Assessing the Economic Impact of U.S. Neutron Scattering Facilities

Amanda Walsh

Senior Economist, Innovation Economics

RTI INTERNATIONAL

Assessment Details

- RTI International leading
  - Technical advising from Ayman Hawari at NC State University and Albert Link at UNC-Greensborro
- Under funding from NIST
  - March 2021 – February 2024
- Report dissemination expected in Winter 2023/24

Assessment Components

- Surveys (N=247) and interviews (N=50) of users from NCNR and ORNL
  - Facility use and outcomes, **impacts of insufficient access**, additional needs
- Analysis of research outputs: publications, patents, research networks
- **Analysis of data on corporations using neutron scattering facilities**
- **Case studies of technologies influenced by neutron scattering**
- Policy Assessments:
  - U.S. University neutron research reactors
  - Comparison of U.S. and international scattering policy and investment
- *Compilation of economic impacts (to be added)*

User-Reported Impacts of Insufficient Access (Pre-Facility Closures)

77% of survey respondents experienced issues due to insufficient access

- 25% either lost or under-utilized grant funds due to access-related research delays or abandonments
  - $5,760,500 in aggregate
  - Hiring post-docs or PhD students who can't conduct planned research
  - Losing funds from inflexible sources (e.g., DOE)
- 32% reported research quality reductions
  - Depth of information gained from research reduced by 44% on average
  - Publication quality reduced by 39% on average
- 19% took research overseas

Common Issues Described in Surveys & Interviews

- Delays disincentivize students from pursuing scattering
- Over-subscription disincentivizes:
  - Recruitment of new (especially corporate) users
  - Acceptance of high-risk-high-reward research
- All reduces future pool of U.S. scattering researchers

Data on Corporate Use of Neutron Research Facilities

- Public records from NCNR, ORNL, Brookhaven, Argonne, and LANSCE
  - 372 U.S. based companies
- Pitchbook data on global employment
  - 265 companies with data
  - 398,500+ total employees
  - 45% SMEs (<250 employees)
- Pitchbook data on global revenue
  - 158 companies with data
  - $3.2 trillion total revenue

Average Revenue and Employment in U.S. Sectors with the Most Frequent Neutron Scattering Facility Use

Sector	Top Using Industries	Average Revenue ($M)	Average Employment
Energy	Exploration, Production and Refining; Energy Equipment	71,274	13,226
Consumer Products and Services	Automotive; Consumer Non-Durables	54,116	57,174
Healthcare	Pharmaceuticals and Biotechnology; Healthcare Devices and Supplies; Healthcare Services	15,492	21,196
Business Products and Services	Aerospace and Defense; Machinery; Other Business Products and Services; Construction and Engineering; Other Commercial Products; Industrial Supplies and Parts; Electrical Equipment; Other Commercial Services	13,514	18,989
Information Technology	Semiconductors; Computer Hardware; Software	8,587	10,048
Materials and Resources	Chemicals and Gases; Other Materials	7,995	6,172

Top Revenue and Employment Companies within 20 Industries with Highest Neutron Scattering Facility Usership

Companies with Highest Global Revenue

Company	Industry	Revenue ($M)
Exxon Mobil	Energy Production and Refining	$394,585
Chevron	Energy Production and Refining	$232,245
Phillips 66	Energy Production and Refining	$168,207
Ford	Automotive	$165,055
General Motors	Automotive	$160,740

Companies with Highest Global Employment

Company	Industry	Employment
Raytheon	Aerospace	182,000
Ford	Automotive	173,000
General Electric	Business Products and Services	172, 000
General Motors	Automotive	167,000
Boeing	Aerospace	156,000

