

### **Problem Statement**

- Examine the feasibility of 3D printing impact limiters for Transportation, Aging, and Disposable Canister Casks as well as Impact Limiters on both a full and prototype scale.
- Examine the possibility for 3D printing with two or more metals to allow signal transmission through the part without penetration.

### Process

### Research

- -Establish what we know, fill in the gaps
- -Scholarly Articles
- -UNCC Professors
- -Government Documents
- -Materials Testing

### Fabrication

- -Research identifies methods -AHP's identify best methods
- -UAM, SPD, DED
- -Different methods for





### Design

- -Iterative Process
- -Design change with each informative meeting
- -Different design for each 🗸 📝
- manufacturing process
- -Based on NRC and DOE regulations

### **Testing and Analysis**

- -DOE and NRC specifications -Digital Simulation/Finite Element
- Analysis

-Ansys



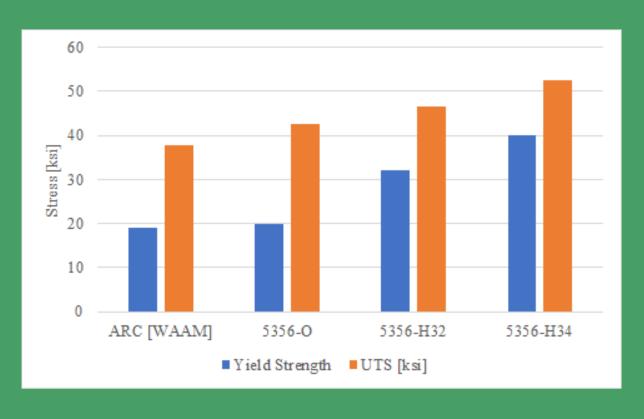
### Material Testing Research

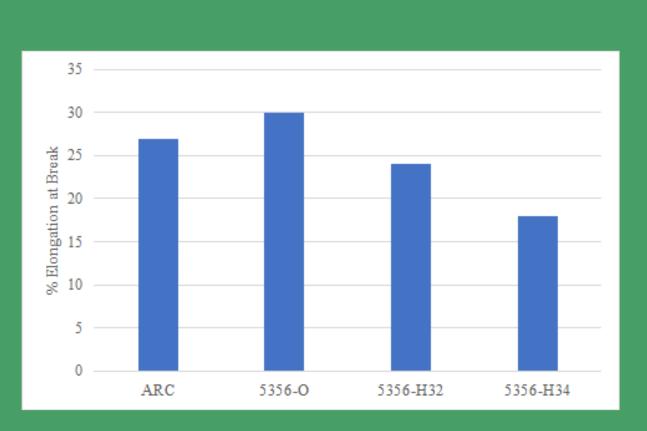
### 5356 Aluminum

- -Tensile Testing ["dogbone" specimens]
- -Yield Strength
- -Ultimate Tensile Strength -% Elongation

### Purpose

- -AM process may alter mechanical properties of our materials -Incorrect mechanical
- properties may lead to part failure
- -Research conducted to find accurate mechanical
- properties
- -Compare AM vs Traditional





# **Optimization Study for Off-Loading the Shearon Harris Spent Nuclear Fuel Pool** using Transportable Aging and Disposal (TAD) Canisters Phase II Senior Design 2 – Spring 2021

Team Members: Mikayla Harkey (mharkey7@uncc.edu), John Gasson (jgasson@uncc.edu), Bhargav Gajjar (bgajjar1@uncc.edu), Albert Shank (ashank3@uncc.edu), Andriy Bilovol (abilovol@uncc.edu), Nathan Pearce (npearce@uncc.edu), Victoria Kuntz (vkuntz@uncc.edu), Sydney Rowan (srowan2@uncc.edu).

Faculty Mentors/Industry Supporters: Dr. Yesim Sireli, Dr. Michael Smith/ Dr. Sven Bader, Brad Crotts

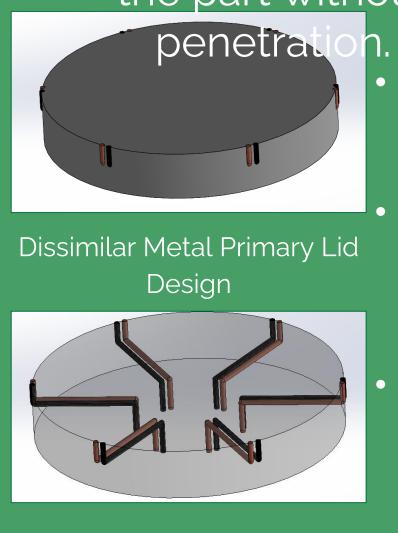
### **Project Expected Deliverables**

- Research the feasibility to complete the 3D print deliverables from Phase I of the ORANO\_TAD project
- Research and examine the potential of 3D printing impact limiters with the honeycomb structure and TAD canister primary lid with dissimilar metals
- Research the ability to transmit signal through the primary lid and TAD canister shell using dissimilar metal printing
- Phase III considerations and future implementations

### **Design and FEA of Impact Limiter**

- Radial Design Honeycomb crash test Strong axis always faces impact zones • Proposed • Simulated Tensile test corner model for WAAM
  - Elongation: 12%

### **Dissimilar Metal Prototypes and Simulations**

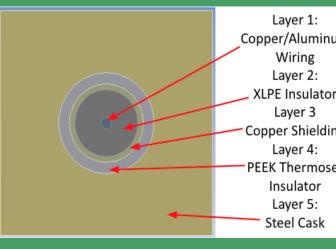


printing

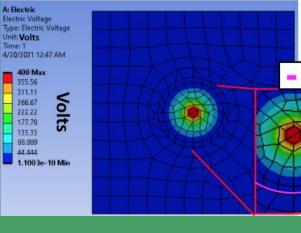
Dissimilar Metal Lid Internal view

### Primary Lid

- Designed with UAM Process from Fabrisonic in mind
- Wires are bent to help with manufacturing restrictions and radiation shielding
- Complex wire designs offer great protection from radiation, heat, corrosion, and EMF interference



RMD Sensor Wire Design



RMD Sensor Wire Simulation

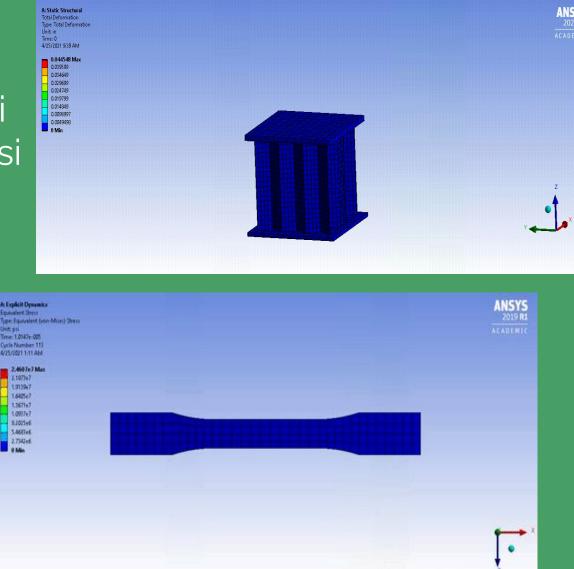
### FMEA and Manufacturing Analysis

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	FAILURE MODE AND EFFECTS ANALYSIS														FAILURE MODE AND EFFECTS ANALYSIS																		
Item:								n	FMEA number: 2						Item: Impact Limiter Responsibility:						V. Kuntz &	S.Rowan		FMEA number:		3							
Model:	Current		Prepared by:		V.	Kuntz			_		1 of 1				Model	l: Current		1	Prepared by:		V.Kuntz			Page :		1 of 1		_		-			
Core Team: ORANO_TAD2									FMEA Date (Orig): <u>11/18/2020</u> Rev: 2						Core 7	Team: ORANO	_TAD2							FMEA Date (Ori	g):	11/21/2020	F	Rev:		1			
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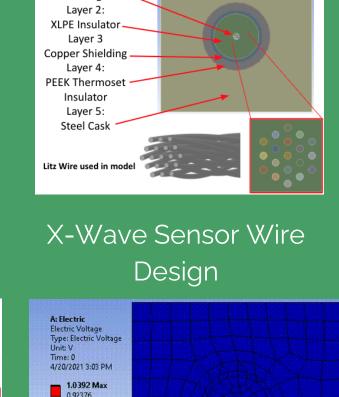
### • Simulated 2'x2' Honeycomb

8.77 inch deformation at 2000 psi 13.52 inch deformation at 8000 psi

Yield Strength: 15,420 psi Tensile strength: 28,310 psi Young's Modulus: 9,934 ksi



