# Realizing the Benefits from Earth Science Applications Research: Methodological Frontiers and New Approaches

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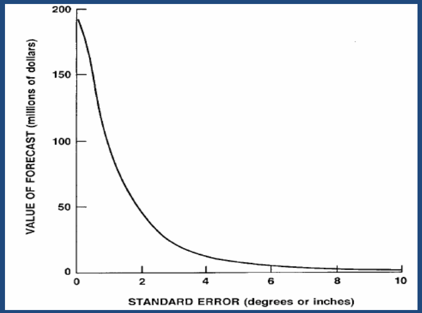
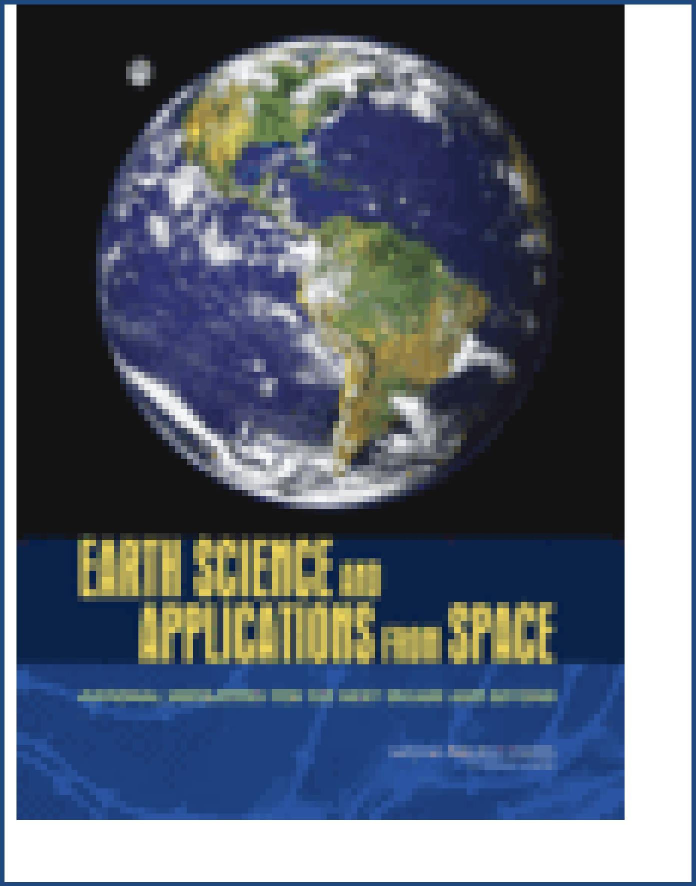
RESOURCES FOR THE FUTURE

