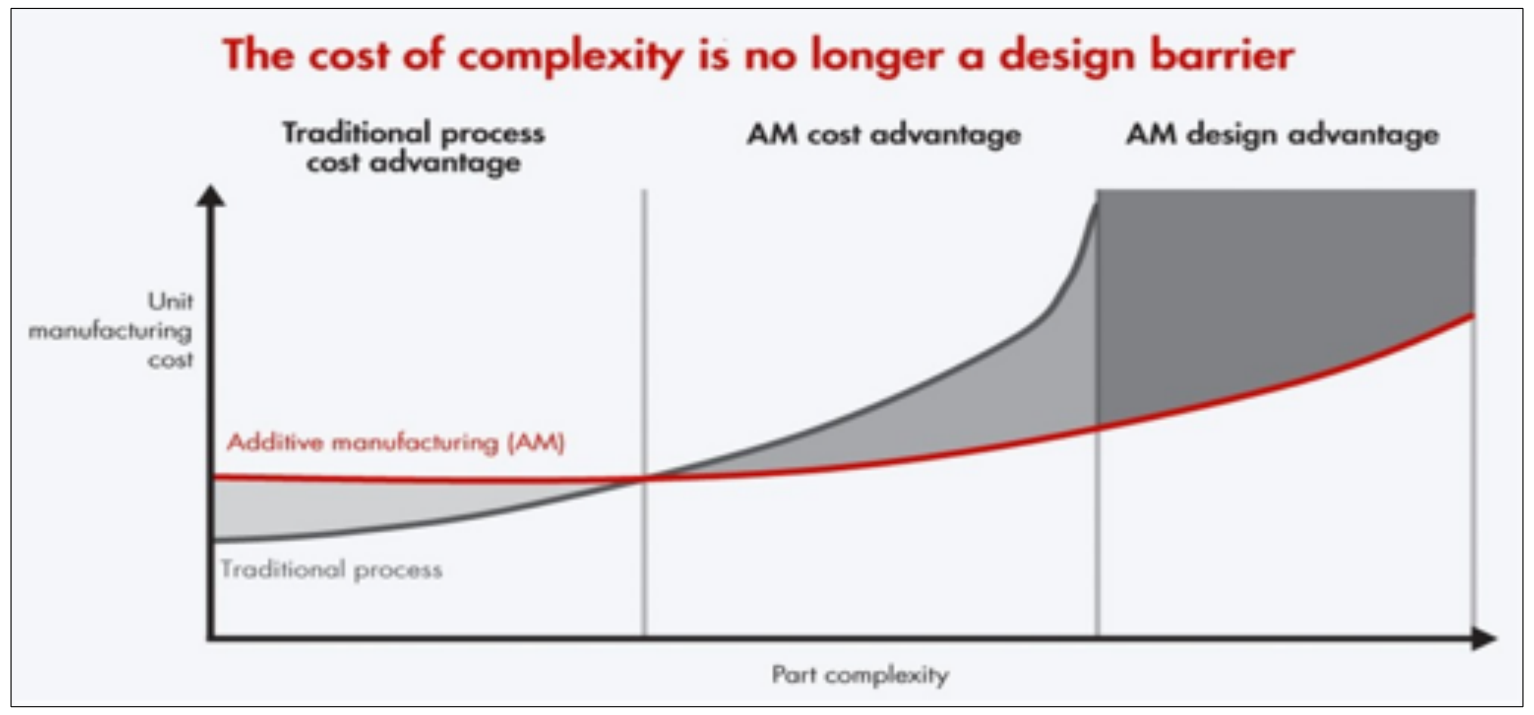
3D Design and Manufacturing Analysis of Liquid Propellant Rocket Engine (LPRE) Nozzle

Samuel O. Alamu[1], Marc J Louise Caballes[1], Yulai Yang[1], Orlyse Mballa[1], and Guangming Chen[2]
[1]Graduate Student; [2]Professor, Department of Industrial and Systems Engineering

