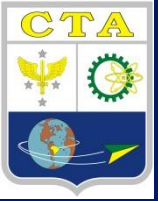


Nuclear Space Applications: A Brazilian View

Lamartine Nogueira Frutuoso Guimarães

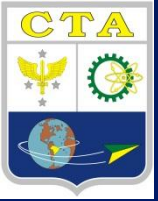
**Nuclear Energy Division
Institute for Advanced Studies
“Instituto de Estudos Avançados - IEAv”
guimarae@ieav.cta.br
lamartine.guimaraes@pq.cnpq.br
www.ieav.cta.br**

**To be presented at
The XVIII Meeting on Nuclear Reactor Physics and
Thermal Hydraulics (ENFIR)
Round Table
Recife, PE, Brazil, November 28th, 2013**



Overview

- **Institute for Advanced Studies – Brazil (3 slides)**
- **Graduate Program – PG-CTE (4 slides)**
- **Nuclear Energy Division (1 slide)**
- **TERRA Project – Historical and technical aspects (14 slides)**
- **Historic Meeting (1 slide)**
- **Where we want to go (2 slides)**
- **Conclusions (1 slide)**

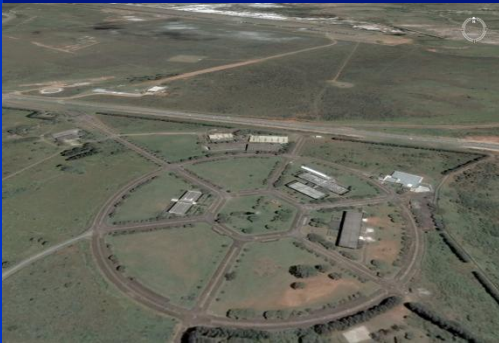


DEFENSE MINISTRY AERONAUTICS COMAND

Aerospace Science and Technology Department
Institute for Advanced Studies

IEAv:

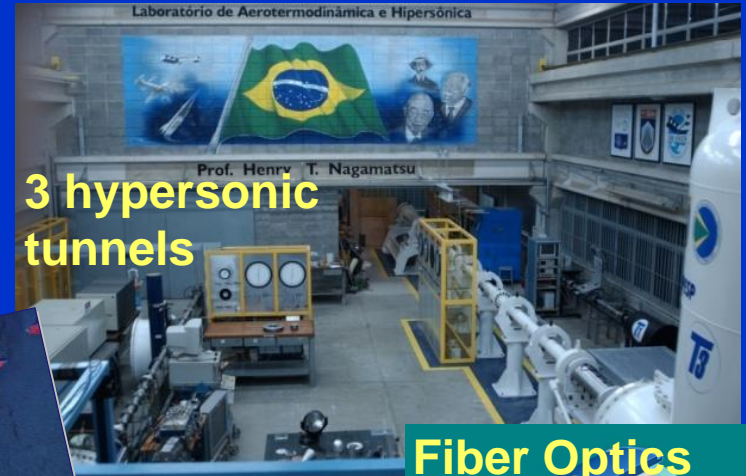
Innovative technologies for access to orbit and deep space



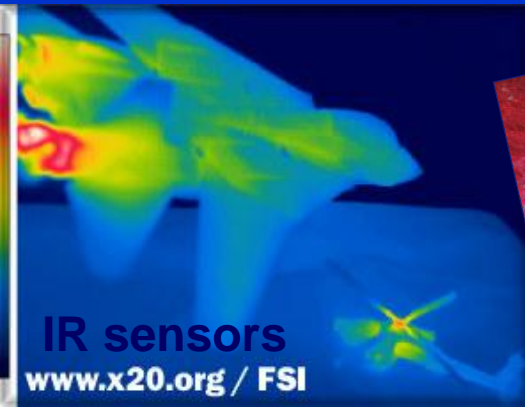
Cel Av Vilson, Eng PhD
IEAv's Director

IEAv

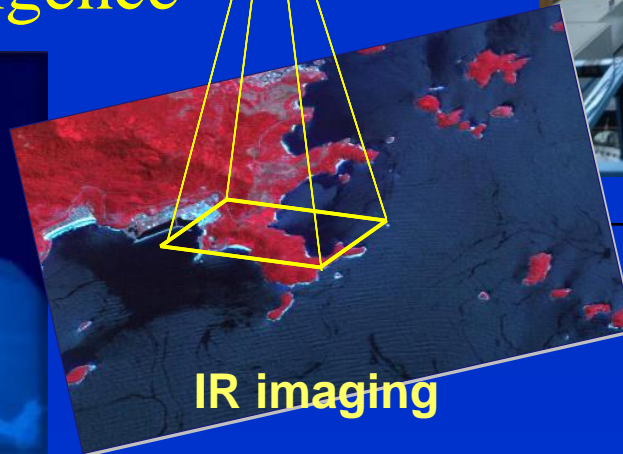
- Alternative technologies to provide access to space
 - Hypersonic
 - Lasers and its Applications
 - Sensors
 - Nuclear Energy
 - Geo-intelligence



3 hypersonic tunnels



IR sensors
www.x20.org / FSI



IR imaging

Fiber Optics
Gyroscopes





PG-CTE

- The Graduate Program in Space Sciences and Technologies was approved by CAPES at the Master and PhD levels.
- It started its activities on the 2012 first semester.
- The Program is a Partial IES Association (CAPES), which includes:
 - ❖ “Instituto Tecnológico de Aeronáutica” – ITA - main IES 
 - ❖ “Instituto de Aeronáutica e Espaço” - IAE 
 - ❖ “Instituto de Estudos Avançados” - IEAv 

The Program is connected to ITA, and its professors are researchers from all three Organizations. Also, all the labs and installations of all Organizations, such as libraries, room for students and classes, computational resources are available for this graduate program.



PG-CTE

**Large Area
Engineering III**

**Specific Area
Aerospace Engineering**

**Space Sciences
and Technologies
Program**

**Applied Physics
and Mathematics**

**Materials
Chemistry**

**Hypersonic
and Spatial
Propulsion**

**Space Sensors
and Actuators**

**Launchers
and Space
System Tests**



PG-CTE

www.posgrad.ita.br

http://www.ieav.cta.br/CPPG_IEAv/pg-cte.php

**You may have the money,
You may have the equipment,
If you do not have the Human Being,
Nothing gets done!!!**





Nuclear Energy Division Organization

- **Nuclear Energy Division**
 - **Neutronics and Shielding Subdivision**
 - ✓ Radiation Effects Laboratory
 - ✓ Nuclear Technology Computational Lab.
 - **Nuclear Data Subdivision**
 - **Heat Transfer and Materials Subdivision**
 - ✓ Heat Pipe Laboratory (Viviane H.T.R. Hirdes)
 - ✓ Thermal Systems Laboratory

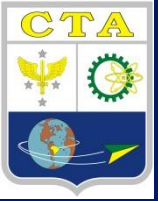


TERRA Project

TERRA – “TEcnologia de Reatores Rápidos Avançados”

Advanced Fast Reactor Technology

- Long term objective: research key technologies for advanced fast micro reactors, for space and for special terrestrial applications.
- Medium term objective: establish advanced fast micro reactor concept to generate heat and electrical energy for isolated locations and inhospitable situations.
- Short term objectives:
 1. Develop and built a closed Brayton Cycle, to evaluate the thermal cycle technology to be used as a conversion system to balance a plant for a micro nuclear reactor;
 2. Computational analysis to define the nuclear fuel types and enrichments, the geometrical forms and the components of an advanced fast micro nuclear reactor core;
 3. Identify R&D needs for an electric generation system based on advanced nuclear reactor technology;
 4. Develop and built heat pipe systems to be used as a passive system for a passive heat conduction and rejection system; and
 5. Coupling the developed closed Brayton Cycle with the developed heat pipe ensemble.



