SMART Wind Roadmap Briefing

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

May 18, 2016

Today’s Briefing

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

Heather Rhoads-Weaver eFormative Options
Dr. Tom Lettieri NIST
Trudy Forsyth Wind Advisors Team
Rob Wills Intergrid
Roger Dixon Skylands Renewable Energy
Dr. Patrick Lemieux Cal Poly
Brent Summerville Summerville Wind & Sun
Ian Baring-Gould NREL
Mike Bergey Bergey Windpower
Charles Newcomb Endurance Wind Power

Bios online at http://distributedwind.org/staff-category/roadmap-virtual-briefing-panelists/

Online Order Form
distributedwind.org/order-roadmap-materials
Full Roadmap copies, posters, and sets of 10 summary handouts may be purchased for $10 each

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  

DWEA speaks for all the Major Players  

Academic-Research University Participation in Consortium
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)

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 – WIS, Collegiate competitions; inspire future workforce to invent

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

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: Key recommendations & next steps: Top priorities by timeframe and topic

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

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

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

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

<table>
<thead>
<tr>
<th></th>
<th>Short-Term (0-3 years)</th>
<th>Mid-Term (3-7 years)</th>
<th>Long-Term (7-10 years)</th>
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<tbody>
<tr>
<td>Composites</td>
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<tr>
<td>Explore new efficient</td>
<td></td>
<td>Develop coatings and</td>
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<td>manufacturing materials,</td>
<td></td>
<td>systems that resist</td>
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<td>fixtureing, and tooling</td>
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<td>erosion, icing, etc.</td>
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<tr>
<td>costs</td>
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<td>Develop better open-</td>
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<td></td>
<td></td>
<td>source blade design</td>
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<td></td>
<td></td>
<td>and structural analysis</td>
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<td>tools</td>
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<td></td>
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<td>Explore ways to</td>
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<td></td>
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<td>monitor blade</td>
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<td></td>
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<td>degradation over time</td>
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<td></td>
<td></td>
<td>Explore modular</td>
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<td>space-frame blade</td>
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<td></td>
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<td>design</td>
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<td>Identify and apply</td>
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<td>advanced composites</td>
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<td></td>
<td></td>
<td>and new materials</td>
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</tbody>
</table>

Included in Executive Summary Actions ranked as top in both sectors Q&A

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)

<table>
<thead>
<tr>
<th></th>
<th>Short-Term (0-3 years)</th>
<th>Mid-Term (3-7 years)</th>
<th>Long-Term (7-10 years)</th>
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</thead>
<tbody>
<tr>
<td>Support Structure</td>
<td></td>
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<tr>
<td>Develop new approaches</td>
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<td>Model and explore the</td>
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<tr>
<td>to hot-dip galvanization</td>
<td></td>
<td>use of slip-fit,</td>
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<td>tapered tower to</td>
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<td>address loads and</td>
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<td></td>
<td></td>
<td>dynamics</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Understand tower</td>
<td></td>
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<tr>
<td>Design cost-efficient</td>
<td></td>
<td>dynamics and how</td>
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</tr>
<tr>
<td>foundations for a range</td>
<td></td>
<td>other tower industries</td>
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<tr>
<td>of tower configurations</td>
<td></td>
<td>can address</td>
<td></td>
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<tr>
<td>and soil conditions</td>
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<td>distributed wind</td>
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<tr>
<td>Refine TIA 222-G Addendum</td>
<td></td>
<td>industry needs</td>
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<tr>
<td>4; develop an alternative</td>
<td></td>
<td>Develop turbine and</td>
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<tr>
<td>or improve the small</td>
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<td>tower design to ease</td>
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<td>wind turbine addendum</td>
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<td>operation and</td>
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<tr>
<td>Increase U.S. tower</td>
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<td>maintenance</td>
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<td>supply by adapting</td>
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<td>Explore a standard</td>
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<tr>
<td>approaches used in the</td>
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<td>industry tower with</td>
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<td>utility and communications</td>
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<td>flange attachments</td>
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<tr>
<td>industries</td>
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<td>Investigate commercial</td>
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<td>Gather test data to</td>
<td></td>
<td>viability of other</td>
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<tr>
<td>validate turbine dynamic</td>
<td></td>
<td>anchoring systems</td>
<td></td>
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<tr>
<td>models</td>
<td></td>
<td>Develop common,</td>
<td></td>
</tr>
<tr>
<td>Design, build, and test a</td>
<td></td>
<td>pre-fabricated</td>
<td></td>
</tr>
<tr>
<td>family of towers that</td>
<td></td>
<td>foundations for</td>
<td></td>
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<tr>
<td>could be used by several</td>
<td></td>
<td>multiple OEMs</td>
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<tr>
<td>OEMs</td>
<td></td>
<td>Investigate the</td>
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<tr>
<td>Develop U.S. monopole</td>
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<td>functional and</td>
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<tr>
<td>tower supply</td>
<td></td>
<td>commercial viability</td>
<td></td>
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<tr>
<td>Develop tower</td>
<td></td>
<td>of spread-leg</td>
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<tr>
<td>certification strategy</td>
<td></td>
<td>foundations</td>
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<td></td>
<td></td>
<td>Facilitate international</td>
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<td>forum on differing</td>
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<td></td>
<td></td>
<td>local requirements</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(soil/structural, other)</td>
<td></td>
</tr>
</tbody>
</table>

Included in Executive Summary Actions ranked as top in both sectors Q&A
Top Mechanical Actions, Q&A
Dr. Patrick Lemieux, Cal Poly

Mechanical Actions,

Q&A

Dr. Patrick Lemieux, Cal Poly

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)

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

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

[Diagram of BOM with % Cost]
Table 5-1. Summary of Top Priority Actions by Subgroup and Timeframe (continued)

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

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

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

**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*
Next Steps: Sustaining SMART Wind Collaboration

SMART Wind Consortium Development

- Subgroup Meetings (face-to-face)
- Consortium Launch; Mechanical Systems; Composites; Electrical Systems; Support Structures
- OEM Steering Group & Subgroup Virtual Meetings
- Continue 2-4x/year
- Commitment Letters, Sustainability Plan, Board Resolution & Guidance
- Annual January DWEA Board Retreats: Strategic Planning
- Annual Membership Appeals

SMART Wind Technology Roadmap Development and Implementation

- Develop Draft Roadmap (Sec 1-4)
- Develop Detailed TOC
- OEM Steering Group Review of TOC
- Consortium subgroup vision and goals, needs and opportunities
- Finalize Roadmap (Sec 5, Prioritized Actions)
- Manufacturing Forum
- Review & Prioritization
- Rank action plans & opportunities
- Roadmap Production & Dissemination
- Final Report to NIST
- SMART Wind Consortium

Goal: Develop near-term and mid-term strategies and actions to increase cost competitiveness and productivity; decrease installation costs while maintaining safety

Orders due: May 27

Orders placed by May 27 are free with discount code SMARTWIND

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

Q&A, Ideas on Future Consortium Funding Opportunities
Heather Rhoads-Weaver, eFormative Options

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
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

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


  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