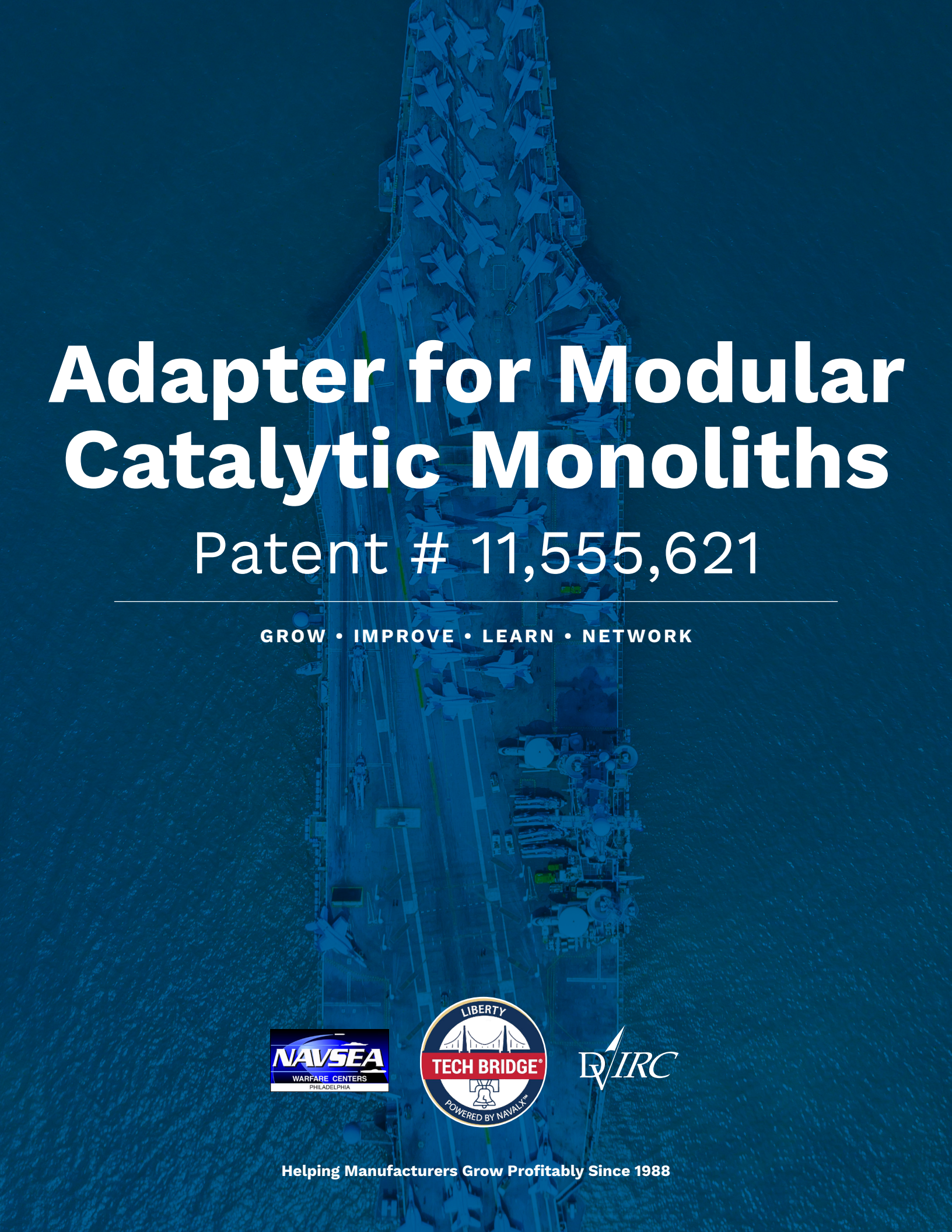

Adapter for Modular Catalytic Monoliths

Patent # 11,555,621

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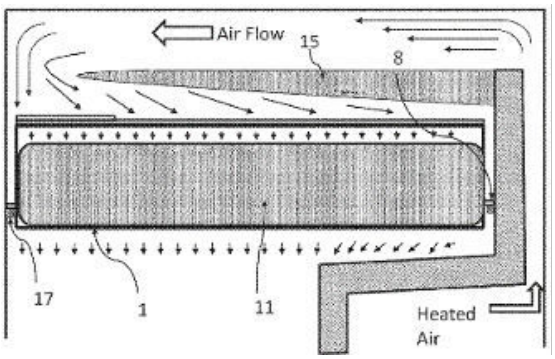
Technology Overview

Adapter for Modular Catalytic Monoliths – Patent #11,555,621

The Adapter for Modular Catalytic Monoliths is an improved device and method for adapting catalytic converters to use catalytic monoliths where space is restricted and not amenable to the use of long, straight ducting, expansion zones, and/or other flow-straightening means requiring more space. The adapter is applicable to both burners and other catalytic converters, such as NOx converters capable of catalytically converting NOx to N2. The adapter device is made to slide into the catalyst chamber of the burner and supports an air flow straighter element upstream from one or multiple catalytic monolith modules which slide into the adapter. The adapter is not part of the catalytic monolith module itself, so the adapter may be reused when an old or exhausted catalytic monolithic module is exchanged.



Note:

- The invention is optimized for systems originally designed for fixed-bed catalysts that seek a switch to a monolith;
- The switch to a monolith is often not possible if catalyst poisoning is a problem;
- Gas turbines, cars, etc. are typically designed to minimize the impact of flow maldistribution; if, however, space constraints prevent the design of a system to avoid flow distribution problems, the invention would be very useful;
- Utility boilers would also use monoliths for NOx control because of their low pressure drop; and
- Gas turbines and cars typically use monoliths because the pressure drop for a fixed bed would be much too high.

Capabilities

- The reusable monolith adapter would be favored in coal- or oil-fired power plants if flow distribution is a problem and there is not enough space to solve it another way; pressure drop in these units is critical.
- Useful in a wide variety of catalytic converters where it would be desirable to use catalytic monoliths to purify air, but space limitations have posed obstacles to their use.
