SMART Wind Roadmap Briefing

Developing a Consensus-Based
Sustainable Manufacturing, Advanced Research & Technology
Roadmap for Distributed Wind

May 18, 2016

DWEA Distributed Wind Energy Association

NIST National Institute of Standards and Technology
U.S. Department of Commerce

Today's Briefing

Review key findings of the 2016 SMART Wind Roadmap and priority actions


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Rob Wills
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Roger Dixon
Skylands Renewable Energy


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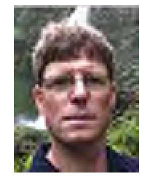
Ian Baring-Gould
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Charles Newcomb
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Bios online at http://distributedwind.org/staff-category/roadmap-virtual-briefing-panelists/

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Orders placed by May 27 are free *with discount code SMARTWIND*

Free file downloads:
- Full Roadmap
- Key Takeaways
- Roadmap Summary
- Consortium Directory

NIST Support of Manufacturing Innovation

Dr. Tom Lettieri, NIST

Figure 4-1. Manufacturing Extension Partnership Centers across the U.S. (www.mep.nist.gov)

Value of Roadmapping Process

Heather Rhoads-Weaver

eFormative Options

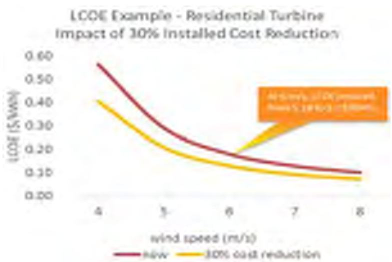

Figure 2-11. Example of LCOE impact from 30% reductions in installed cost

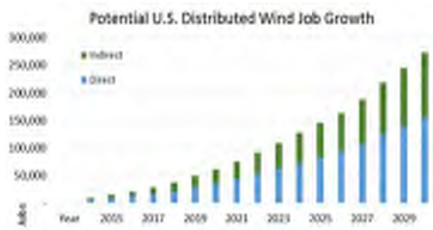

Figure 2-9. Distributed wind job growth under DWEA's 30 GW by 2030 Vision

Participants in Consensus Process

Figure 1-2. SMART Wind Consortium participants

Industry Participation and Support

DWEA speaks for all the Major Players

Academic-Research University Participation in Consortium

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SMART Wind Consortium Outreach

- Condition/Health Monitoring (Jan 2015)
- Rare Earth Magnets in Distributed Wind (Apr 2015)
- Reducing Installation Costs (May 2015)
- PEIC & SMART Wind Collaboration (June 2015)
- Composite Materials & Process Opportunities (July 2015)
- Inverters & Variable Frequency Drives (August 2015)
- Past, Present & Future Blade Design (Oct 2015)
- Tower & Foundation Design (Nov 2015)

Ideas for Future Webinars

Electrical
- Power America – WBG materials applications, inverters
- Utilizing robotics and modern generator manufacturing processes
- Gearboxes
- Commonalities and shortcuts with EV industry

Support Structures
- Metalizing
- Prognostic condition monitoring
- Pole manufacturers forum
- Lifting
- Installation process
- Tower grounding
- Anchoring systems to reduce concrete

Composites
- Coatings, Applications
- Blade manufacturing best practices
- IACMI opportunities

Mechanical
- Latest condition monitoring hardware, development
- Additive manufacturing, applied to DW industry
- Robotics, low-cost automation techniques
- Bearings; standardization in other industries

Turbine System
- Real world training
- Training on computer-aided tools in DW
- Mentoring, cross-training – WfS, Collegiate competitions; inspire future workforce to invent

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Overview of Action Plan to Address Industry Barriers & Key Takeaways