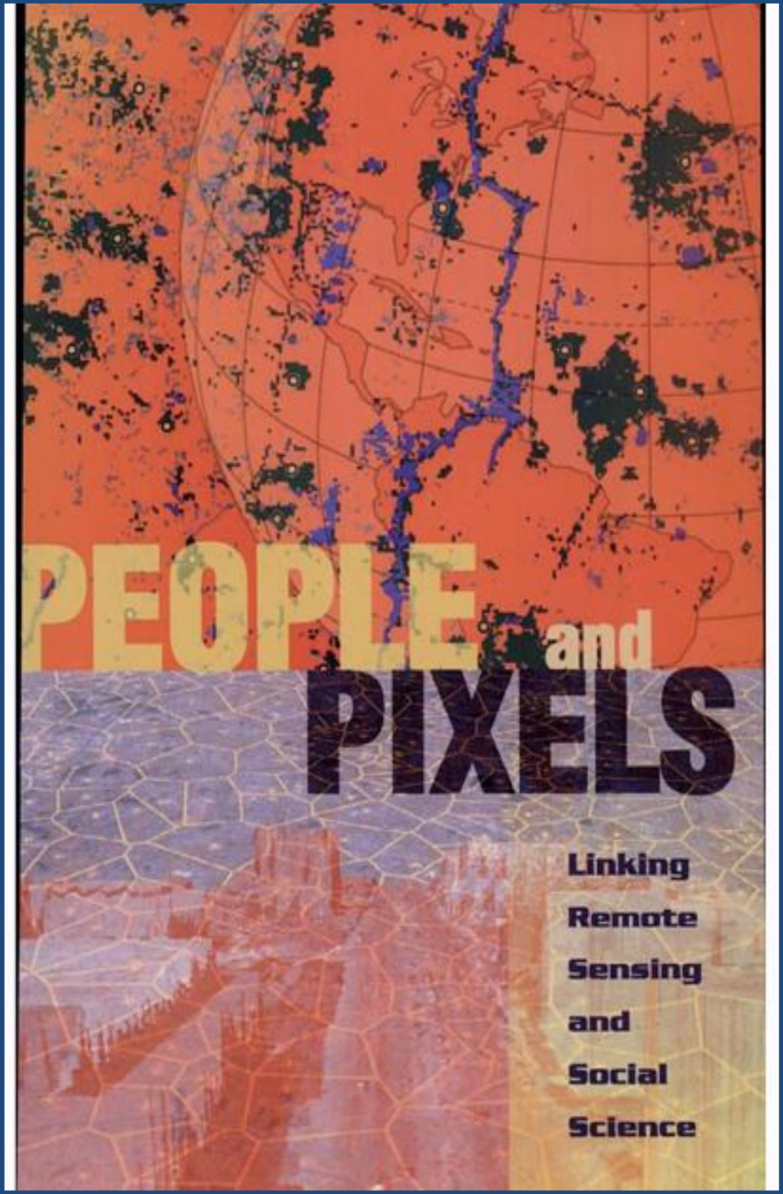




Here we are now. What can we collectively deliver and advance?




*Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*

"The scientific community must focus on meeting the demands of society explicitly, in addition to satisfying its curiosity about how the Earth system works" (ES-1)




"…to realize more of the apparent potential of remotely sensed data…

…to identify ways of making satellite observations more useful sources of data for social science, research on human-environment relations, and other applications….

…to make potential uses more evident, eventually to the broader social science community…." (pp. vii-viii)


"Remotely sensed data provide a spatial perspective on human health issues not typically incorporated into human health research and applications…Health professionals do not typically observe the human land uses and ecological conditions affecting human health from the viewpoint of the remote sensing satellites…

…the visual and spatial perspective fosters a more integrative approach…

…Interdisciplinary and international collaboration are needed between remote sensing scientists, ecologists, and human health scientists to realize the full potential of remote sensing applications…" ("Challenges and Potential," p. 33)

*Research Funding as an Investment: Can We Measure the Returns?*, US Congress, Office of Technology Assessment, 1986.

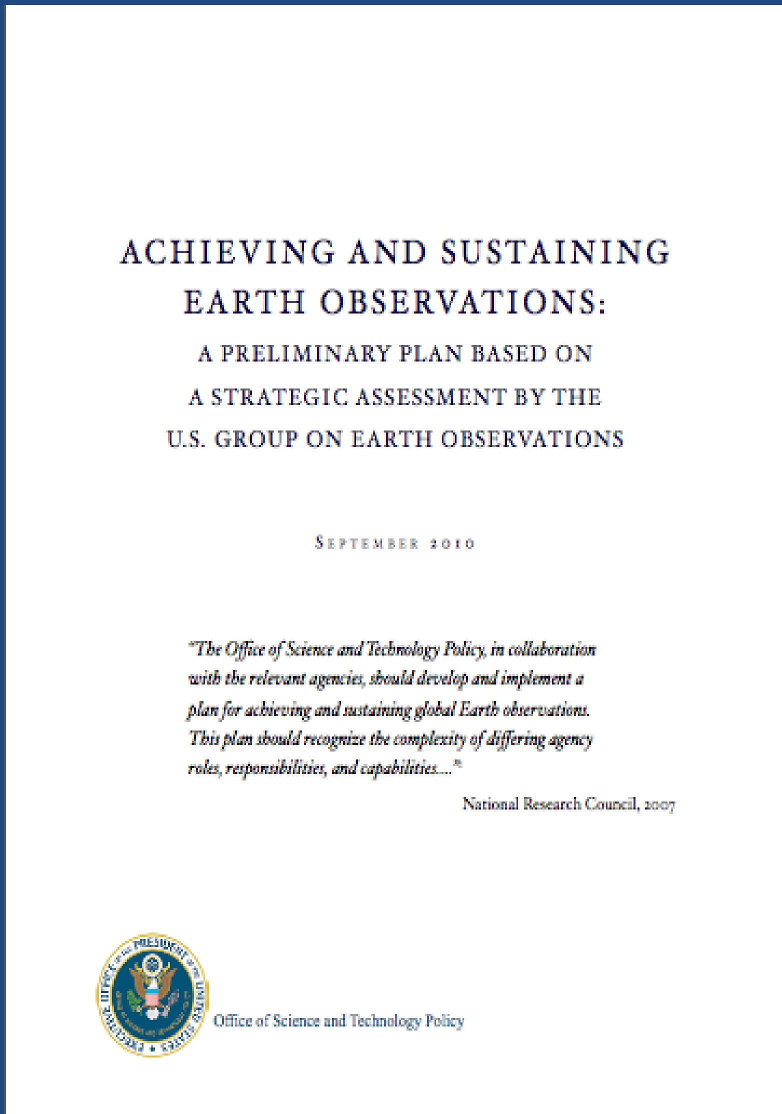
*Transforming Remote Sensing Data into Information and Applications*, National Research Council, 2001