- Useful for catalytic converters designed to control NOx or VOC emissions from stationary sources such as coal- or oil-fired power plants where the use of catalytic monoliths assists in compliance with emissions requirements, but where space is also limited.
- Useful for systems designed for fixed bed catalysts and used in space-limited environments.
- The adapter may be made from rigid materials such as stainless steel or other metals or alloys resistant to corrosion, oxidation, and carbonization at high temperatures.
- Monoliths are also used for control of carbon monoxide (CO) from gas turbine engines in cogeneration plants.

Benefits

- Reduces dust when switching from a fixed-bed to a monolith. (Note: switch not possible in all applications.)
- Provides more uniform, straightened air flow, directing contaminated air toward a monolith module inserted into the adapter (applicable in space-constrained gas turbines; power generation systems design around this.)
- Reduces necessary labor, variability, and the creation of dust when loading the catalyst into the burner; minimizes health risks.
- Permits more economic production of catalytic monolithic modules.

Benchmarks

Benchmarks are unique qualities that are used to compare against existing patents, patent filings, and commercially available products in this assessment tool.

Index Number	Title	Description
1	**Uniform Air Flow**	Provides more uniform airflow by supporting the flow-straightening element a distance upstream from the monolith inlet surface to permit flow straightening before air enters the monolith.
2	**Reduction of Dust/ Minimize Health Risks**	Permits the use of catalytic monolith modules, which are easily handled using gloved hands and can be used in a system incorporated in space-constrained environments. This reduces necessary labor, variability, and the production of dust when loading the catalyst into the burner. Minimizes health risks.
3	**Economical Production**	Enables more economical production of catalytic monolith modules. Simplifies rectangular dimensions; flow straightener elements and supporting tabs are included in the adapter.