### opper/Aluminu Wiring Layer 2: XLPE Insulator Layer 3 Copper Shielding Layer 4: PEEK Thermoset



0.46198 0.34641 0.23094 0.11547 **2.8588e-13 Min** 

X-Wave Sensor Wire Simulation

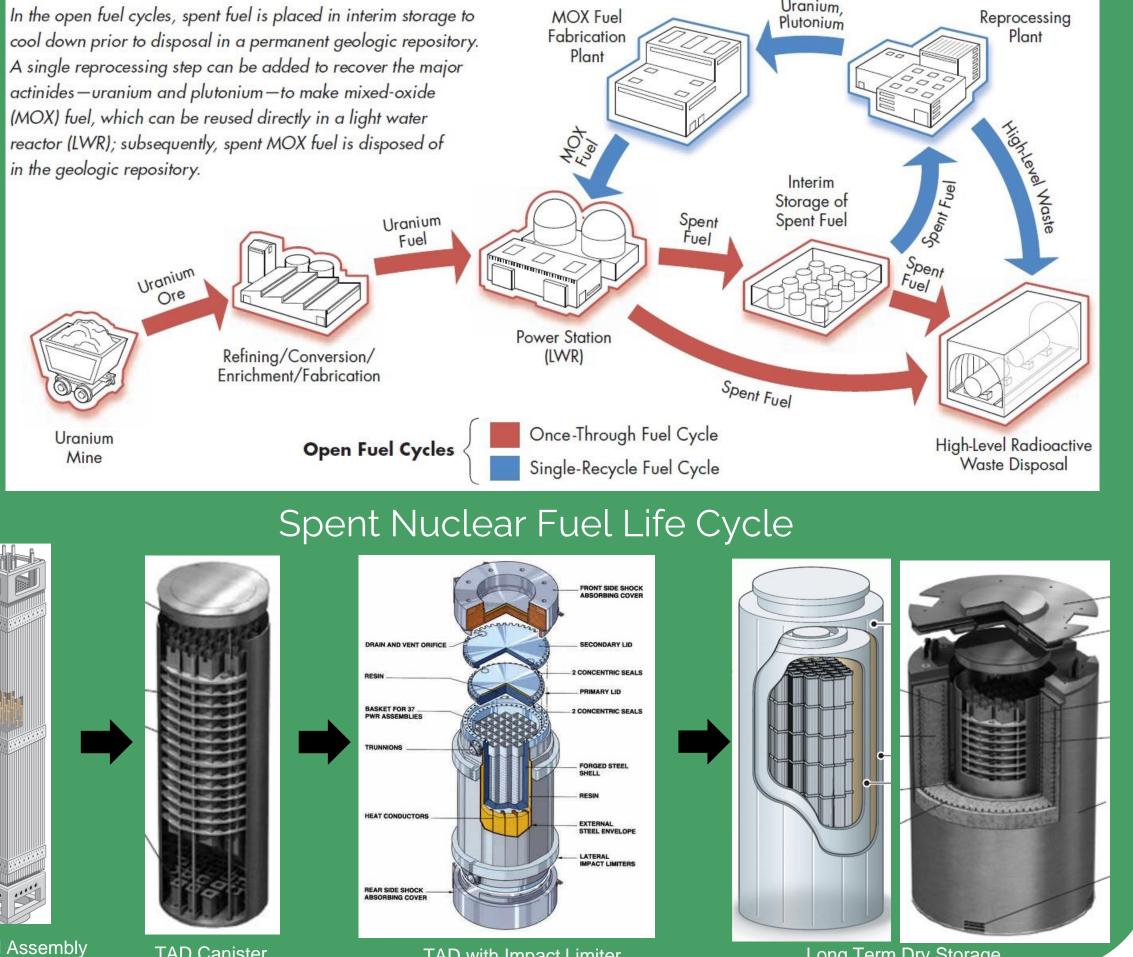
### Wire Simulations

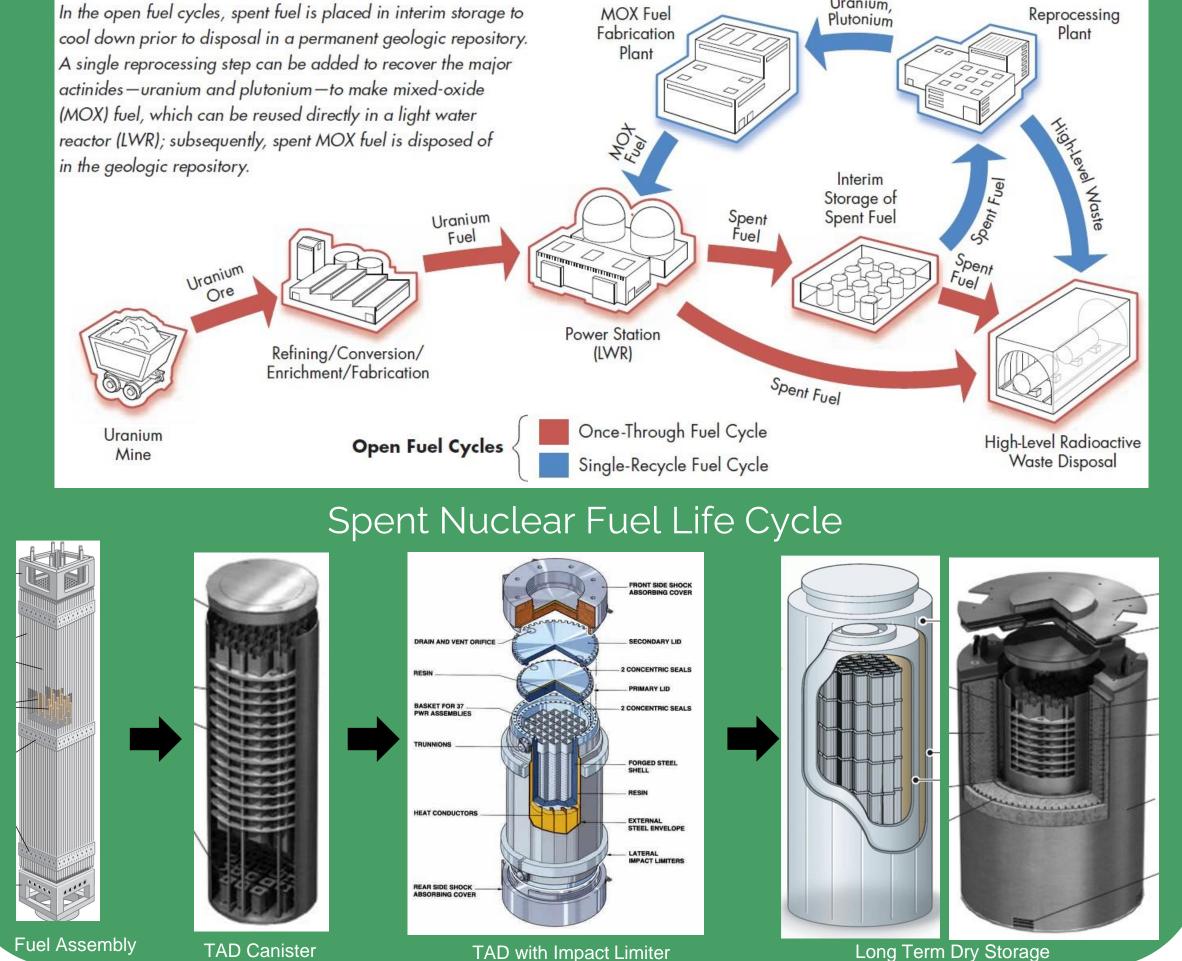
- RMD Sensor: 400 V Power Supply ○ 3.5 - 5 V Data Signal
- X-Wave Sensor: • 1 Vpp @ 20-30 MHz
- pulse signal. XLPE fully insulates wire.
- Woven Copper shielding protects against EMF interference
- Outer PEEK Plastic adds extra environmental protection while insulating against any possible outer electric contact.



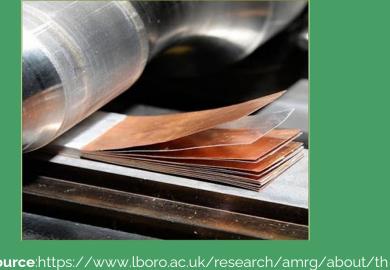
S=Severity number 1-10, 10 is the highest severity) O=Occurrence (A number 1-10, 10 is the highest occurrence) D=Detection (1-10, 10 is the hardest to detect)

Note: All ratings generated from design review meetings with Fabrisonic, Oerlikon, Aerosint, and ARC specialties as well as case study research and journal publications.





• UAM (Ultrasonic Additive Manufacturing) Most viable process for full scale manufacturing of the lid due to superior hermetic seal



• 3D printing methods for large scale industry purposes are still relatively new and can be extremely expensive depending on the complexity and size of the product required.

