

# A Needs-Based Assessment of Nanotechnology Environmental Health & Safety

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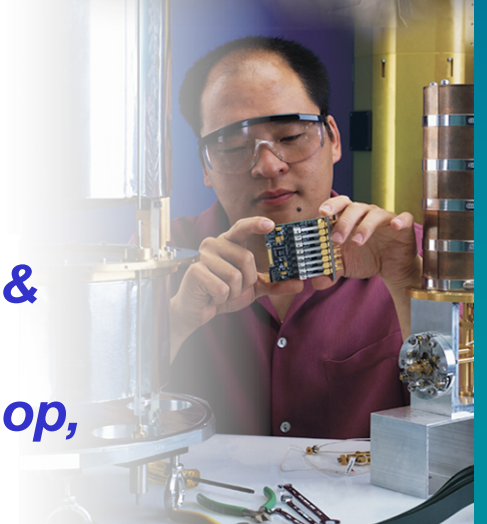
National Institute of Standards and Technology

**NIST**

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



*Environmental, Health &  
Safety Issues in  
Nanomaterials Workshop,  
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# Outline

- **USMS initial results**
- **Nanotechnology-EHS focus**

## Nanomaterials and the USMS Assessment: Observations

High demand for new advanced measurement instrumentation for **accurate, high resolution characterization of physical, chemical and biological properties of materials at nanometer dimensions**

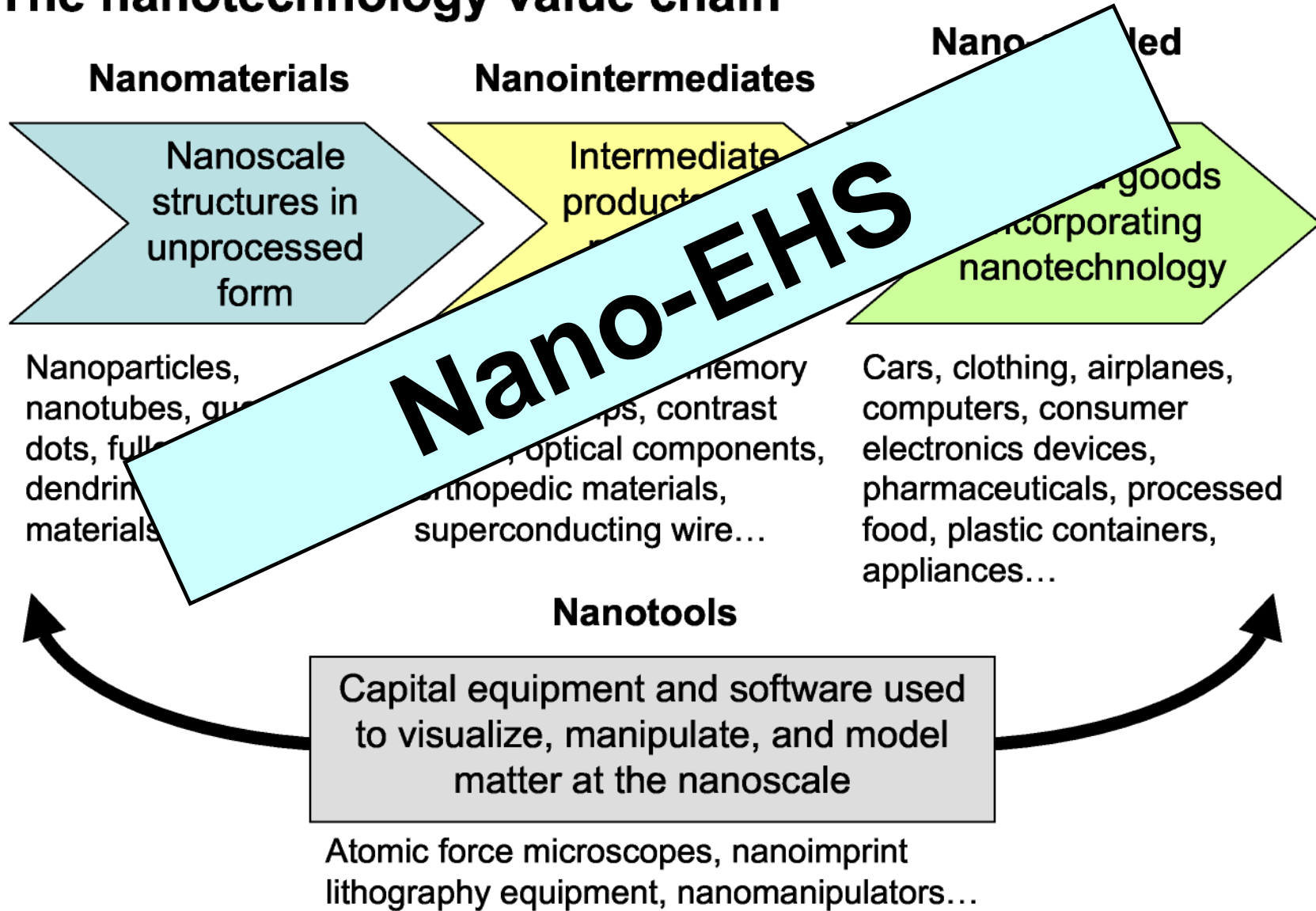
Principal measurement barrier to innovation is the absence of measurement instruments, techniques and methods capable of **accurately characterizing the behavior of complex materials systems and structures**