Market Research

Executive Summary

This section provides insights into market size, trends, and barriers to entry for the commercial applications of the technology, as well as recommendations for deeper market research. Potential markets include Air Pollution Control systems, Catalytic Converter Manufacturers, and Gas turbines. The fastest growing market is Catalytic Converter manufacturers, with a Compound Annual Growth Rate (CAGR) of 9.3%. Each of these potential markets is quite fragmented, and all have many competing companies and growth potential ahead

Potential Markets	Market Insights
Air Pollution Control systems Rapid industrialization has substantially contributed to the pollution of the environment	**Market Size** • The global Air Pollution Control Systems market size was valued at $66.5 billion in 2017 and is expected to exhibit a CAGR of 5.0% through 2025. **Market Trends** • Favorable government regulations, along with alarming levels of pollution, are encouraging the adoption of these systems. • Rising population levels and growing respiratory issues in urban areas are also expected to contribute significantly to market growth. • Scrubbers emerged as the dominant product segment in the Air Pollution Control Systems market, with a revenue share of over 18.0% in 2017. • Catalytic converters are poised for significant growth, which could result in majority of the revenue share. **Barriers to Entry – Medium** **Key Players** • BASF and Johnson Matthey; Babcock & Wilcox Enterprises, Inc; Mutares AG; Elex AG; FLSmidth & Co. A/S; Feida Group Company Limited.
Catalytic Converter Manufacturers Devices reducing the emissions of pollutants from vehicles	**Market Size** • The global Catalytic Converter market was valued at $49.3 billion in 2021 and is predicted to reach $76.7 billion by 2030 (a CAGR of 9.3%) between 2022 and 2030. • Catalytic converters in small (space constrained) vehicles may represent a strong market. **Market Trends** • The market is projected to grow at a significant rate due to the growing concern over air pollution across the globe. • Diesel oxidation catalysts showed the largest market share in 2021. **Barriers to Entry – High** • Catalytic converters are expensive to manufacture. **Key Players** • Tenneco, Faurecia, Bosal, and Eberspächer.

Market Research (cont.)

Potential Markets

- **Gas Turbine**
  Combustion turbines, a type of continuous internal combustion engine

Market Insights

Market Size

- The global Gas Turbine market is expected to grow from $13.8 billion in 2021 to $17.3 billion in 2028 (a CAGR of 3.3%).

Market Trends

- The global market fell 19.1% in 2020.
- Global electricity demand is growing because of increasing urbanization and infrastructure development.
- Coal-burning boilers generate NOx and often insert monoliths to control this pollutant. Moreover, these applications are very space-constrained because the rest of the system cannot be moved easily.
- Older utilities using gas turbines (oil- or natural gas-fired) must remove carbon monoxide from the exhaust, yet there is little room to install the catalyst due to the presence of heat recovery tubes in the system. (Newer utilities are designed with this in mind and usually are not space-constrained.)

Barriers to Entry – High

- Natural gas prices are affected by supply disruptions.
- Geopolitical tensions are a disruptive factor causing uncertainty regarding the availability of gas.

Key Players

- GE, Siemens, Mitsubishi Hitachi Power Systems Ltd., Ansaldo Energia.

Conclusions

- Air Pollution Control Systems is a viable market for this invention due to its growth and the rise in concern and prioritization for the health and safety.
- The Catalytic Converter Manufacturing market could be a fit for this invention, but because it is mainly driven by automobiles, the application may be limited. Automotive manufacturers incorporate design changes to mitigate the same emissions as the Adapter for Modular Catalytic Monoliths.
- The Gas Turbine market remains a large and growing market but the instability in natural gases and the shift to electric power market limits the application of Adapter for Modular Catalytic Monoliths.

Market Research (cont.)

