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Cost Effective Large Diameter Rockets Using Extruded Propellant Rocket Motors

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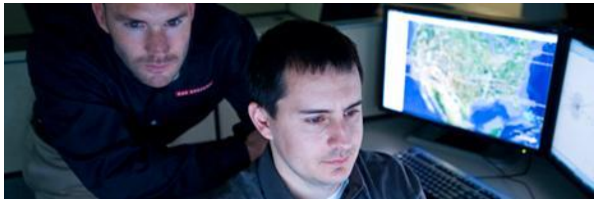

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Traditional Large Diameter Motors

Cast-Cure Motors

Advantages:

- High I_{sp} formulations well characterized
- High density
- Complex configurations easier to produce
- No known diametric limitations

Disadvantages:

- Expensive grain production
- Labor intensive
- Low volume production
- Tedious, complex, expensive components

Extruded Motors

Advantages:

- Inexpensive grain manufacturing
- High rate, high volume
- Low cost, low complexity motor components
- Superior IM properties in some configurations

Disadvantages:

- Comparatively low I_{sp}-density
- Machining required for complex grain designs
- Monolithic diametric limitations

Applications for Large OD Extruded Motors

<u>Economic Considerations</u>

- Programs where cost is of high importance benefit from cheaper component and assembly costs
- Economies of scale are a factor for large production runs

<u>Production Volume</u>

- Programs where large production quantities are required benefit from tooling amortization, fast extrusion times
- Weapon systems that need more units per $ spent (i.e. tactical programs)

<u>Realistic Engagement Envelopes</u>

- CONOPS where the largest percentage of missions do not require current impulse expenditure

<u>Unique Propellant Properties</u>

- Environments that could benefit from:
  - Stiffer mechanicals
  - Higher burn rates
  - Improved IM sensitivity

Large OD Extrusion Challenges

Consolidation

- Larger diameters/thicker webs cause issues with consolidating propellant
- As the diameters approach the diameter of the press, mixing/work is reduced

Thermal Cycling

- Stiffer mechanical properties cause issues with thermal cycling at large diameters
- Case bonding requires specialized elastomeric epoxies

Volumetric Performance

- I_{sp}-Density reduces performance with respect to cast-cure solutions
- Cartridge loaded designs result in lower propellant volumes

Historical Large OD Extrusion Work

Monolithic Extrusion

- Propellant grains at least 8” diameter if not larger
- Tactical and boost motors

Ram-Mold Extrusion

- Grain extruded into a mold w/ sprue
- Diameters greater than 11” successfully tested
- Issues with temperature cracking

Segment Assembled Grains

- Up to 18” diameter grains successfully tested
- Stress relief for temp cycling

Multi-Ply Process

- Grains up to 55” in diameter
- Demonstrated ability for multi-propellant grains

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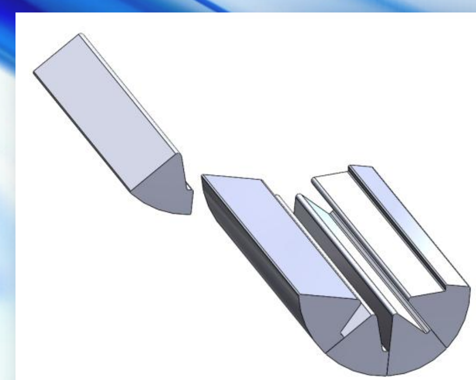
Current Proposed Methods

Monolithic Extrusion

- Motors up to 8” diameter
- Cartridge load grains
- Provide low cost alternatives for tactical motors

Segment Assembled Grains

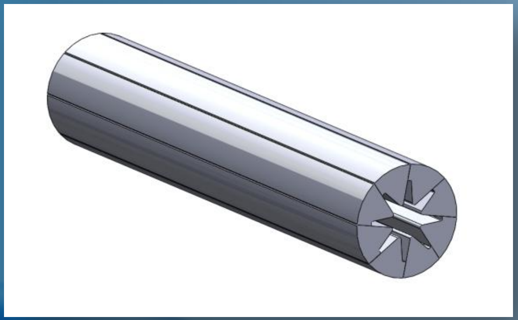
- Up to more than 25” diameter
- Extrude radial “wedges” of propellant grains
- Bond with elastomeric epoxy
- Cartridge loaded and case bonded designs



Enabling Technologies

Large Grain Extrusion

Low Cost Nozzle



Segmented Grain

High Energy Formulations

Low Cost, Large Diameter Motors

Current Development Work

Five Inch Heavyweight Demo

- Key technologies:
  - Monolithic extrusion
  - Composite nozzle
  - Pyrogen igniter
  - Reusable test platform