- and project improvements.



### Research

- -Electroplating with WAAM -Reducing cost of AM
- Testing
- -Crush test honeycomb structure
- -Materials testing with FDM

# Orano Background

### **Full-Scale Applications**

### • WAAM (Wire Arc Additive Manufacturing)

Most viable process for full scale manufacturing of the impact limiter. Easy to scale up



**Source:**https://www.additivemanufacturing.media/articles/ wire-arc-additive-manufacturing-delivers-low-buy-to-fly-

### Lessons Learned

• Certain 3D printing methods are incapable of printing certain combinations of materials and as a result this limits manufacturing and cost options. Focus groups are important for compiling information from relevant professionals and running project related ideas by other engineers to gather input about design

• When planning projects, more time needs to be given to contact manufacturers and start production earlier in the project timeframe to account for lengthy leadtimes.

### **Phase III Considerations**

### Fabrication

-Complete printing of phase 2 TN44 -Complete printing of impact limiter honeycomb

-Materials testing with 17-4 stainless steel -Continue WAAM materials testing -Test for anisotropic properties in AM materials



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# **Optimization Study for Off-Loading the Shearon Harris Spent Nuclear Fuel Pool** using Transportable Aging and Disposal (TAD) Canisters Phase II Senior Design 2 - Spring 2021

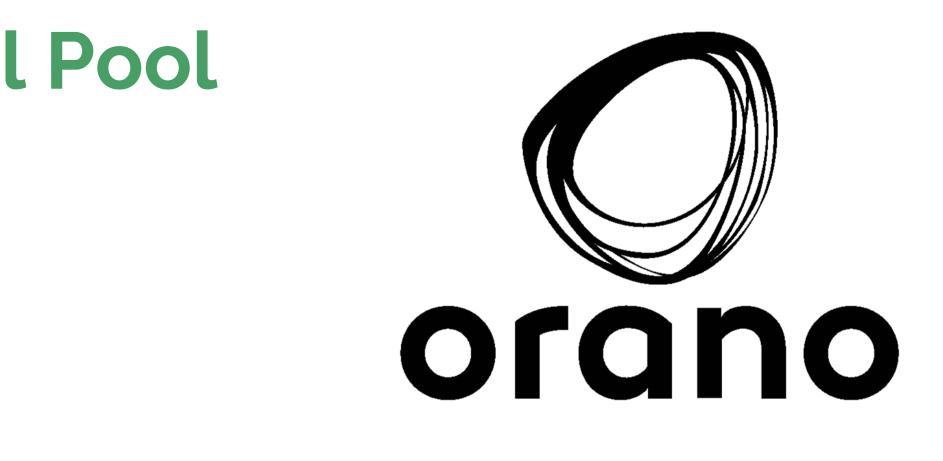
Team Members: Mikayla Harkey (mharkey7@uncc.edu), John Gasson (jgasson@uncc.edu), Bhargav Gajjar (bgajjar1@uncc.edu), Albert Shank (ashank3@uncc.edu), Andriy Bilovol (abilovol@uncc.edu), Nathan Pearce (npearce@uncc.edu), Victoria Kuntz (vkuntz@uncc.edu), Sydney Rowan (srowan2@uncc.edu). Faculty Mentors/Industry Supporters: Dr. Yesim Sireli, Dr. Michael Smith/ Dr. Sven Bader, Brad Crotts

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# **Project Expected Deliverables**

