NNS (Near Net Shape) manufacturing vision at GE

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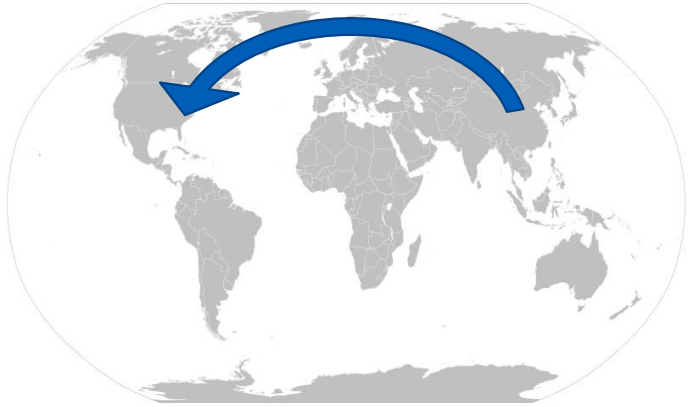
NNS current challenges

Vast majority of the supply chain located in Asia



- Current **outsourcing** to China → drastic reduction of foundry capabilities in the US. Close to 90% of castings for Offshore wind come from China.
- **No foundries** in U.S. capable of producing castings of the size, quantity and quality required.
- Outdated industry technology. Lack of **technical knowledge** for large casting manufacturing in the US. Short supply of manufacturing labor.
- High labor rates, health benefits and pension costs.
- **US environmental** restrictions and **EHS** - unhealthy work environment.
- **Logistics** costs when importing to US. Significant CO2 emissions. Lack of infrastructure for domestic transport.
- Worldwide **limited** capacity to fulfill orders for large castings.
- **Raw materials** current fluctuations in the market and lack of an efficient supply chain to meet large demand.
- **Machining** is largely unavailable in the US for large castings.
- Increasing energy costs.

Future vision

Creating opportunity for significant change revitalizing industry

Innovative manufacturing technology as foundation for new supply chain

- Establish a **US based** supply chain to enable local foundries and related industry to be competitive with those in Asia, opportunities for **local content** into our supply chains.
- **New casting technology** will need to be developed to reduce increasing logistics costs and address productivity limits in Asia and EU.
- US **industry revitalization** through creation and implementation of new advanced technology.
- Partner with EU industry.
- Support **across businesses** as OFW, ONW, Gas and steam power, Hydro, Oil and Gas, etc.
- Advances in technology, research and development will result in exponential job creation.

Advanced Manufacturing and an "Innovation Ecosystem" *will help the US overcome supply chain vulnerabilities including raw material availability, logistics, and workforce.*

In partnership with private industry, the DOE plays a key role supporting industrialization of new technologies and manufacturing processes to tackle the most pressing issues facing the energy sector

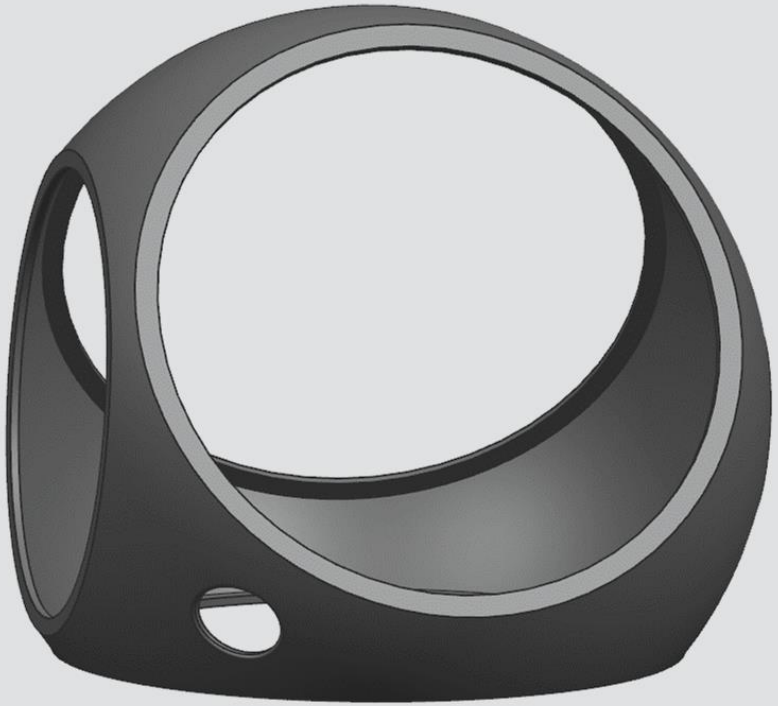
Significant new renewable power generation, especially for onshore and offshore wind, will be required to achieve the President's 2035 and 2050 decarbonization goals

Needs/challenges (technical, economic, logistics) for onshore wind, offshore wind, and hydro.