*Using Remote Sensing in State and Local Government*, National Research Council, 2003

"Ascribing Societal Benefit to Applied Remote Sensing Data Products: An Examination of Methodologies Based on the Multi-Angle Imaging SpectroRadiometer Experience," M.K. Macauley and D.J. Diner, *J. Appl. Remote Sens.* (1), 2007.

"Assessing the Value of Information for Water Quality Management in the North Sea," J.A. Bouma, H.J.van der Woerd, et al., *J. Env. Management* 90(2), 2009.

"From Science to Applications: Determinants of Diffusion in Use of Earth Observations," M.K. Macauley, J. Maher and J.S.Shih, *J. Terr. Obs* 2(1),2010.



ACHIEVING AND SUSTAINING EARTH OBSERVATIONS:

A PRELIMINARY PLAN BASED ON A STRATEGIC ASSESSMENT BY THE U.S. GROUP ON EARTH OBSERVATIONS

SEPTEMBER 2010

*"The Office of Science and Technology Policy, in collaboration with the relevant agencies, should develop and implement a plan for achieving and sustaining global Earth observations. This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities...."*

National Research Council, 2007

Office of Science and Technology Policy

# What's At Stake?

I. Our Welfare and Our Productivity

*Climate and Energy*

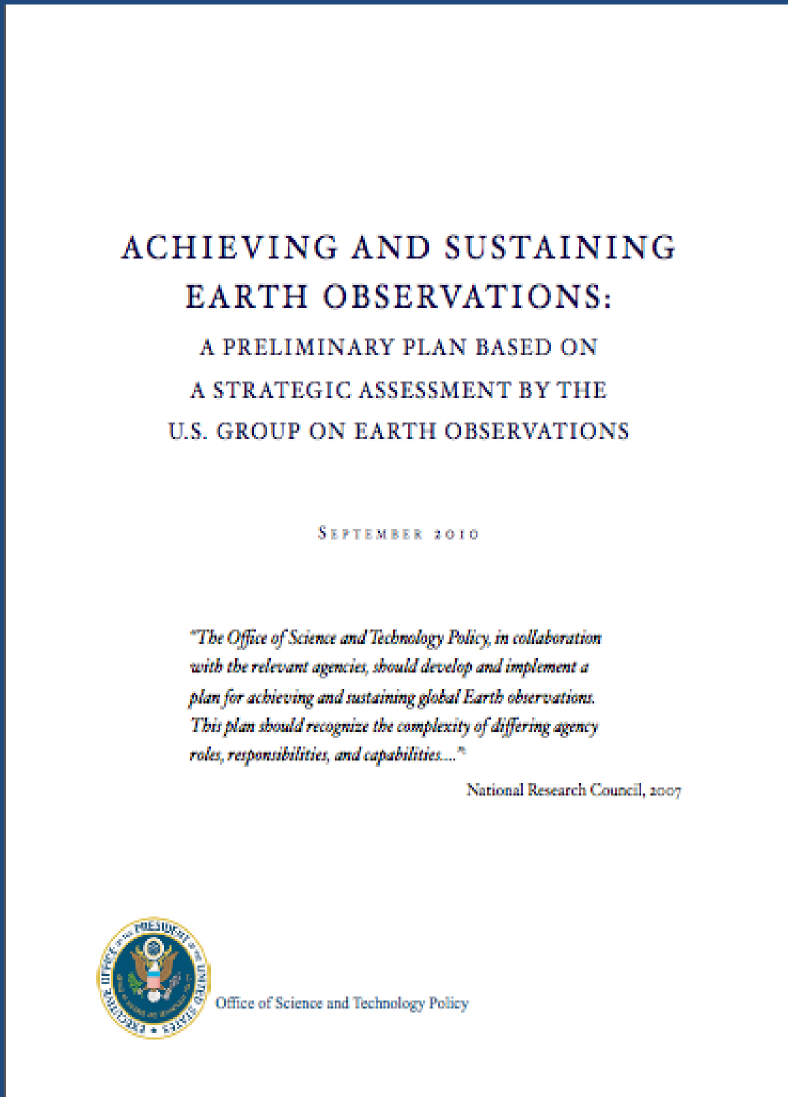
II. Life on Earth

*Nature, Food, Water, Health*

(air quality, water quality, disease)

III. Our Lives and Property

*Disasters and Extreme Weather*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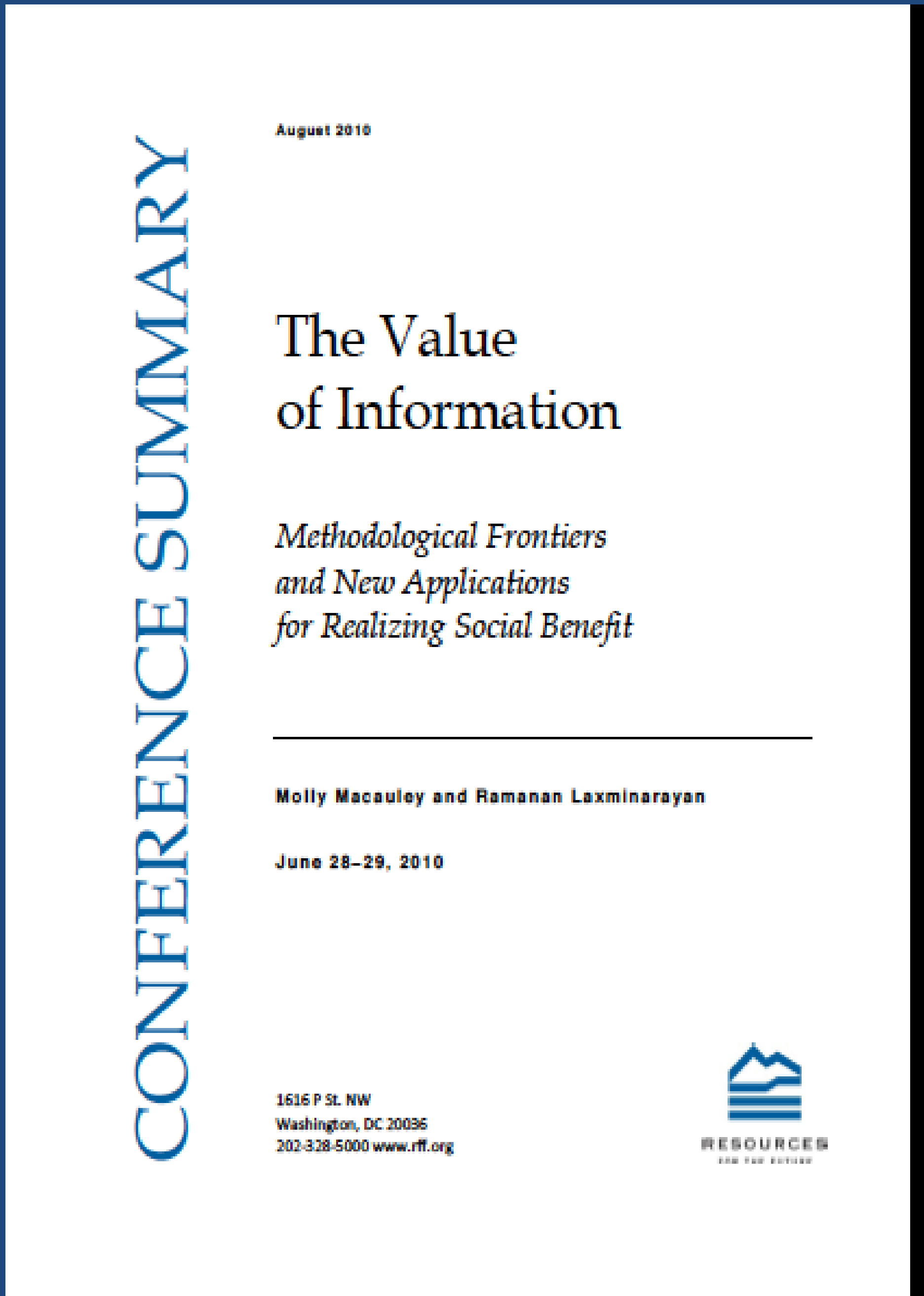
"Through these national and international strategies to advance Earth observations, the Obama Administration is working to ensure that our Nation's decision makers, businesses, farmers, health care workers, and indeed all our citizens have the information they need to take actions to improve human well-being and the health of our environment."