Novel Formulation Research

- Increase density and Isp
- Composites and composite modified double base
- High solids extrusion technology

Demonstration Program Goals

Grain/Motor Scale

- Successful extrusion of a monolithic large diameter grain
- Successful static test of a tactical scale EDB motor

Testing Platform

- Development of a reusable heavyweight test motor
- Simulated tactical performance

Demonstrated Impulse

- Demonstrate impulse in a reasonable range with “off-the-shelf” formulation
- Show path for performance improvements with formulation R&D

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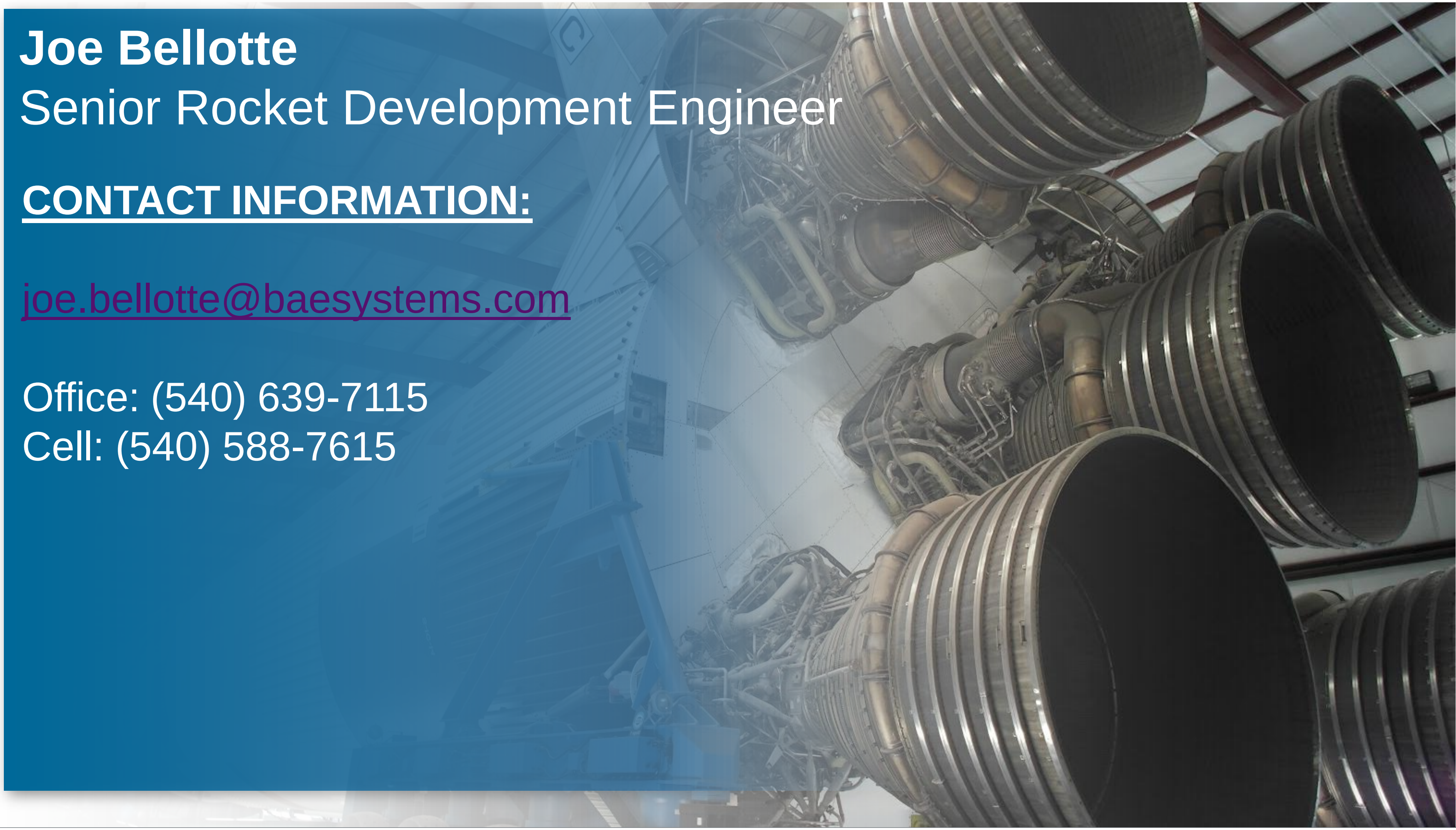
Questions And Contact Information



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