Decarbonization Research Consortium

WELCOME

24 April 2024

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Decarbonization Research Consortium Meeting
24 April March 2024 / 1 – 3 pm ET / 10 am – Noon PT
Working Session Agenda

1 - 1:10	**Welcome/Overview/Admin** **Date Preferences for Aug/Sept mtg**
1:10 - 1:40	**Session1: Research Project Technology Maturation** **Lead: Sage Kokjohn, University of Wisconsin**
1:40 - 2:15	**Session 2: Researcher Collaboration / Student Collaboration** **Leads: Sang Hee Won, University of South Carolina** **Kirk Waltz, American Bureau of Shipping**
2:15 - 2:45	**Session 3: Roadmap V2.0** **Lead: Petros Sofronis, University of Illinois**
2:45 - 3	**Wrap up/review of action items, etc.**

Decarbonization Research Consortium

Path Forward

May	**14 May 2024 / 1 – 3 pm ET / 10 – Noon PT** **Virtual**
June	**14 June 2024 / 1 – 3 pm ET / 10 – Noon PT** **Virtual**
July	**12 July 2024 / 1 – 3 pm ET / 10 – Noon PT** **Virtual / Partner Presentations**
Aug/Sept	**Date TBD: *Aug 28-29 or Sept 4-5*** **Location: Washington, DC (GWU)** **In-Person Working Session**

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SESSION 1: RESEARCH PROJECT TECHNOLOGY MATURATION

Lead: Sage Kokjohn, University of Wisconsin – Madison
Engine Research Center

Technology Maturation and Risk Reduction (TMRR)

- Disclaimer:
  - I am not an expert in Technology Maturation
  - Some references I looked at

1. Technology Readiness Assessment Guidebook, Office of the Executive Director for Systems Engineering and Architecture Office of the Under Secretary of Defense for Research and Engineering, June 2023
2. GAO-16-410G, Technology Readiness Assessment Guide, US Government Accountability Office (GAO), Aug. 2016

Technology Maturation and Risk Reduction (TMRR)

- Google says, "**an iterative process of maturing technologies and refining user performance parameters to accommodate those technologies that are not sufficiently mature**."

Microsoft Co-Pilot says

- **Concept Exploration:** In this initial phase, concepts are explored, and potential technologies are identified.
- **Technology Development:** Technologies are developed and matured through research, prototyping, and testing.
- **Risk Reduction:** Efforts focus on reducing technical risks associated with the chosen technologies.
- **Prototype Development:** Competitive prototyping occurs to refine requirements and develop baselines.
- **Systems Engineering Trade-Off Analysis:** Trade-offs are analyzed to inform decisions on cost, capability, and parameters.
- **Technology Readiness Assessment (TRA):** Critical technologies are assessed for readiness.

Technology Maturation and Risk Reduction (TMRR)

- Typically, TMRR discussion goes along with TRL level discussion
- One challenge with typical TRL assessments are that they seem well suited for stand-alone devices, but it is often challenging to apply in a complex system (e.g., an engine or ship)
- Interaction with stakeholders is key to allow meaningful movement from low to high TRL levels
- System level modeling can support complex assessments
- Competitive analysis is useful throughout the TRL path

Technology readiness level (TRL)		Description
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively low fidelity compared with the eventual system. Examples include integration of ad hoc hardware in the laboratory.
5	Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include high fidelity laboratory integration of components.
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in its relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7	System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requirement demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, a vehicle, or space).
8	Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Source: GAO simplification of agency documents. | GAO-16-410G

Technology Maturation and Risk Reduction (TMRR)

- TRL becomes murky in our applications (i.e., integrating technology into an existing device rather than creating a new device)
- Integration Readiness Level (IRL) is probably as important (or more important) than TRL