CONFERENCE SUMMARY

August 2010

# The Value of Information

*Methodological Frontiers and New Applications for Realizing Social Benefit*

Molly Macauley and Ramanan Laxminarayan

June 28–29, 2010

1616 P St. NW
Washington, DC 20036
202-328-5000 www.rff.org

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# The value of information (VOI)--general principles

- Not all information has value
  - Can action be taken in response?
  - Are the consequences of a wrong decision large?
  - How costly is it to use the information?

- The value of perfect information may not justify the cost of its acquisition

- Information has value even if it introduces more uncertainty (it reveals that what was thought to be certain may not be)

- Some attributes of information may confer more value than others

# Some challenges

- Few compendia, no best practices, no general guidelines, no systematic collection and accessibility of findings
- Information as a public good about public resources
- Government role in provision of the information without charge (price)
- Little incentive for research community beyond peer review publication and funding agency's reporting requirements
- Valued information poorly understood. Which information? How much information? What quality (for example, spatial, spectral, temporal resolution or accuracy/precision)?

# Describing the benefits: usual approaches

- Scientific (non-peer-reviewed) publications
- Technical conference proceedings
- Government reports
- Occasional news item
- Peer-reviewed studies

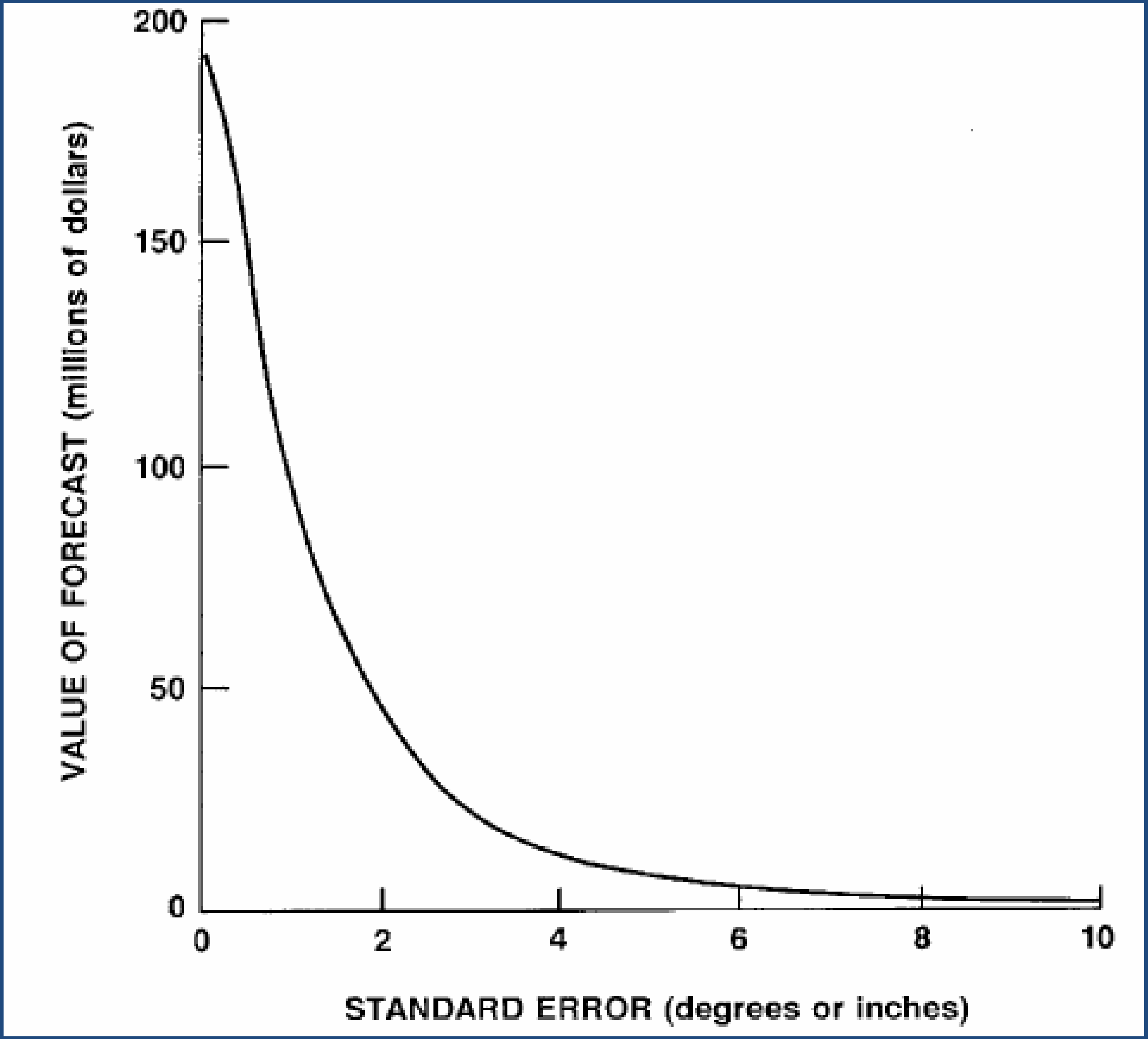
# The “value” of information: could we add analyses and add value?