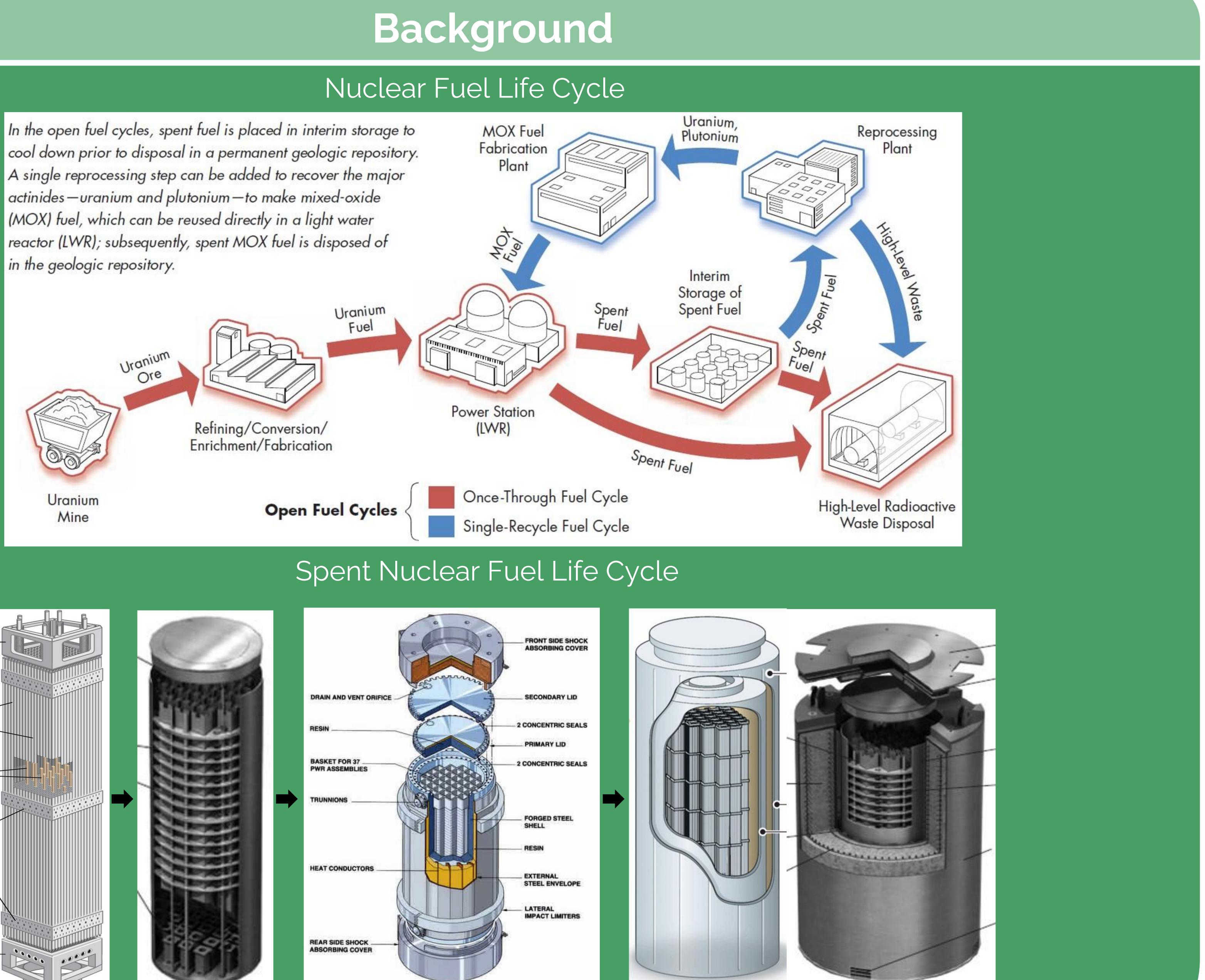




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TAD with Impact Limiter



### Long Term Dry Storage







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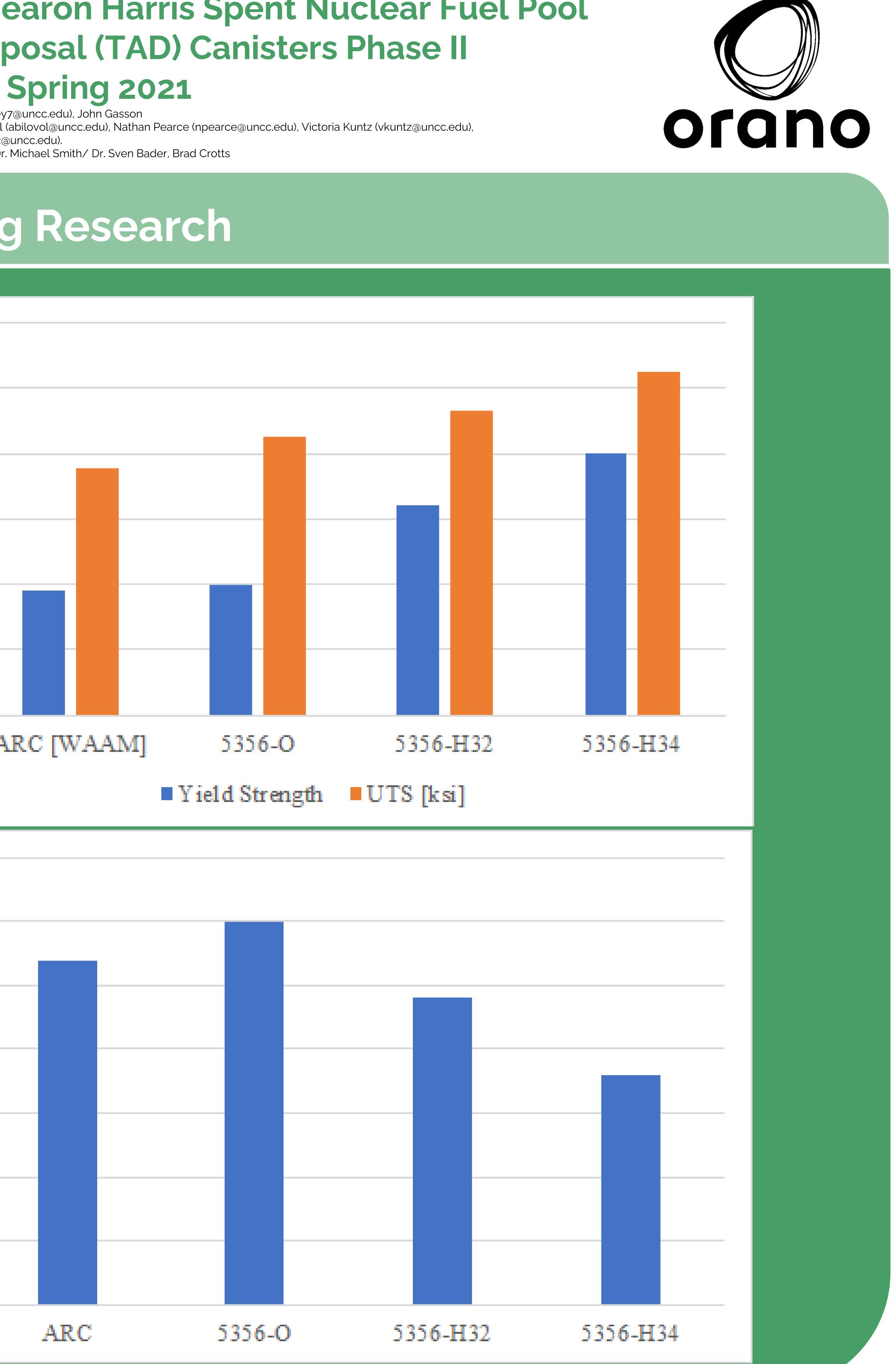
# 5356 Aluminum -Tensile Testing ["dogb -Yield Strength -Ultimate Tensile Stren -% Elongation

Purpose

-AM process may alter r properties of our materia -Incorrect mechanical p lead to part failure -Research conducted to mechanical properties -Compare AM vs Traditio

# Material Testing Research

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# Research

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# Fabrication

- Research identifies methods
- AHP's identify best methods
- UAM, SPD, DED
- scale

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# • Different methods for prototype and full-



# Design

- Iterative Process
- Design change with each informative meeting
- Different design for each manufacturing process
- Based on NRC and DOE regulations

# **Testing and Analysis**

- DOE and NRC specifications
- Digital Simulation/Finite Element Analysis
- Ansys

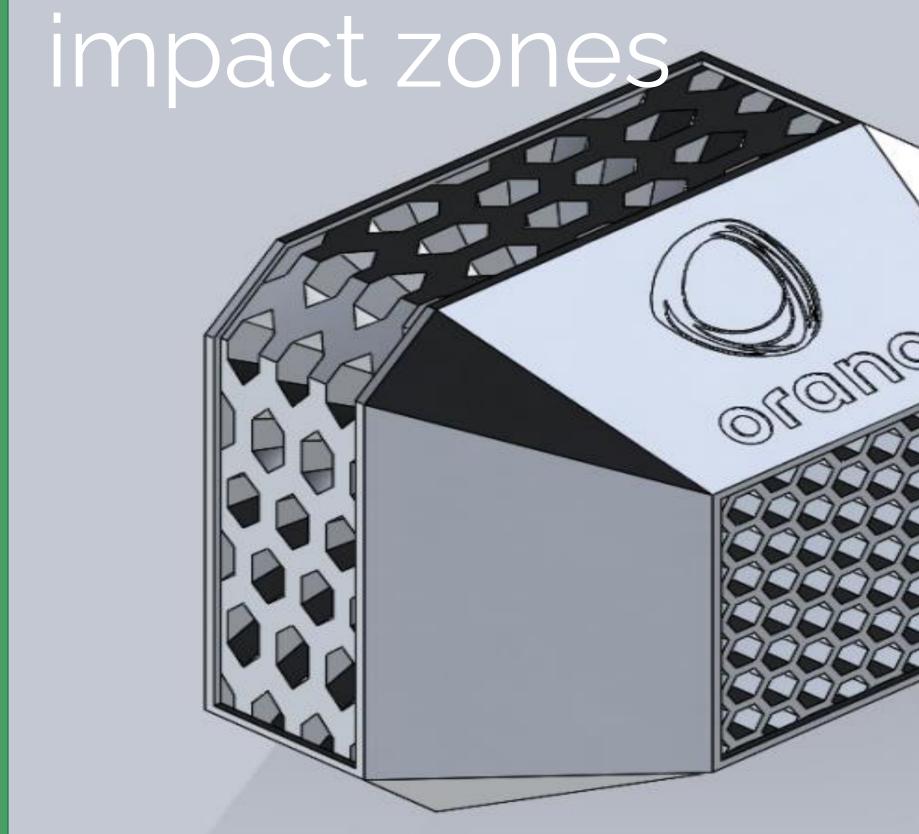




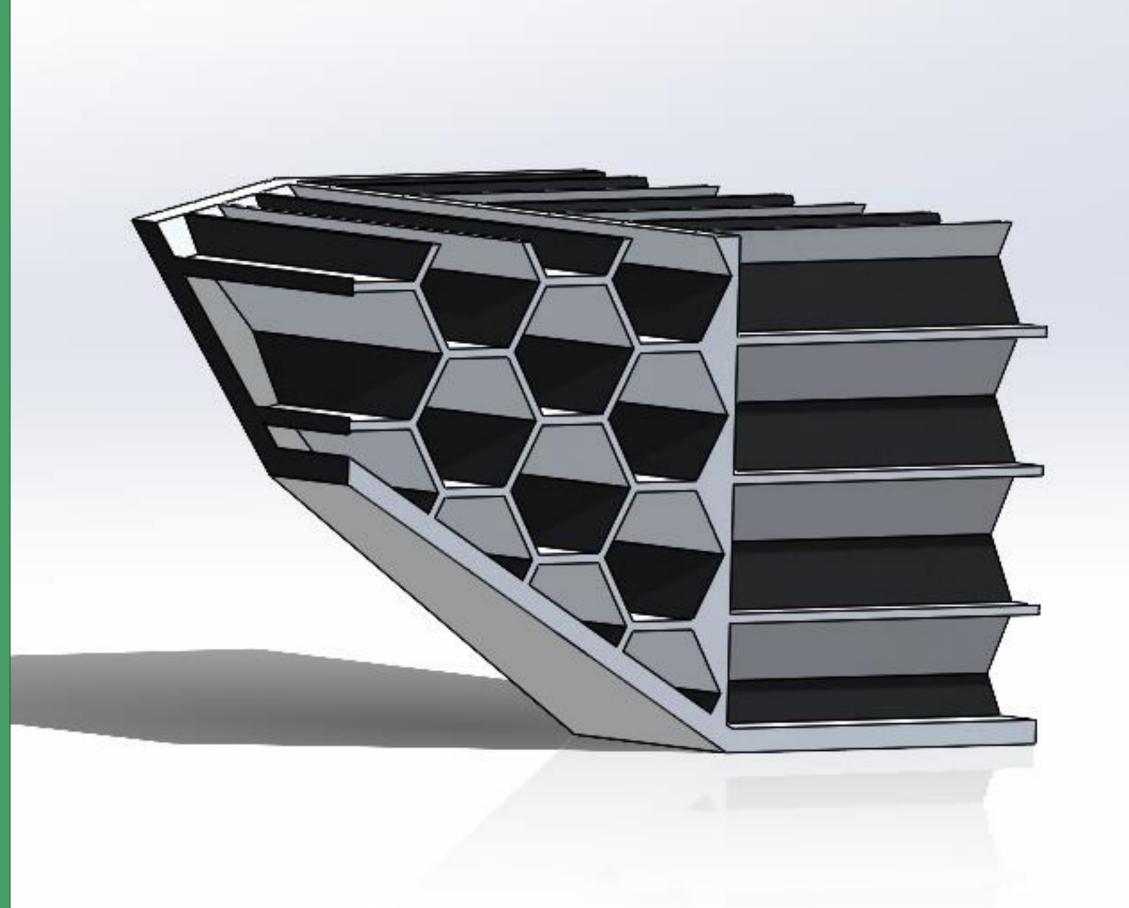




# Radial Design Honeycomb Strong axis always faces



# Proposed corner model for WAAM printing



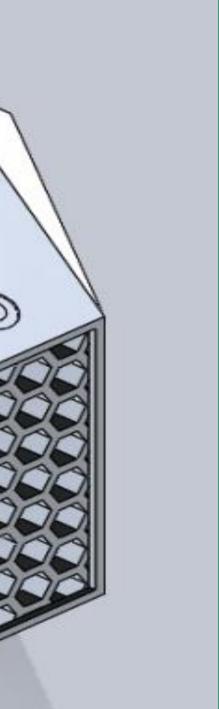
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DS

