

In-Space Cryogenic Propulsion Development

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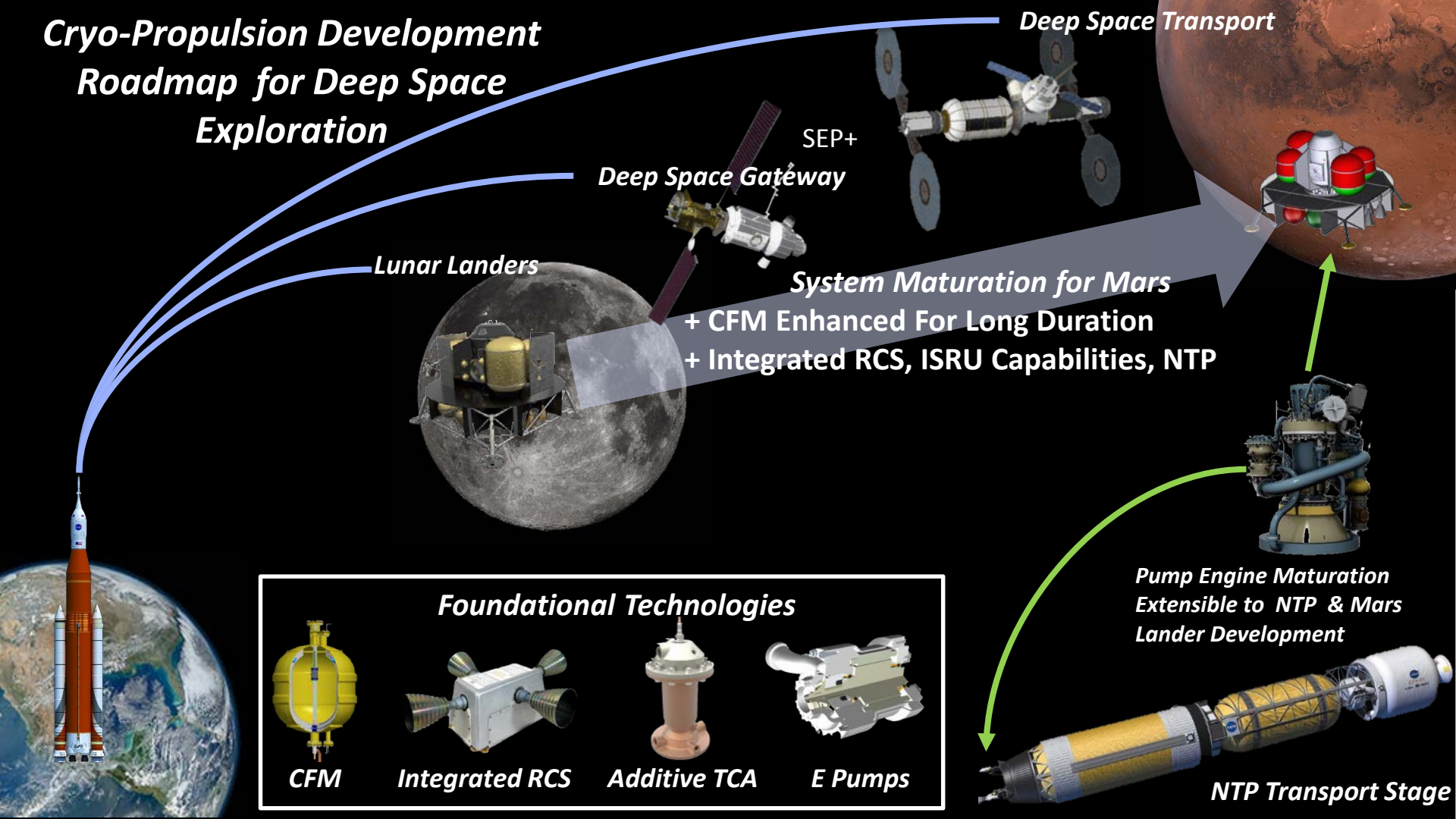
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National Aeronautics and
Space Administration



MARSHALL
SPACE FLIGHT CENTER

Cryo-Propulsion Development Roadmap for Deep Space Exploration



MSFC is currently developing components & engine systems to support in-space propulsion