- Formal mathematical modeling of decisions under uncertainty (Luce and Raiffa 1957, Hirschleifer and Riley 1992)
- Standard topic in economics and management textbooks (Nicholson 1989, Varian 1999)

*EXAMPLE* Table 1. Matrix for assessing benefits (adapted from Macauley and Diner 2007, based on NRC 2001)

| | Realized Benefits | Options Benefits* | Knowledge Benefits |
|---|---|---|---|
| Economic Benefits | Entries here are economic benefits conferred, perhaps from data products | Entries here are future benefits | Entries here are new knowledge informing economic benefits |
| Environmental Benefits | Entries here are environmental benefits conferred, perhaps from data products | Entries here are future benefits | Entries here are new knowledge informing environmental benefits |
| Public Health Benefits | Entries here are health benefits conferred, perhaps from data products | Entries here are future benefits | Entries here are new knowledge informing health benefits |
| Security Benefits | Entries here are security benefits conferred, perhaps from data products | Entries here are future benefits | Entries here are new knowledge informing the nation's security interests |
| Knowledge Benefits | Entries here are data products conferred, perhaps by adding to knowledge | Entries here are future benefits | Entries here are new fundamental science |

Note:* Providing an "option" for a benefit to be realized in the future but requiring additional investment; for example, if additional algorithms were to be developed or if the mission and/or instrument were extended ( perhaps to operational status)




*Agnew and Anderson 1977*

*EXAMPLE* Table 2. Enabling and Improving Human Health and Environmental Protection: a Hypothetical Earth Science Application for Monitoring Invasive Plant Species (Macauley 2006)

| (a) Benchmark cost factors | (b) Benchmark allocation of costs (%) | | (c) Earth science contribution to cost reduction | (d) Enabled cost reduction ($ millions/year) |
|---|---|---|---|---|
| Data collection: In situ $20M/yr | Access | 80% | ↓ 5% to 8% | $0.8 to 1.28 |
| | Routine measurement | 5 | | |
| | Frequency of measurement | 5 | ↓ 20% to 25% | $0.2 to 0.25 |
| | Quality | 10 | | |
| Data collection: Remote $10M/yr<br>Validation and verification $.05M/yr<br>Data analysis $15 M/yr | Interpretation | 80 | ↓ 3% to 8% | $ 0 .07 to 0.2 |
| | Forecast, prediction | 15 | | |
| | Quality control | 5 | | |

Note: All entries are for illustrative purposes only.

