- ER - Error