Trudy Forsyth, Wind Advisors Team

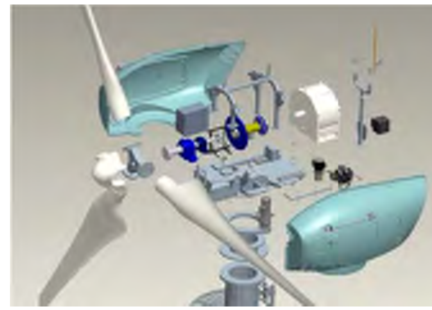
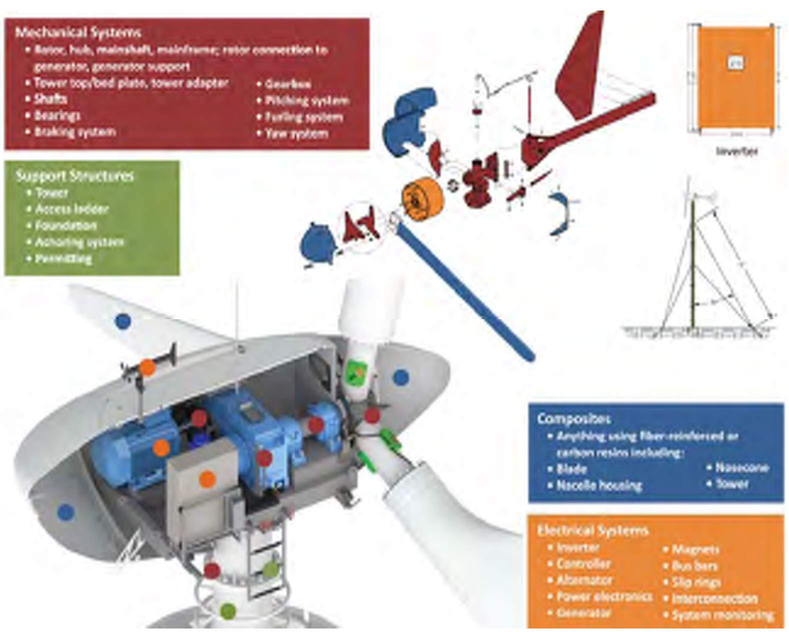


Figure 2-1. Sample exploded diagram, Eocycle

Figure 2-2. Northern Power Systems factory

SMART Wind Consortium Subgroup Focus Areas



Consensus decision making:

One response/position per company, balance OEMs and other stakeholders

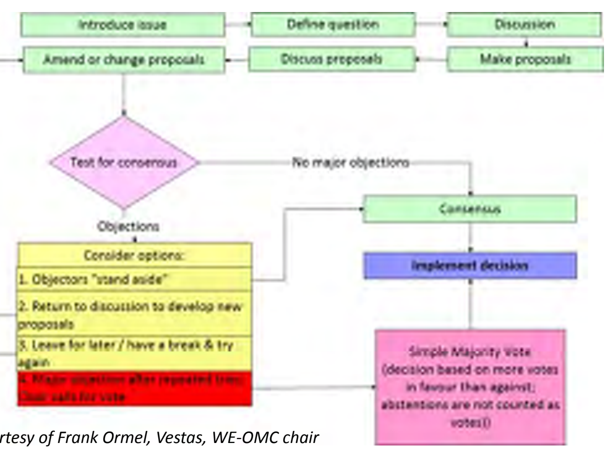
✓ Core team addressed 200+ comments on 2 review drafts

✓ Incorporated results from Action Timeframe poll of SMART Wind OEM Steering Group *(100% participation)*

✓ Obtained, analyzed and incorporated 80 responses to Prioritization Poll

✓ Held meetings to discuss and develop consensus on final draft

✓ Published & widely disseminating full report & handouts



Courtesy of Frank Ormel, Vestas, WE-OMC chair

SMART Wind Roadmap Contents

Foreword: Roadmap to Reach Shared Vision

Executive Summary *Actions ranked as top in both sectors*

Section 1: Introduction *Rationale on importance of document, Consortium overview*

➢ *Domestic content, foreign participation*

Section 2: State of Distributed Wind Turbine Industry & Market Opportunities
Baselines & benchmarks, growth potential, project's market impact-LCOE goal

Section 3: Distributed Wind Turbine Technology, Manufacturing Opportunities & Actions
Technology & manufacturing barriers & actions: Top and Medium by Subgroup

Section 4: Research and Partnering Opportunities *U.S. Dept of Commerce, DOE, Research & testing laboratories, Universities & technical colleges, State agencies & others*

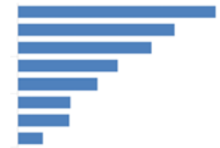
Section 5: Strategy Summary and Conclusions: Action Plan to Address Industry Barriers
Key recommendations & next steps: Top priorities by timeframe and topic

References, Appendices *Baseline & benchmark detailed info, Consortium directory*

➢ *Ranking of all Near-term, Mid-term and Long-term Actions by Sector and Subgroup*