- Transfer Stages
- Lander Systems

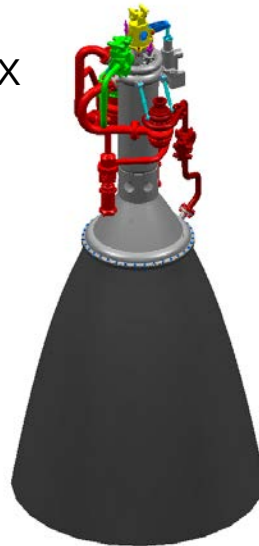
AMPed

- 5 klbf, EPump
- Lunar Lander
- CH₄-LOX
- LH₂-LOX



LSAM

- 9 klbf, CLEX
- Lander
- LH₂-LOX

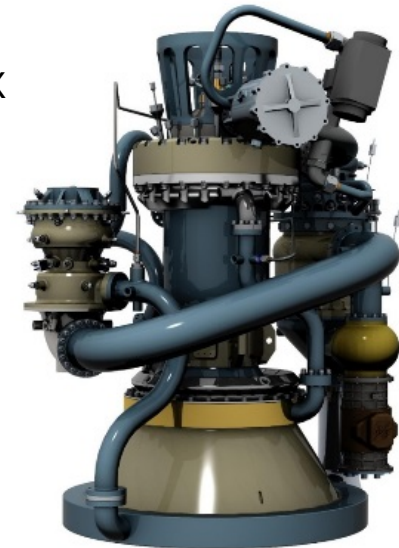


AMDE-H

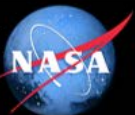
- 35 klbf, OPEX
- In-Space
- LH₂-LOX

AMDE-M

- 22 klbf, GG
- Mars Lander
- CH₄-LOX



Additive Manufacturing Demonstrator Engine



Design

