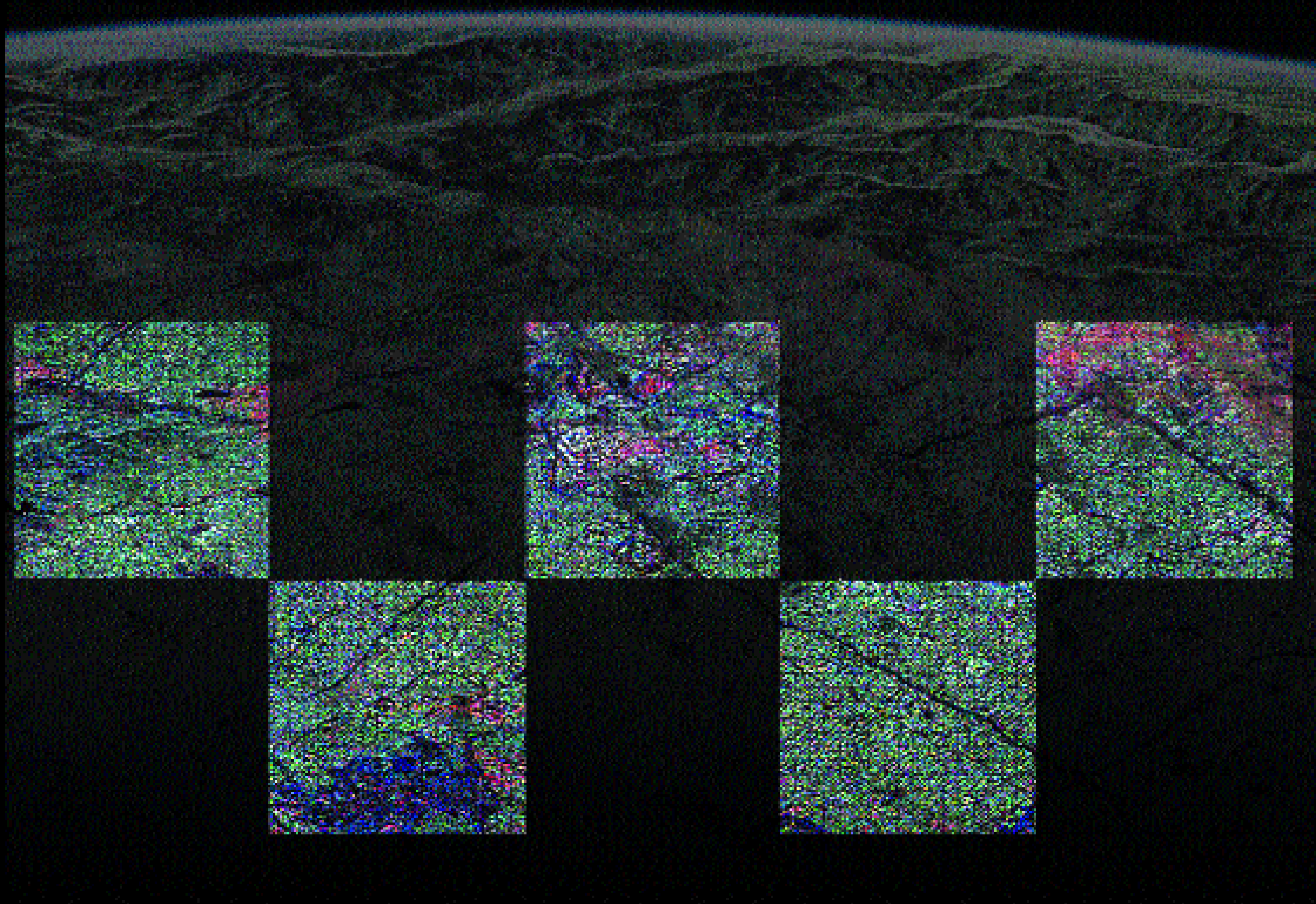
The Earth Below

Purchasing Science Data and the Role of Public-Private Partnerships



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RAND Science and Technology Policy Institute

Documented Briefing

The Earth Below: Purchasing Science Data and the Role of Public-Private Partnerships

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PREFACE

The United States is participating in a major international scientific effort to better understand global environmental changes. Data derived from space-based sensors are key to the success of this effort, and NASA is constructing a series of spacecraft that will make up a complete Earth Observing System as well as experimental Pathfinder missions. Within NASA, research and development efforts related to the global environment are organized under the Earth Science Enterprise.