Top Priority Action Areas

1) Optimize and harmonize wind turbine designs to improve levelized cost of energy (LCOE) and achieve parity with U.S. retail electricity rates in more markets
   - ➢ Develop common core modular inverter
   - ➢ Utilize wide bandgap materials in power electronics
   - ➢ Create new standard support structure designs



2) Improve manufacturing parts, materials, and processes including incorporating lean manufacturing practices
3) Optimize standards and certification to enable technology evolution and maintain quality
4) Streamline installation and maintenance of wind turbine system; develop low-cost prognostic condition monitoring to provide feedback on field performance
5) Sustain SMART Wind Consortium activities and partnerships
   - ➢ Further refine costs and benefits of top actions
   - ➢ Create a supplier directory and industry-wide reliability and materials databases
   - ➢ Secure funding for R&D and workforce training

Top Electrical Actions, Q&A

Rob Wills, Intergrid

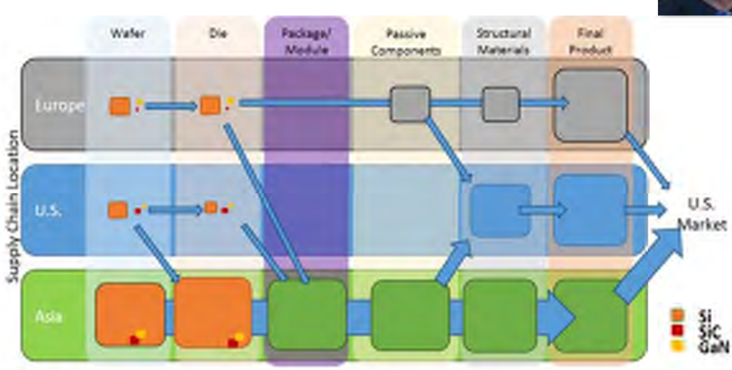


Figure 4-2. PEIC power electronics supply chain, materials (PEIC 2015)

Table 5-1. Summary of Top Priority Actions by Subgroup and Timeframe

	Short-Term (0-3 years)	Mid-Term (3-7 years)	Long-Term (7-10 years)
Electrical	• **Develop a common core modular inverter; utilize wide bandgap materials** • **Apply variable-frequency drives (VFDs)** • **Incorporate microgrids** • **Design and improve manufacturing processes of alternators/generators** • **Validate electrical design through component testing to standard and smart grid/resiliency requirements** • **Address impact of LVRT/HVRT requirements on induction machines** • Collaborate with electric vehicle industry	• Leverage electromagnetic and thermal design capabilities at NREL • Integrate wind turbines into "Internet of Everything" • Leverage latest research results on new magnetic and capacitive components	• Research emerging/innovative power electronics • Encourage power electronics training at trade schools/universities

Included in Executive Summary *Actions ranked as top in both sectors*

Q&A

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Top Composites Actions, Q&A

Trudy Forsyth, Wind Advisors Team

Figure 3-3. Endurance Wind Power wind turbine blades

Table 5-1. Summary of Top Priority Actions by Subgroup and Timeframe *(continued)*

	Short-Term (0-3 years)	Mid-Term (3-7 years)	Long-Term (7-10 years)
Composites	• **Explore new efficient manufacturing materials, fixturing, and tooling costs** • **Develop post-manufacturing non-destructive testing methods** • Develop new blade design based on blade manufacturing technique • Develop blade that can be incorporated into multiple turbine designs	• Develop coatings and systems that resist erosion, icing, etc. • Develop better open-source blade design and structural analysis tools • Explore ways to monitor blade degradation over time • Explore modular space-frame blade design • Identify and apply advanced composites and new materials	• Develop tools that integrate production processes with blade design, performance analysis and tests • Develop a shared industry-wide materials database

Included in Executive Summary *Actions ranked as top in both sectors*

Q&A

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Top Support Structures Actions, Q&A

Roger Dixon, Skylands Renewable Energy

Figure 3-5. Prefabricated foundation installed by Skylands Renewable Energy

Table 5-1. Summary of Top Priority Actions by Subgroup and Timeframe *(continued)*