Table 14: Integration Readiness Levels

IRL	Definition	Evidence Description
0	No integration	No integration between specified components has been planned or intended
1	A high-level concept for integration has been identified.	Principle integration technologies have been identified Top-level functional architecture and interface points have been defined High-level concept of operations and principal use cased has been started
2	There is some level of specificity of requirements to characterize the interaction between components	Inputs/outputs for principal integration technologies/mediums are known, characterized and documented Principal interface requirements and/or specifications for integration technologies have been defined/drafted
3	The detailed integration design has been defined to include all interface details	Detailed interface design has been documented System interface diagrams have been completed Inventory of external interfaces is completed and data engineering units are identified and documented
4	Validation of interrelated functions between integrating components in a laboratory environment	Functionality of integrating technologies (modules/functions/assemblies) has been successfully demonstrated in a laboratory/synthetic environment Data transport method(s) and specifications have been defined
5	Validation of interrelated functions between integrating components in a relevant environment	Individual modules tested to verify that the module components (functions) work together External interfaces are well defined (e.g., source, data formats, structure, content, method of support, etc.)
6	Validation of interrelated functions between integrating components in a relevant end-to-end environment	End-to-end Functionality of Systems Integration has been validated Data transmission tests completed successfully
7	System prototype integration demonstration in an operational high-fidelity environment	Fully integrated prototype has been successfully demonstrated in actual or simulated operational environment Each system/software interface tested individually under stressed and anomalous conditions
8	System integration completed and mission qualified through test and demonstration in an operational environment	Fully integrated system able to meet overall mission requirements in an operational environment System interfaces qualified and functioning correctly in an operational environment
9	System integration is proven through successful mission proven operations capabilities	Fully integrated system has demonstrated operational effectiveness and suitability in its intended or a representative operational environment Integration performance has been fully characterized and is consistent with user requirements

Disclaimer: The IRL scale does not attempt to address or account for programmatic lifecycle activities or responsibilities. This scale is intended to be used to assign integration readiness levels based on the applicable definitions and supported by the evidence descriptions.

Source: GAO 2020 citing Marc Austin and Donald York, Conference on Systems Engineering Research

Figure 6-1. Integration Readiness Levels

Technology Maturation and Risk Reduction (TMRR)

Discussion Questions

- Who are the key stakeholders?
- Are they the same for each group?
- Are there external stakeholders (e.g., engine OEMs) that should provide guidance?
- What is the best way to get key system constraints?
- How do we allow flexibility for future constraints?

SESSION 2: RESEARCHER COLLABORATION & STUDENT COLLABORATION

Leads:

Sang Hee Won, University of South Carolina

Kirk Waltz, American Bureau of Shipping

Discussion Items

- **Increasing the researcher collaboration**
  – Are organic discussions enough, or do you want targeted/facilitated time?
  – How would you structure this?

- **Student collaboration**
  – How do we increase/emphasize student involvement?
  – Any suggestions for collaborations among the student teams?

- **Industry collaboration**
  – Are there examples of specific technology/collaboration ideas?
  – Is there potential for collaborative demonstration projects?

SESSION 3: ROADMAP 2.0

Lead: Petros Sofronis, University of Illinois

Roadmap V2.0
Thrust Areas and Technology Options

	CO2 reduction	Thrust areas	Technology options	University Projects									
		Category	Sub-Category	USC	CSU	PSU	USNA	GWU	NPS	NPS2?	UW	U of Ill	NSWC-Philly
Major Thrust Areas	0% - 15%	Energy Efficiency	Propulsive efficiency improvements & direct drag reduction										
			Propulsion & power generation improvements									X	
			Electrification & hybridization										
			Thermal management, WHR									X	
			Demand reduction										
			Energy storage										
			Lightweight materials										
	0% - 15%	Operational Efficiency Improvements	Route optimization										
			Plant & speed optimization										
			Trim optimization										
	TBD	Force Structure	Unmanned systems										
			"Single mission optimized" platforms										
			Attritable assets										
			UxV system modeling										
	0% - 100%	Fuel Technologies *Production, Distribution, Storage and/or Use*	Blended or drop-in fuels (bio-, renewable-)									X	
			Non drop-in liquid fuels (ammonia, methanol, etc.)									X	
			Hydrogen									X	
			Batteries										
			Nuclear										
			Renewable energy										
			Fuel cell technology										
	TBD	Carbon Capture, Use and Storage	Shipboard									X	
			Terrestrial									X	
			Other emissions capture/reduction										
Cross-Cutting Initiatives	N/A	Whole ship and system level design considerations	Ship design process										
			System level design considerations									X	
	N/A	Ship integration and technology scaling for	Ship integration (e.g., retrofit-ability, durability, etc.)									X	
			Scaling for shipboard use									X	
	N/A	Modeling, test sites and demonstration capability	Modeling & data analytics									X	
			Bench scale testing									X	
			Demonstrations & testing										
	TBD	Education and Training	Education & training									X	