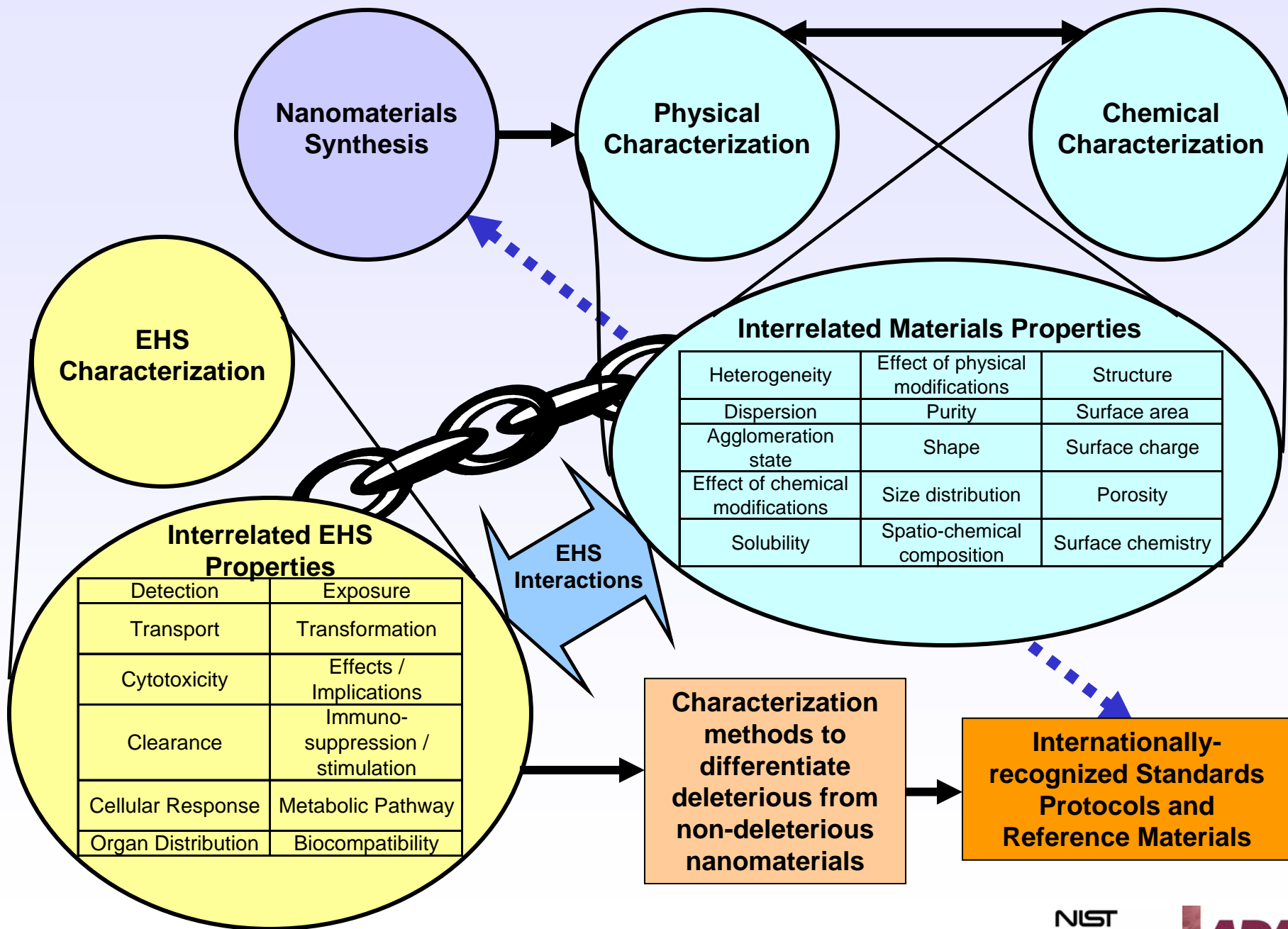
**Absence of regulations** is having a serious impact on innovation

**Timely delivery of materials measurement solutions** is increasingly challenging

Key factor driving the need for innovation is anticipation of the production/marketplace needs for the evaluation of **Materials Performance, Manufacturability, and Reliability**

# The nanotechnology value chain





Heterogeneity	Effect of physical modifications	Structure
Dispersion	Purity	Surface area
Agglomeration state	Shape	Surface charge
Effect of chemical modifications	Size distribution	Porosity
Solubility	Spatio-chemical composition	Surface chemistry

Detection	Exposure
Transport	Transformation
Cytotoxicity	Effects / Implications
Clearance	Immuno-suppression / stimulation
Cellular Response	Metabolic Pathway
Organ Distribution	Biocompatibility

# What are the Components of an Authenticated MN (How)?

- MN Template
  - Technological innovation at stake
  - Economic significance of the innovation
  - Technical barrier to the innovation
  - Stage of innovation at which technical barrier appears
  - Measurement-problem part of the technical barrier
  - Potential solutions to the measurement problem
  - Potential providers of these solutions
- Tags / Indicators
  - MN Characteristics that may be used to compare MNs
- Authentication
  - Evidence that MN represents a significant portion of Measurement Solution Users

## 31 Measurement Needs (MNs) submitted by Scientists & Engineers – *examples include:*

- o Nano-scale drug delivery
- o Toxicology of nanoparticles in biological systems
- o Real time measurements for pharmaceuticals and biologics manufacturing
- o Advanced drug delivery systems, including implantable devices that automatically administer drugs and sense drug levels
- o Sensors for airborne chemicals or other toxins
- o Nanocrystal biophotonic sensors
- o Nanomagnetic MRI contrast agents
- o Inhalation insulin delivery/diabetes management
- o Small particle monitoring for advanced semiconductor manufacturing
- o Health care/nanotechnology – cancer diagnosis and treatment
- o Quality control in cytometry for improved clinical diagnostics
- o C60 carbon nanomaterials for nanobiotechnology