Barriers to Increased Corporate Adoption

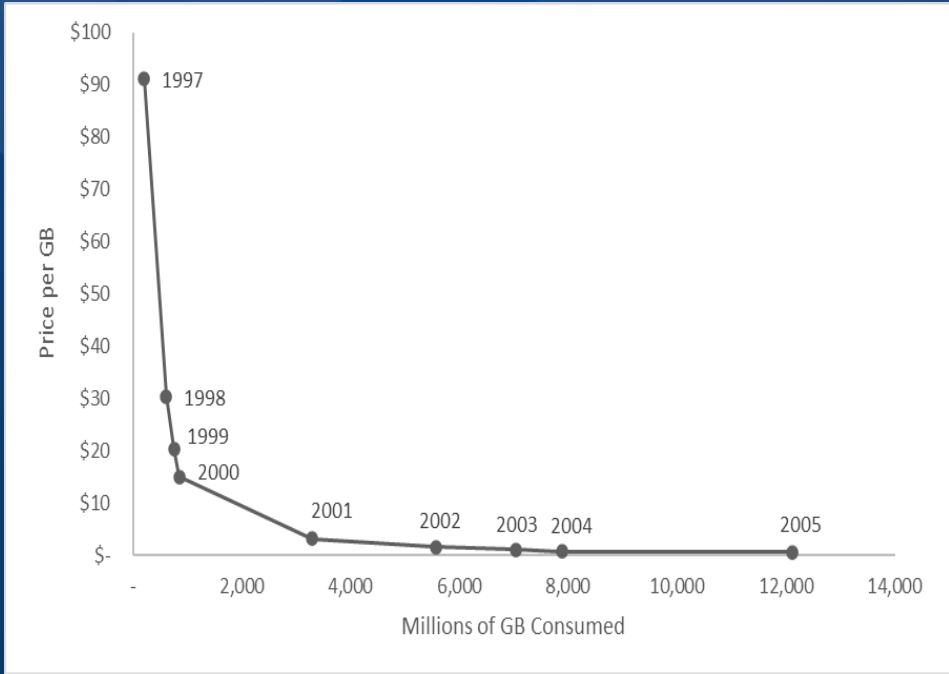
- Awareness
  - Most U.S. neutron researchers gain exposure during graduate school
  - Need improved recruitment for non-academic users (*e.g.,* J-PARC)
- Accessibility
  - Oversubscription decreases success of new users through free application process
    - Application timelines also do not align with corporate needs
  - nSoft does streamline corporate access and subscription cost is reasonable
    - However, new users have unknown value proposition – reluctant to pay for access
- Usability
  - Neutron scattering sources are complicated to use
  - Corporate users need more direct and intensive assistance throughout the entire process
    - Also increased instrument automation and improved data processing software
  - *e.g.,* ample staff on iMATERIA instrument at J-PARC dedicated to assisting corporate users

Case Studies of Key Technologies Influenced by Neutron Scattering

- Hard Drives
  - Polarized neutron reflectometry for GMR [1-3]
- Aerospace Safety
  - SANS for aviation fuel polymers [4-5]
  - Diffraction for identifying residual stress [6-8]
- Weight-Loss Drugs
  - SANS to optimize drug delivery systems [9-11]
- Electric Vehicles
  - Multiple methods for battery performance [12-13]

Economic Impact of Hard Drive Advancements from 1997–2005

Long-Run Hard Drive Demand: 1997–2005



Consumption was calculated using data on annual shipments of computer storage devices from U.S. manufacturers[14] plus computer storage device imports minus exports[15] as well as the percentage of the global computer storage device industry that is held by hard drives[16] and average hard drive prices[17]

- Consumer Surplus: Additional value consumers receive above and beyond the value reflected in the purchase price of a product
  - Area under the demand curve above the equilibrium price and quantity
- Increase in consumer surplus from 1997–2005: **$75 billion**
  - $9.5 billion per year on average

Neutron Research for Improved Aircraft Safety

Improved Technology & Innovation

- Fluid Efficiency: CalTech spinout
  - Developed fuel additive to reduce or fully eliminate flammability[4]
  - Polymer research done at NCNR[18]
- Non-destructive identification of micro-cracks in aircraft components
  - Enables manufacturers to reduce residual stress by improving materials, designs, or processes[6-8]
  - Research at ORNL, LANL, NCNR, …