Roadmap V2.0

- **Based on our collective experience are there any gaps that we need to pursue more deeply? How can the Navy dive deeper into any of the Thrust areas?**
  - Roadmap and analysis of future vision is needed for PIs to understand and collaborate towards critical areas
    - equivalent to something like the SAF Grand Challenge Roadmap
  - Strong coordination between the individual schools working on similar technologies
  - Definitely bring in additional resources, personnel to address technical deficiencies

Roadmap V2.0

- **Prioritize the specific technology options currently being pursued within each university**
  - Potential for CO_2 reduction
  - Efficiency increase, low carbon intensity, device development or device implementation
  - Depending on boundary conditions: space, weight, power, cooling, etc.
- **Identify technical challenges and risks**
  - Create timelines for each individual project within each individual technology option
  - Project timelines need to have short-, mid-, and long-term milestones in consideration for the removal of the roadblocks in the development and deployment timing of the various promising technology options
- **For each individual project**
  - Assess/evaluate quantitative impact on decarbonization
  - Sharpen the project timelines annually, re-derive quantitative analysis of impact on overall decarbonization, and re-assess the enabling of the relevant technology option

Roadmap V2.0

- **Updates or changes to the above?**
  - We should de-emphasize or increase emphasis in certain areas as the program progresses
  - There should be an effort to outline a tech transfer plan (or outlook) for each area
  - Maybe schedule a technology demonstration some time into the program
- **Are there any other technology options that can apply toward the decarbonization goals?**
  - Hybrid power generation architecture
  - Hydrogen based power generation
- **Where do we want to get information from the Navy regarding thrusts and technology options**
  - Information regarding materials currently in use on vessels (engine components included)
  - Composition of Navy exhaust
  - How much modification can be made to hardware on current naval vessels
  - Ratio between solid/safe solutions and high-risk disruptive technologies
- **Are there other researchers that can bring added value?**
  - Information regarding materials currently in use on vessels (engine components included)
  - How much modification can be made to hardware on current naval vessels
  - Ratio between solid/safe solutions and high-risk disruptive technologies

Materials Performance for Blended Fuels
Navy fuels blended with NH_3, H2, CH_4, other Electrofuels, Sustainable Diesel

Project Description

Project	Objectives	Research Efforts	Researchers
Materials performance in blended fuels Degradation in Hydrogen-rich environment	• Modified oxidation kinetics • H-enhanced creep deformation • Gas interactions with surface scales, dissociation, adsorption • Identify degradation mechanisms • Explore materials modification or new compositions for optimum performance	• Microstructural & Surface characterization • Atomistics of surface interactions • Macroscopic testing • Modeling degradation mechanisms	J.A. Krogstad P. Sofronis T. Lee

Project Timeline or Project Roadmap

Project	2025 (short)	2025-2030 (mid)	2030-2035 (long)
Materials degradation in hydrogen-rich environment	Survey the degradation mechanisms of existing superalloys in the relevant standard operating conditions Expose coupons to the new blended-fuel gaseous environment Understand gas interactions with metallic surfaces and underlying microstructural changes	Establish validated physical descriptions and models of oxidation kinetics, creep, and failure for existing superalloys Explore these physical descriptions in relation to new chemically improved alloy designs	New alloy design based on the understanding of degradation mechanism in the new gaseous environment Validate enhanced material properties and resistance to

From Research to Technology to CO_2 Reduction

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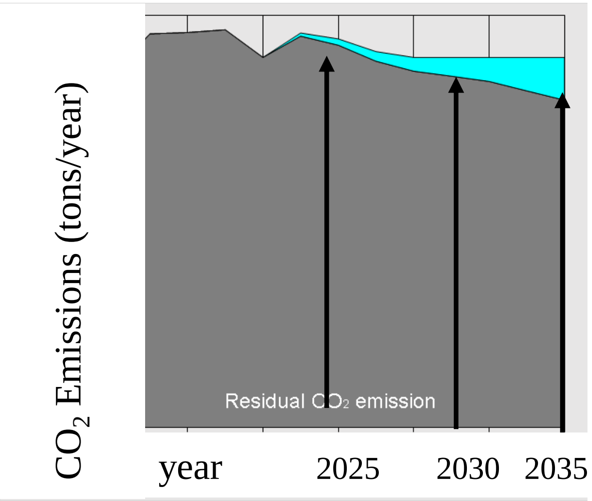
Enabling improved or new-materials implementation

Year	2025	2030	2035	...
Impact	Low	medium	high	...

Corresponding reduction in CO_2 emissions

Estimated reduction of CO_2 through Implementation of research-enabled improved materials or new alloys



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