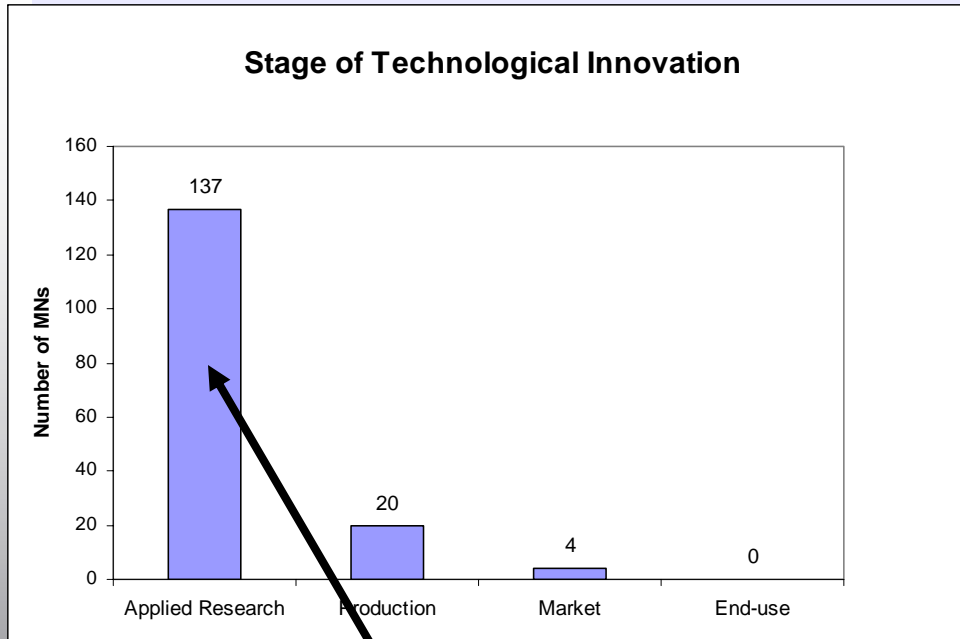
# 104 Roadmap Measurement Needs (RMNs) identified from roadmaps, workshop reports, and white papers – sources include:

Roadmap, White Paper or Workshop Report	Year	Source	# of RMNs
Strategy for Nanotechnology-Related Environmental, Health, and Safety Research	2008	<a href="http://www.nano.gov/">http://www.nano.gov/</a>	4
Toxicology steps up to nanotechnology safety	2008	<a href="http://www.rdmag.com/">http://www.rdmag.com/</a>	7
Strategic Plan for NIOSH Nanotechnology Research and Guidance	2008	<a href="http://www.cdc.gov/niosh/topics/nanotech/strat_plan.html">http://www.cdc.gov/niosh/topics/nanotech/strat_plan.html</a>	3
Nanotechnology - A report of the US FDA Nanotechnology Task Force (FDA)	2007	<a href="http://www.fda.gov/nanotechnology/taskforce/report2007.html">http://www.fda.gov/nanotechnology/taskforce/report2007.html</a>	3
Prioritization of EHS Research Needs for Engineered Nanoscale Materials - An interim document for public comment (NEHI Working Group)	2007	<a href="http://www.nano.gov/Prioritization_EHS_Research_Needs_Engineered_Nanoscale_Materials.pdf">http://www.nano.gov/Prioritization_EHS_Research_Needs_Engineered_Nanoscale_Materials.pdf</a>	21
Nanomaterials in the workplace - Policy and planning workshop on Occupational Safety	2006	<a href="http://www.rand.org/pubs/conf_proceedings/2006/RAND">http://www.rand.org/pubs/conf_proceedings/2006/RAND</a>	2
<b>EHS Research Needs for Engineered Nanoscale Materials (NNI)</b>			6
The national nanotechnology initiative - Strategic Plan	2007	<a href="http://www.nano.gov/nitmi/about/strategicplan/nitmi">http://www.nano.gov/nitmi/about/strategicplan/nitmi</a>	3
Nanotechnology environmental health & safety standards	2007	<a href="http://www.iso.org/iso/iso-focus-index">http://www.iso.org/iso/iso-focus-index</a>	2
EHS Research Needs for Engineered Nanoscale Materials	2006	<a href="http://www.nano.gov/NNI_EHS_research_needs.pdf">http://www.nano.gov/NNI_EHS_research_needs.pdf</a>	4
<b>Prioritization of EHS Research Needs for Engineered Nanoscale Materials (NEHI)</b>			31
Assessment Study on Sensors and Automation in the Industries of the Future	2004	<a href="http://www.doe.gov/n/pdfs/doe_report.pdf">http://www.doe.gov/n/pdfs/doe_report.pdf</a>	1
International Technology Roadmap for Semiconductors	2004	<a href="http://www.itrs.net/Common/2004Update/2004Update.htm">http://www.itrs.net/Common/2004Update/2004Update.htm</a>	1
Chemical Industry R&D Roadmap for Nanomaterials By Design	2003	<a href="http://www.chemicalvision2020.org/pdfs/nano_roadmap.pdf">http://www.chemicalvision2020.org/pdfs/nano_roadmap.pdf</a>	1
Nanoscale Science and Engineering for Agriculture and Food Systems	2003	<a href="http://www.nseafs.cornell.edu/web_roadmap.pdf">http://www.nseafs.cornell.edu/web_roadmap.pdf</a>	1
Nanobiotechnology	2003	<a href="http://www.nano.gov/nni_nanobiotechnology_rpt.pdf">http://www.nano.gov/nni_nanobiotechnology_rpt.pdf</a>	3
Nanotechnology	2003	<a href="http://www.technology.gov/reports/TechPolicy/Nanotech/030523.pdf">http://www.technology.gov/reports/TechPolicy/Nanotech/030523.pdf</a>	2
Nanotechnology and the Environment: Applications and Implications STAR Progress Review Workshop	2002	<a href="http://es.epa.gov/ncer/publications/workshop/nano_proceed.pdf">http://es.epa.gov/ncer/publications/workshop/nano_proceed.pdf</a>	3
Nanotechnology Innovation for Chemical, Biological, Radiological, and Explosive Detection and Protection	2002	<a href="http://www.wtec.org/nanoreports/cbre/CBRE_Detection_11_1_02_hires.pdf">http://www.wtec.org/nanoreports/cbre/CBRE_Detection_11_1_02_hires.pdf</a>	2
Vision 2020 Materials Technology Roadmap	2000	<a href="http://www.eere.energy.gov/industry/chemicals/pdfs/materials_tech_roadmap.pdf">http://www.eere.energy.gov/industry/chemicals/pdfs/materials_tech_roadmap.pdf</a>	1