	Short-Term (0-3 years)	Mid-Term (3-7 years)	Long-Term (7-10 years)
Support Structure	• **Develop new approaches to hot-dip galvanization** • **Explore a range of standard industry towers for economies of scale** • **Design cost-efficient foundations for a range of tower configurations and soil conditions** • **Refine TIA 222-G Addendum 4; develop an alternative or improve the small wind turbine addendum** • Increase U.S. tower supply by adapting approaches used in the utility and communications industries • Gather test data to validate turbine dynamic models • Design, build, and test a family of towers that could be used by several OEMs • Develop U.S. monopole tower supply • Develop tower certification strategy	• Model and explore the use of slip-fit, tapered tower to address loads and dynamics • Understand tower dynamics and how other tower industries can address distributed wind industry needs • Develop turbine and tower design to ease operation and maintenance • Explore a standard industry tower with flange attachments • Investigate commercial viability of other anchoring systems • Develop common, pre-fabricated foundations for multiple OEMs • Investigate the functional and commercial viability of spread-leg foundations • Facilitate international forum on differing local requirements (soil/structural, other)	• Validate turbine design for O&M procedures that maximize human safety • Investigate the use of composite towers **Included in Executive Summary** *Actions ranked as top in both sectors* **Q&A**

Top Mechanical Actions, Q&A

Dr. Patrick Lemieux, Cal Poly

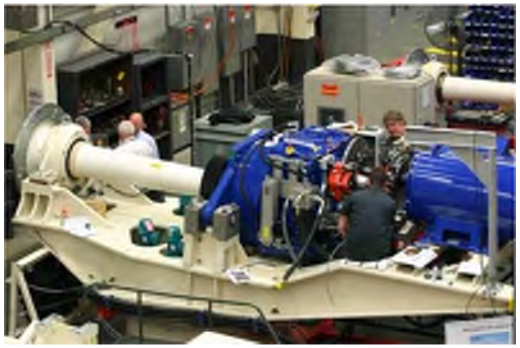

Figure 3-6. Aeronautica Windpower mainframe assembly

Table 5-1. Summary of Top Priority Actions by Subgroup and Timeframe *(continued)*

	Short-Term (0-3 years)	Mid-Term (3-7 years)	Long-Term (7-10 years)
Mechanical	• **Develop low-cost prognostic condition monitoring to provide a feedback loop on field performance to OEMs** • **Develop a supplier directory for wind turbine parts, components, and designers** • **Research advanced casting and mold manufacturing techniques; develop new competitive partnerships** • Identify regional manufacturer expertise	• Research additive manufacturing for prototyping, molds, and real parts • Work with machining companies on manufacturability • Research materials, lubricants, and gear oil in cold climates • Monitor progress on mechanical innovations, e.g. intensive quench for gears	• Develop methods for accelerated life testing • Position industry as a test bed for utility-sale wind drive train concepts • Implement automation and robotics

Included in Executive Summary *Actions ranked as top in both sectors*

Q&A

Top Overall System Actions and BOM, Q&A

Brent Summerville, Summerville Wind & Sun

Top 3 Cost Contributors

Micro/small
1. Tower
2. Alternator
3. Inverter

Commercial
1. Tower
2. Blades
3. Gearbox

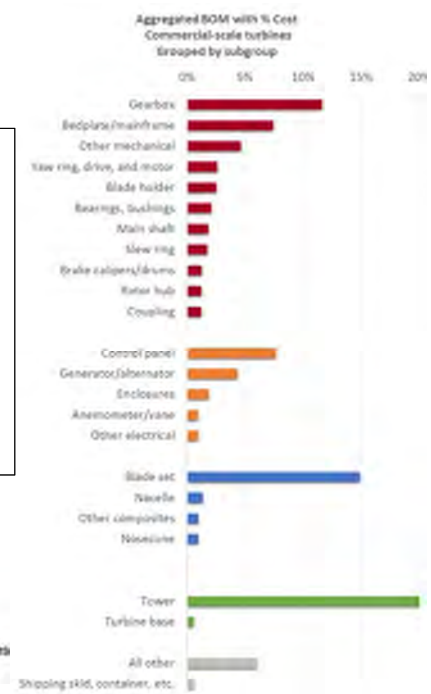

Table 5-1. Summary of Top Priority Actions by Subgroup and Timeframe *(continued)*