Recommendations

Priority Key:

- **Must:** A critical and time sensitive recommendation to advance technology with respect to the area of focus.
- **Should:** An important recommendation to advance technology but is dependent upon predecessor recommendations or is not time sensitive.
- **Could:** A recommendation that will have insignificant impact on advancing the technology but could be a beneficial consideration.

Recommendations	Priority	ROM Cost	ROM Timeline
Advance TRL and MRL Plan	2	$15,000	4 months
Market Planning and Scouting	3	$35,000	6 months
License technology	1	$15,000	2 months
ROM Total:		**$65,000**	

Level of Market Opportunity

Analyst: DVIRC

Competitor Analysis

Competitor Analysis Intent

The intent of this section is to identify potential commercially available competing technologies and provide conclusions and recommendations based on the information provided at the time of assessment. The resulting information may be used to identify technology strengths or weaknesses in features or claims as well as potential licensing partners.

Research Methods

Various resources to uncover information about different companies that perform similar functions

Markets	Competitors
Pollution Control	• **Babcock & Wilcock:** Industry leader in providing advanced air emissions control and energy recovery equipment and technologies for power plants and industrial processes. Engineered solutions control a wide range of pollutants and emissions. • **Mutares AG:** With the aim of minimizing environmental impact, Mutares AG implements continuous measures to reduce CO2-footprint, although the generation of CO2-emissions is sometimes unavoidable. • **FLSmidth & Co. A/S:** Combine project, product and service offerings in a way that contributes the least possible cost to the environment by reduced water usage and costs, lower energy usage, and slashed emissions. • **BASF/Johnson Matthey:** Utilities, oil refineries, etc. typically work with an engineering company to design the system. The monoliths are often manufactured/ designed by BASF or Johnson Matthey.
Catalytic Burner Manufacturers	• **Tenneco:** Minimizes the impact on the planet through operational eco-efficiency and renewable energy sources to limit environmental impacts as part of the commitment to responsible production. • **Faurecia:** Faurecia has developed a breakthrough innovation particularly well-adapted for use on hybrid vehicles which will represent 30% on the powertrain mix by 2025. By operating in electric mode more often, fuel economy is improved and CO2 emissions are reduced. • **Bosal:** Powertrain manufactures fully integrated emission control systems that meet future demands for near-zero emissions, in close collaboration with many of the established Original Equipment Manufacturers (OEMs).
Gas Turbine	• **GE:** Aeroderivative and heavy-duty gas turbines feature an output range from 34 MW to 571 MW which are proven performers in simple and combined-cycle operation for pure power generation, cogeneration, mechanical drive, and waste-to-power. Products can run on up to 100% H2 gas for emission control. • **Siemens:** Gas turbines fulfill the high requirements of a wide spectrum of applications in terms of efficiency, reliability, flexibility, and environmental compatibility. • **Mitsubishi Hitachi Power Systems Ltd:** Mitsubishi Power Aero LTSAs has a proven track record of maximizing reliability and predictability. Their sister company EPC designs and constructs cost effective, environmentally friendly power generation facilities.

Competitor Analysis (cont.)

Markets	Competitors
	Substitutes
	The desire to design a system in which flow mal-distribution is not a problem, rendering this technology unnecessary.

Conclusions

The markets above hold the potential for the proposed adapter to deliver effective pollution/emission control. Non-consumption of the adapter is the only substitute, given its specificity to a specific burner type.