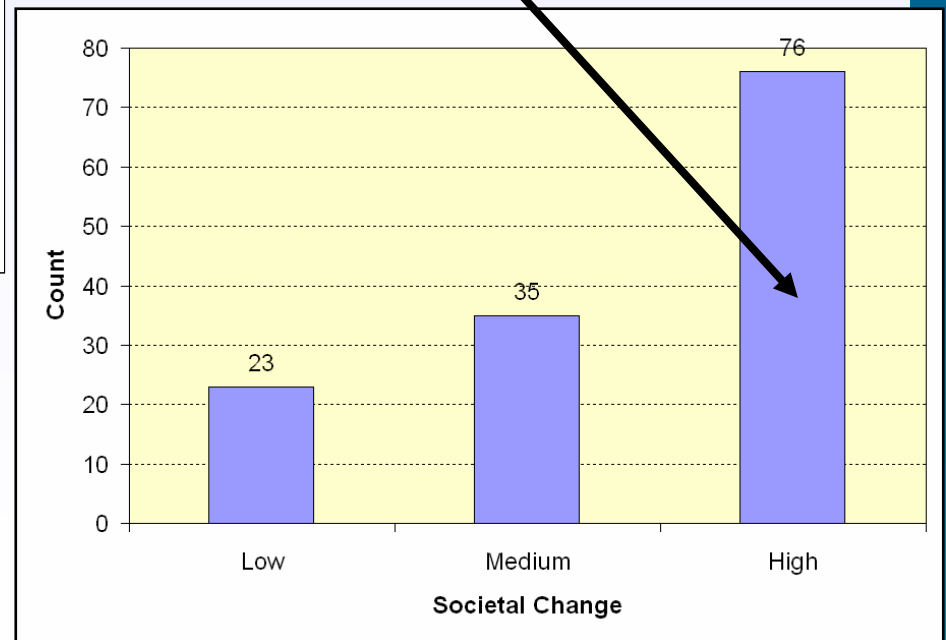
# Preliminary Inferential Analysis of nano-EHS Measurement Needs (MNs) & Roadmap Measurement Needs (RMNs)

Data analyzed from 31 MNs and 104 RMNs

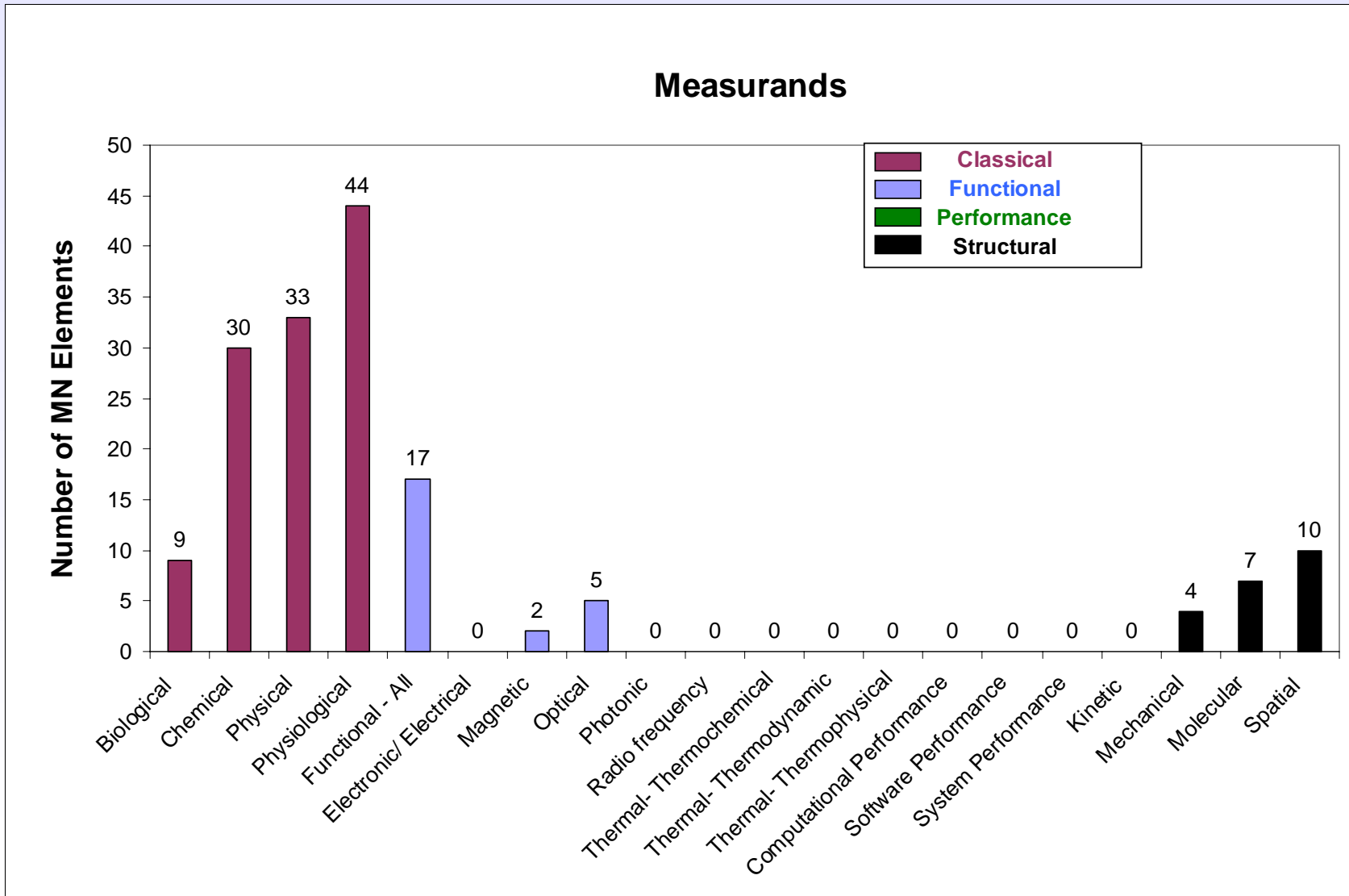


We've only just begun...