	Short-Term (0-3 years)	Mid-Term (3-7 years)	Long-Term (7-10 years)
Overall System/Industry	• **Conduct a gap analysis for certification requirements for various global markets; educate and promote certification to maintain quality** • **Assess how changing turbine design impacts certification requirements** • **Explore new efficient manufacturing materials and processes** • **Improve/simplify process for turbine re-certification** • Refine FAST to account for full turbine dynamics and control • Address accuracy of performance modeling of distributed wind turbines • Provide public education and economic tools, especially refuting myths; permitting support	• **Encourage the development of common international requirements (e.g., U.S., U.K., Japan, building codes)** • **Educate developing markets on certification** • Train installers for small wind O&M • Develop installation processes with an emphasis on safety and cost reduction • Develop a shared industry-wide reliability database	• Establish/support national zoning and interconnection rules • Encourage mentorship and outreach to increase workforce diversity • Monitor utility-scale wind technology development for distributed wind applications **Included in Executive Summary** *Actions ranked as top in both sectors* **Q&A**

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Reflections, How Actions Relate to DOE/NREL/WINDExchange Efforts

Ian Baring-Gould, NREL

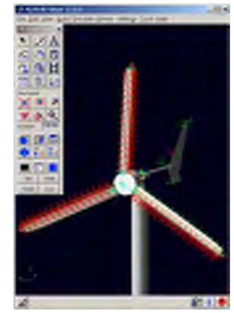

Figure 3-7. FAST wind turbine model Source: NREL

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Section 4: Partnering Opportunities

- U.S. Department of Commerce: MEPs, PEIC, FIBERS
- U.S. Department of Energy: WWPTO, CIP, RTCs, IACMI, Power America, SBV
- Research & Testing Labs: ANL, LLNL, NREL, PNNL, SNL, others
- Universities & Tech Colleges: AppState, Cal Poly, Clarkson, JMU, K-State, UC-Davis, UMass-Lowell
- State Agencies & Other Partners

DW is a particularly micro-capitalized so high matching requirements can be prohibitive

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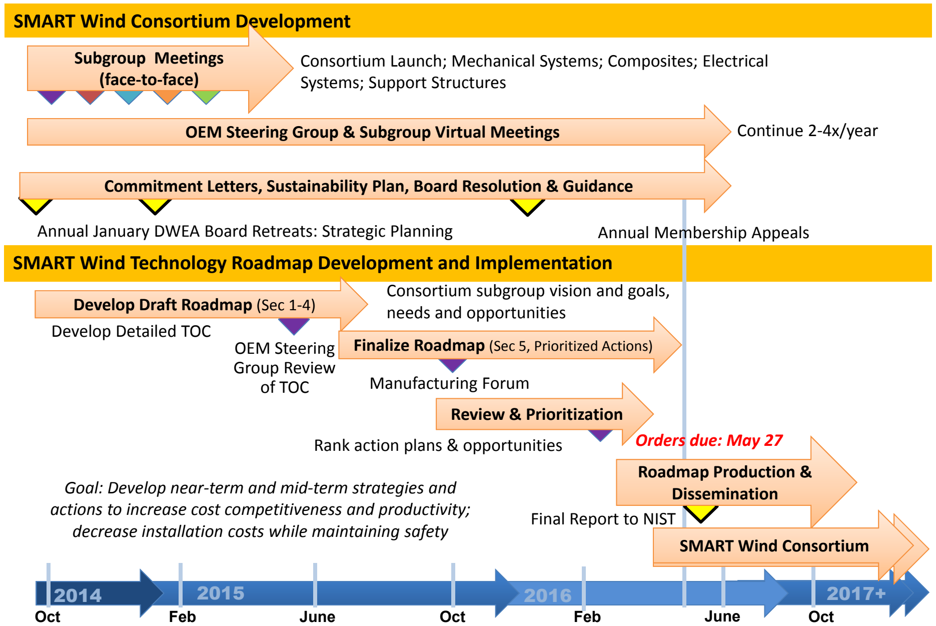
OEM Views & Next Steps, Q&A

Mike Bergey, Bergey Windpower

Charles Newcomb, Endurance Wind Power

Figure 2-10. U.S. small wind turbine exports Source: PNNL (U.S. DOE 2015a)

Next Steps: Sustaining SMART Wind Collaboration



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Q&A, Ideas on Future Consortium Funding Opportunities

Heather Rhoads-Weaver, eFormative Options

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Thank you for sharing your time, expertise, and collaboration to create