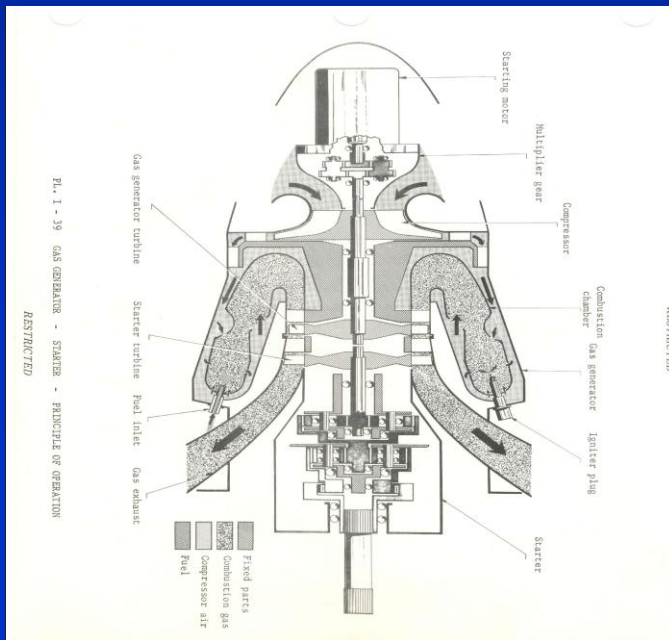
TERRA Project Interests

- Brayton Cycles
- Computer Simulations and Calculations
- Passive multi-fluid turbines (TESLA)
- Stirling engines
- Heat Pipe
- Fast Reactor Micro cores

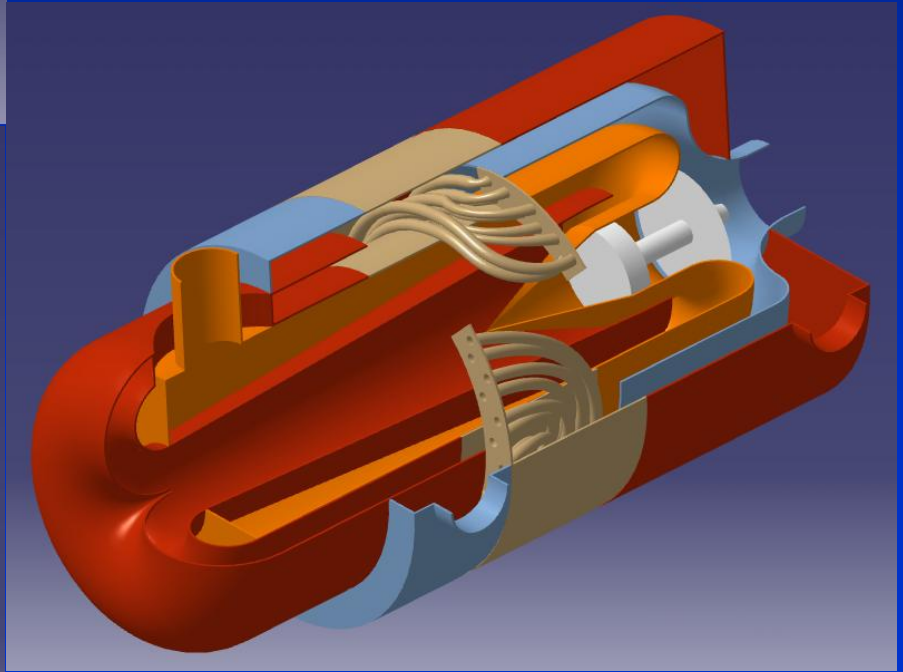
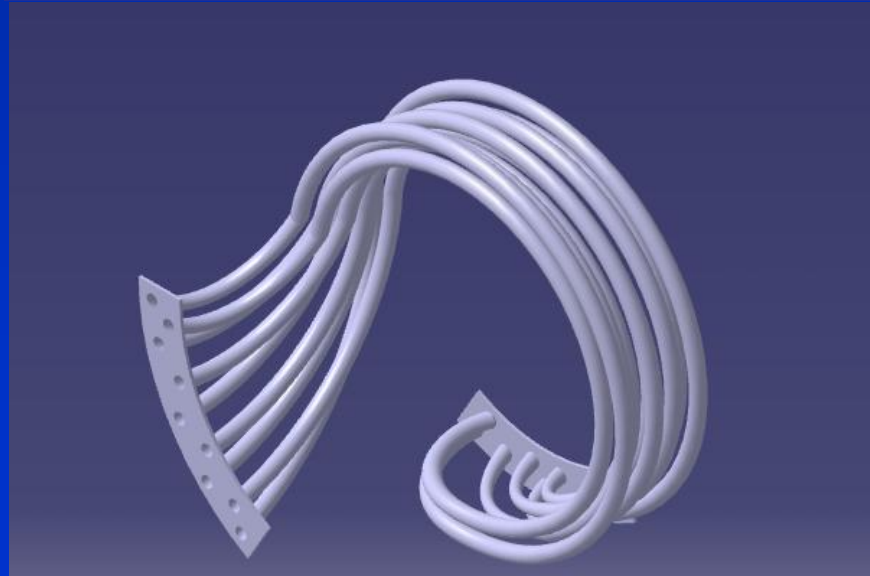
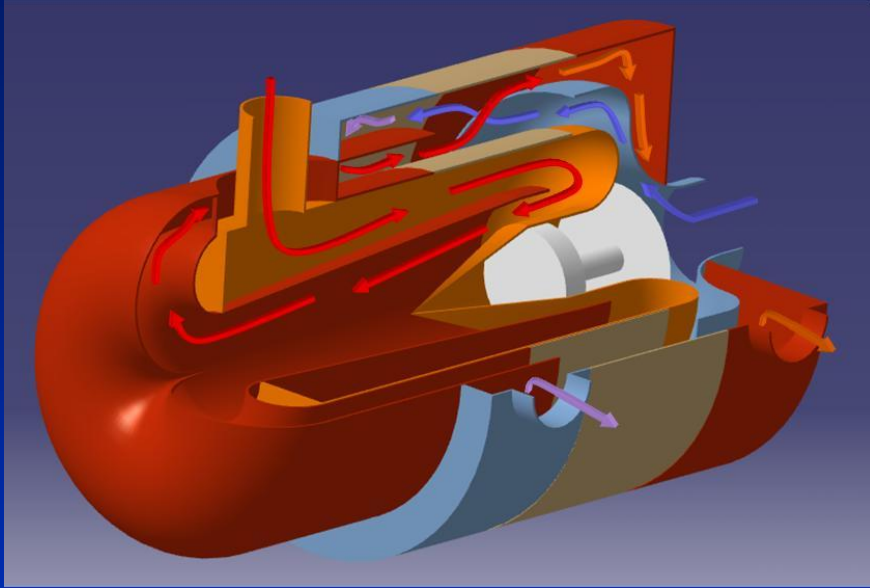
NOELLE 60290 schematic and disassembling

Disassembling the micro turbo allowed great understanding of its internal parts and workings. Which allowed its re-design to be used in a closed circuit.

NOELLE 60290 schematic drawing extracted from the maintenance manual.