Impact Data Sources

- National Transportation Safety Board Accident Data from 2008-2022[19-20]
  - Annual aircraft incidents by type
    - Crashes with/without post-impact explosions
    - Aircraft structural failures
  - Number of casualties, injuries, and level of aircraft damage
- FAA *Benefit-Cost Analysis*[21]
  - Value of a statistical life (VSL)
  - Cost of aircraft damage and destruction

Total Estimated Costs Avoided by Eliminating Post-Crash Fuel Explosions in the United States from 2008 through 2022

	Sample of U.S. Aircraft Crashes *without* Post-Impact Explosions [19]	All U.S. Aircraft Incidents *with* Post-Impact Explosions [20]	Counter-Factual Scenario without Post-Impact Explosions [a]
Total Incidents	8,522	34	34
Resulting in complete destruction of aircraft	1,108 (13%)	26 (76%)	4.4 (13%)
Resulting in substantial damage to aircraft	7,438 (87%)	8 (23%)	29.7 (87%)
Resulting in at least one casualty	2,301 (27%)	32 (94%)	9.2 (27%)
Average casualties per incident	1.7	2.2	1.7
Resulting in at least one serious injury	1,125 (13%)	3 (9%)	4.5 (13%)
Average serious injuries per incident	1.7	1	1.7

[a] Calculation Methods: Proportions from the data on crashes without post-impact explosions were multiplied by the number of incidents which did result in a post-impact explosion (34) to produce the counterfactual results.

	Estimated Change in Incidents by Eliminating Post-Impact Explosions [a]	Average Estimated Cost Per Incident [21] (2021$M)	Estimated Cost Avoided (2021$M)
Casualties	-55.4	$10.7 ($6.0 – $14.9)	$592.8 ($332.4 – $825.5)
Serious Injuries	+4.7	$2.7 ($1.5 – $3.8)	-$12.7 (-$7.1 – -$17.9)
Planes Completely Destroyed	-21.7	$18.6	$401.8
Planes Substantially Damaged	+21.7	$3.8	-$82.5
Total Estimated Cost Avoided	---	---	**$899.4** ($644.6 – $1,126.9)
Average Cost Avoided per Year	---	---	**$60.0** ($43.0 – $75.1)

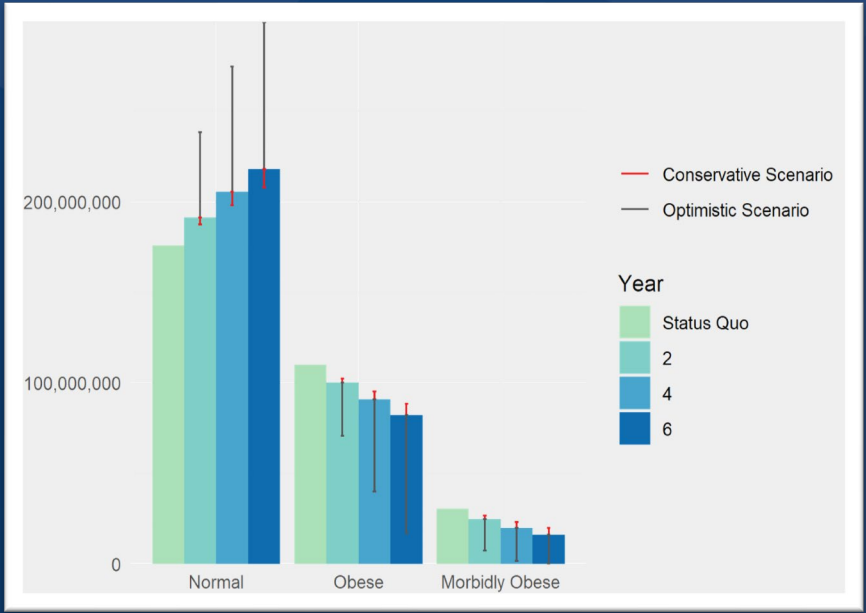
[a] Calculation methods: These figures were calculated by subtracting the estimates for the counterfactual scenario in Table 1 from the actual values of these metrics based on the 34 incidents which resulted in a post-impact explosion.