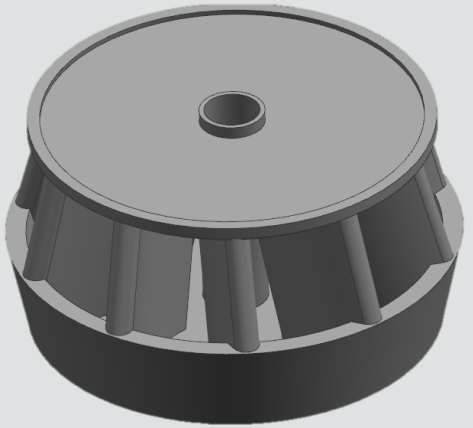
Specifications (Note- very dependent to specific part*)	Hydro	Onshore	Offshore
Key Issue to Industry	**Maintenance** and repair due to aging fleet (lead time correlated to down time and cost)	**Expanding** U.S. deployment and scale of turbines	**Enabling** U.S. Offshore Wind deployment
Material	Stainless steel	Nodular Iron - SSDI	Nodular Iron
Weight (single component)	5-45 tons	Up to 30 tons	Up to 65 tons and increasing
Size	Up to 9m	Up to 5 m	Up to 7m x 7m x 7m, some larger than 9m
US market volume production need	500-3000 MT/yr.	120,000-180,000 MT/yr.	35,000 MT/yr.
Cost per kg (relative) Cost to ship	Relatively expensive compared to onshore and offshore	Medium, similar to offshore	Very low to mfg. Transport cost potentially very high
Countries	Mostly China; assembled elsewhere and shipped	Mostly China, or India*	Mostly China*
Unique considerations	Stainless steel more expensive that Nodular Iron; More welding in hydro currently. Current work in DED Vast differences in part specifications (size, complexity, function)- each part will have unique considerations and potentially different solutions	Vast differences in part specifications (size, complexity, function)- each part will have unique considerations and potentially different solutions	-Already cheap to make; transport costs unique -Component specifications for one that requires 3 sections then welding -Vast differences in part specifications (size, complexity, function)- each part will have unique considerations and potentially different solutions

Example representations of large NNS components that would be desirable to produce domestically

Component 1:
Weight 45.5 t
5m diam. outer flange
2.5m high
Material: Nodular Iron