<table>
<tr><td colspan="2">EXAMPLE Table 3. “Impact” or “Socioeconomic Benefit” Measures Based on Earth Science Value of Information: Stylized Description (based on Macauley 2006)</td></tr>
<tr><td colspan="2">(1) Identify a decisionmaker’s problem or agency mandate: Save lives, protect the environment, improve agricultural competitiveness, etc.</td></tr>
<tr><td rowspan="3">An approach</td><td>(2a): Identify range of values of the cost of the decision support to implement (1)</td></tr>
<tr><td>(3a): Identify range of values of savings or productivity gains due to earth science data by way of their role in the decision making process</td></tr>
<tr><td>(4a): Estimate the VOI (subtract (3a) from (2a))<br>(5a): Express as a range, with associated contingencies/uncertainties/caveats described explicitly; conduct sensitivity tests of main assumptions</td></tr>
<tr><td rowspan="3">Another approach</td><td>(2b) Estimate range of size of benefit due to Earth science via supporting decisions required to implement (1)</td></tr>
<tr><td>(3b) Estimate the VOI (weight (multiply) (2b) by relevant base value<br>(4b) Express as a range, with associated contingencies/uncertainties/caveats described explicitly; conduct sensitivity tests of main assumptions</td></tr>
<tr><td></td></tr>
<tr><td colspan="2"><u>Examples</u>:<br>Aviation safety:<br>Benefits per year (estimates of lives saved) as y to z lives/year. Implied earth science VOI is y to z multiplied by federal value of statistical life ($/yr, from US Department of Transportation OMB circular).<br>Agricultural competitiveness:<br>Value of output: $x/yr Improvement in output due to earth science data in decisonmaking is y to z%/yr. Implied earth science VOI: product of $x and y to z%/yr.</td></tr>
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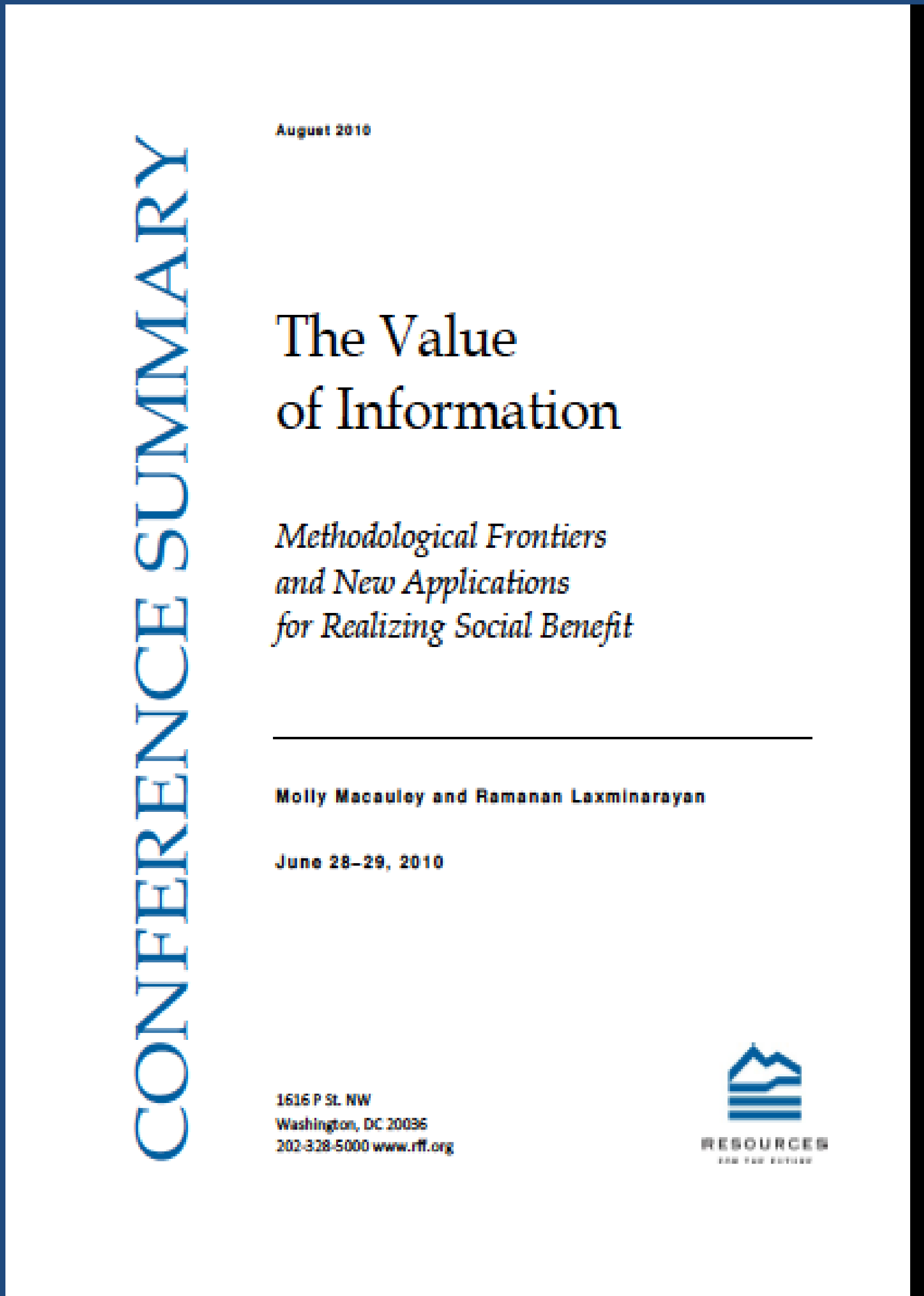