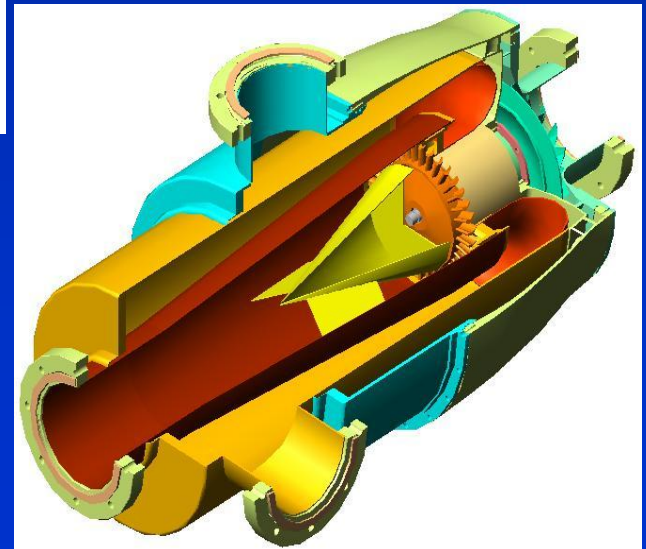
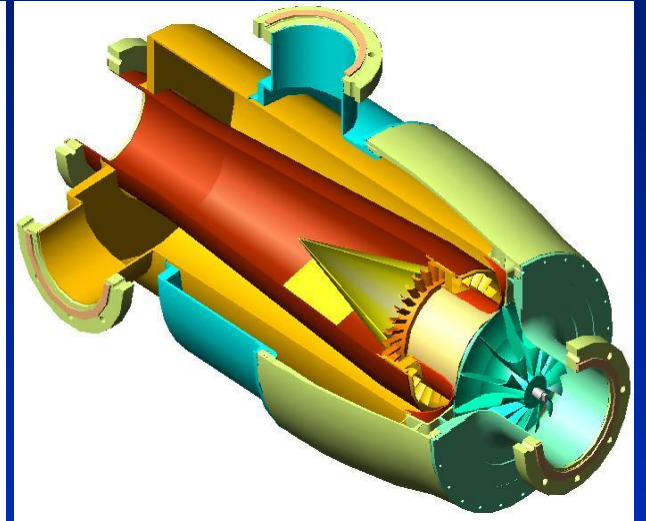
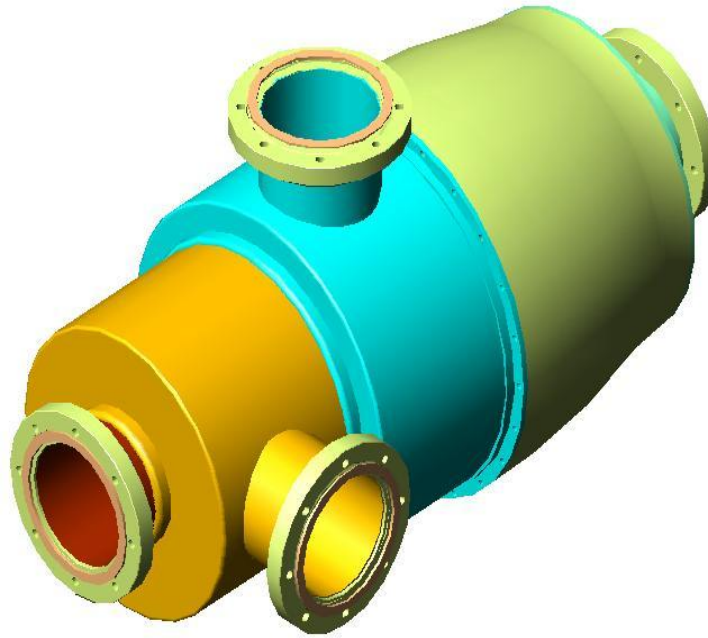
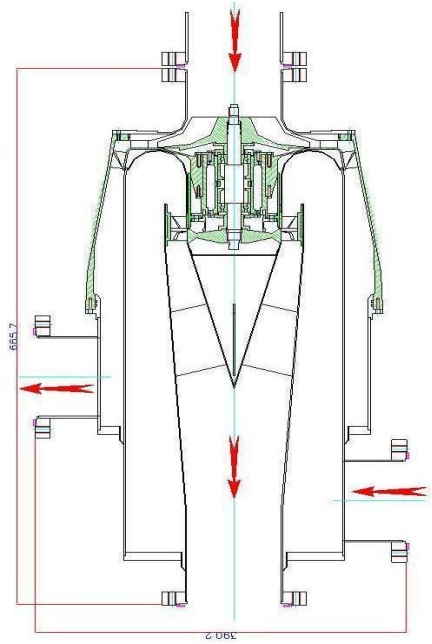


NOELLE 60290 first ideas



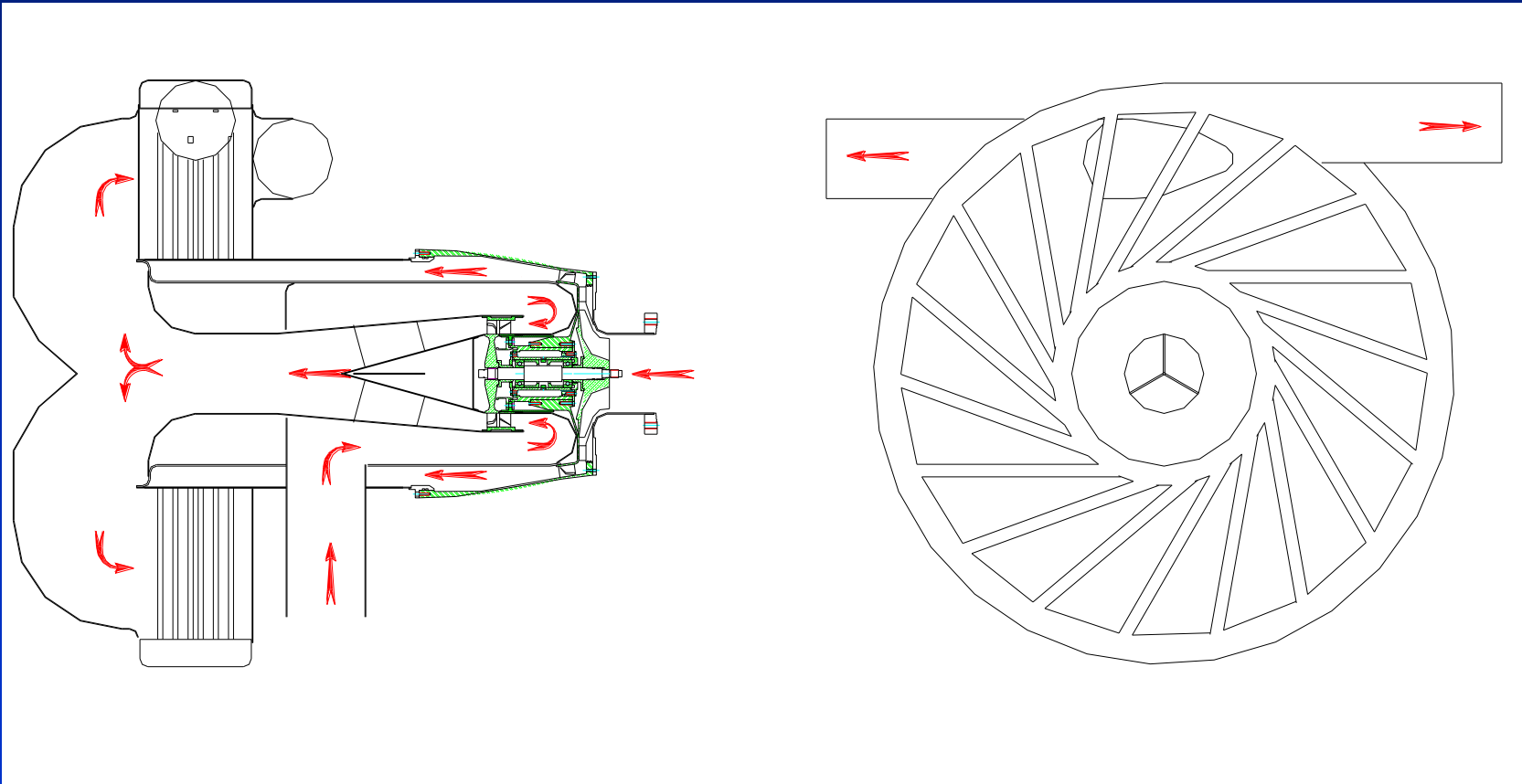
NOELLE 60290 first ideas

Re-visited.



