



Development and testing of a small hybrid rocket motor for space applications

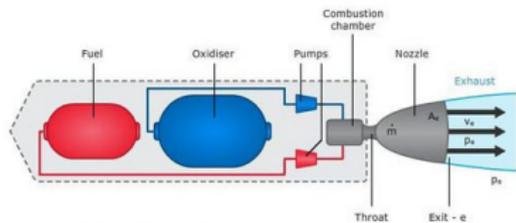
Enrico Paccagnella

24 October 2016

Università degli Studi di Padova

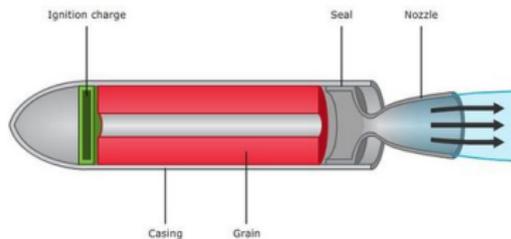
Centro di Ateneo di Studi e Attività Spaziali "Giuseppe Colombo"

Introduction to hybrid rocket motors



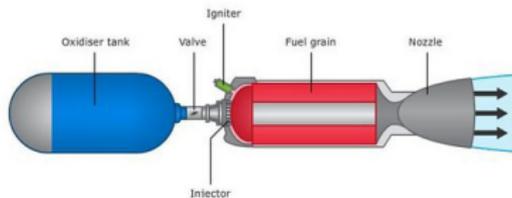
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Liquid rocket motors



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Solid rocket motors



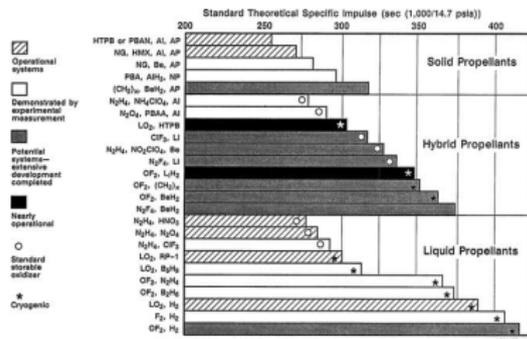
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Hybrid rocket motors

Advantages of hybrid rocket motors

Advantages of hybrid rocket motors:

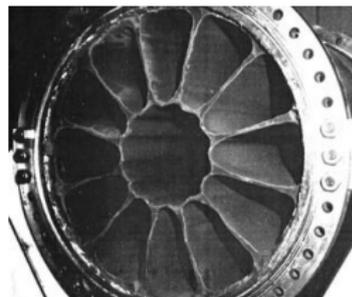
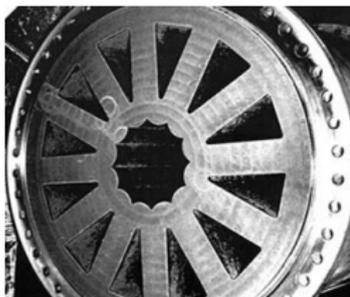
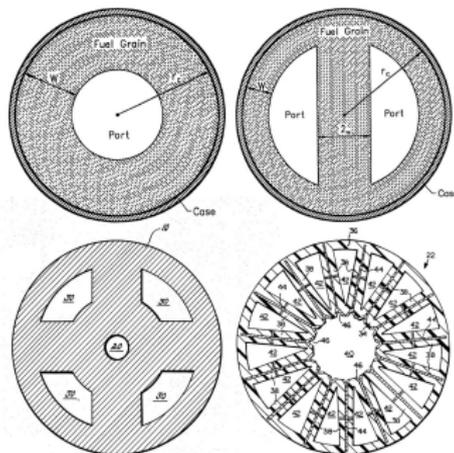
- Safety
- Operational reliability
- Propulsive performance
- Throttling
- Stop and restart capability
- Environmental friendliness
- Low cost



Disadvantages of hybrid rocket motors

Disadvantages of hybrid rocket motors:

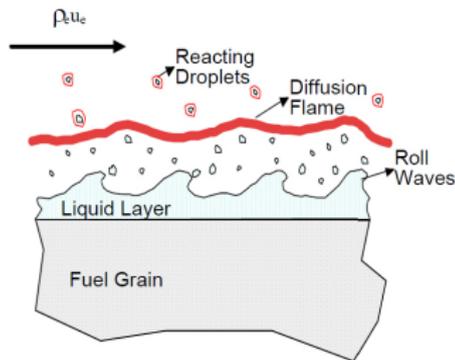
- Low regression rate
- Fuel residuals
- Low volumetric loading
- Combustion inefficiency
- Mixture ratio shift
- Slower transient



Possible solutions to disadvantages of hybrid rocket motors

To increase low regression rate and low combustion efficiency:

- Solid fuel additives
- Liquefying solid fuels
- Diaphragms
- Nonconventional solid fuel grain geometries and unique injector designs



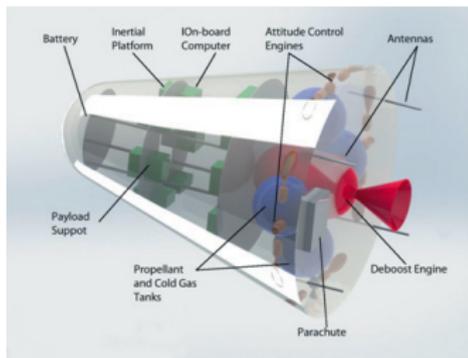
Applications of small hybrid rocket motors



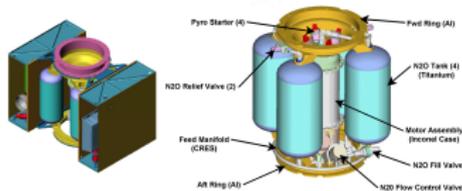
Sounding rockets



Deorbiting systems

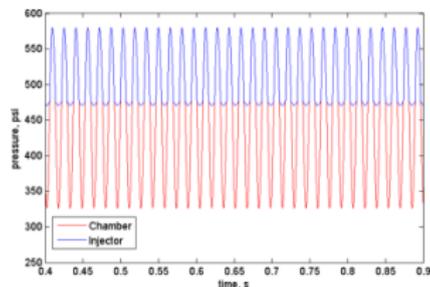
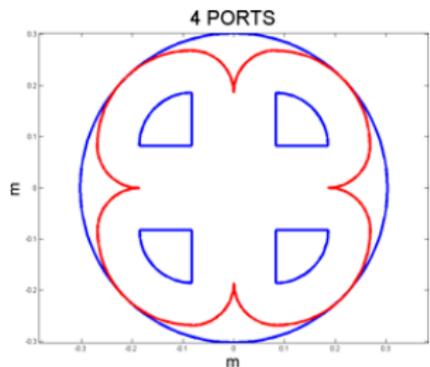


Orbit raising and reentry maneuvering system

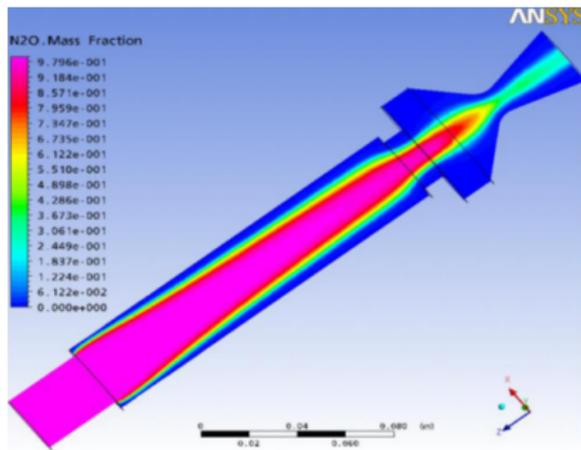


Maneuverable adapter rings

Hybrid rocket propulsion group heritage



0D and 1D analysis



CFD with customization

Hybrid rocket propulsion group test facility



Report on the activities program

Level	Work Package	Hours	First year				Second year				Third year			
1 0 0	State of the art research	320	220	100										
1 1 0	Bibliographical research	120	80	40										
1 2 0	Methods of numerical analysis	100	70	30										
1 3 0	Methods of experimental analysis	100	70	30										
2 0 0	Numerical Analysis	1020	40	230	260	240	180	70						
2 1 0	Definition of the driving parameters	80		80										
2 2 0	Design of the nozzle materials	200	20	80	80	20								
2 3 0	Design of the rocket motor	170	20	30	80	40								
2 4 0	Numerical analysis of the nozzle materials	310		40	100	90	80							
2 5 0	Numerical analysis of the rocket motor	260				90	100	70						
3 0 0	Experimental Analysis	1560				20	140	180	240	290	250	230	130	80
3 1 0	Experimental set-up	390				20	120	30	30	130	30	30		
3 2 0	Test campaign of the nozzle materials	330					20	130	130	30	20			
3 3 0	Test campaign of the rocket motor	340								50	120	120	50	
3 4 0	Data analysis and validation	500						20	80	80	80	80	80	80
4 0 0	Exploitation	150											20	130
4 1 0	Sounding rockets	60											20	40
4 2 0	Deorbiting systems	30												30
4 3 0	Orbit raising maneuvers	30												30
4 4 0	Monopropellant reaction control thrusters	30												30
5 0 0	Thesis and Reports	700					30	50	50	70	100	100	150	150

Thank you for your attention