Develop

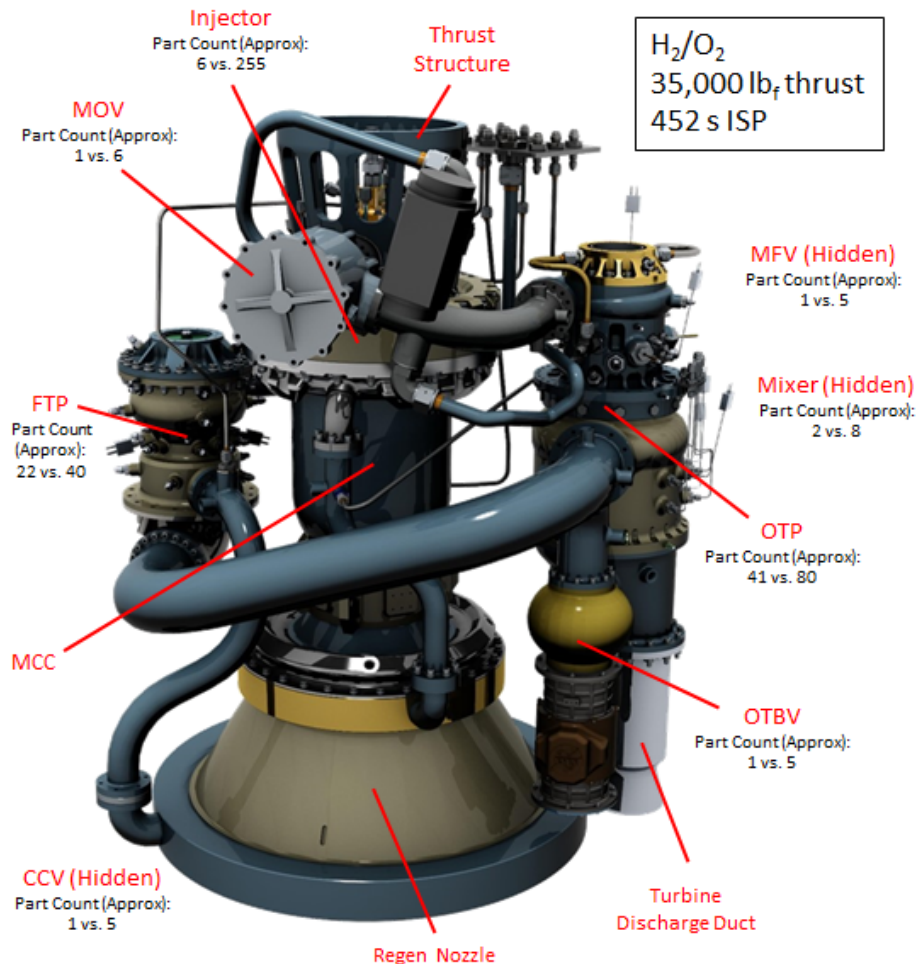
Test

Evaluate



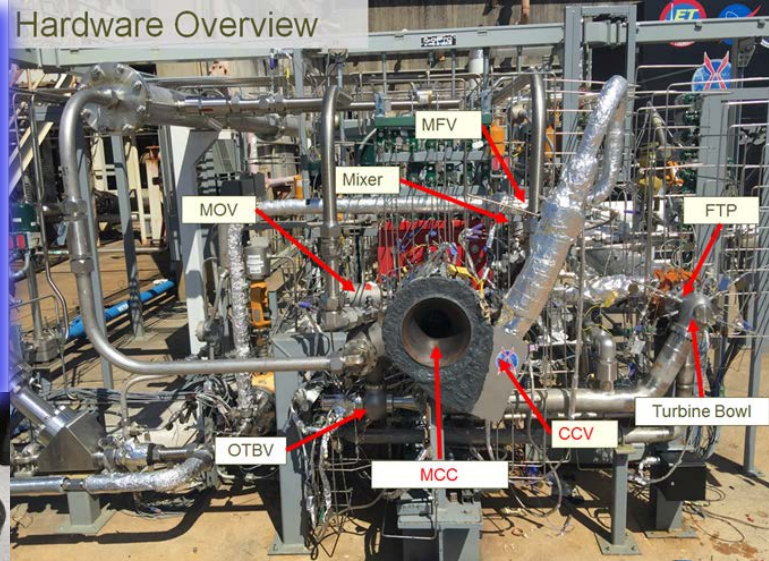
Engine Basics

H_2/O_2
35,000 lb_f thrust
452 s ISP



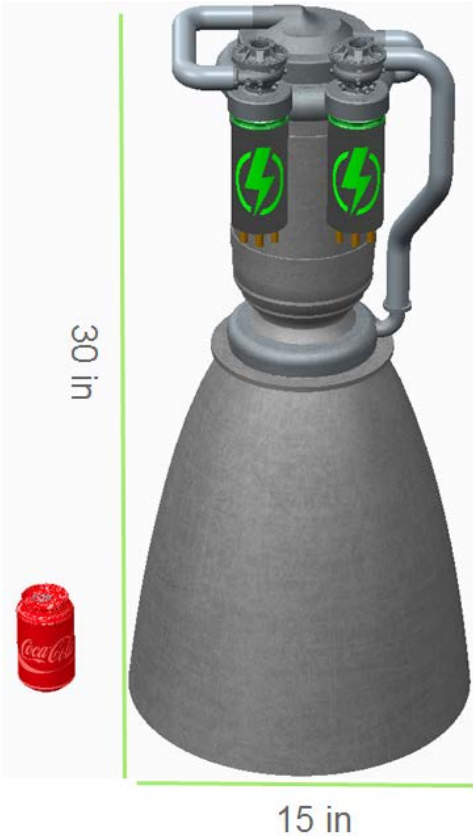


- **Completed Testing**
 - Cryogenic Valve Testing
 - Injector Testing
 - Chamber Testing
 - Nozzle Testing
 - Turbopump Testing
 - Breadboard Engine Testing
- **Planned Testing**
 - Prototype Engine Testing