### Design and FEA of Impact Limiter



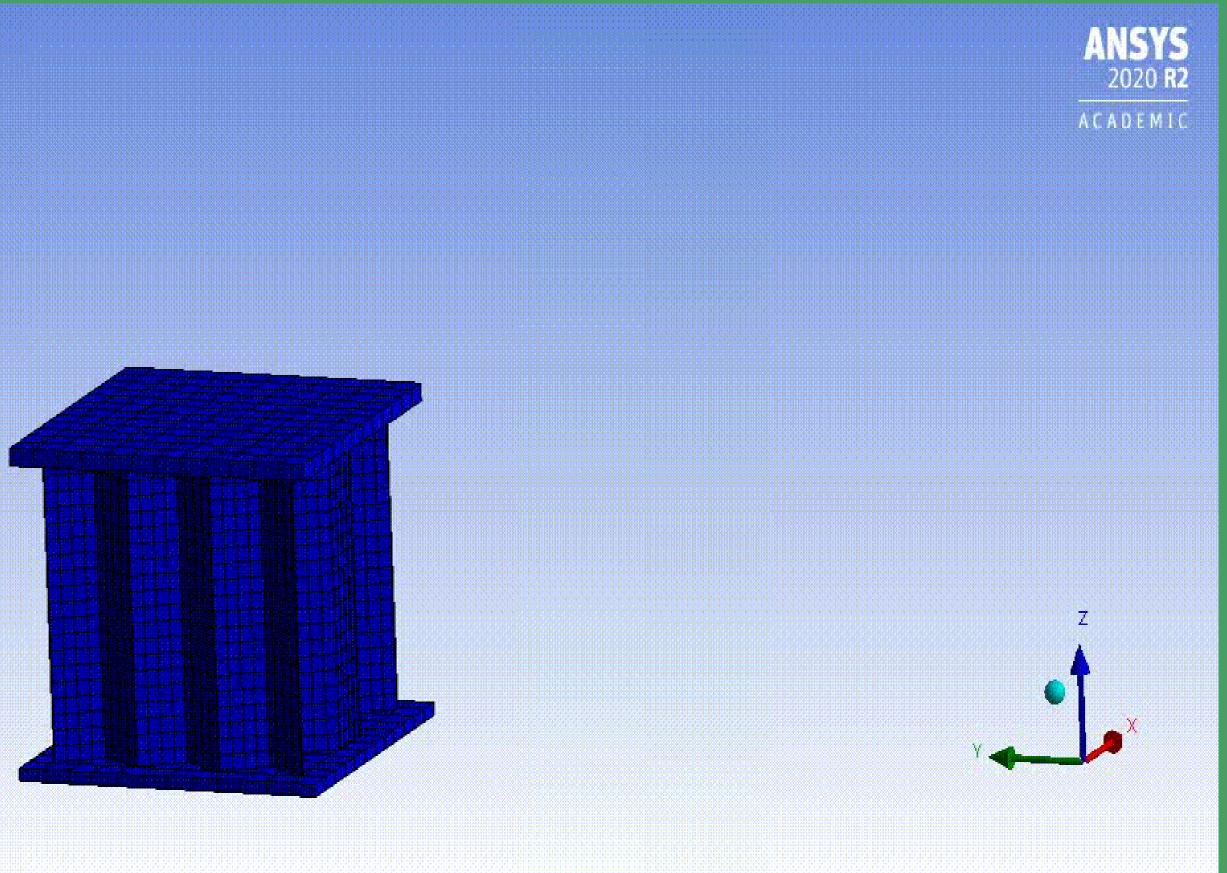




# • Simulated 2'x2' Honeycomb crash test 8.77 inch deformation at 2000

A: Static Structural Total Deformation Type: Total Deformation Unit: in Time: 0 4/25/2021 9:39 Af

-	0.044548 M
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	0.034649
	0.029699
	0.024749
	0.019799
	0.014849
	0.0098997
	0.0049498
	0 Min



# • Simulated Tensile test Yield Strength: 15,420 psi Tensile strength: 28,310 psi Young's Modulus: 9,934 ksi Elongation: 12%

Time: 1.0147e-00 Cycle Number 11 4/25/2011 1:11 AM

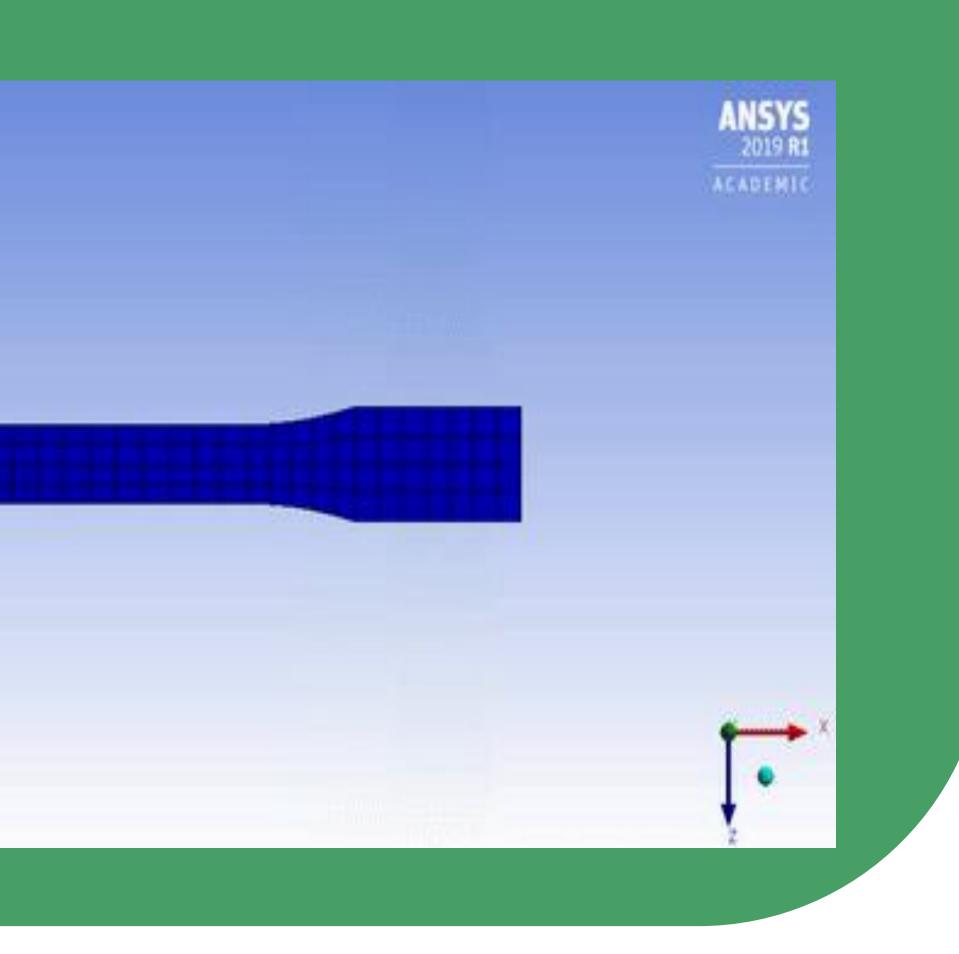
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1.3671e7 1.0937e7