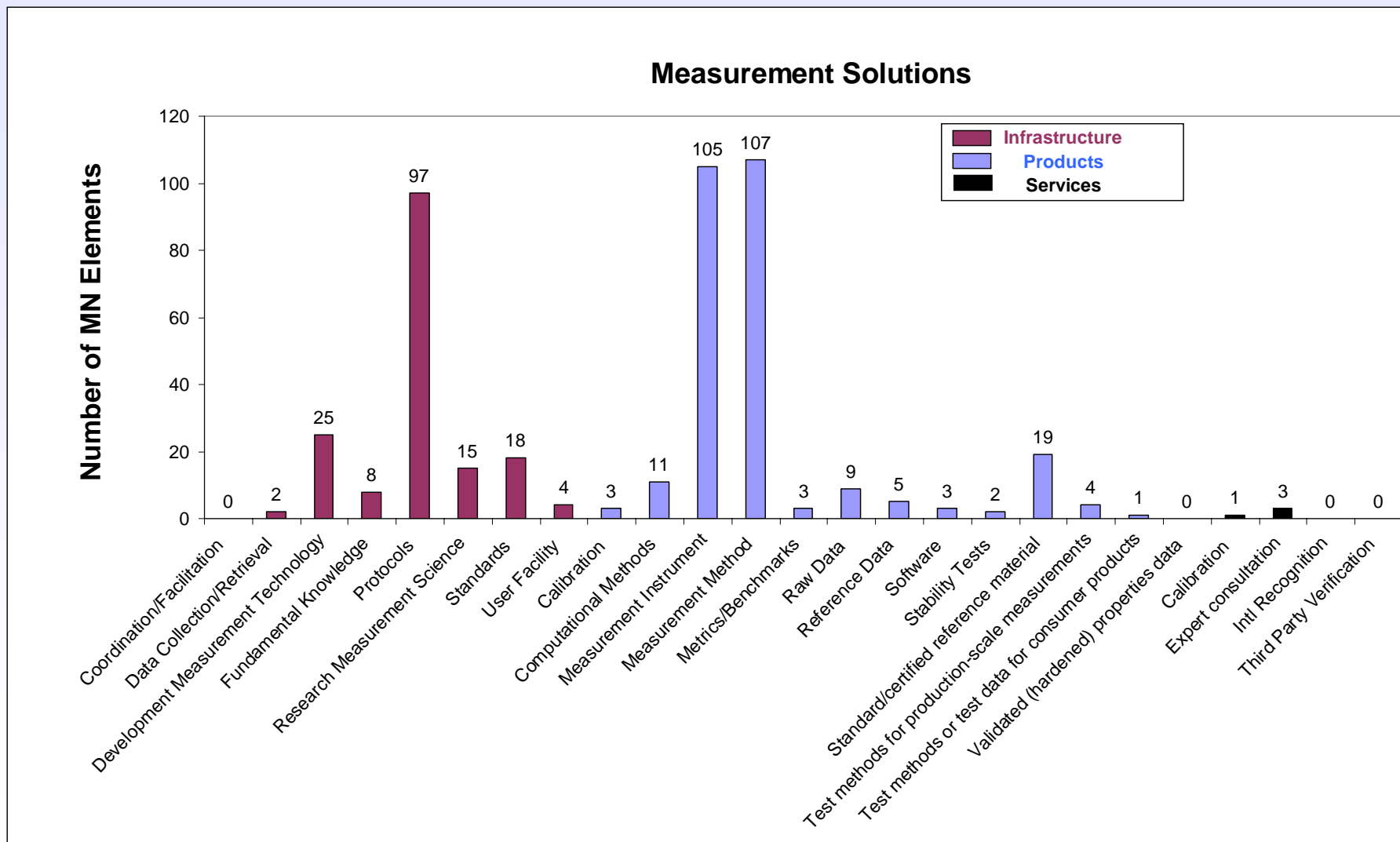
...but the effects on society could be significant.



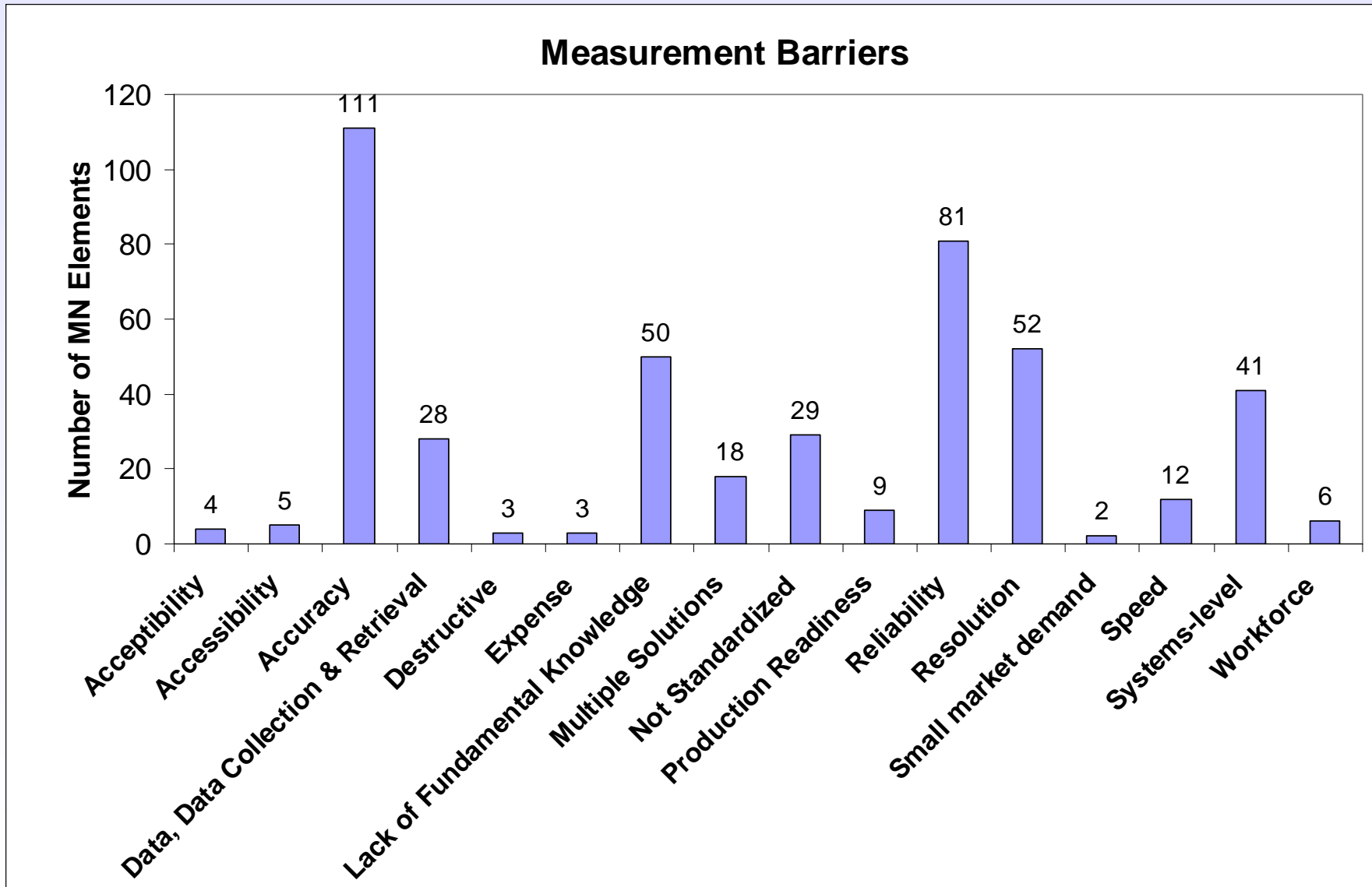
# Preliminary Inferential Analysis of Nano EHS