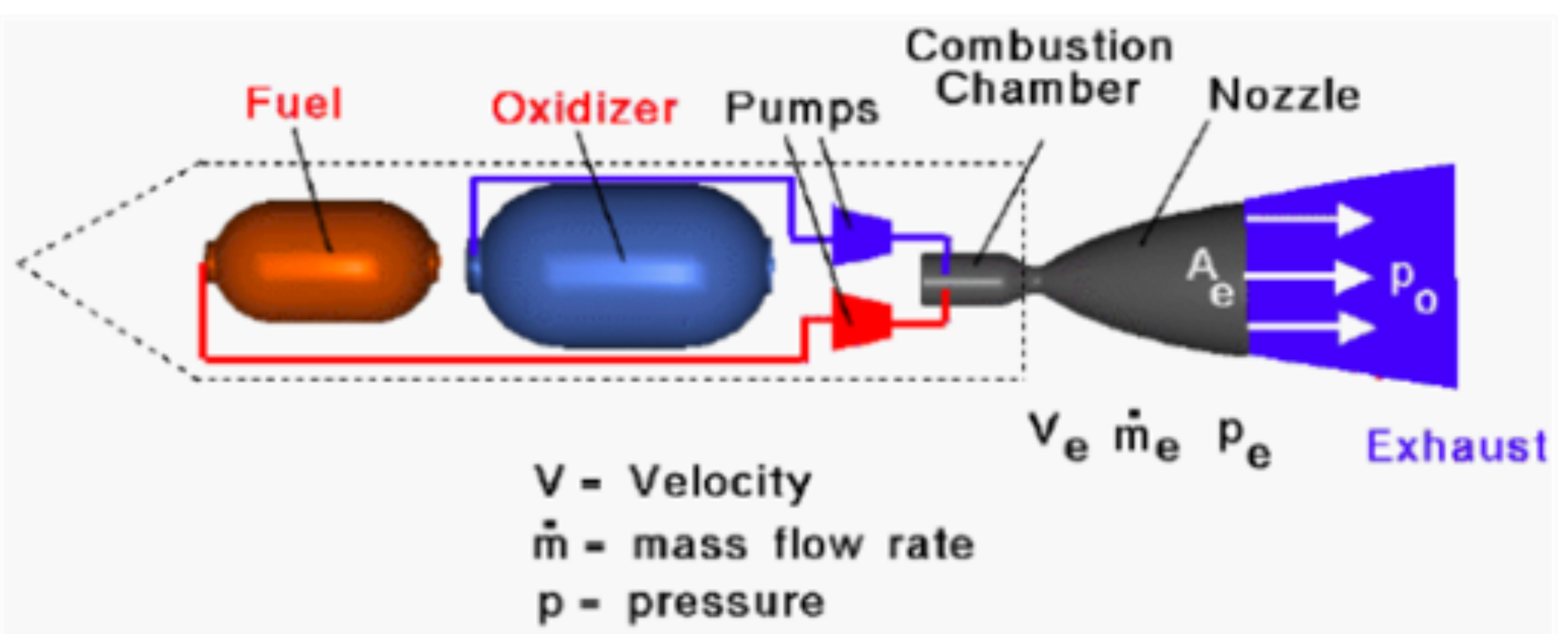
Background

- Morgan State University has recently received a grant from a private organization BASE 11 to develop a rocketry program on campus.
- 3D printing technology - design & fabrication of parts and model structure of aerospace products.
- Additive manufacturing (AM) or commonly called as 3D printing, is a method and process of manufacturing and fabricating parts layer by layer.
- AM is widely used in different major industries and fields such as – automotive, aerospace, defense, research, and health industry.