A Consensus-Based, Shared-Vision

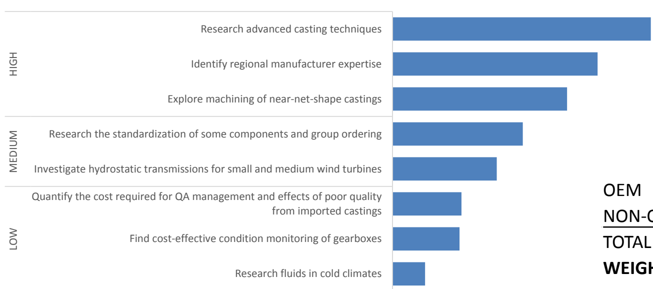
Sustainable Manufacturing, Advanced Research & Technology Action Plan for Distributed Wind

Backup Slides for Q&A

Poll Analysis Methods

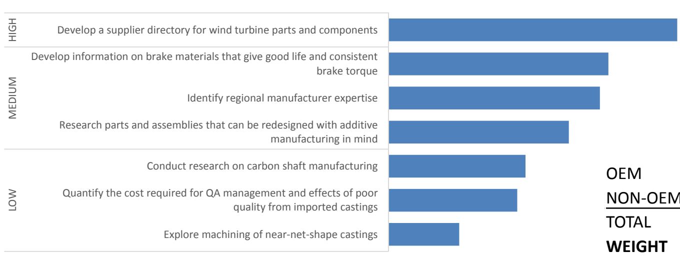
- OEM Timeframe Poll Weighting scores:
  - Near-term = 3 (weighted scores above 2)
  - Mid-term = 2 (weighted scores between 1-2)
  - Long-term = 1 (weighted scores under 1)
  - Not Important = 0 (all actions deemed important by at least 2 OEMs)
- Prioritization Poll Weighting to balance OEMs per question

Mechanical - Micro/Residential - Near-term



OEM	5
NON-OEM	22
TOTAL	27
WEIGHT	**4.4**

Mechanical - Commercial/Mid-size - Near-term



OEM	5
NON-OEM	27
TOTAL	32
WEIGHT	**5.4**

Consensus positions

Agree: "I agree with / support the proposal."

Non-support: "I don't see the need for this, but I'll go along with it."

Standing aside: "I personally can't do this, but I won't stop others from doing it." The person standing aside is not responsible for the consequences. This should be recorded in the minutes. *(Can capture in footnotes)*

Agree to disagree: The group decides that no agreement can be reached on this issue, at this time. Take a break, amend the proposal, explain positions are options to continue at this moment. *(Can note in body of Roadmap)*

Major objection: A (single) major objection blocks the proposal from passing. If you have a major objection it means that you cannot live with the proposal if it passes. A major objection isn't an "I don't really like it" or "I liked the other idea better." It is an "I cannot live with this proposal if it passes, and here is why!" The major objection is a powerful tool as it will cause various attempts to reconcile through amended proposals and should be used with caution.

Recommendations on project evaluation*

- ✓ Attainment of goals, quality of scientific results, published roadmaps
- ✓ Demonstration of how research proposed to address gaps
- ✓ Effectiveness of management in assuring goals are met
- ✓ A vision that includes a "grand challenge"
- ✓ Successful inclusion of small and mid-sized firms
- ✓ Robust diffusion of technology and commercialization
- ✓ Amount of resources leveraged with other government (including state) agencies, universities, others

** Based on NIST Visiting Committee on Advanced Technology, Recommended Design Principles for AMTech, February 7, 2012 (in response to PCAST Report, June 2011, which concluded "PCAST researched the current state of manufacturing and concluded that U.S. leadership in manufacturing is declining, and this is detrimental to the well-being of the Nation overall."*

Next Steps: Roadmap Rollout & Future Funding

- ➢ Dissemination: *DC Briefings; WP16 poster/2-pager – topics for Collegiate participants, SWC Release party, PR/blog articles, academic journal articles*

NIST SBIR (submitted April 14) http://www.nist.gov/tpo/sbir/upload/FY16-Phase-I-SBIR-FFO-final.pdf

DOE SBIR (webinar July 25, due Oct 17) http://science.energy.gov/sbir/funding-opportunities/fy-2017/

USDA SBIR (due Oct) http://nifa.usda.gov/phase-i-phase-ii-solicitations

ORNL CRADA (rolling) http://web.ornl.gov/sci/manufacturing/industry/

IACMI TBA – membership/match requirements expected

NSF I/UCRC – membership requirements prohibitive

AMTech – now merged into NNMI; no FOA in 2016; possible future funds for univ/gov lab research
Watch Power America, Additive Mfg IMI