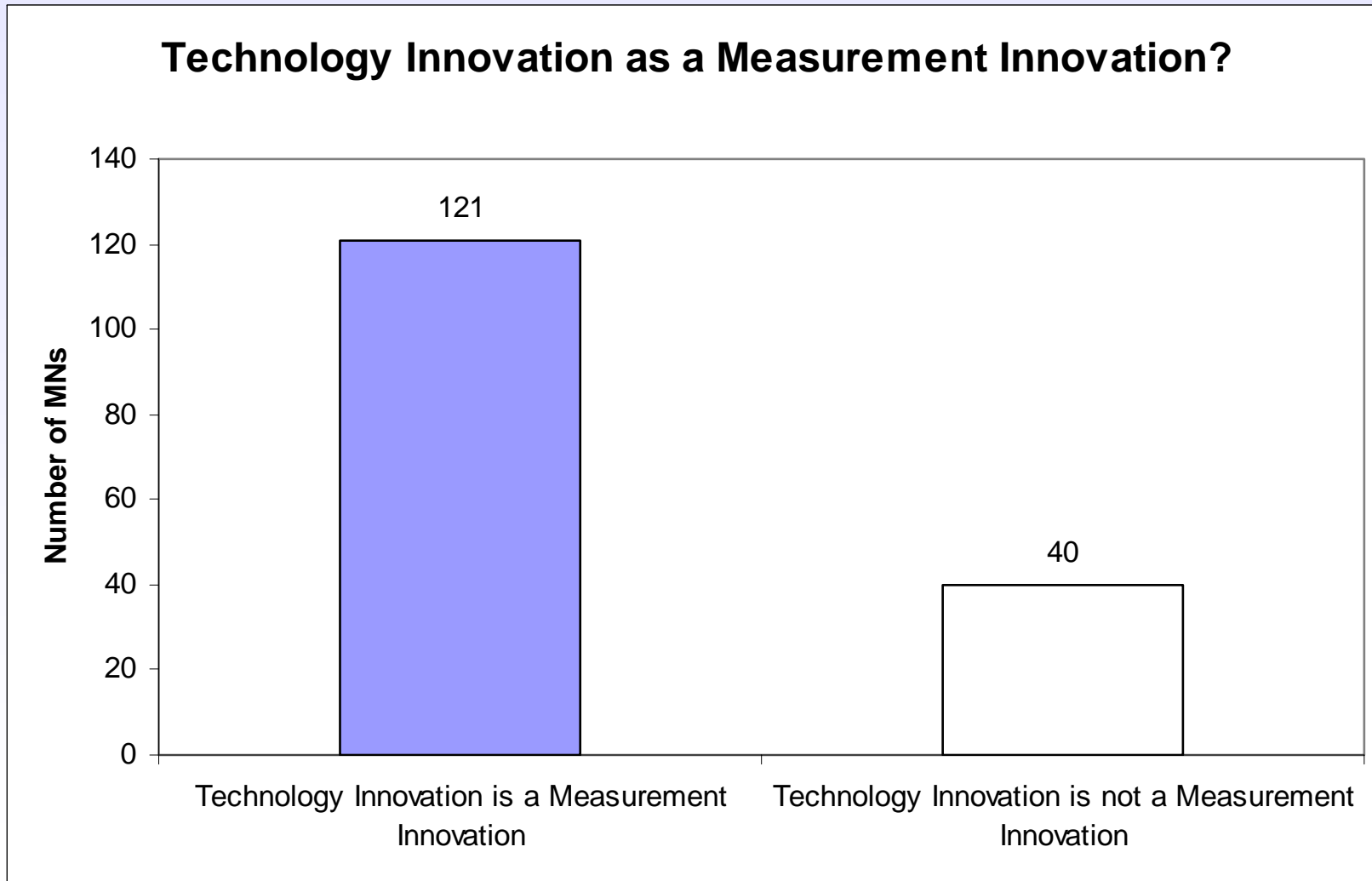
# Preliminary Inferential Analysis of Nano EHS