Technology Readiness Level – Hardware

Technology Readiness Level Intent	Current TRL
The intent of this document is to determine the level of effort required to advance the technology from its current state to a desired future state. Project tasks may be proposed to assist in technology advancement. The *Technology Readiness Level (TRL) Deskbook* version July 2009 served as the reference document for the TRL assessment. TRLs run from 1 to 10.	**5**

Research Methods

TRL determination has been conducted on applicable levels as seen below. The assessment was conducted by reviewing the following materials:

- Technology Overview
- Patent No. 11,555,621
- Q&A call with inventor

Findings

The Adapter for Modular Catalytic Monoliths is an improved device and method for adapting catalytic converters to use catalytic monoliths where space is restricted and not amenable to the use of long straight ducting, expansion zones, and other flow-straightening means requiring more space. The technology is categorized as a TRL 4 and a protype has been built and integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. The prototype generated some data with the monolith in the Mark V but a significant amount of testing is needed to validate the prototype in a relevant environment. Most of the components used in the adapter are commercial, off-the-shelf (COTS) since the purchasing of Hastelloy sheet is a viable material that is readily available. To build the technology, experience with Hastalloy sheets and skills as cutting, bending, and welding metal are necessary. A Technical Data Package (TDP) and Bill of Materials (BOM) are available. The device is not ready for manufacturing, but with further development in manufacturability of the prototype, the technology will be. Please note that Hastelloy is required only if corrosion is expected to be a problem in the system.

Conclusions

For the Thermal Adapter for Modular Catalytic Monoliths to advanced TRLs, validation in a relevant environment is necessary. In terms of additional testing, validation that the same effectiveness is achieved by the burner with the adaptor integrated would be essential.

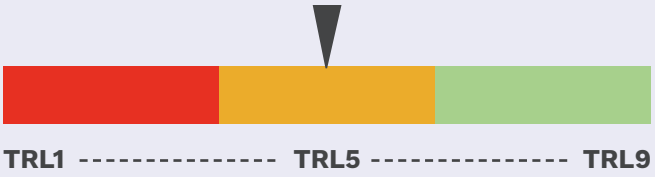
Technology Readiness Level – Hardware (cont.)

Recommendations

Priority Key:

- **Must:** A critical and time sensitive recommendation to advance technology with respect to the area of focus.
- **Should:** An important recommendation to advance technology but is dependent upon predecessor recommendations or is not time sensitive.
- **Could:** A recommendation that will have insignificant impact on advancing the technology but could be a beneficial consideration.

Recommendations to advance TRL to 9	Priority	ROM Cost	ROM Timeline
Finalize design, create TDP and BOM	Must	$3,500	2 months
Build multiple prototypes and test in operational environment	Must	$2,500	1 month
Integration of components	Must	$1,000	1 month
Integration with existing systems	Must	$2,500	1 month
Design for manufacturing	Should	$1,500	1 month
ROM Total:		**$10,000**	**5-6 months**



Analyst: DVIRC

Manufacturing Readiness Level

Manufacturing Readiness Level Intent	Current MRL
The intent of this effort is to determine the level of effort required to advance the technology from its current state to a desired future state. Project tasks may be proposed to assist in the advancement of the technology. The *Manufacturing Readiness Level (MRL) Deskbook* version 2.0 served as the reference document for the MRL assessment. MRLs run from 1 to 10.	**4**

Research Methods

Although a contractor has not been identified, an MRL determination has been conducted on applicable levels as seen below. The assessment was conducted with the following events and materials:

- Technology Overview
- Patent No. 11,555,621
- Q&A call with inventor

Findings

The MRL will generally track with the TRL but be slightly lower. The following is an assessment of the technology's current MRL and reasoning for the rating.

The Adapter for Modular Catalytic Monoliths has demonstrated development in a laboratory environment, categorizing the device as a MRL 4. The technology is comprised of metal sheets that are cut and welded to produce the Adapter. This stand-alone device is reusable if the monolith must be replaced in the system. Although there is no current cost model for the prototype, Hastelloy (a more expensive metal than stainless steel, required only if corrosion is expected to be a problem in the system) was used. Both Hastelloy and stainless steel could be applicable. The manufacturing of the adaptor is not a novel construction process but rather relies on basic bending, cutting, and welding. Ensuring the manufacturer is familiar with using Hastelloy would be essential (assuming Hasetelloy is selected as the burner material). The adapter does not require any approvals or accreditations, but safety considerations would be important.