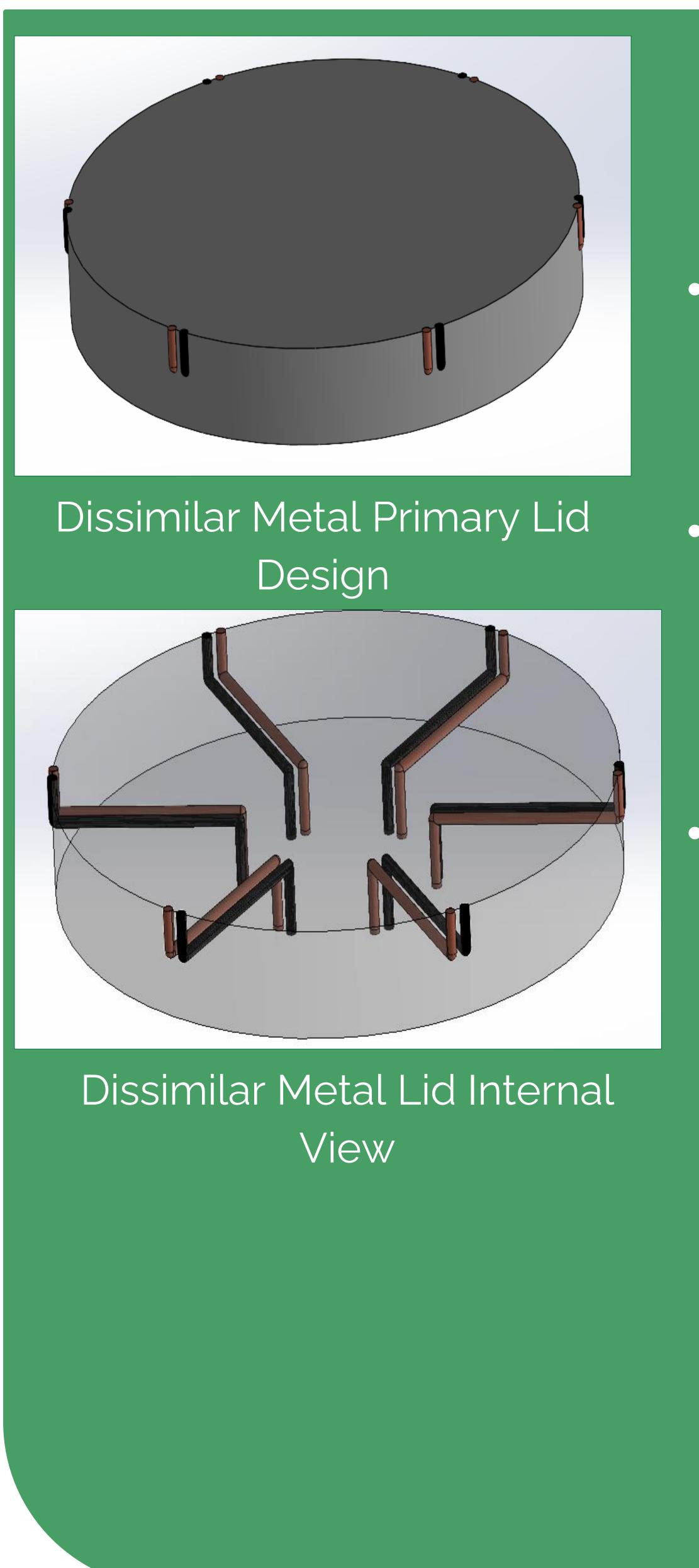
8.2025e6 5.4680e6 2.7342e6 0 Min











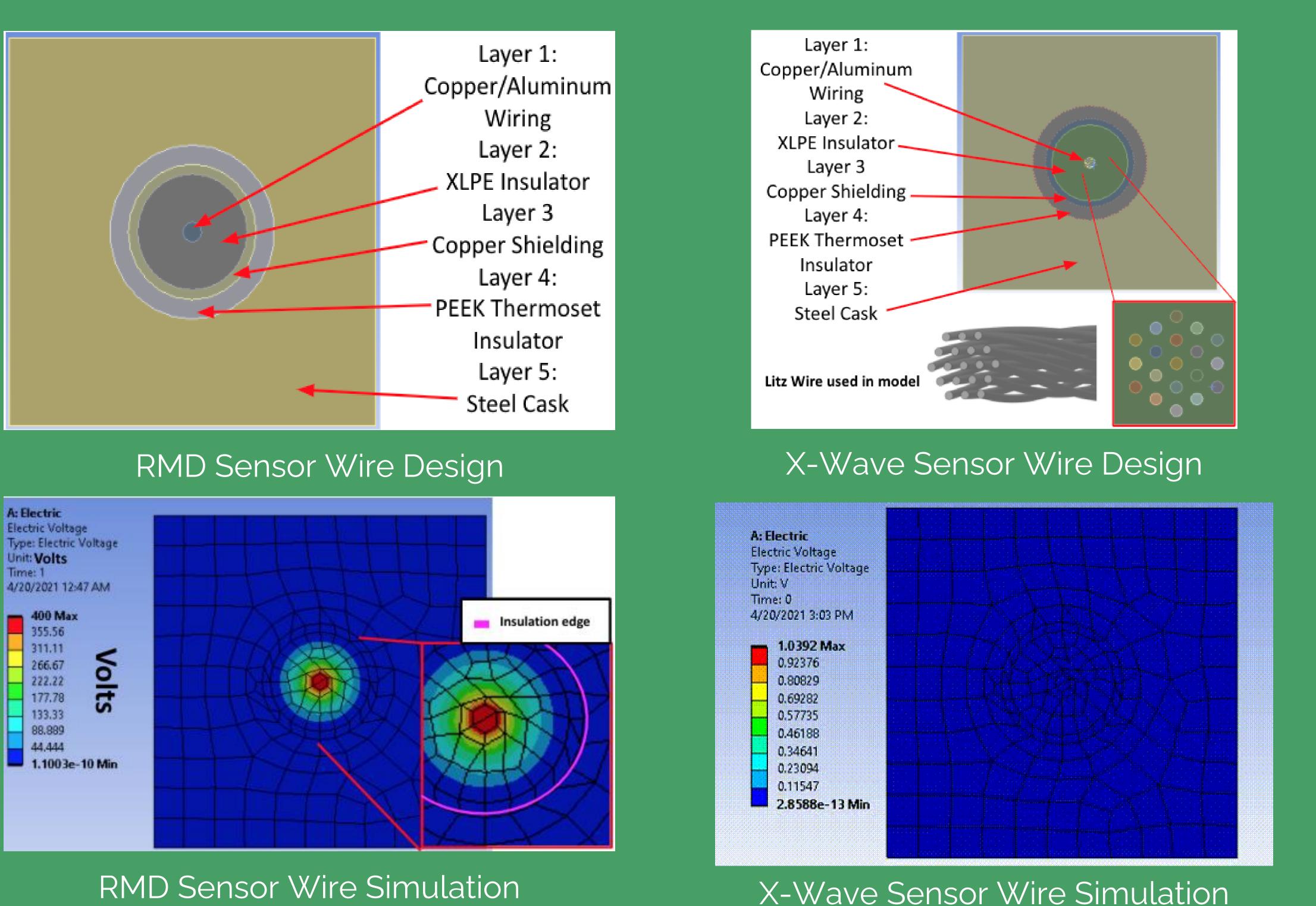
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# **Dissimilar Metal Prototypes**

# Primary Lid

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- Wires are bent to help with manufacturing restrictions and radiation shielding
- Complex wire designs offer great protection from radiation, heat, corrosion, and EMF interference



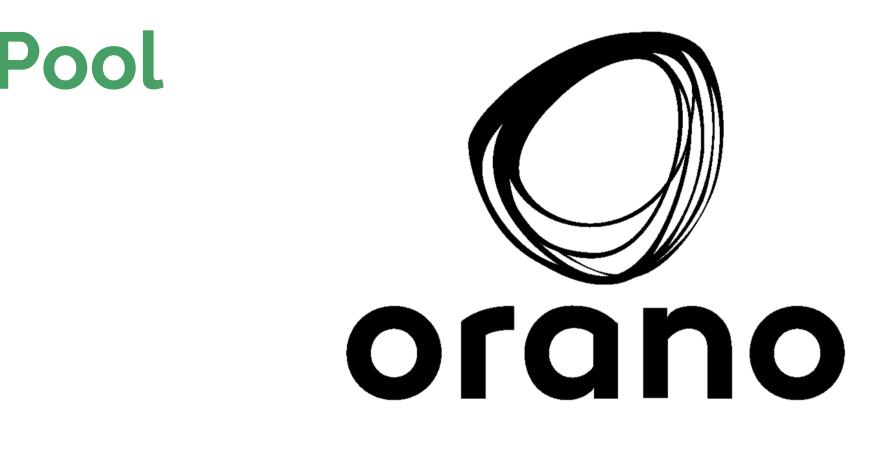
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# Wire Simulations

 RMD Sensor: 400 V Power Supply 03.5 - 5 V Data Signal X-Wave Sensor: 1 Vpp 

 20-30 MHz pulse signal.

 • XLPE fully insulates both wires. • Woven Copper shielding protects against EMF interference Outer PEEK Plastic adds extra environmental protection while insulating against any possible exterior electric contact.