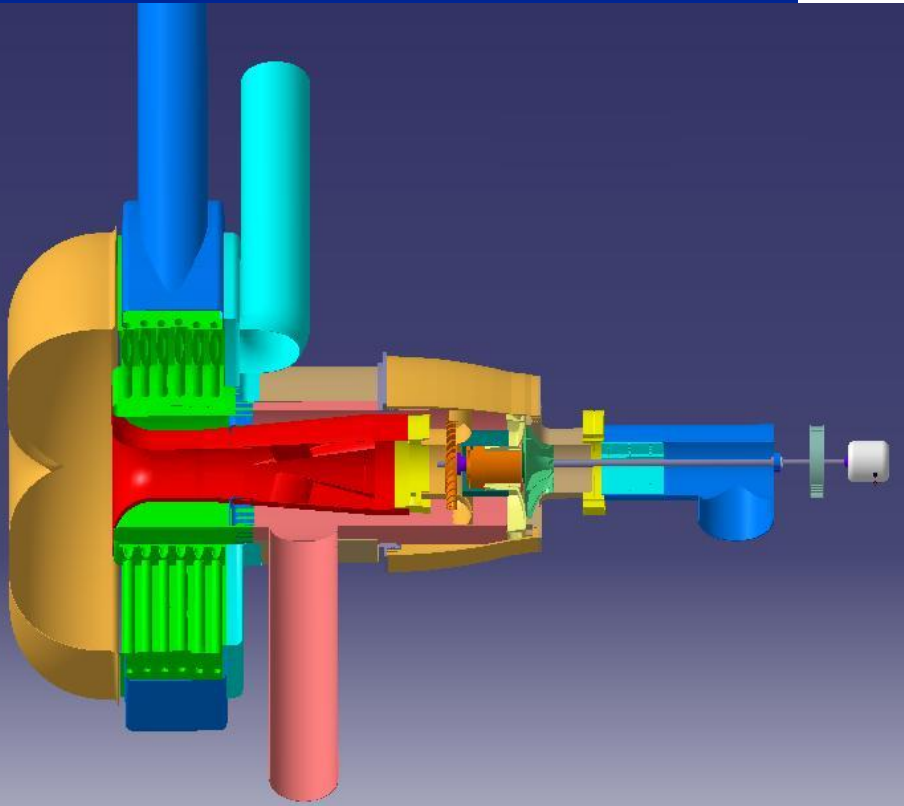
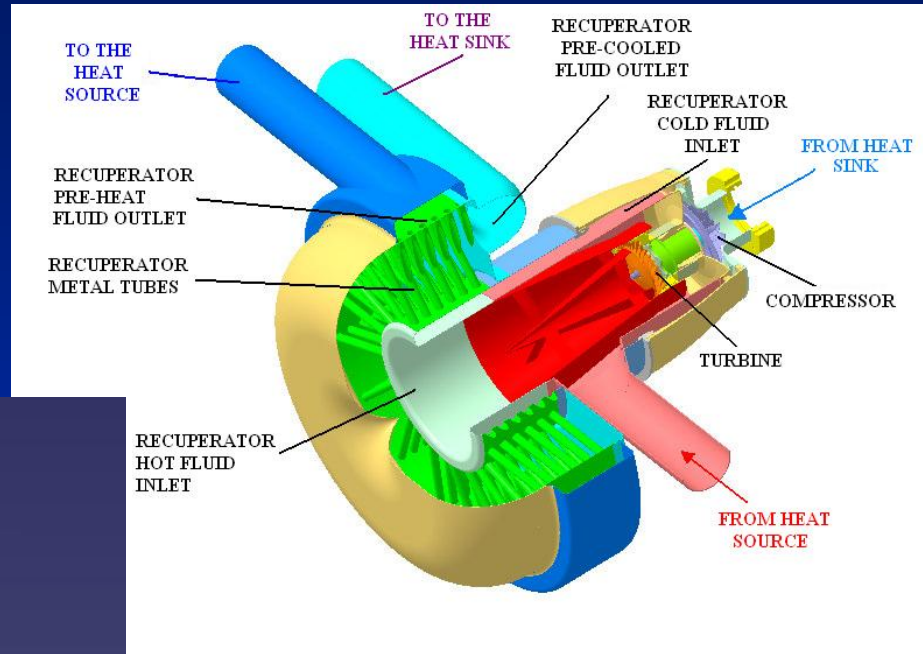
NOELLE 60290 second ideas

Planar Vision re-drawing and including the recuperator at the NOELLE 60290.

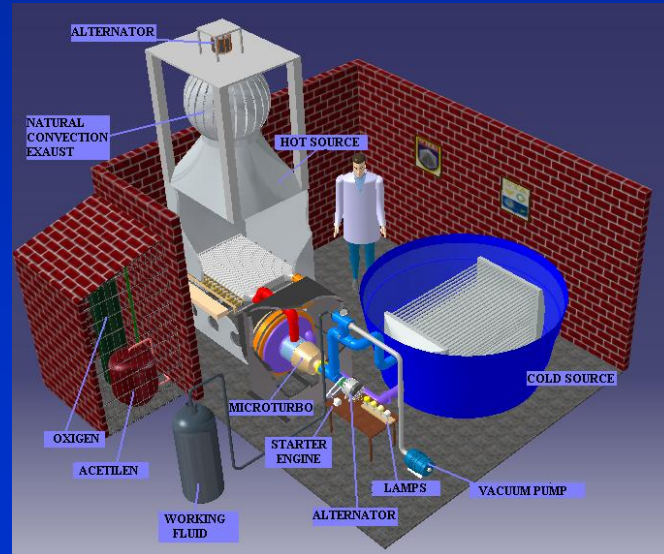
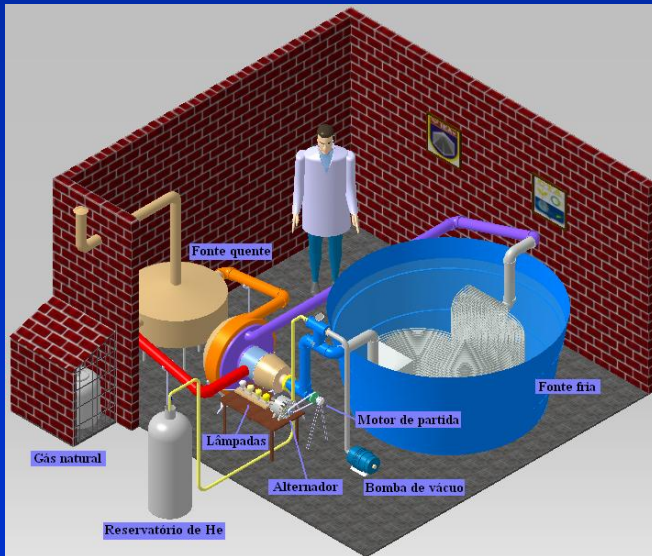
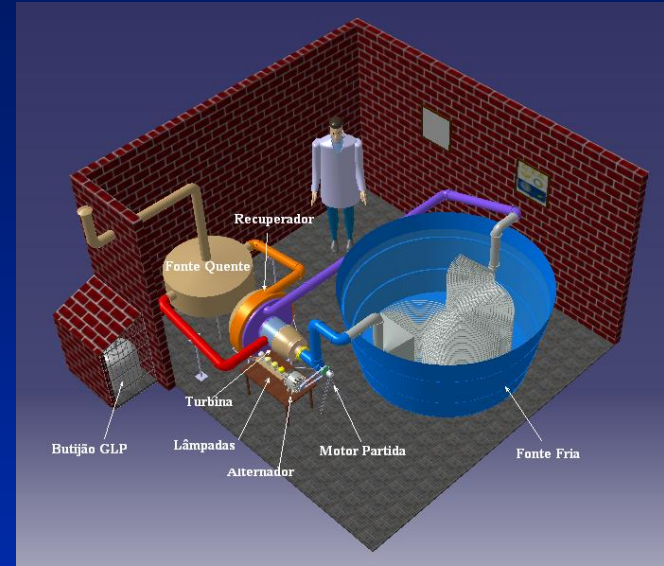
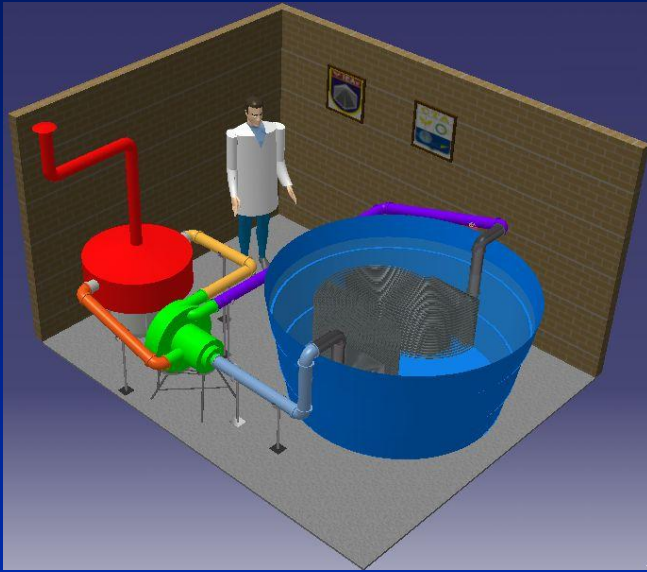