Component 2:
Weight 37.5 t
8m diam. sphere
6 meters high
Material: Nodular Iron



Hydro Component :
Weight 20 t
3.5m diam.
Material: Stainless Steel

Current GE work on NNS manufacturing

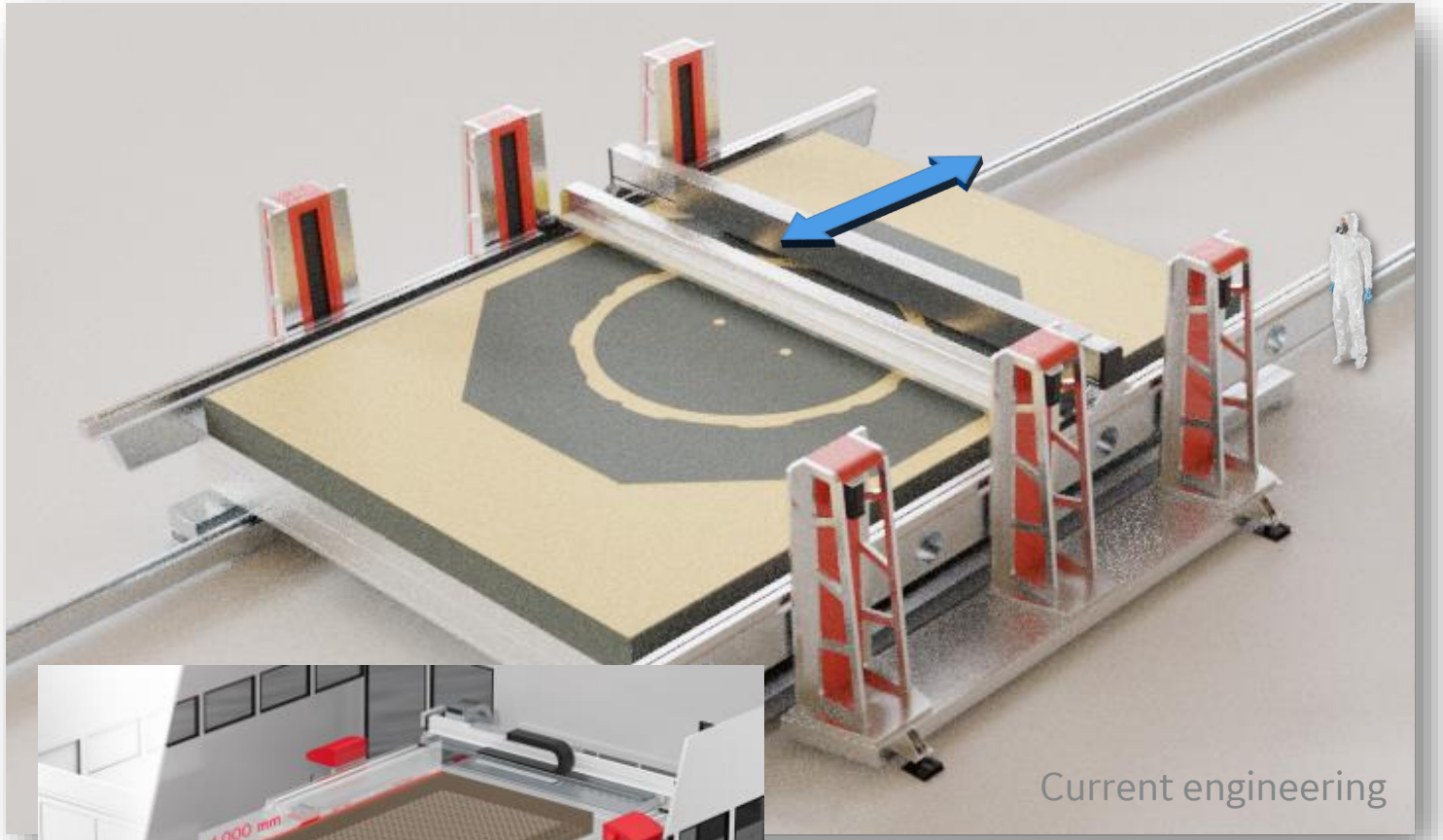
Foundry of the future

The ACC (Advanced Casting Cell)
Solution for large NNS components

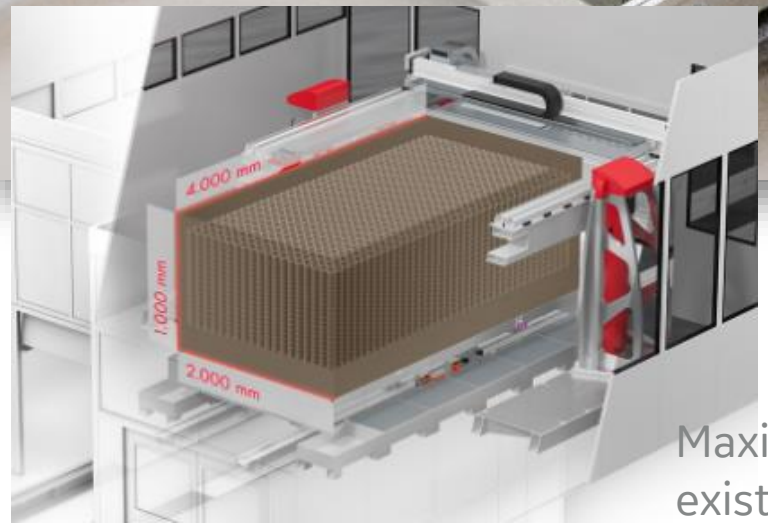
ACC is a GE proposed fully automated system, to be **located at the foundry** floor and capable of creating large 3D printed sand molds.

- Unmatched mold **design capabilities.**
- Shorter prototype and production **lead times.**
- Significant **mold and part quality** improvement.
- Step change in production efficiency and **cost** of large castings.
- **Revitalize industry,** local content and reduction of labor cost.
- Regions with **higher labor cost** will be able to compete head-to-head with current sourcing channels.

Will provide foundries a distinct **commercial and technology advantage** over the competition.



Current engineering



Maximum build capacity existing today

Enables new design freedom, weight and cost reduction, time to market, improved casting quality and mitigation of foundry EHS issues.

ACC consortium

External funding, Collaboration Partners/Work Packages

Project origin

GE

Initial Engineering and Mechanical Design

- First IP submission.
- 2-meter POF engineering.
- Support project Mechanical engineering and continuing IP.
- Help program coordination.
- Business case.
- Process and Part qualification.