In addition to constructing government sensors, spacecraft, and data processing systems, NASA is exploring new ways to do business that are intended to use relevant private sector capabilities to achieve desired scientific research results. As a result NASA is examining how to best purchase science data from commercial firms or use public-private partnerships to acquire data for scientific purposes. The data acquired may be unique or complementary to current and planned government data sources. Such data may also be used for practical applications by agencies besides NASA as well as for pure scientific research.

The White House Office of Science and Technology Policy and NASA asked RAND to identify and assess metrics for evaluating public-private partnerships in remote sensing under NASA's Earth Science Enterprise. This documented briefing describes the results of that study. In particular, it suggests particular types of partnerships that may be most relevant to NASA's Earth Science Enterprise, key metrics for evaluating partnerships, and policy implications associated with partnership choices. It should be of interest to NASA program planners, private remote sensing firms, value-added resellers, environmental scientists, and policy analysts concerned with the problems of creating, sustaining, and evaluating public-private sector partnerships.

This effort built upon two earlier RAND reports related to applications of remote sensing: "Using Intelligence Data for Environmental Needs," completed in 1997 for the Intelligence Community Management Staff, and "Data Policy Issues and Barriers to Using Commercial Resources for Mission to Planet Earth," written in 1999 for NASA. Both of these reports touched upon issues of public-private partnership, albeit in less depth.

This study was conducted under the RAND Science and Technology Policy Institute. This Institute is a federally funded research and development center sponsored by the National Science Foundation and managed by RAND. Created by Congress in 1991 as the Critical Technologies Institute, it was given its current name in 1998. The Institute's mission is to help improve public policy by conducting objective, independent research and analysis on policy issues that involve science and technology. To this end, the Institute:

1. **Supports the Office of Science and Technology Policy and other executive branch agencies, offices, and councils**

2. **Helps science and technology decision-makers understand the likely consequences of their decisions and choose among alternative policies**

3. **Helps improve understanding in both the public and private sectors of the ways in which science and technology can better serve national objectives.**

Science and Technology Policy Institute research focuses on problems of science and technology policy that involve multiple agencies. In carrying out its mission, the Institute consults broadly with representatives from private industry, institutions of higher education, and other nonprofit institutions.

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SUMMARY

Study Motivation, Background, and Approach

The passage of the Commercial Space Act of 1998 called on NASA to acquire, when cost-effective, space-based and airborne Earth remote sensing data, services, distribution, and applications from commercial providers. The Congress allocated $50 million in 1997 to procure a mix of products and services, and NASA proceeded to implement this activity through the Commercial Remote Sensing Program (CRSP) office at the NASA Stennis Space Center in Mississippi. Under the aegis of an experimental Science Data Purchase Program, scientists received data obtained from commercial providers in support of NASA's Earth Science Enterprise (formerly known as Mission to Planet Earth) research programs.

The Science Data Purchase Program, also commonly known as a Science Data Buy (SDB), has an uncertain future. In terms of commercial response and quality of products and services, the SDB has been an experimental success in meeting its requirements—some observers were initially skeptical that industry could or would be able to respond in a useful way. However, as of this writing, NASA has not requested and Congress has not allocated any additional funds for the program to continue. NASA has said that it "will purchase science data from commercial sources, rather than build new satellites, when these data sources meet Earth Science Enterprise science requirements and are cost-effective."[1] This would seem to answer the policy question of "build or buy" but provides little guidance in terms of how and when cost-effectiveness is determined.

This study was organized to answer five major questions.

- What are public-private partnerships?
- What can be learned from past experiences with them?
- What metrics should be used to evaluate partnerships?

[1] NASA, "Mission to Planet Earth Commercial Strategy," Washington, DC, March 1997.

- **What types of public-private partnerships are most appropriate in using commercial data for NASA's Earth Science Enterprise?**

- **What options are available for the future of NASA's Science Data Buy?**

The study began with a broad focus on public-private partnership case studies and literature. Initially, we examined more than 50 examples of partnerships, collaborations, and data clearinghouse efforts that involve public-private partnerships or data distribution. Then the project focused more specifically on the most relevant "successful" examples.

In the second phase of the research, we developed a quantitative model of partnerships to elucidate the economic consequences of various actions on the part of the public and private partners. The model also helped to identify the key factors that public partners should understand when interacting with markets and the potential consequences of not understanding them. Some of the results of this phase are discussed in Appendix 1 on the value of understanding NASA's market position.

The third phase addressed the problem of metrics for evaluating partnerships. The study developed a general approach and a set of metrics for assessing the utility of science data purchases and similar programs. NASA should be able to test our proposed approach to evaluate its suitability for evaluating partnership activities and to provide a basis for developing more rigorous measures to assist in managing partnership programs and similar efforts.