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# Incorporating VOI analyses: some examples from the health workshop

- Price- and cost-based derivation
  - Weather data for weather insurance (Osgood, forthcoming)
  - Drought and land use information for index insurance (Skees et al., 2007)
  - Losses averted from vector-borne disease (Hartley, forthcoming)
- Probabilistic approaches
  - Bayesian belief networks (Cooke and Kousky, forthcoming)
  - Expert elicitation (probabilities of various tipping points, Interagency Working Group on Social Cost of Carbon, p. 32)

# Methods and examples (continued)

- Regulatory cost-effectiveness
  - Implementation of land use regulation (Bernknopf et al. forthcoming)
  - Monitoring water quality (Bouma, van der Woerd, et al. 2009)
- Econometric modeling and estimation
  - Productivity (agriculture; Tenkorang and Lowenberg-DeBoer 2008)
  - Years of life expectancy (Obersteiner et al. forthcoming)
  - Other quality of life dimensions
- Simulation modeling and estimation

# Using VOI to increase the benefit and value

- Ascertain through the applied research effort:
  - what attributes are required (e.g., spatial, spectral, and temporal resolution, accuracy, precision, frequency, annotation, access)
- Identify and reduce barriers to use
- Identify and lower decisionmakers' constraints
  - enhance actions that can be taken
  - increase the number of people who know about the information
  - demonstrate that information <u>has value</u>
- Demonstrate that information <u>is valued</u>
- Use the valuation exercise to think through data, research, partnerships, and assembly of results in a structured way
- Feedback findings into mission design, next decadal survey, and ROSES- and other funding opportunities
- Offer guidance for transferability of results and findings
- Share findings more widely to audiences beyond the research team and partners

# Opportunities for the near-term

- Horizontal (activities within our community)
  - Collect successes and results within a "compendia"
  - Increase sophistication of use of measurement and evaluation of the benefits: that is, the quality and usability of research findings and the data and tools on which they are based (the information)
  - Identify and collaborate with other research communities
  - Identify and standardize best practices and methodologies: what works for which applications and sub-themes (e.g., public health, environmental health, emergency/disasters)

- Vertical (extending success beyond our community)
  - Design a compendia of benefits and VOI across applications and sub-themes
  - Identify which data attriibute(s) seem most highly valued
  - Start with an applications area(s) that volunteers to be a prototype
  - Publish and disseminate to a wide audience.

Partial list of social science and other colleagues who'd like to be involved:

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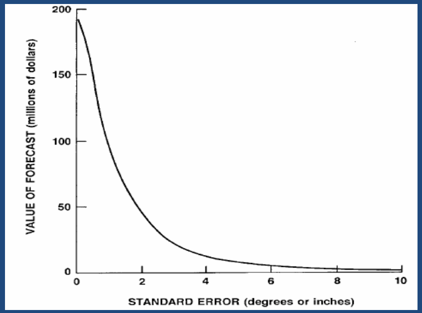


Here we are now. What can we collectively deliver and advance?

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