# **Optimization Study for Off-Loading the Shearon Harris Spent Nuclear Fuel Pool** using Transportable Aging and Disposal (TAD) Canisters Phase II Senior Design 2 - Spring 2021

FAILURE MODE AND EFFECTS ANALYSIS													FAILURE MODE AND EFFECTS ANALYSIS																									
Model:						Current			Responsibility: Prepared by:						V.Kuntz & S.R. V.Kuntz		1	- - -	FMEA number: Page: MEA Date (Orig):	1 of 1			Item: Model: Core Team	Impact Limiter Current n: ORANO_TAD2			Responsibility: Prepared by:		V. Kuntz & V.Kuntz	S.Rowan		_ FMEA number: _ Page : _ FMEA Date (Orig)	):	3 1 of 1 11/21/2020	3 1 of 1 11/21/2020 <b>Rev:</b>		1	
Part Design	Potential Failure Mod	e Potential Effect(	s) e v	Potential Cause(s)	O c c	Current Process Controls	D e t	R P N	Recommended Action(s)	Responsibility		ction R S e v	esults O c c	D e t	R P N	Part Design	Potential Failure Mode	Potential Effect(s)	S e v	Potential Cause(s)	O c c	Current Process Controls	D e t	R P N	Recommended Action(s)	Responsibility	Actions Taken	Actio S e v	n Results O c c	D e t	R P N							
TAD Canister Lid	Cracking	Serap part	8	Stress when printing or temperature expansion	6	None	5	240	Use UAM	Lid Design Team	Use UAM	4	2	5	40	Impact Limiter honeycomb structure	Cracking	Decrease in performance	8	Stress when printing	6	None	8	384		Impact Limiter Design Team, Manufacturer	Thicker walls	8	3	8	192							
	Warping	Potential to affect signal transmissio		Stress when printing or temperature expansion	8	None	2	80	Use UAM	Lid Design Team	Use UAM	4	3	2	24		warping	Decrease in performance	5	Stress when printing	8	None	8	320	Thicker walls, NDT internal testing Consult ARC	Manufacturer	Thicker walls	5	3	8	120							
TAD	Print failure	Serap part	9	Machine error	6	None	1	54	Consult Fabrison experts	c Manufacturer: Fabrisonics	Use UAM	9	3	1	27	Turnent	Print failure	Scrap part	9	Machine error	б	None	1	54	Specialties experts	Manufacturer: ARC Specialties	N/A	9	6	1	54							
Canister Lid Wiring	-	No signal	7	Wire fracture	3	None	1	21	Anodized wire	Lid Design Team	Anodized wire	4	2	1	8	Impact Limiter walls	Warping	Decrease in performance	7	Stress when printing	8	None	3	168	Add supports, NDT internal testing	Impact Limiter Design Team, Manufacturer	Add supports	7	3	3	63							
	Inability to transmit signa through wall	No signal	7	Insulation failure	5	None	1	35	Insulate with titanium or ceramic	Lid Design Team	Insulate with titanium or ceramic	6	2	1	12		Cracking	Scrap part	8	Stress when printing	6	None	5	240	Add supports, NDT internal testing	Impact Limiter Design Team, Manufacturer	Add supports	8	3	5	120							
	Voltage leak	electrocution effect	5	Melted Insulator	2	None	5	50	Choose insulator with high melting temperature. Perform tests.		Choose insulator with high melting temperature. Perform tests.	5	1	5	25		Print failure	Scrap part	9	Machine error	6	None	1	54	Consult ARC Specialties experts	Manufacturer: ARC Specialties	N/A	9	6	1	54							
	Fraying of insulator/ conductor	No Signal	5	Lid placed on or removed from cask	4	None	1	20	Use embedded wires and use protective metal layer over them.	Lid Design Team	Use embedded wires and use protective metal layer over them.	5	1	1	5					FA	AILURI	E MODE ANI	D EFFEC	TS ANAI	LYSIS													
	Electromagne Field Interference	ic Interrupt data signals and break sensors	9	Alternating current	8	None	2	144	add electromagnetic shielding	Lid Design Team	add electromagnetic shielding	9	1	2	18	Item: Model: Core Team	Current	aring Phase 1 Pri TAD2	ints	Responsibility Prepared by:	:	V.Kuntz & V.Kuntz	S. Rowan		_ FMEA number: _ Page : _ FMEA Date (Orig	;):	4 1 of 1 11/21/2020	Rev	v <b>:</b>	2								
	Loss of Confinement	Gas and radiation leakage	8	confinement seal; leak where gas can get through	6	None	3	144	Use fabrasonic manufacturing process Use ceramic insulators instead	Lid Design Team	Use fabrasonic manufacturing process Use ceramic insulators instead	8	2	3	48	Part Design	Potential Failure Mode	Potential Effect(s)	S e v	Potential Cause(s)	O c c	Current Process Controls	D e t	R P N	Recommended Action(s)	Responsibility	Actions Taken	Actio S e v	on Results O c c	D e t	R P N							
	Insufficient Shielding	Radiation Exposure	9	Insulation breaking down	5	None	3	135	of polymers and minimize the size of cross sectional insulator area	Lid Design Team	of polymers and minimize the size of cross sectional insulator area	9	2	2	36	TAD Canister Shell Wall	Cracking		8	Stress when printing	5	None	5	200	Add internal and external supports	s Design Team	Add internal and external supports	5	2	5	50							
	Contraction ar Expansion		9	High temperatures affecting resistivity, melting,	5	None	3	135	Use ceramics and polymenrs that provide better	Lid Design	Use ceramics and polymenrs that provide better	9	2	3	54		Warping Print	canister	5	Stress when printing Post print	8	None	3	120	Add internal and external print supports Minimize size of	Design Team	Add internal and external supports Minimize	4	3	3	36							
	LAPAIISIOII	pressure on insulators		expansion, and contraction					thermal properties	Team s	thermal properties					TAD Canister	Failure	Serap part	7	processes Stress when	8	None	1	56 200	print Add internal and	Design Team	size of print Add internal	7	4	1	28							
		' I / A									<b>'</b>					Basket Walls		Scrap part Affect shape	8	printing	5	None	5	200	external supports Add internal and	s Design Team	and external supports Add internal	3	2	3	50							
				nber 1-1					Ŭ								Warping	-	5	Stress when printing	8	None	4	160	external print supports	TAD Canister Design Team	and external supports	4	3	4	48							
•	Dccu	rrence	(A	numbe	r:	1-10	, 10	) is	the h	ighest	occur	re	nc	e)			Print Failure	Serap part	7	Post print processes	8	None	1	56	Minimize size of print	f TAD Canister Design Team	Minimize size of print	7	4	1	28							

• D=Detection (1-10, 10 is the hardest to detect)

Team Members: Mikayla Harkey (mharkey7@uncc.edu), John Gasson (jgasson@uncc.edu), Bhargav Gajjar (bgajjar1@uncc.edu), Albert Shank (ashank3@uncc.edu), Andriy Bilovol (abilovol@uncc.edu), Nathan Pearce (npearce@uncc.edu), Victoria Kuntz (vkuntz@uncc.edu), Sydney Rowan (srowan2@uncc.edu).

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# FMEA and Manufacturing Analysis

Note: All ratings generated from design review meetings with Fabrisonic, Oerlikon, Aerosint, and ARC specialties as well as case study research and journal publications.





# • UAM (Ultrasonic Additive Manufacturing) Most viable process for full scale manufacturing of the lid due to superior hermetic seal



