# ERSEUS

## **HADES** Project

Design and optimization of space launch systems

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## Context

- CNES
- French Space Agency
- PERSEUS

European Student Project of Science and Research in Space Launch Vehicle

 HADES Help on Advanced launcher DESign

Open project of pedagogic and innovative tool for global sizing and optimisation of space launcher concepts:

- Centralize and develop preliminary design codes
- Improve the efficiency of engineer by achieving best solutions
- Bring users to space vehicles' domain and teach them how to preliminary design

Currently involved: CNES, Bertin, SIREHNA/ESTECO, IRRCyN, ONERA, INSA Lyon, etc.

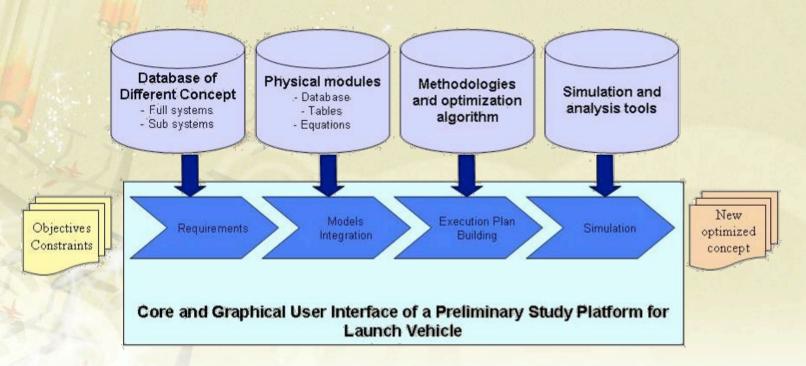
## HADES platform (1)

HADES is a software platform to perform feasibility design of space transportation systems and is intended to students and engineers

General objectives:

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- To design and evaluate launcher, stage or sub-system concepts
- To perform comparative and parametric analysis



## **ERSEUS** HADES platform (2)

#### **Design approach:**

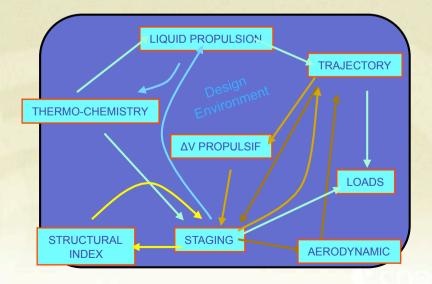
- Use elementary tools dedicated to preliminary design: simple, fast and robust
- Offer a quick estimation of launcher characteristics from basic choices
- Apply MDO to manage and optimize the design process

1st study case: Expendable Launch Vehicle preliminary design system loop Find the most effective launch system for recurring cost and/or