Public-Private Partnerships

A public-private partnership, broadly defined, is a productive relationship between a government entity and a private organization. The relationship is established—either through formal collaboration or simply via a market—in order to produce or distribute a particular good or service. In general, this good or service is thought to possess characteristics of a public good: Although valuable, the private sector alone would not have sufficient incentive to produce it.

Five factors were considered in selecting public-private partnership cases for closer examination. These factors were selected to correspond to the general organizational and technical conditions faced by NASA's Earth Science Enterprise and commercial remote sensing firms. First, the partnership involved data from many different suppliers and

employed by many different users; models that involved remote sensing or other geospatial data were more relevant due to the cost structures resulting from these technologies and their markets. Second, the partnership involved mixing or integrating data from the various sources. Third, a partnership involving a combination of government, industry, and/or university scientists or other nongovernmental organizations (NGOs) was more relevant than a simple bilateral teaming arrangement. Fourth, partnership cases that employed a diverse range of pricing and cost strategies were of interest in understanding cost efficiency. Fifth, we were interested in partnerships affected by intellectual property concerns, because such issues also arise when dealing with commercial remote sensing firms.

The partnership model with the closest fit across all criteria was the data clearinghouse. A data clearinghouse is an organization that acquires, maintains, and distributes data or provides information services about data for many different data users. Such an organization may also integrate the data, generate the data, or perform other types of data processing functions. A data clearinghouse may include many different types of partnerships to achieve its functions, including teams, collaborations, and markets. If collaboration is involved in conducting the clearinghouse, often a lead organization physically operates the clearinghouse.

Metrics for Evaluating Partnerships

From a natural beginning in the assessment of commercial firms, performance measurement has been at the forefront of much research of late in both the public and nonprofit sectors. Measuring the performance of public-private partnerships involving private firms, NGOs, and government agencies is thus an important topic.

Like other federal agencies, NASA must use measures to track progress in attaining program goals under the Government Performance and Results Act of 1993 (GPRA). Choosing metrics for R&D-related activities has proven difficult for NASA and for the larger scientific community. Many of the metrics attractive under GPRA, such as measures of efficiency and productivity, are somewhat awkward to apply to R&D. Current measures of effectiveness for the Science Data Purchase Program tend to be simple counts, such as numbers of data requests made or fulfilled. These measures of inputs and outputs are important but are not themselves indicative of higher-order measures of

effectiveness such as client satisfaction or attainment of public policy goals.

Because no single criterion is satisfactory, multiple criteria and perspectives are helpful in measuring the effectiveness of public-private partnerships. We divided the "effectiveness" metric into several interrelated categories:

- **Resource acquisition effectiveness (or having the means to invest adequately)**
- **Efficiency of operations**
- **Consumer satisfaction**
- **Attainment of partnership goals**

Resource acquisition effectiveness can be measured via the profit margin of an enterprise, or (in the case of a public partnership) capital investment as a percentage of total revenues. Efficiency is the most familiar effectiveness dimension and already has well-known metrics, including cost as a percentage of revenues and per-unit average production costs. Consumer satisfaction can be measured in a number of ways, including the direct solicitation of client feedback as well as the percentage of return clients within a particular period.

While resource acquisition effectiveness, efficiency, and client satisfaction are largely direct questions, understanding goal attainment requires a multi-step process. First, the partnership must identify its organizational mission, for example, maximizing the public accessibility of remote sensing data. As obvious as this may be, many partnerships will likely find this a challenge, having been formed without a clearly defined mission. Next, the partnership must identify goals that are compatible with that mission, such as a specified annual increase in public consumption of data.[2] Finally, measures can be taken of the attainment of these intermediate goals. For scientific research, goal attainment can be measured by reviewing the citation frequency of scientific papers produced using commercial data sources. If commercial data sources were used for more practical applications, such as natural resource management, other metrics applicable to specific

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[2] Conflicts within an agency over what its mission should be and the anticipated consequences, e.g., building spacecraft or analyzing data, can provide strong internal incentives to avoid asking these questions.

agencies would have to be added. Such metrics would ideally already be in place to respond to the oversight requirements of GPRA.

Perhaps most important, prior to developing specific metrics, NASA should first understand its buying power in commercial remote sensing markets and choose what type of buyer it will be. That is, does NASA act as just another commercial buyer among many or does it dominate the market as the primary or even sole customer for remote sensing data? Suffice to say, if NASA misreads the market it may find itself paying too much for data or deterring suppliers from entering the market by paying too little.