# Preliminary Inferential Analysis of Nano EHS

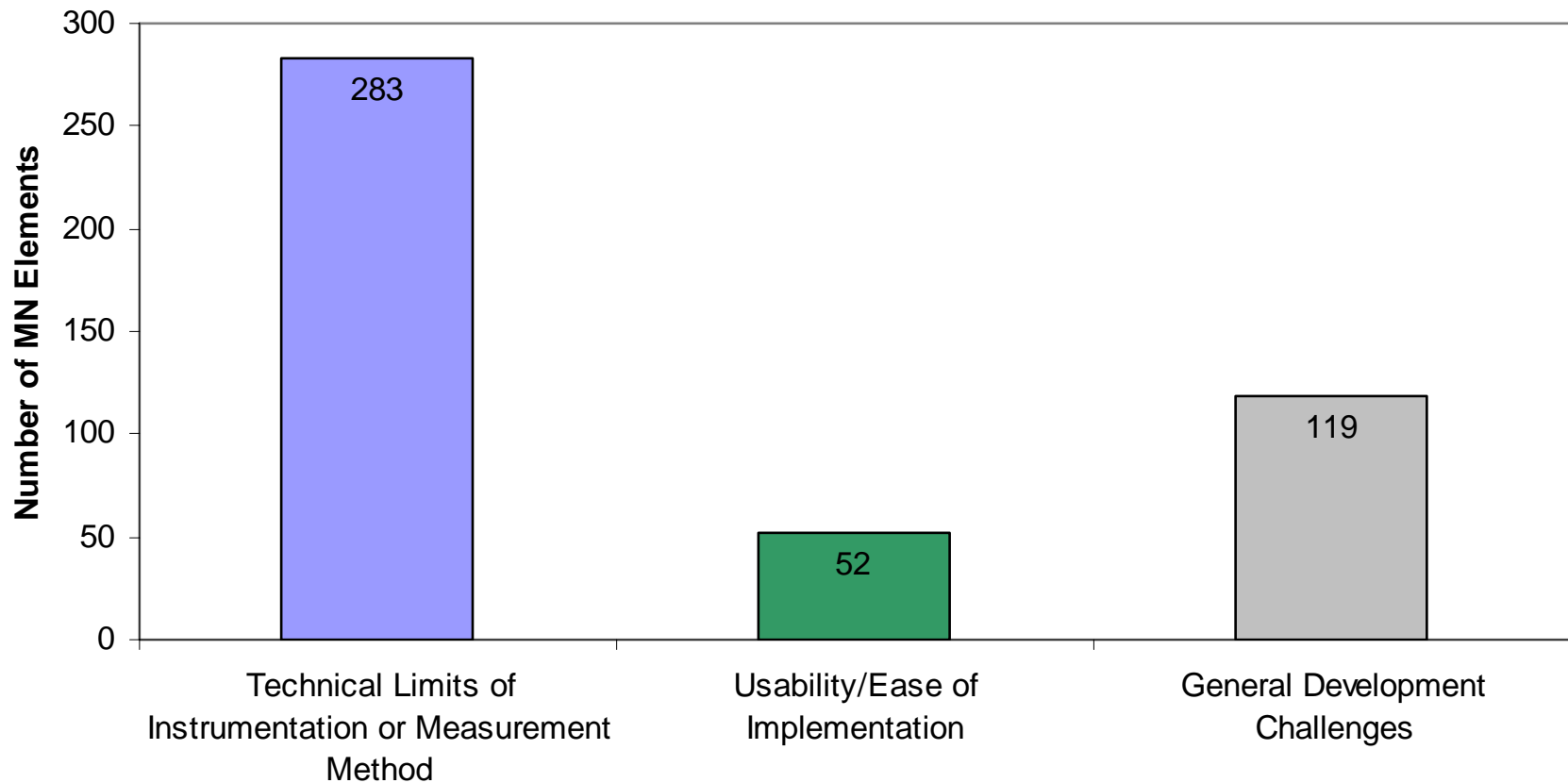


# Preliminary Inferential Analysis of Nano EHS



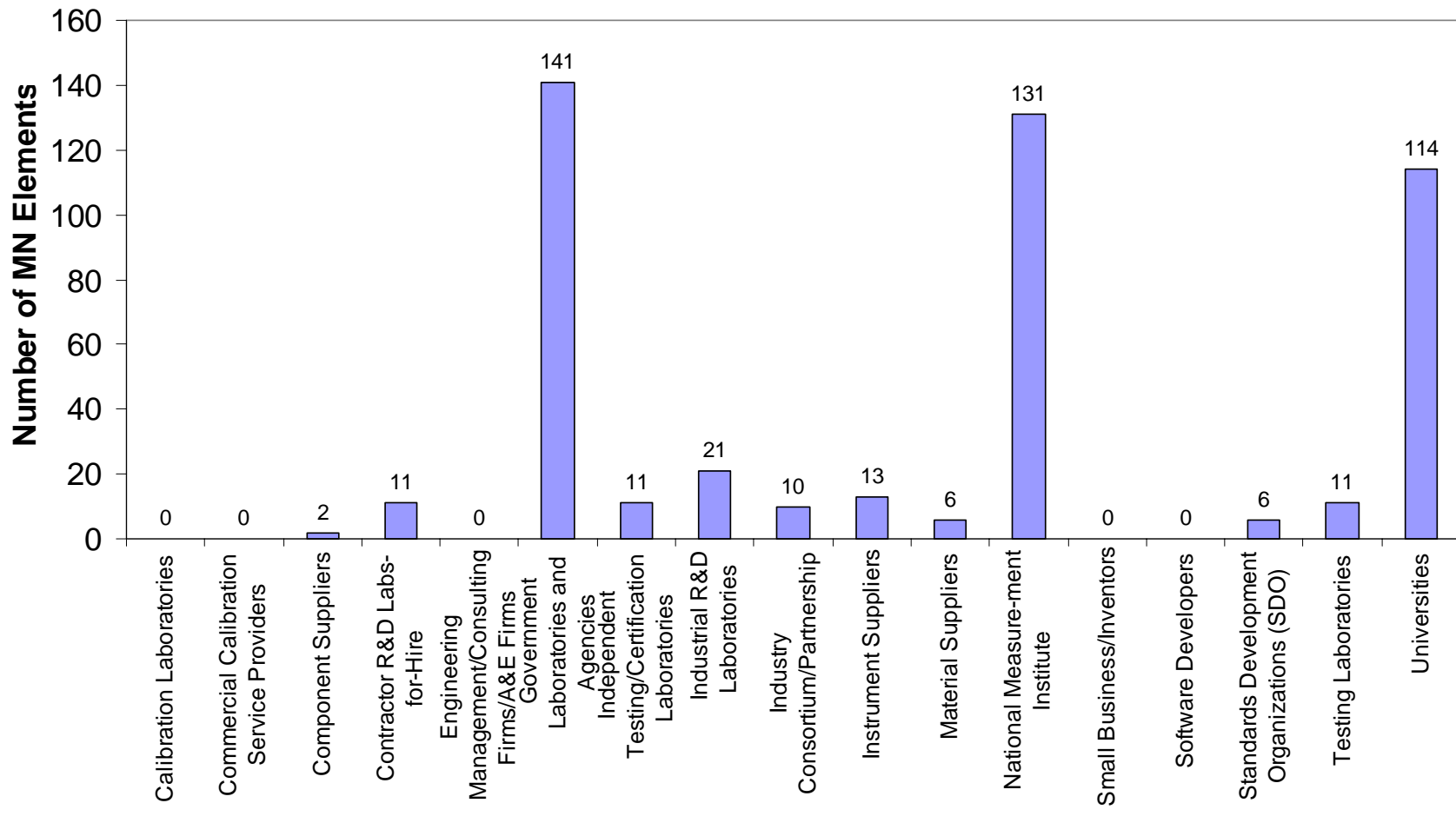
# Preliminary Inferential Analysis of Nano EHS