Find the most effective launch system for recurring cost and/o performance

pject Study Execution's plan Modules Tools Frames H		, , , ,			
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Study's management	🖌 🛃 Data's manag	ement (235/296 d	ata shown)		
ICARUS (of type : study)	idOwner	name	type	value	convertUni
- 🛅 Optimisation (of type : optimization)	Etage 1	Coef_Debit	coefficient	1.0	none
<ul> <li>C5G Kourou (of type : launchBase)</li> </ul>	ICARUS	Coef_ISP	coefficient	1.0	none
🛛 🧰 Mission de reference (of type : mission)	Etage 2	Cz	coefficient	0.0	none
<ul> <li>Terre (of type : astre)</li> </ul>	Etage 3	Cz	coefficient	0.0	none
<ul> <li>Orbite LEO (of type : orbit)</li> </ul>	Etage 2	Cx	coefficient	0.0	none
Charge Utile (of type : payload)	Etage 3	Cx	coefficient	0.0	none
🛛 🧀 NanoLanceur (of type : launcher)	Etage 3	index	coefficient	3.0	none
😑 🍋 Etage 1 (of type : stage)	Etage 2	index	coefficient	2.0	none
<ul> <li>Module 1B (of type : propulsionSystem)</li> </ul>	ICARUS	tf	time	342.0	second
😑 🇀 Module 1A (of type : propulsionSystem)	Options optimisation	TolCon	coefficient	1.0E-6	none
Structure module 1A (of type : structure)	Discretization elem	tf	time	106.25	second
<ul> <li>reservoir LOX 1A (of type : tank)</li> </ul>	Etage 1	Cz	coefficient	0.0	none
😑 🧰 Moteur Hybride 1A (of type : motor)	ICARUS	TolCon	coefficient	1.0E-6	none
<ul> <li>Turbopompe (of type : turbopump)</li> </ul>	Discretization elem	tf	time	1043.0	second
<ul> <li>tuyauteries module 1 (of type : pipes)</li> </ul>	Flight phase 9	index	coefficient	9.0	none
tuyère sol (of type : nozzle)	Moteur Hybride 2	rmi	fakeType	2.0	fakeUnit
<ul> <li>Generateur de gaz hybride (of type : gasGenerato</li> </ul>	r) Moteur Hybride 3	rmi	fakeType	2.0	fakeUnit
<ul> <li>injecteurs (of type : injector)</li> </ul>	Etage 1	Cx	coefficient	0.3	none
<ul> <li>Chambre de combustion 1 (of type : chamber)</li> </ul>	Discretization elem	tf	time	10.0	second
😑 🚞 Etage 2 (of type : stage)	Discretization elem	ť	time	11.0	second
<ul> <li>Reservoir de pressurisation 2 (of type : tank)</li> </ul>	Discretization elem	tf	time	5.0	second
<ul> <li>structure 2 (of type : structure)</li> </ul>	ICARU5	ISP	time	280.0	second
Reservoir de LOX 2 (of type : tank)	Etage 1	index	coefficient	1.0	none
😑 🛅 Moteur Hybride 2 (of type : motor)	ICARU5	Temps Final	time	280.75	second
🗣 tuyère (of type : nozzle)	Etage 1	Masse_ergols_Allu	mass	0.0	kilogram
<ul> <li>injecteurs multiples (of type : injector)</li> </ul>	Discretization elem	tf	time	280.75	second
••• tuyauterie (of type : pipes)	Etage 3	Masse_ergols_Prop	mass	160.0	kilogram
Chambre de combustion (of type : chamber)	Etage 1	Section Tuyere	surface	0.15	fakeUnit
😑 🗀 Etage 3 (of type : stage)	Etage 2	Masse ergols Prop	mass	600.0	kilogram
Moteur Hybride 3 (of type : motor)	Etage 1	Masse Etage	mass	4080.0	kilogram
B- Dight sequence (of type : flightSequence)	ICARUS	Surface Reference	surface	5.0	fakeUnit
<ul> <li>Flight phase 2 (of type : flightPhase)</li> </ul>	Etage 2	Masse ergols Allu	mass	0.0	kilogram
<ul> <li>Flight phase 1 (of type : flightPhase)</li> </ul>	Etage 3	Masse ergols Allu	mass	0.0	kilogram
Flight phase 4 (of type : flightPhase)	Moteur Hybride 1A	ISP	time	270.0	second

A HADES software (Help for Advanced launcher DESign) - V1.0.0 (22th September 2005) - project : nanoComplet



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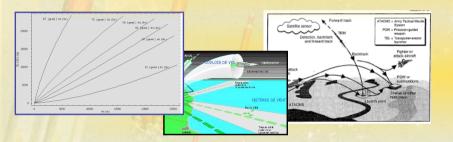
#### RSEUS **Development** approach First works are based on a representative study case that is a 3 stages launch vehicle Study Execution's plan Modules Lools Brames Help 🚔 🛷 🖬 🗐 🖓 🗉 🗿 🔘 🗩 端 🍪 I GUI Data management none none none none none none none second se •Execution of modules •Execution of scenarii Guide for analysis •Post-processing dedicated to space application **Modules** Specification, development ve $(mt + (Mo - mt) Log[1 - \frac{mt}{m}]) Sin[\Theta]$ Sz, i (t) = $-\frac{gt^2}{2} + t \forall zi + .$ and integration of codes n t Vxi + ve Cos[Θ] **HADES Vx** x, i (t) Refinements specification (nt Vxi + ve Cos [0] Si (t) = ((-M+Mo) (Vxi+veCos Scenarii Definition of process Workflow development in modeFRONTIER CONCEPTION •Choice of optimisation algorithm and parameters **Platform administration**

**Project management** 

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## **Preliminary design modules**

• **Staging and Structural Ratio:** Payload mass on Global Lift-Off Mass Optimization considering specific structural ratio database



• **Trajectory:** Trajectory optimization and performance calculation for a multi-stage rocket.

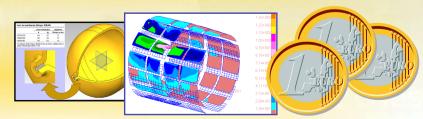
• **Thermo-chemistry and Propulsion:** Design and performance calculations of a liquid propellant rocket engine



• **Structure and Cost:** Tanks sizing, buckling of cylindrical tanks and specific cost calculation

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• Aerodynamic and General Loads: Drag and Lift coefficients, general loads calculation based on simplified geometry



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## **Why using modeFrontier?**

### **Offers HADES:**

- User-friendly and didactic interface
- Quick and simple integration procedure for both in-house codes and external applications (as Excel/OpenOffice, Matlab/Scilab, ...)
- Easy chaining of modules : multi-platforms, any code executable on command line with input/output text files
- Executable in batch mode, with specification of parameters in XML file
- Wide range of statistical and graphical analysis tools
- Includes a collection of optimisation algorithms adapted to a variety of problems