Options for NASA

In the case studies examined, we found a wide variety of structures for organizing a partnership. In examining NASA's options with respect to the process of the Science Data Buy, two critical design choices are the centrality of NASA's role as an intermediary and whose utility is to be maximized. Two possible exemplar options for NASA to consider are termed the "supply-push" and "demand-pull" approaches.

In the supply-push case, which approximates the current SDB, NASA is in the middle of transactions between data providers and the scientific community. NASA essentially chooses the data that match both the requests coming into NASA from affiliated scientists and are consistent with NASA's perspective on strategic collection requirements and priorities. While the original scientific requirements for the Earth Science Enterprise might approximate the priorities of the research community, in many cases the strategic directions of NASA and the community at large are probably very different. The Earth science research community, or at least parts of the community, can change its research interests far more quickly than NASA can change strategic directions underpinning development programs spanning many years.

The demand-pull case is one in which NASA plays a less central role and acts as a neutral intermediary to facilitate data acquisition. Control over the choice of data in this case is pushed to the periphery as users choose the data they need. This creates a more direct line of feedback between data suppliers, vendors, and the end-use customers, namely the scientists. NASA exercises oversight through the control and allocation of funding to research areas and leaves most decision-making to the scientists themselves. Thus research priorities for the use of public funds are still the responsibility of a public agency, but the implementation of those priorities is decentralized.

We developed three alternative public-private partnership strategies that span the two extremes of "supply-push" and "demand-pull." The first strategy maintains NASA as the central decision-maker and actor in the Science Data Buy with an emphasis on satisfying NASA's own strategic objectives. The focus of research would be on traditional scientific missions, such as global change research, that do not have direct practical applications. The second strategy involves NASA as an active intermediary but with a less central role. The emphasis on global change research would continue, but with a broader focus to include applications research that would be of interest to state and local governments as well as nongovernmental organizations. Finally, the third strategy has NASA acting in the role of a data clearinghouse. In this case, scientists would have more direct influence and buying power. Presumably, many would continue existing lines of research, but with more flexibility to change directions and create new cooperative efforts outside of the federal government. For the last two strategies, in which NASA's role becomes less central, there are several specific implementation mechanisms to choose from. One set of mechanisms emphasizes quasi-market solutions, and the second emphasizes cooperatives.

Quasi-market mechanisms

The first quasi-market mechanism is a data catalog that allows purchasers to order data conveniently from vetted providers. A catalog lowers the transaction costs for buyers and sellers and provides some assurance of data quality by virtue of being selected for inclusion. However, the ability to deny inclusion in the catalog creates a barrier to entry that may result in higher costs by restricting competition. In addition, it may not be necessary or appropriate for NASA to bear responsibility regarding the quality and usefulness of data given knowledgeable end users (e.g., scientists).

The second quasi-market mechanism is vouchers. These could be issued to affiliated scientists (e.g., those receiving research grants or conducting research of interest to the NASA Earth Science Enterprise) and would be redeemable for remote sensing data and/or value-added products. Thus scientists would directly choose what data they wanted, just as they would purchase other forms of technical hardware and software. Vendors would be able to redeem the vouchers for cash from NASA or other government agencies. Vouchers offer the possibility of efficient transactions, though they depend heavily on the existence of a true market and well-informed consumers.

Cooperative mechanisms

Cooperatives could be created among the potential user communities for remote sensing data. As noted earlier, a prominent form of cooperative is the data clearinghouse. A clearinghouse can lower the transaction costs of matching buyers and sellers of data and lower prices by enhancing buyer market power. Such an organization typically requires a neutral organization for its operation and may depend on the quality control of vendors if it cannot sustain its own validation and verification program.

Buyer cooperatives can similarly lower prices for participants and need not require a neutral organization for its operation. However, the cooperative may have little incentive to acquire data that is not of immediate interest to members; potentially useful sources can be easily overlooked; and coordinating purchases for a very diverse set of clients (such as Earth scientists) can be complex and costly in itself.

A fundamental organizational challenge for NASA is its limited flexibility in responding to dynamic markets and rapidly changing customer needs for remote sensing. Should NASA decide to expand the range of customers it serves with the SDB program, it may need to create a nongovernment intermediary organization. NASA has already done this in the case of the Space Telescope Institute to manage competing demands for that facility. Similarly, a nongovernment intermediary could be created to operate a clearinghouse for data and products from public and private remote sensing sources.

Future Questions

NASA needs to clearly articulate the mission of the SDB. Defining the mission makes the treatment of secondary issues such as how to best acquire data much easier. If, for instance, NASA identifies its Earth Science Enterprise collection objectives as the primary mission, it might make the most sense to continue with its current supply-push approach. On the other hand, if NASA sees its primary objective as supporting the Earth science community and the public in general, then demand-pull strategies and partnering arrangements would be more effective.