Re-Designed NOELLE 60290

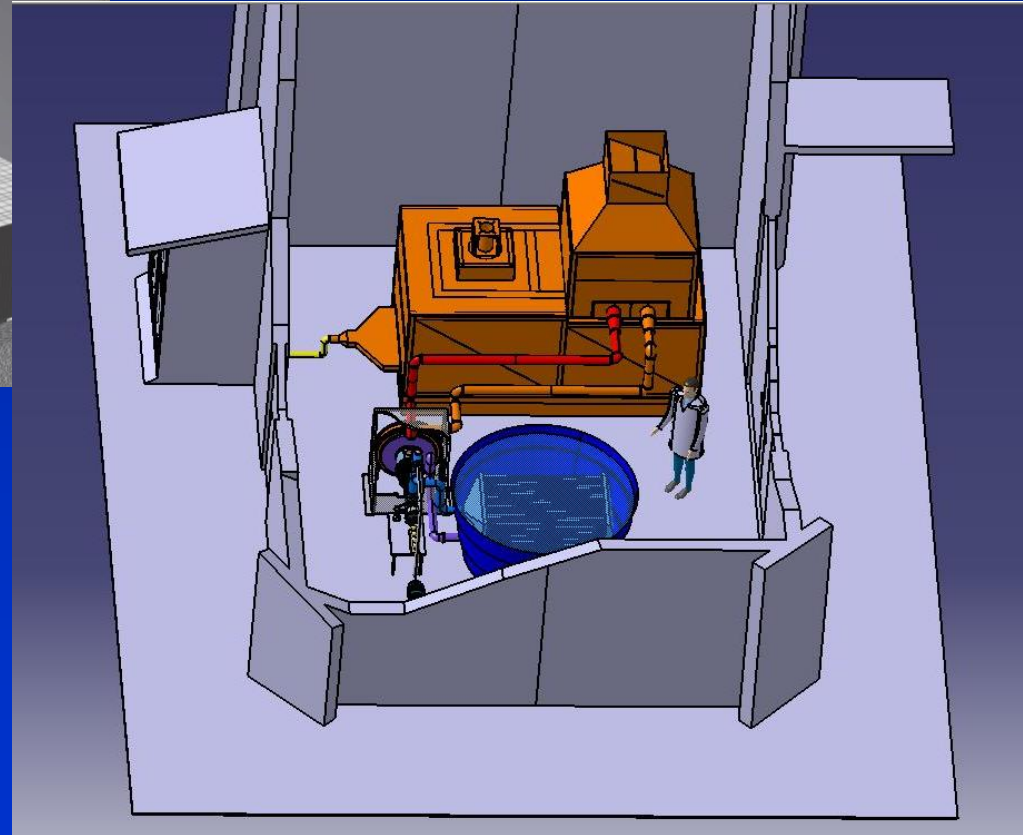
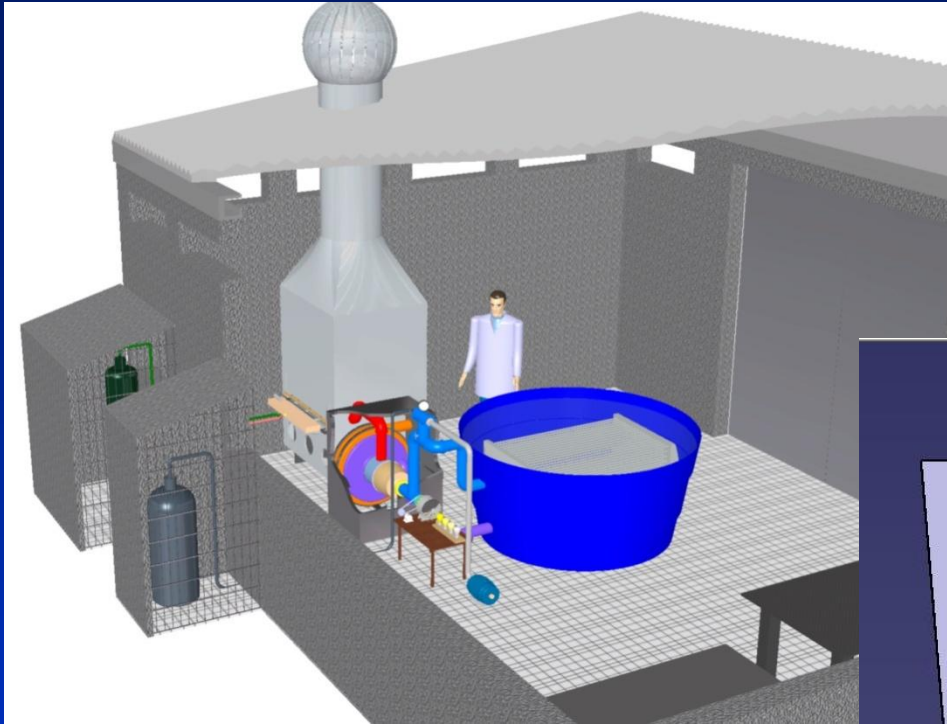
✓ The actual parts of the NOELLE 60290 are in the back part of the this figure.