## Aggregated Measurement Solution Barriers



# Preliminary Inferential Analysis of Nano EHS

## Measurement Solution Providers



# Preliminary Inferential Analysis of Nano EHS

Stage of Technological Innovation	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Applied Research	2	3	101	22	3	2	44	16	18	6	72	48	2	9	38	2
Production	2	2	8	4		1	6	2	7	3	5	4		3	3	4
Market			2	2					4		4					
End-use																



# Preliminary Inferential Analysis of Nano EHS

Stage of Technological Innovation	Measurement Solutions																								
	Infrastructure								Products											Services					
	Coordination/ facilitation	Data Collection/ Retrieval	Development for Measurement Technology	Fundamental Scientific Knowledge	Protocols	Research for Measurement Science	Standards	User Facility	Calibration Method	Computation Method	Measurement Instrument	Measurement Method	Metrics/ Benchmarks	Raw Properties Data	Reference Data	Software	Stability Tests	Standard/CRM	Test Methods - Production Scale	Test Methods - Consumer Products	Validated Data	Calibration Services	Expert Consultation	International Recognition	3rd Party Verification
Applied Research		2	21	8	87	15	10	4	3	7	95	97	3	9	4	3	2	9	1					3	
Production			4		8		4			2	10	10		1				8	2			1			
Market					2		4			2								2	1	1					
End-use																									

# Preliminary Inferential Analysis of Nano EHS

Aggregated Measurands	Measurement Solution Barriers															
	Acceptability/compatibility	Accessibility	Accuracy	Data, data collection and/or retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple solutions exist	Not standardized	Production readiness	Reliability	Resolution	Small market demand	Speed	System-level problem	Workforce
Classical	2	1	80	21	2	2	35	16	21	5	65	38	1	7	32	4
Functional	1	4	15	7	1		8	1	5	2	6	6		1	6	2
Performance																
Structural	1		16			1	7	1	3	2	10	8	1	4	3	

# Preliminary Inferential Analysis of Nano EHS

		Stage of Technological Innovation			
Measurand		Applied Research	Production	Market	End-Use
Classical	Biological	7		2	
	Chemical	23	7		
	Physical	31		2	
	Physiological	36	8		
Functional	All	15	2		
	Electronic/Electrical				
	Magnetic	2			
	Optical	3	2		
	Photonic				
	Radio frequency				
	Thermal - Thermochemical				
	Thermal - Thermodynamic				
Thermal - Thermophysical					
Performance	Computational Performance				
	Software Performance				
	System Performance				
Structural	Kinetic				
	Mechanical	3	1		
	Molecular	7			
	Spatial	10			

# Preliminary Inferential Analysis of Nano EHS

		Measurement Solution Barriers															
Measurand		Acceptability/compatibility	Accessibility	Accuracy	Data, data collection and/or retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple solutions exist	Not standardized	Production readiness	Reliability	Resolution	Small market demand	Speed	System-level problem	Workforce
Classical	Biological			7				2	2	3		9	2		2		
	Chemical		1	22	7			8	4	3	1	18	17		3	3	1
	Physical	2		26	11	2	1	7		9	1	17	10			6	
	Physiological			25	3		1	18	10	6	3	21	9	1	2	23	3
Functional	All	1	4	8	7	1		4	1	5	2	6	3		1	6	2
	Electronic/Electrical																
	Magnetic			2				2					2				
	Optical			5				2					1				
	Photonic																
	Radio frequency																
	Thermal - Thermochemical																
	Thermal - Thermodynamic																
Thermal - Thermophysical																	
Performance	Computational Performance																
	Software Performance																
	System Performance																
Structural	Kinetic																
	Mechanical	1		3						1		2	2		2	1	
	Molecular			5				3	1		2	3			1		
	Spatial			8			1	4		2		5	6	1	1	2	

# Preliminary Inferential Analysis of Nano EHS

Aggregated Measurement Solutions	Measurement Solution Barriers															
	Acceptability/Compatibility	Accessibility	Accuracy	Data, Data Collection and/or Retrieval	Destructive	Expense	Lack of fundamental knowledge	Multiple Solutions Exist	Not Standardized	Production Readiness	Reliability	Resolution	Small Market Demand	Speed	System-Level Problem	Workforce
Infrastructure	4	5	125	35	3	4	57	18	27	5	86	63	2	10	35	4
Products	5	7	189	40	5	4	82	36	45	17	149	87	4	23	75	10
Services	1			3			2		1						4	1

# CONCLUSIONS

- o Measurement Needs and Roadmap Measurement Needs are being assessed within the Nano-EHS sector
- o Preliminary indications are that Nano-EHS is *early-stage* in its development of measurement solutions
- o Nano-EHS measurement needs will *push the envelope* of metrology equipment in the near future
- o A concerted effort across multiple disciplines is needed to solve many of the Nano-EHS measurement needs
- o It is critical to engage experts in this activity for their opinions on techniques, priorities and strategic directions

## ***PURPOSE OF WORKSHOP***

- o Engage experts in the field in the development of Measurement Needs to make an accurate assessment of the state-of-the-art Nano-EHS USMS
- o Initiate a dialogue about the best means for obtaining measurement *solutions* to addressing measurement needs
- o Create a new opportunity for networking among experts in the Nano-EHS research and business sector