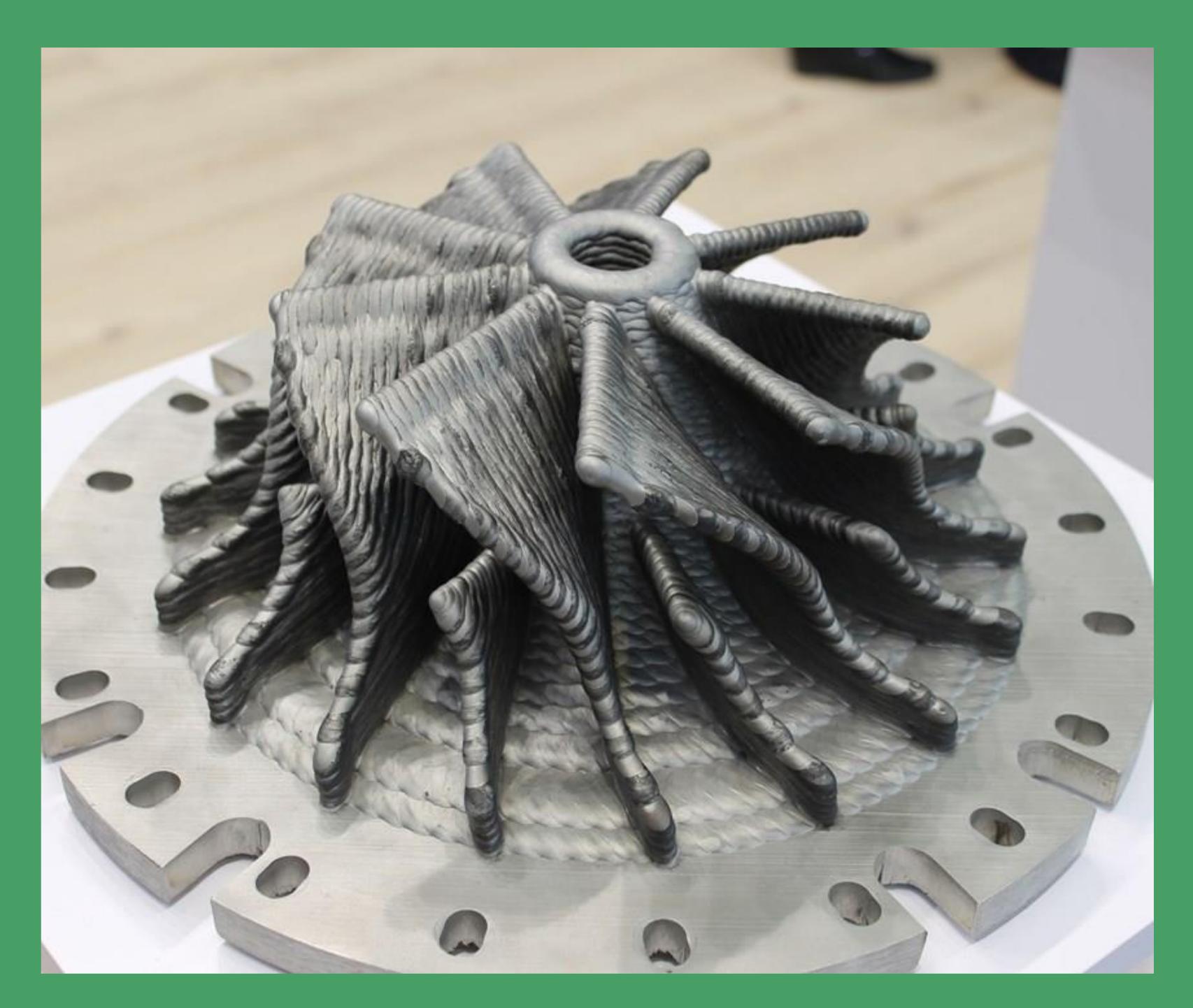
**Source**:https://www.lboro.ac.uk/research/amrg/about/the7categories ofadditivemanufacturing/sheetlamination/

# **Optimization Study for Off-Loading the Shearon Harris Spent Nuclear Fuel Pool** using Transportable Aging and Disposal (TAD) Canisters Phase II Senior Design 2 - Spring 2021

Team Members: Mikayla Harkey (mharkey7@uncc.edu), John Gasson (jgasson@uncc.edu), Bhargav Gajjar (bgajjar1@uncc.edu), Albert Shank (ashank3@uncc.edu), Andriy Bilovol (abilovol@uncc.edu), Nathan Pearce (npearce@uncc.edu), Victoria Kuntz (vkuntz@uncc.edu), Sydney Rowan (srowan2@uncc.edu). Faculty Mentors/Industry Supporters: Dr. Yesim Sireli, Dr. Michael Smith/ Dr. Sven Bader, Brad Crotts

# Full Scale Applications

• WAAM (Wire Arc Additive Manufacturing) Most viable process for full scale manufacturing of the impact limiter. Easy to scale up



Source: https://www.additivemanufacturing.media/articles/wire-arcadditive-manufacturing-delivers-low-buy-to-fly-ratios







• 3D printing methods for large scale industry purposes are still relatively new and can be extremely expensive depending on the complexity and size of the product required.

• Certain 3D printing methods are incapable of printing certain combinations of materials and as a result this limits manufacturing and cost options.

• When planning projects, more time needs to be given to contact manufacturers and start production earlier in the project timeframe to account for lengthy leadtimes.

# **Optimization Study for Off-Loading the Shearon Harris Spent Nuclear Fuel Pool** using Transportable Aging and Disposal (TAD) Canisters Phase II Senior Design 2 - Spring 2021

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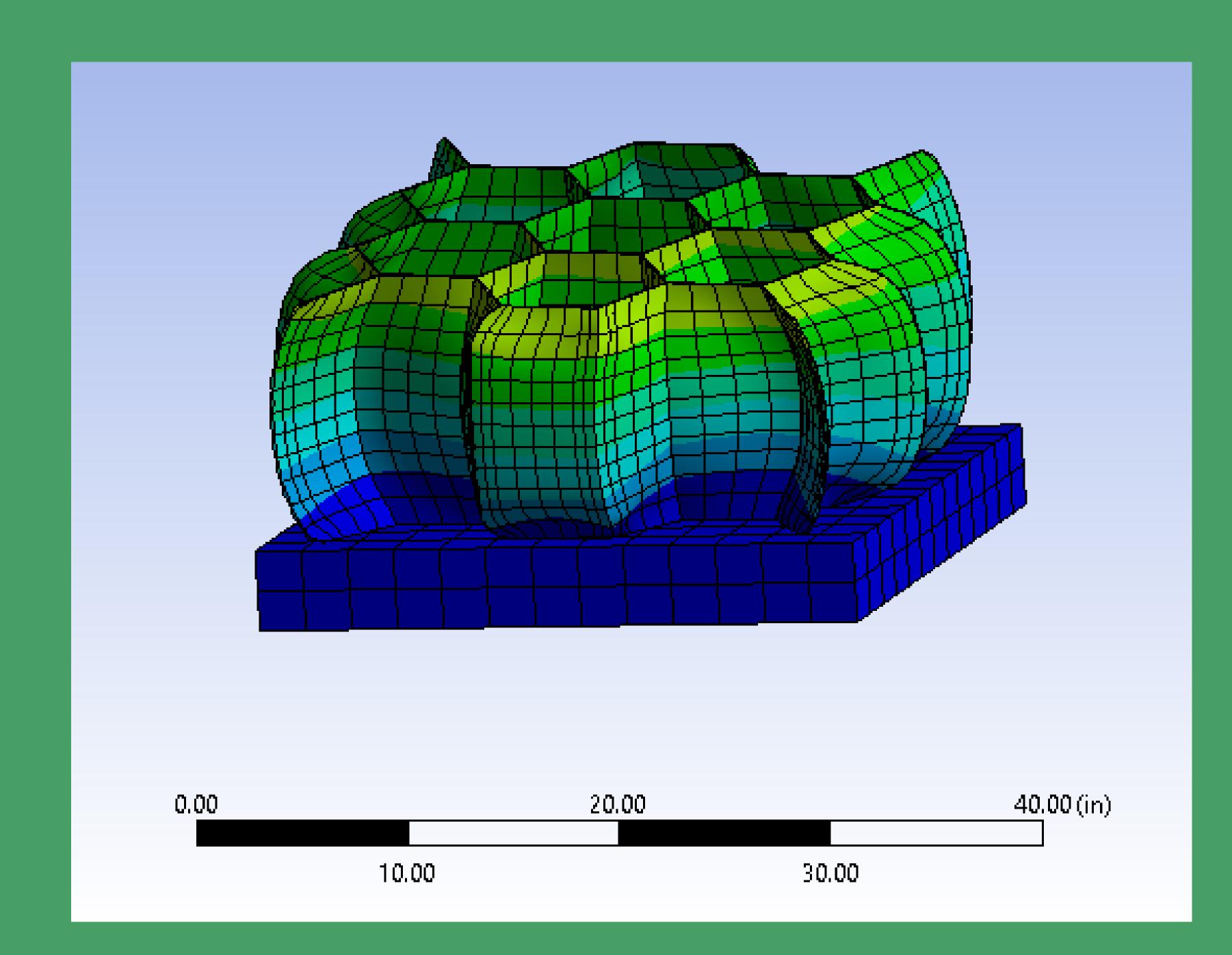
# Lessons Learned

• Focus groups are important for compiling information from relevant professionals and running project related ideas by other engineers to gather input about design and project improvements.





# Research -Electroplating with WAAM -Reducing cost of AM



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# **Phase III Considerations**

Fabrication -Complete printing of phase 2 TN44 -Complete printing of impact limiter honeycomb





-Crush test honeycomb structure -Materials testing with FDM -Materials testing with 17-4 stainless steel -Continue WAAM materials testing -Test for anisotropic properties in AM