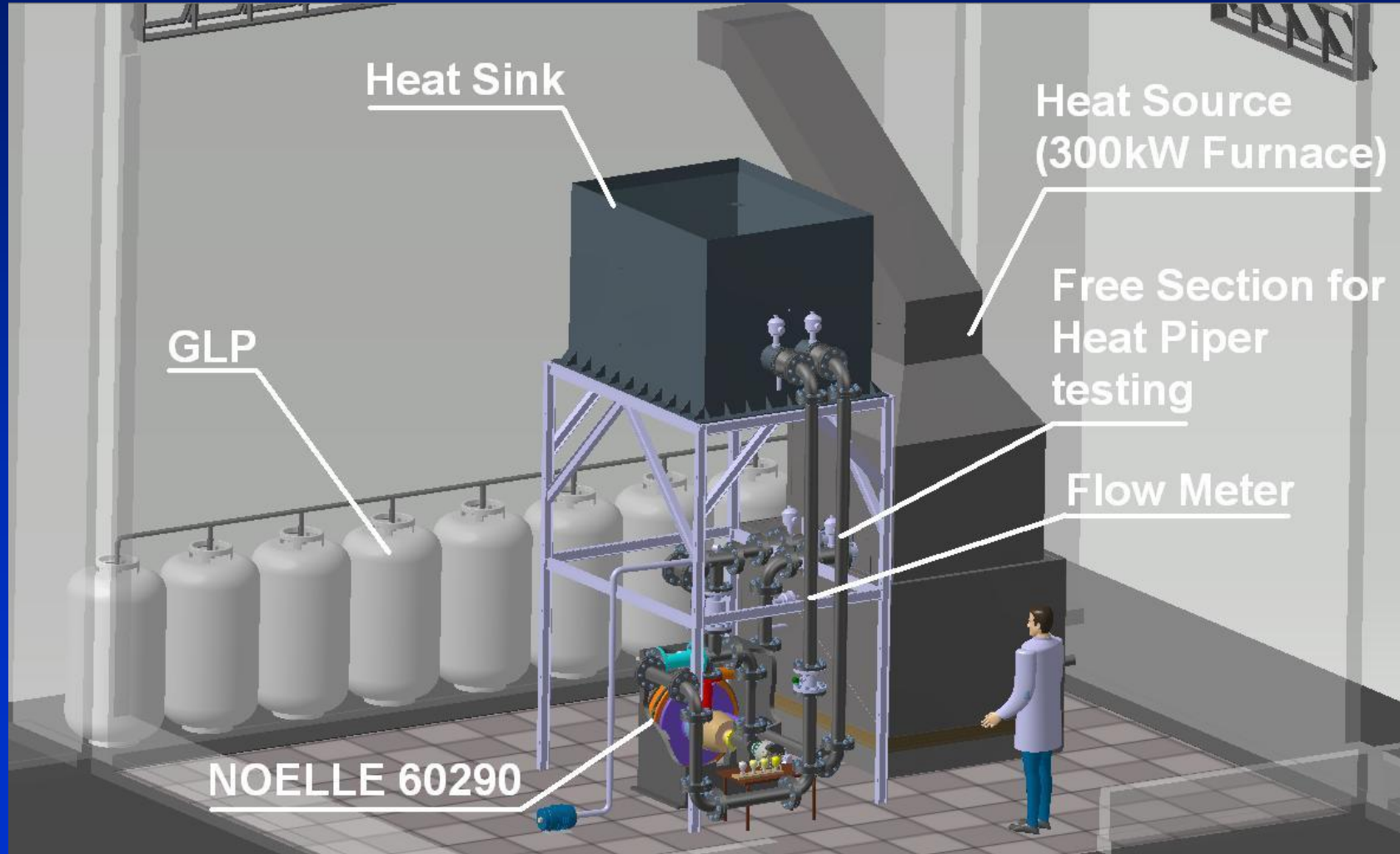
How was the Brayton Cycle imagined.



How was the Brayton Cycle imagined.



Brayton Loop latest design

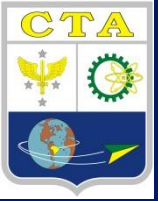




Simulation and computer design

Nuclear Technology Computational Laboratory.





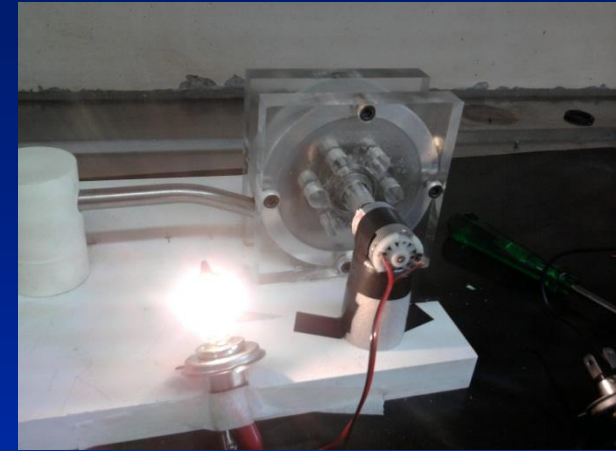
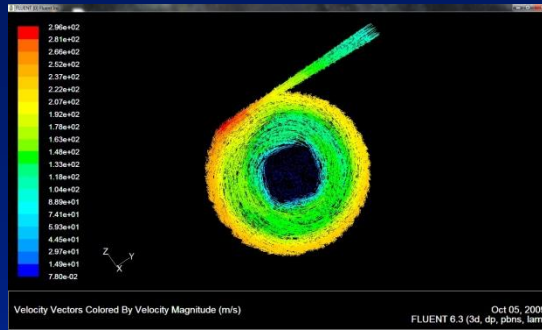
Simulation and computer design

Nuclear Technology Computational Laboratory.

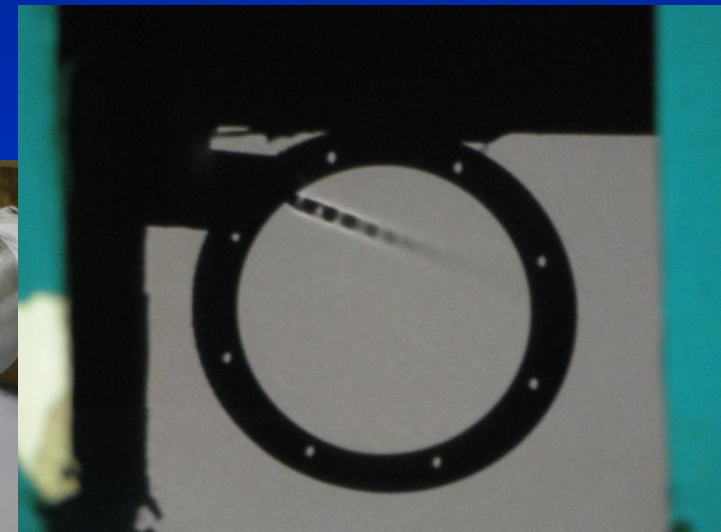
- All the CAD/CAE produced for this presentation were made with CATIA.
- Neutronic calculation scheme for fuel and core design of a space nuclear reactor.
- Code modernization:
 - ✓ NALAP (RELAP 3B for Na).
 - ✓ ANISIN-BR.
- Code available:
 - ✓ RELAP5-3D
 - ✓ FLUENT
- Computer graphic interfaces to ease up the design and simulation work.
- Continuing simulation of liquid metal pumps.

Passive Multi-fluid Turbine

Tesla turbine as an alternative to the modified NOELLE 60290.