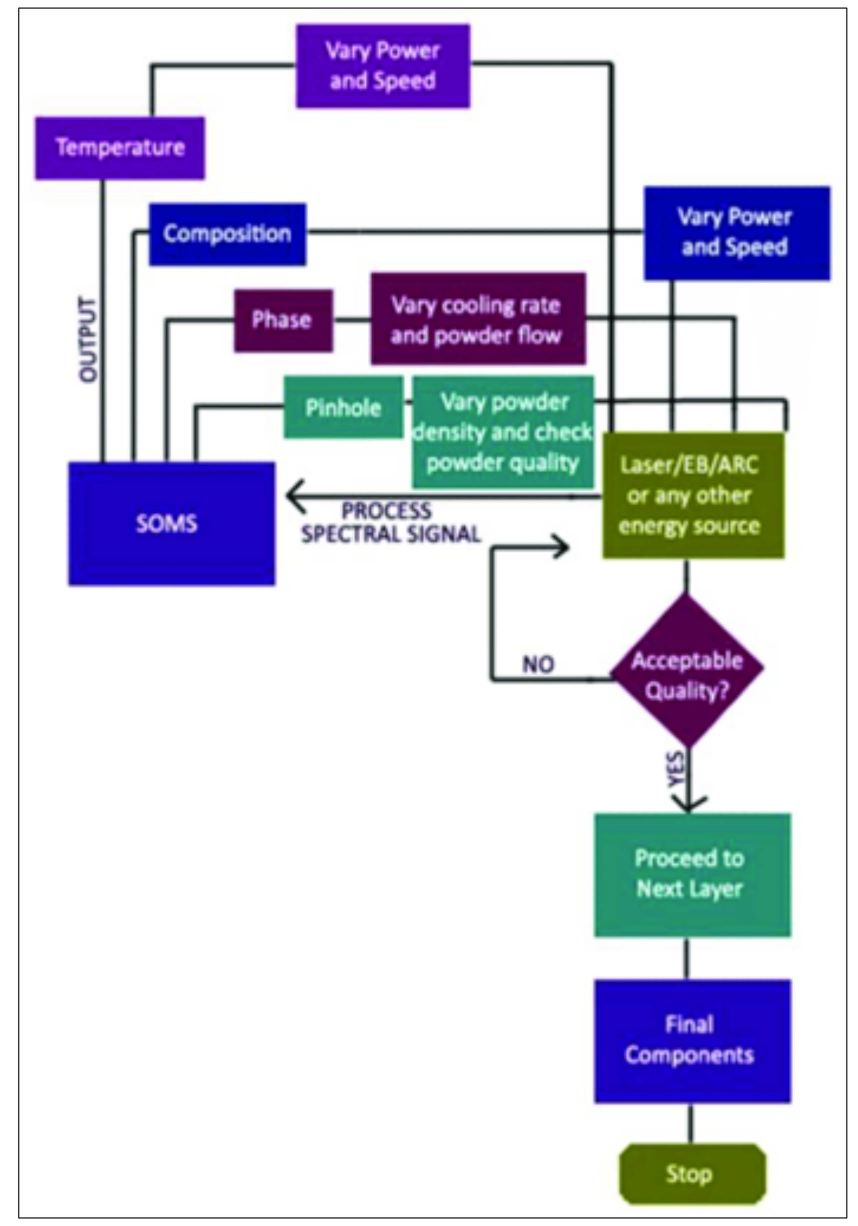


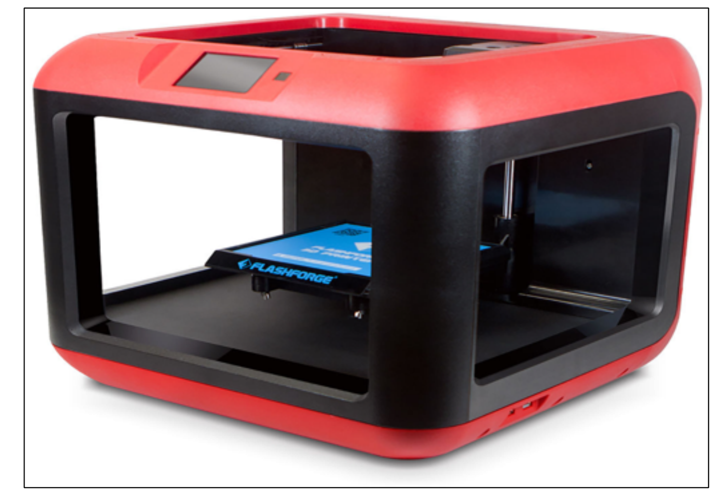
Research Objectives

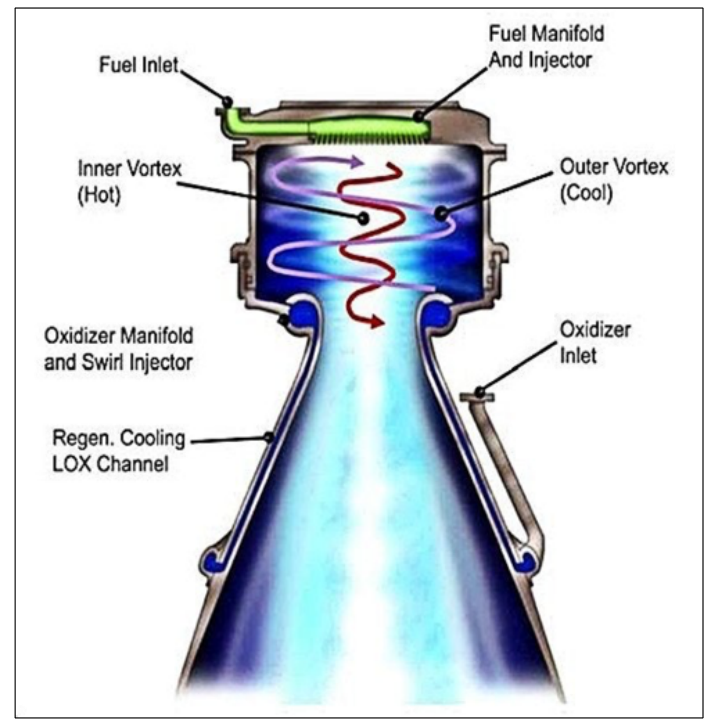
- To design and print a 2D and 3D Model of the LPRE Nozzle that will be used as a guide and visualization for the MSU Rocketry project.
- To show how efficient and convenient additive manufacturing process is, not only in academia but as well as in the manufacturing and technology industry.
- To analyze the performance of the design nozzle using an established JAVA applet nozzle simulator.