Costs of Aircraft Structural Failure Incidents in the United States from 2008 through 2022

	Incidents Caused by Aircraft Structural Failure [20]	Average Estimated Cost Per Incident [21] (2021$M)	Estimated Cost (2021$M)
Incidents Requiring Investigation	191	$0.9	$171.9
Casualties	229	$10.7 ($6.0 – $14.9)	$2,450.3 ($1,374.0 - $3,412.1)
Serious Injuries	23	$2.7 ($1.5 - $3.8)	$62.1 ($34.5 - $87.4)
Planes Completely Destroyed	51	$18.6	$948.6
Planes Substantially Damaged	129	$3.8	$490.2
Total Estimated Cost	---	---	**$4,123.1** ($3,019.2 – $5,110.2)
Average Cost per Year	---	---	**$274.9** ($201.3 – $340.7)

SANS for Weight Loss Drug Development

Projected Distribution of U.S. Population among Weight Classes After 2 to 6 Years of Weight Loss Medication Use



Weight Class BMIs: Normal (18-29), Obese (30-39), Morbidly Obese (40 or greater)
Projections based on modelling assumptions and baseline weight class distributions [22]

Cumulative Discounted Medication Costs, Reduction in Obesity-Related Costs, and Net Cost Savings in 2022$M.

	Cumulative Discounted Medication Costs	Cumulative Discounted Reduction in Obesity-Related Costs	Cumulative Net Cost Savings
2023	$62,236.6	$45,021.7	($17,214.9)
2028	$358,158.0	$478,408.4	**$120,250.5**

Modelling Assumptions:

- 20% of Obese+ individuals take medication
- Medication reduces weight by 15% every 2 years [23]
- Annual medical costs attributable to obesity: $2,881 [24]
- Annual cost of the weight loss drugs: $2,214 [25]
- Annual discount rate for future economic impacts: 1.7% [26]

Electric Vehicle Adoption

Modelling Assumptions:

- Improved EV battery technology leads to wider EV adoption
- Wider EV adoption increases auto manufacturer profits and reduces GHG tailpipe emissions
- Period of analysis: 2017 - 2028
- Use of neutron technology accounts for 0.5% of growth in EV adoption
- US car manufacturers' share of all new EVs sold in the US varies by year and ranges from 6% - 78%
- Social cost of carbon is $51
- Emissions avoided by use of an EV compared to an ICEV is 2.97 carbon tons/year

Cumulative Value of Increased Sales Revenues and GHG Emissions Avoided in 2022$M.

	Cumulative Value of Additional Sales Revenue	Cumulative Value of GHG Emissions Avoided	Cumulative Total Value
2023	$4.87	$0.3	$5.14
2028	$45.13	$2.97	**$48.1**

Key Economic Take-Aways

- Case studies highlight substantial economic benefits from technologies enabled by neutron scattering research
- Hundreds of U.S. corporations rely on neutron scattering research facilities
  - Large-scale entities and SMEs
  - Insufficient facility investment has resulted in barriers to entry for corporate users
- User surveys and interviews show high costs of insufficient research capacity
  - Inefficient use of research time and grant funds
  - Reduced research ingenuity and quality

Last Steps

- Compile economic benefits and costs identified through case studies, user surveys, and corporate use data
- Project economic benefits and costs into the immediate future (through 2030)
  - Note: Longer-term modelling (20-30 years) is needed to capture the impacts of changes in neutron source investments
- Disseminate full report and individual components
  - Where would you expect to see this work?

Thank you

Contact: Amanda Walsh | email: awalsh@rti.org

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