Technology dev.

voxeljet

System Design and Development/ Program Management

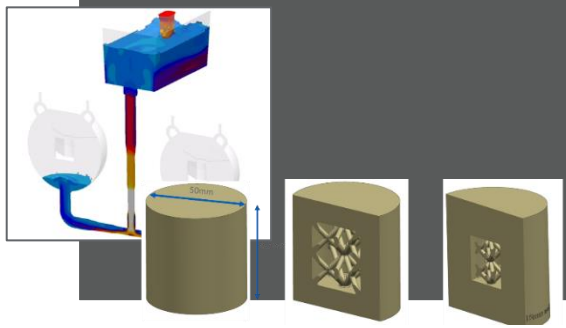
- Engineering, development, production, commercialization and support.
- Manufacturing process development.
- Quality control.
- EHS.

Research

Fraunhofer

R&D

- In direct collaboration with VX
- Testing facility.
- Experimentation of new concepts.
- Simulation & FEA modeling.
- Material requirements and process definition.
- Preliminary casting simulation.
- EHS.
- Subcontracting: Nordcasting foundry.



Implementation

Implementation- 2nd prototype

- Technology application know how to help develop the system.
- Second prototype machine to be installed on the factory floor.
- Foundry experimentation and full-size trials.
- GE quality assurance team to follow up for process and part qualification.
- EHS.
- Foundry partner to be defined.

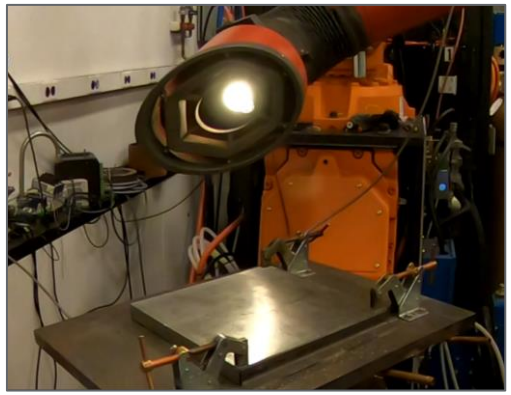
Phase 1 (Q3 2023) Funded by BMWI (Federal Ministry for Economic Affairs and Energy– 6 M euros

Phase 2 (Q4 2024)

Technology transferrable to the US or parallel development

Other technologies for NNS production

Direct Energy Deposition Cladding

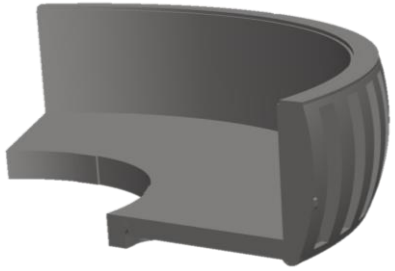


3D print Polymer full size model

Welding of large iron castings

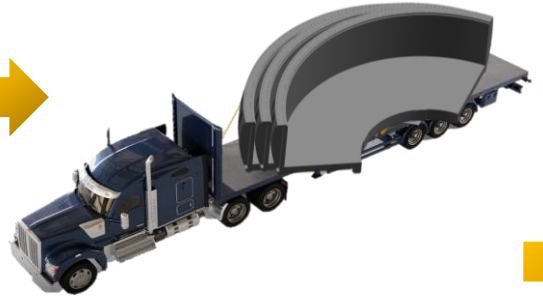
Producing the rotor and transporting such a massive component of almost 10m in diameter is high risk and costly.

Foundry



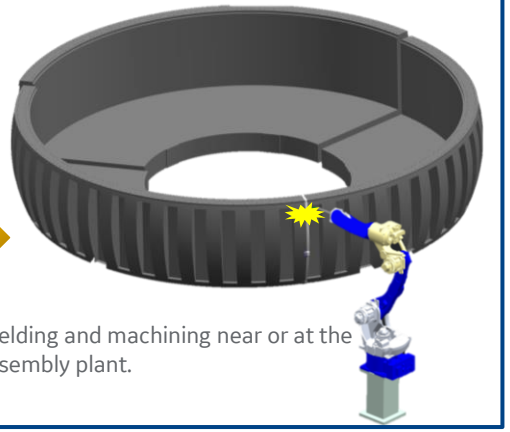
- Minimize risk maximize yield.
- Opportunity for smaller foundries / revitalize industry.
- Easier foundry handling of parts.
- Meet local content requirements.

Logistics



Drastic reduction on transportation fees due to space availability and road limitations.

At the assembly plant



Welding and machining near or at the assembly plant.

DOE NOWRDC awarded GE $800K to develop welding technology for Iron castings, procedure not previously qualified by the DNV.