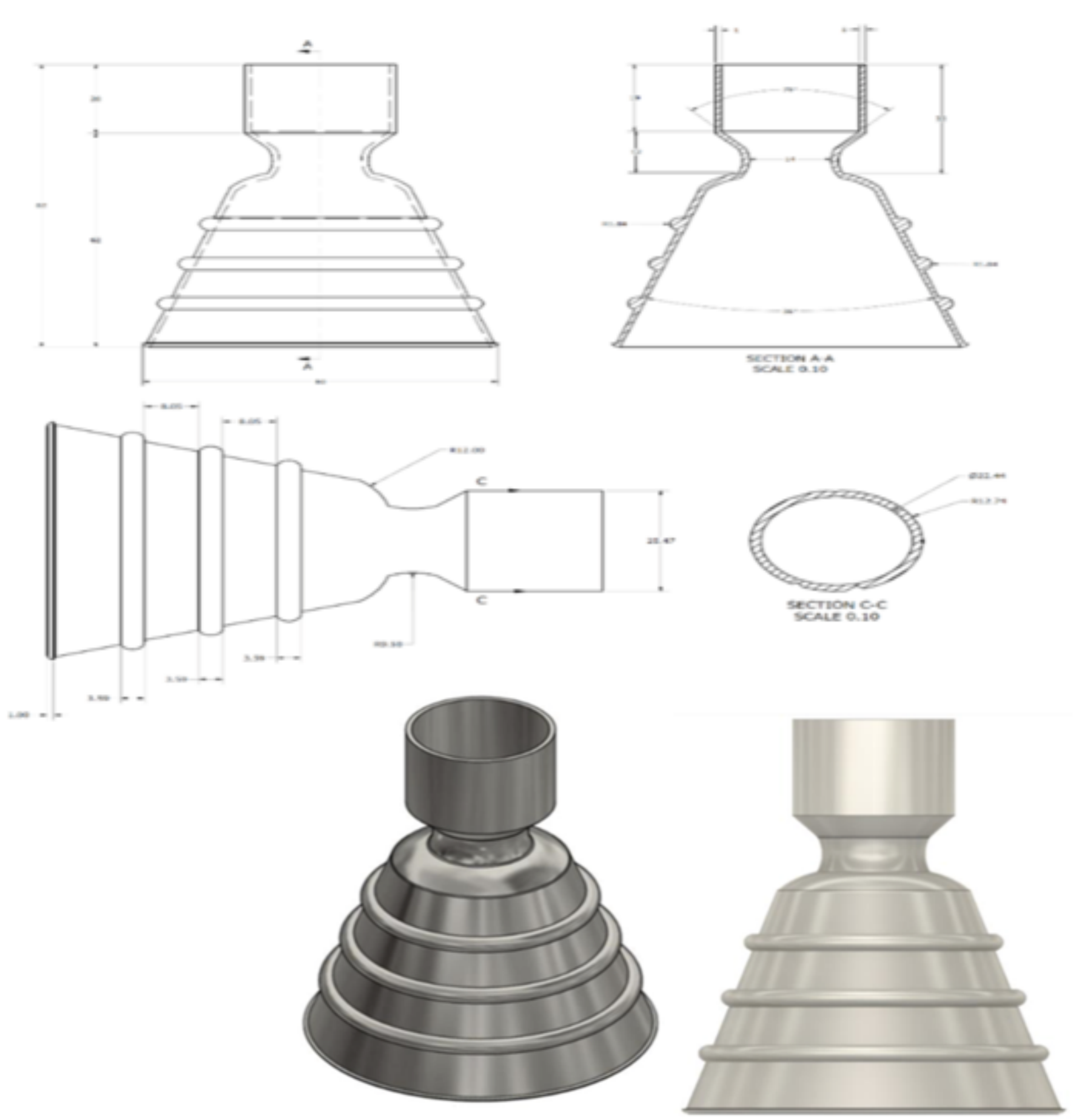
Methodology







2D and 3D Design



Results Discussion

NOZZLE SIMULATION

Table 1: Design Parameters for LPRE Nozzle simulation

Design Parameters	Values
Chamber Pressure (Pc)	160Kpa
Chamber Temperature (Tc)	400K
Design Throat diameter	35.56mm
Exit Diameter	64.69mm

Tablee 2: Simulation result of the LPRE Nozzle Design

Exit Mach Number (Me)	Area Ratio (Ae/At)	Exit Pressure Ratio (Pe/Pc)	Exit Temperature ratio (Te/Tc)	Exit Velocity (Ve) (m/s)	Mass flowrate (Kg/s)	Thrust (N)
2.5	3.31	0.0094	0.459	3384.98	0.174	593.6

Design Equations

Exit Mach Number: $Me^2 = \frac{2}{\gamma-1}\left[\left(\frac{Pc}{Patm}\right)^{\left(\frac{\gamma-1}{\gamma}\right)} - 1\right]$

Exit Velocity: $V_e = M_e\sqrt{\gamma R T e}$

Mass flowrate: $\dot{m} = \frac{A * Pt}{\sqrt{Tt}} * \sqrt{\frac{\gamma}{R}} * Me\left(1 + \frac{\gamma-1}{2} Me2\right)^{-\left(\frac{\gamma+1}{2(\gamma-1)}\right)}$

Thrust: $F_0 = \dot{m}V_e + (P_e - P_0)A_e$

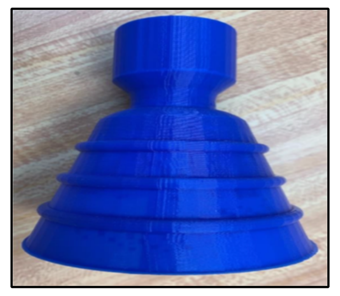
Limitations

The limitations of AM includes:

(1) The energy consumption;
(2) The limited materials;
(3) The takes time to manufacture.

Overall, one cannot deny how 3D printing easily provides countless benefits in the field of industry.

Conclusion



- Additive manufacturing has proven to be very advantageous when compared with conventional manufacturing processes.
- Complex LPRE parts such as nozzle and combustion chamber can be successfully manufactured using additive manufacturing process to save cost and production time.
- The advancement of the technology industry, especially in the aerospace field would be more beneficial for developing quantities of utilized cases, verifiable designs, and projects that demonstrates additive manufacturing can be the standard in assembling innovation.

References

1. Mishra, N. K., Prasad, S.S, Padania, M.A.: Modeling & simulation of rocket nozzle. International Journal of Advanced Engineering and Global Technology 2, 988-95 (2014).
2. Snyder C.A. *NASA Chemical Equilibrium with Applications (CEA)*. Retrieved from https://www.grc.nasa.gov/www/CEAWeb/ (2016).
3. Lu, B., Li, D., Tian, X.: Development trends in additive manufacturing and 3D printing. Engineering, 1(1), 85-89 (2015).

Presenters:

Marc J Louise Caballes
Department of Industrial and Systems Engineering – Morgan State University
Email: macab1@morgan.edu

Samuel O. Alamu
Department of Industrial and Systems Engineering – Morgan State University
Email: olala22@morgan.edu