Latest Hardware & Testing

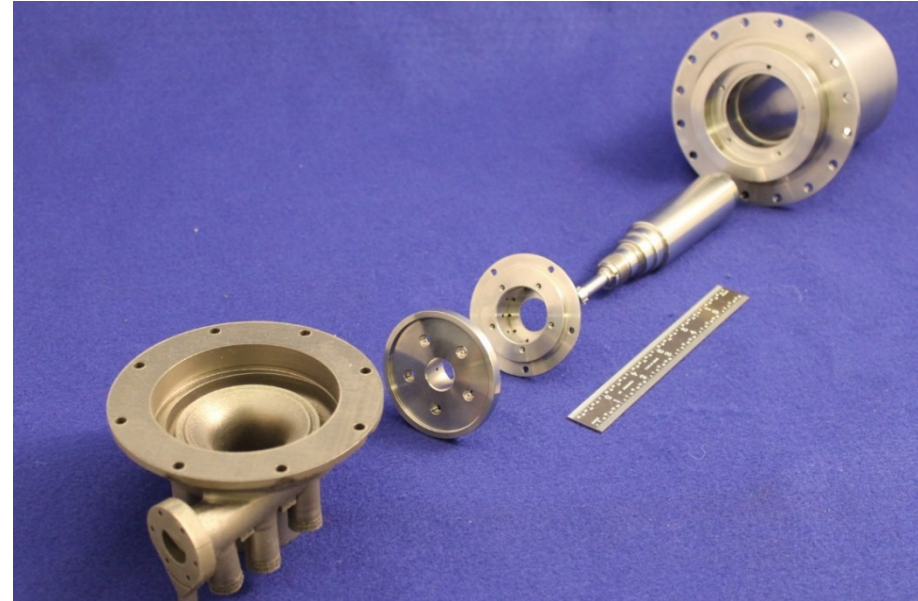
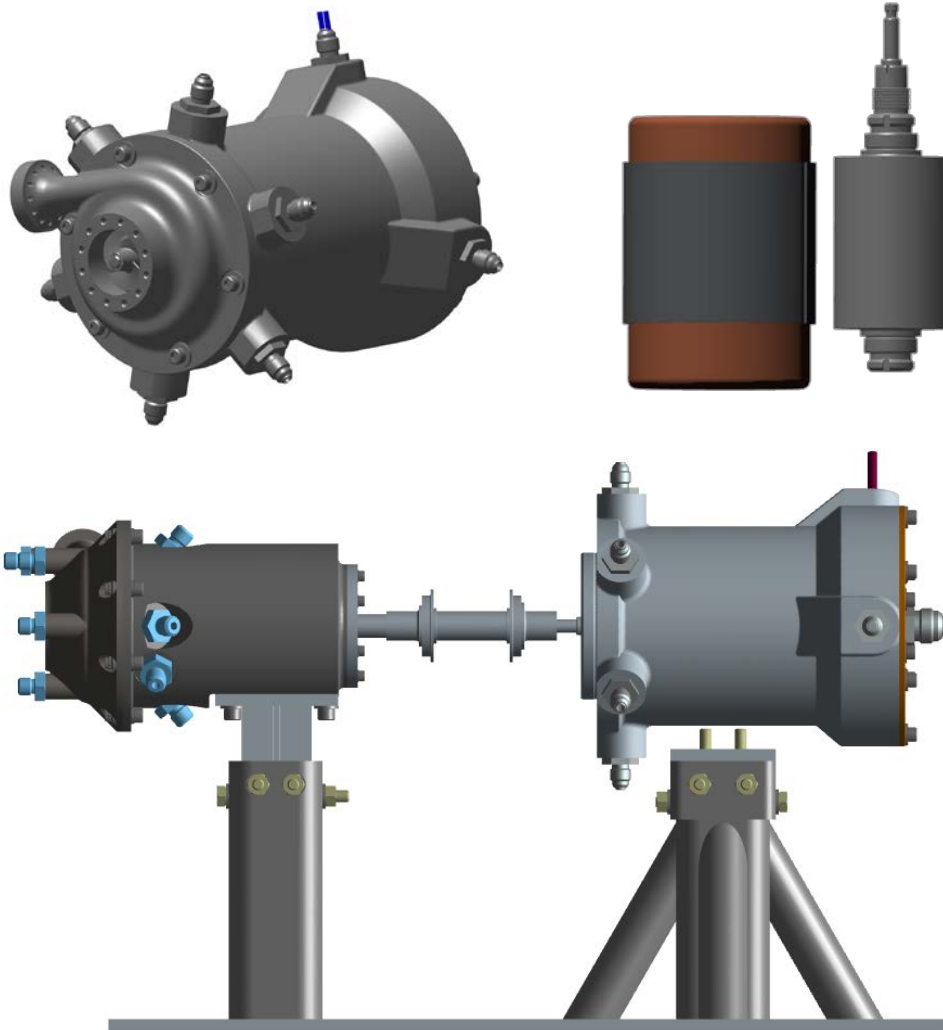
- 5,700 lbf thrust Liquid Oxygen (LOX) / Liquid Methane (LCH4) engine.
- The engine uses 2 similar high-performance electric motor to power the Oxidizer and Fuel pumps separately,
- Power is supplied from lithium ion batteries, and each operated using a separate electronic speed controllers.
- Leverages Epumps & Additive Chamber Technology being developed at MSFC
- Hydrogen Variant In-Work