Conclusions

Until the TRL process (TDP, BOM, testing) is advanced, the MRL will remain low. The adapter is a stand-alone device and will need to be vetted for manufacturability. Depending on the material chosen, the device can advance through the remaining MRL levels without excessive expense. Further development of the manufacturability of the prototype is a crucial next step. It is predicted that 6-8 months of focused work will result in a well refined product.

While the prototype advances towards validation, it is recommended that the inventors finalize suppliers (including possible backups) to widen sourcing options for material and avoid supply chain issues. A more thorough MRL assessment should be completed when these suppliers have been identified and an evaluation can be made in a production environment.

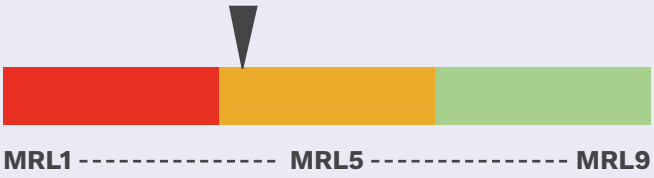
Manufacturing Readiness Level (cont.)

Recommendations

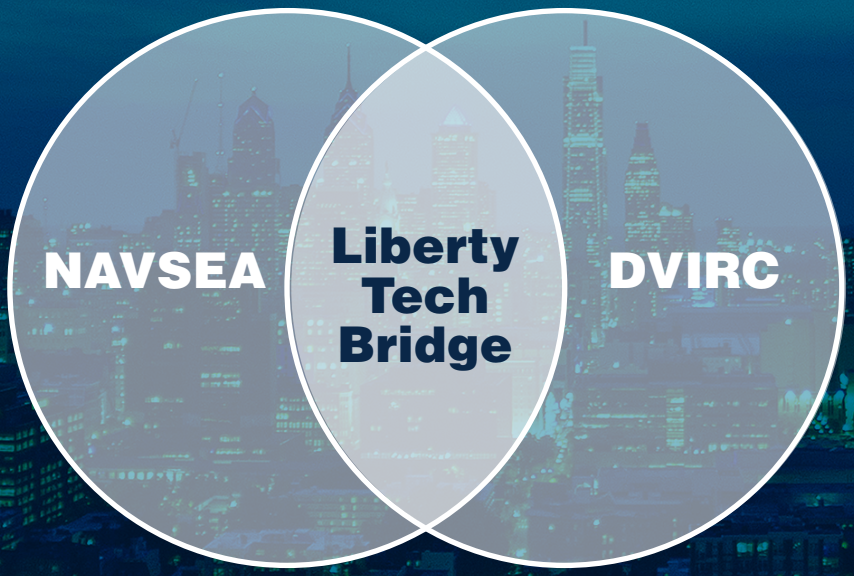
Priority Key:

- **Must:** A critical and time sensitive recommendation to advance technology with respect to the area of focus.
- **Should:** An important recommendation to advance technology but is dependent upon predecessor recommendations or is not time sensitive.
- **Could:** A recommendation that will have insignificant impact on advancing the technology but could be a beneficial consideration.

Recommendations to advance MLR	Priority	ROM Cost	ROM Timeline
Develop Technical Data Package (TDP)	Should	$2,000	1 month
Finalize Cost Model	Should	$1,000	1 month
Scout assembly/COTS suppliers	Must	$1,500	1 month
Complete Design for Manufacturing	Should		
Finalize manufacturer search	Must	$1,500	1 month
Perform a Critical Design Review (CDR)	Should	$1,000	1 month
Manufacture initial product in relevant environment	Must	$1,500	1 month
Third party MRL revision	Could	$3,500	2 months
Progress toward full-rate production	Should	$2,500	2 months
ROM Total:		**$14,500**	**8-10 mos**



Analyst: DVIRC



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