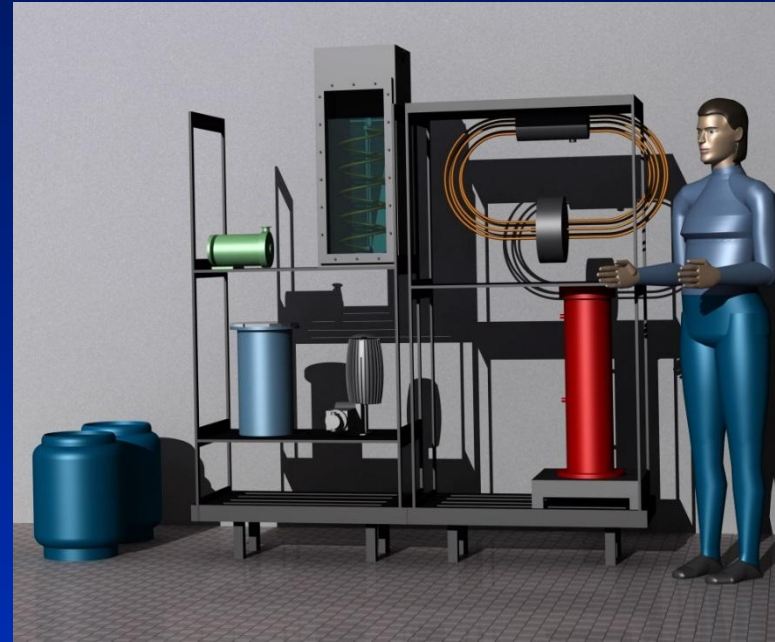
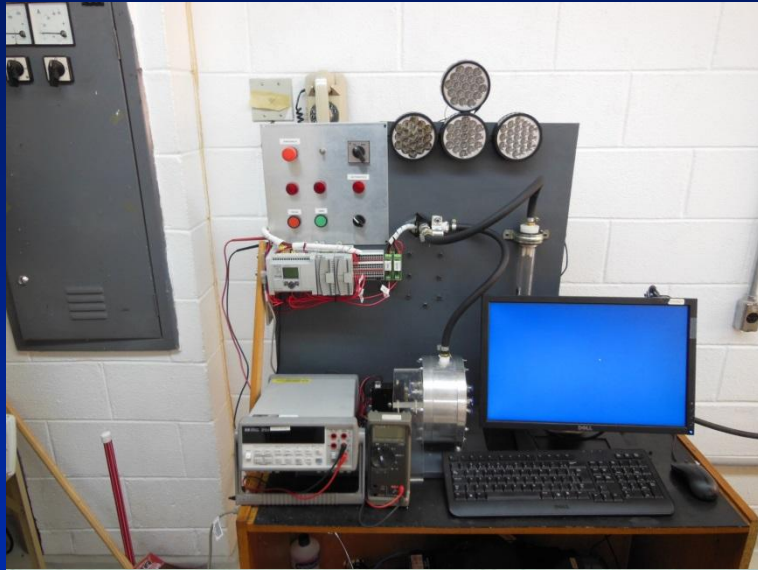
Light bulb from a car head light 55W.

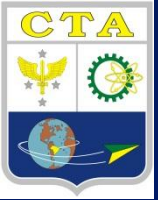


Schlieren Visualization

New Tesla turbine made of Stainless Steel at IEAv, reached 65,000 RPM.