#### Limitations:

- Management of equality constraints
- Embedded loops
- Batch mode seems restricted to some executions (like DOE)

## Application

- Problem to solve:
  - Find the optimal launch vehicle for a fixed orbit (GTO) and a fixed payload
- Optimization parameters (for each stage):
  - Mixture ratio
  - Nozzle exit pressure
  - Thrust to weight ratio
- Objective functions (to maximize):
  - Payload mass on global lift-off weight ratio (Hall)
  - Specific impulse for each stage
- Constraints:
  - Payload mass calculated close to the payload mass targeted
  - Maximum diameter for each stage
  - Constraints on ascent trajectory (maximum loads admitted)

## seus Optimisation

Several levels of optimisations:

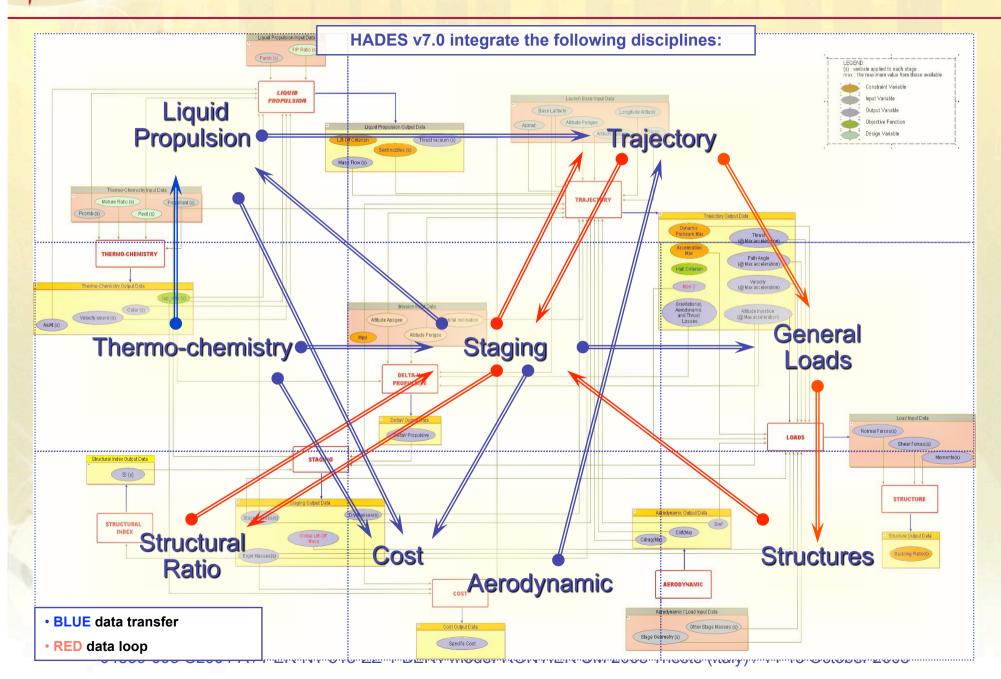
- Internal: inside a module
   Ex: performance module searches optimal trajectory to desired orbit
- Local: fixed point loop

Ex: a Structural Ratio based on experience is given to staging module which defines a given structure corresponding to another ratio, recomputed

Global: multidisciplinary process
 Ex: find the best-cost launcher to achieve putting a given payload on required orbit

## **Global loop of conception**

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## **HADES developments**

#### Next

- HADES GUI for data and modules management, including batch execution of modeFRONTIER
- Physical modules for propulsion options
- Integration of modules in the design process (workflows, role of variables, adaptation of algorithms and parameters)
- MDO: re-arrangement of process, test of new functionalities (batch node for imbricated loop), pre-selection of adequate analyses
- Diffusion aspects

#### Long term

- GUI enhancements: customised specification and execution of optimisation, specific post-processing
- New/improved study cases: suborbital rocket, airborne launch vehicle, boosters management, etc.
- Integration/improvement of modules: interoperability, refinement, etc.

## Conclusion

- modeFRONTIER offers a good framework for HADES ambition:
  - Give students and engineers an easy access to space launcher's design
  - Allow comparison and optimisation of designs on a cost and performance basis
  - Offer them an open background for further developments
- In addition to basic training, HADES team now needs also customised support and solutions on:
  - Internal aspects for managing batch execution
  - Handling of multiple levels in process optimisation
  - Integration of structure and algorithms adapted to satisfy equality constraints

#### Expected perspectives:

- Targeted diffusion of HADES platform (and modeFRONTIER) to a selection of students' group and engineers
- Various works planned on a wide range of aspects: specification/integration of process, MDO architecture
- Feed-back of users from scholar to industrial practice on space domain's applications