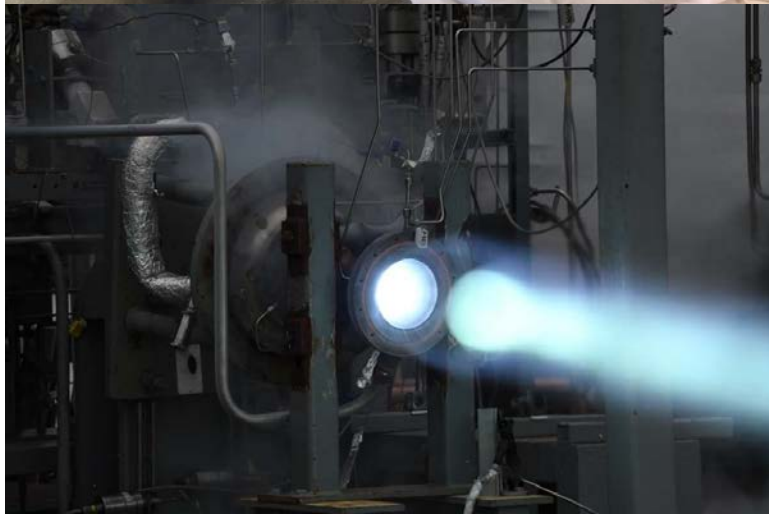


Parameter	Design Value
	100%
Vacuum Thrust (lbf)	5,700
Vacuum ISP (s)	344
Mixture Ratio (TCA)	3.0
LCH4 Flow Rate (lbm/s)	4.14
LOX Flow Rate (lbm/s)	12.4
Chamber Pressure (psia)	475
LCH4 pump speed (RPM)	45 Krpm
LOX pump speed (RPM)	40 Krpm
Engine Height (w/ Noz. Extension)	< 30 in
Engine Width (w/ Noz. Extension)	15 in
Mass (lbm)	~ 131
Starts	4
Single Burn Time	~ 120 s

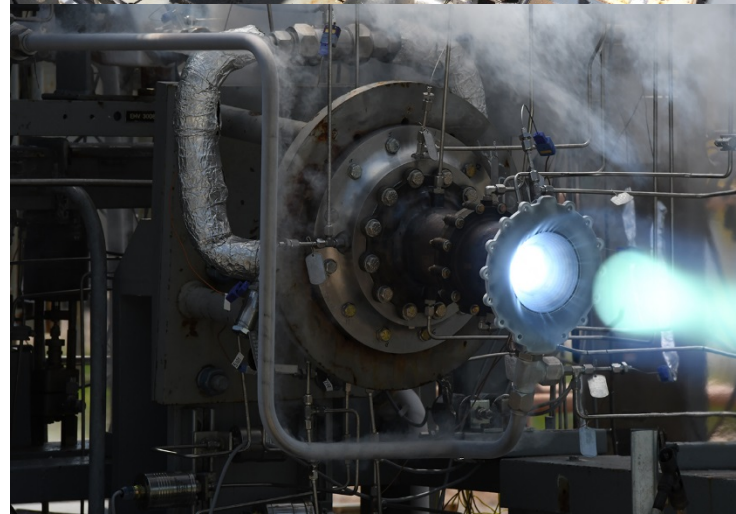
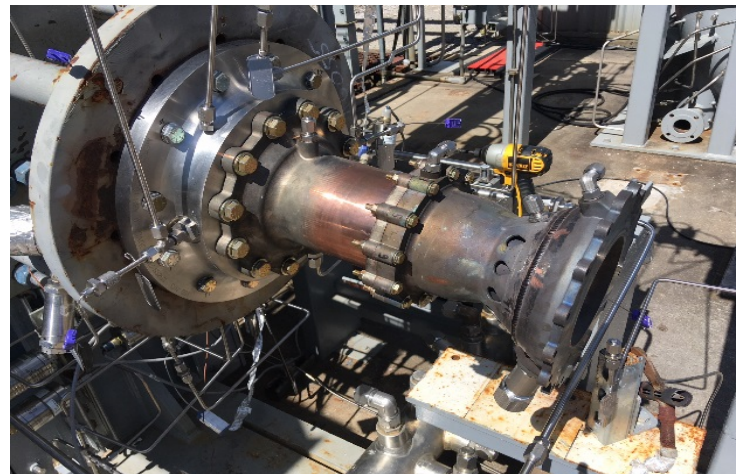
AMPed LOX-LCh4 Lander Engine

Electric Pump Development for AMPed Engine





META4 Tested in April 2018



META4X4 Tested in May 2018



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