Passive Multi-fluid Turbine

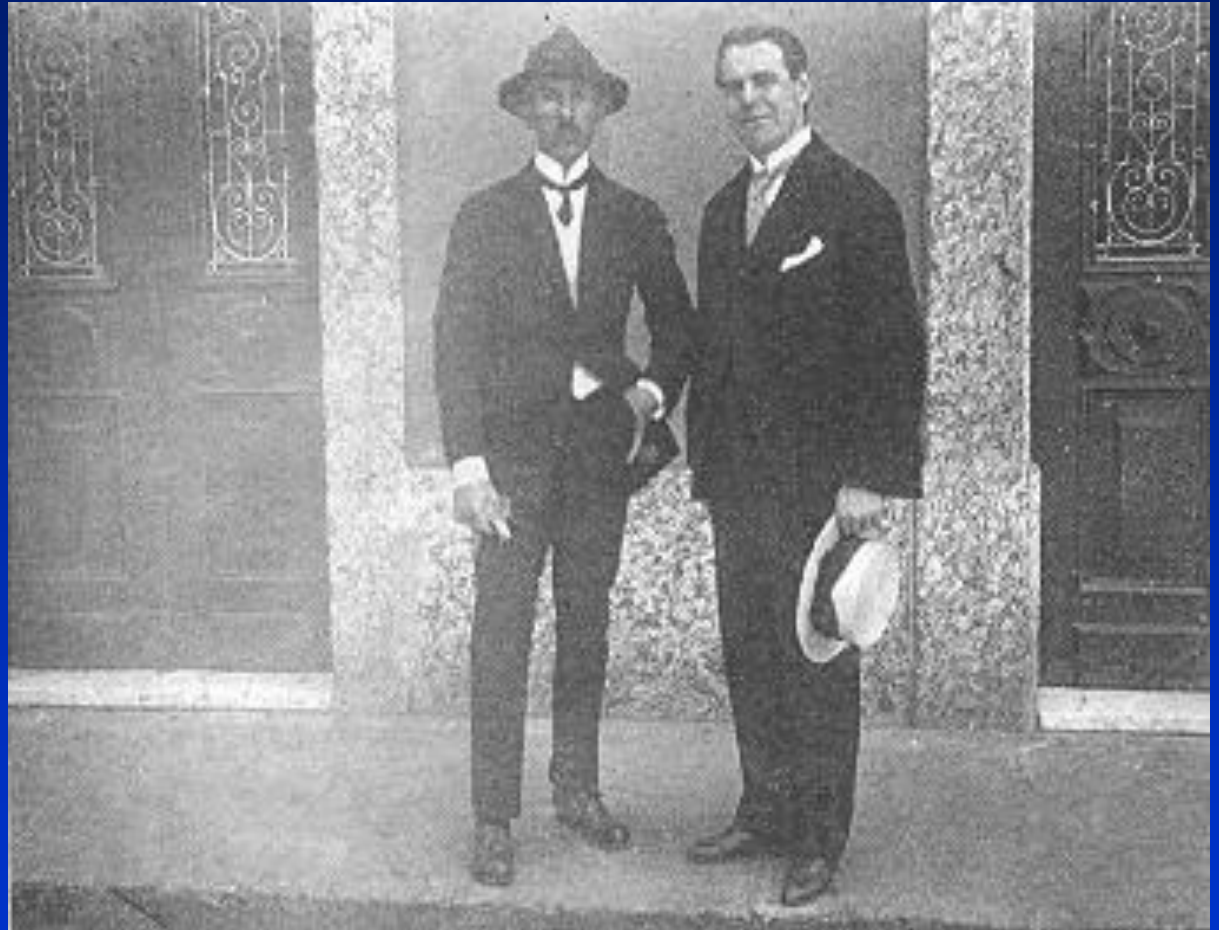




Historic Meeting

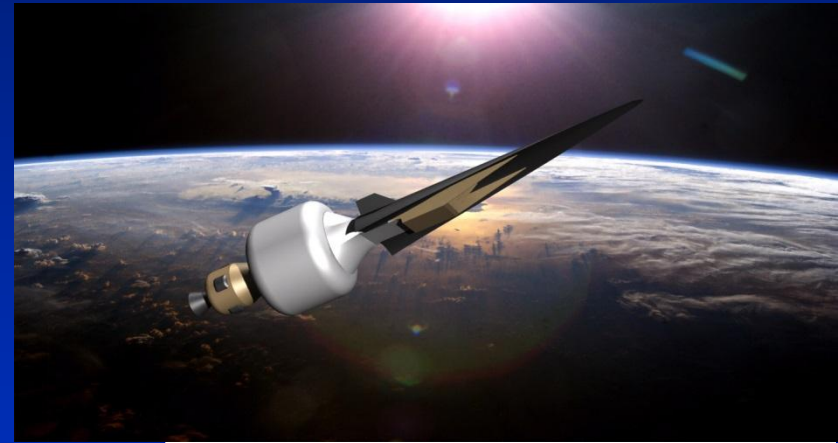
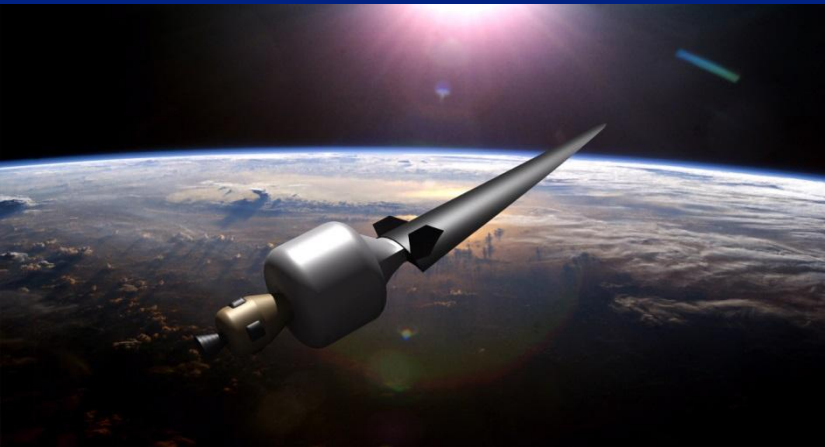
Santos Dumont with Álvaro Alberto, in 12 of November of 1918

This meeting is more than a historic chance event. It is the zero mark for the Brazilian nuclear space propulsion research program.



(de João Carlos Vitor Garcia, Álvaro Alberto – A Ciência do Brasil)

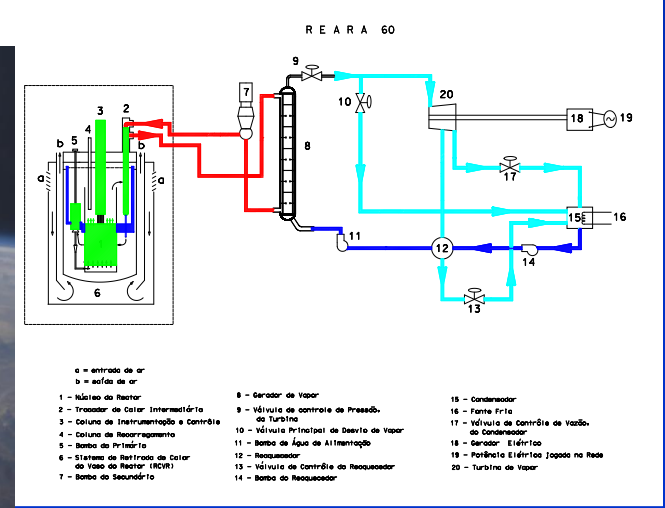
Where we want to go!

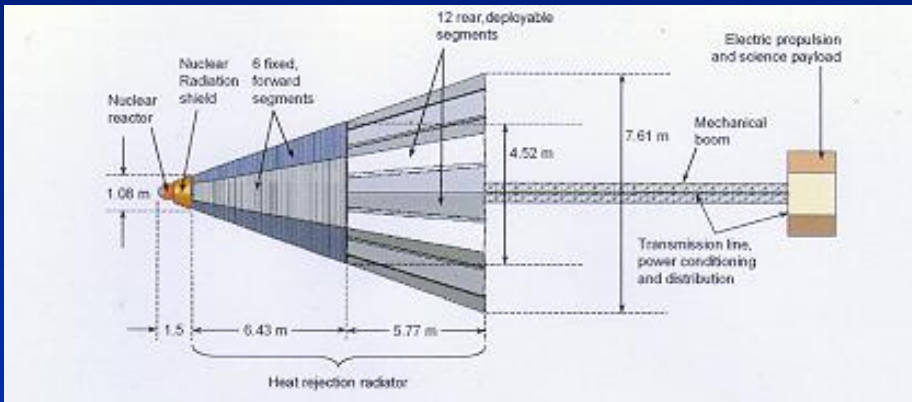
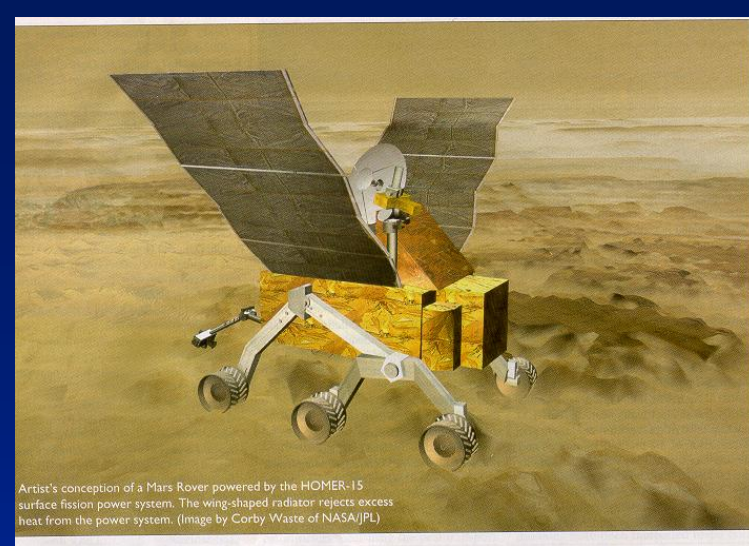
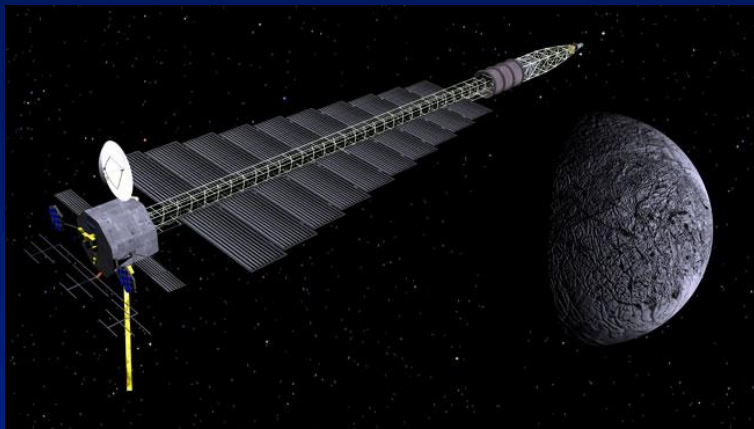


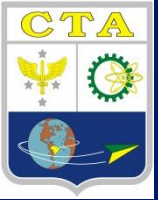
REBOCADORES NUCLEARES BRASILEIROS, LIMPANDO AS ÓRBITAS ESPACIAIS BRASILEIRAS



PROPULSÃO NUCLEAR ESPACIAL
ASAS BRASILEIRAS NO ESPAÇO SIDERAL







Conclusions

- **Preparing Human Resources is considered paramount for the idea of Space Exploration. Hence, the IEAv and its graduate program PG-CTE.**
- **Development products is in the essence of the TERRA project.**
- **The first great example is the passive multi purpose turbine.**
- **The TERRA Project, at this moment, does not have a specific long term timetable for development, its intent is to explore and provide options for the future (of Brazilian Space exploration).**
- **At the inception of this project, it was said, that one “not listed” objective was to be prepared to joint an International Effort for Human Space exploration. It seams that this opportunity is just around the corner “The MEGAHIT workshop”, which will be held next week in Brussels, Belgium.**