Technology Development and Trends
Liquid Rocket Propulsion

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Advanced Manufacturing Enables Propulsion

Fundamental Additive Manufacturing M&P Development

Push
- Material Properties & NDE
- Standards & Specs
- Certification Rationale

Pull

Investment directly benefits prototype engine development and indirectly enables and facilitates technology across multiple current and future activities for NASA, DoD and industry.

Lean & Aggressive Development Philosophy

Parallel & Congruent Activities

Relevant Environment Testing

Building Foundational Additive Manufacturing Industrial Base

RP Engine

Methane Systems

RS-25

CCP

Upper Stage Engine

Advanced Manufacturing Demonstrator (AMD)

Stratasys

INCODEMA

LINEAR

GPM

Additive Manufacturing, Inc.

RTI Directed Manufacturing, Inc.
Reduction in Parts Count with Additive Manufacturing

Note: Part counts examples are for major piece parts and do not include bolts, nuts, washers, etc.
BACK-UP SLIDES
Technology Development – Rapid Fabrication of Regeneratively Cooled Nozzles

- Large scale freeform additive manufacturing processes being developed for channel wall nozzles
- Advanced abrasive water jet milling used to produce unique geometries for coolant channels
- Novel closeout techniques such as explosive bonding and hybrid additive manufacturing being investigated to rapidly reduce lead time and costs
Composite Nozzle Extensions for Deep Space Missions

- NASA continues to invest in high temperature carbon-carbon nozzles for upper stage deep space missions
- Developed domestic supply chain with modern material systems and continue to work with international partners
- Produced a series of 24” diameter nozzles that will be hot fire tested
- Developing methodology to certify and fly composite extensions
Advanced dynamic optical measurement techniques to significantly reduce instrumentation costs for component testing, real-time manufacturing process analysis, and engine testing.
The liner is printed using an astonishing 8,255 separate layers of this copper powder, which is sintered together one layer at a time to build up the final product. In all, it takes 10 full days and 18 hours to complete the printing process of this single part.
END
Game-Changing Aspects of Prototype Additive Engine

State of the Art for Typical Engine Developments

- DDT&E Time
  - 7-10 years

- Hardware Lead Times
  - 3-6 Years

- Testing
  - Late in the DDT&E cycle

- Engine Cost
  - $20 - $50 Million

- Applicability
  - Design for particular mission by a particular contractor
  - Often proprietary

Prototype Additive Engine

- DDT&E Time
  - 2-4 years

- Hardware Lead Times
  - 6 Months

- Testing
  - Testing occurs early in the DDT&E cycle

- Prototype Cost
  - $1-5 Million

- Applicability
  - Provide relevant data to multiple customers (SLS, Commercial partners, other government agencies)
  - Flexible test bed configuration can accommodate other’s hardware / design concepts
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