The SDB has demonstrated that commercial firms are able to provide scientific data and products of value to global change research and the Earth Science Enterprise. However, the policy question remains as to who the real customers are. Is it just global change scientists, Earth scientists in general, or even the public? Is the customer NASA, the federal government (including other civil agencies), or organizations of Earth science researchers such as universities and NGOs? Depending on the answer, how should requirements be defined and prioritized? To what extent is commercial remote sensing itself a "customer" in the sense that SDB purchases help stimulate and grow this industry?[3]

Many possible solutions are available to NASA in terms of public-private partnering arrangements. The structure of the arrangements in themselves is not critical to success. Rather, the critical factors appear to be having an active, informed user community, mechanisms for that community to signal its preferences to the controlling bodies, neutrality of the management organization, an ability and willingness to adapt over time, and adequate funding and material support. In many other areas of the agency, NASA is attempting to shed operational responsibilities in order to focus on R&D and exploration activities.[4] Thus it would seem that a focus on demonstrating and transitioning new remote sensing capabilities would be more in keeping with the future of the agency than operating remote sensing systems for long periods of time.

The Congress and the Administration will likely need to answer the same questions about the focus of the Earth Science Enterprise, the future of Science Data Buy efforts, and the use and evaluation of public-private sector partnerships. The current SDB has been a successful experiment in demonstrating the capabilities of commercial remote sensing vendors. The policy frameworks, structural mechanisms, and evaluation tools are available to pursue further public-private partnerships. However, the continuation of the SDB depends on answering strategic questions about its mission and customers inside and outside of the Earth Science Enterprise.

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3 The provision of space-based communications is dominated by commercial industry, but government agencies such as NASA and the Department of Defense continue to build space systems to meet unique requirements. It is unclear whether the remote sensing industry will follow a similar path; that is, becoming self-sufficient and market-driven while the government funds only a few unique needs.

4 A private contractor, United Space Alliance, operates the Space Shuttle, and NASA is debating whether a private organization should manage commercial uses of the International Space Station.

ACRONYMS

ABI	Association for Biodiversity Information
ADAR	Airborne Data Acquisition and Registration
ARS	Agriculture Research Service
ASPRS	American Society for Photogrammetry and Remote Sensing
BIA	Bureau of Indian Affairs
BP	Business Partner
CAP	Cooperative Agreement Program
CEOS	Committee on Earth Observation Satellites
CIESIN	Center for International Earth Science Information Network
CIP	Commercial Imagery Program
CITO	Central Imagery Tasking Office
CNES	Centre National d'Etudes Spatiales (France)
CRADA	Cooperative Research and Development Agreement
CRSP	Commercial Remote Sensing Program
CSC	Coastal Service Center
CSIL	Commercial Satellite Imagery Library
CUGIR	Cornell University Geospatial Information Repository
DAAC	Distributed Active Archive Center
DARPA	Defense Advanced Research Projects Agency
DC	Data Clearinghouse
DEM	Digital Elevation Model
DIF	Directory Interchange Format

DIS	Data Information System
DoC	Department of Commerce
DoD	Department of Defense
DoE	Department of Energy
DoI	Department of the Interior
DOQ	Digital Orthophoto Quadrangles
DoT	Department of Transportation
ENC	Electronic Navigational Chart
EO	Earth Observing
EOCAP	Earth Observation Commercial Application Program
EOS	Earth Observing System
EOSAT	Earth Observation Satellite Company
EOSDIS	Earth Observation System Data Information System
EPA	Environmental Protection Agency
ERIM	Environmental Research Institute of Michigan
EROS	Earth Resources Observation Systems
ESE	Earth Science Enterprise
ESRI	Environmental Systems Research Institute, Inc.
ETV	Environmental Technology Verification
EW	EarthWatch
FAR	Federal Acquisition Regulation
FCC	Federal Communication Commission
FGDC	Federal Geographic Data Committee
FOIA	Freedom of Information Act
FTE	Full-time equivalent employee
FY	Fiscal year

GASB	**Government Accounting Standards Board**
GIS	**Geographic Information System**
GISCC	**GIS Coordinating Committee**
GISDC	**Geographic Information System Data Clearinghouse**
GPRA	**Government Performance and Results Act**
GPS	**Global Positioning System**
GSFC	**Goddard Space Flight Center**
HTML	**HyperText Markup Language**
IEC	**International Electro-Technical Committee**
IEOS	**International Earth Observation System**
IFSARE	**Interferometric Synthetic Aperture Radar for Elevation**
IGOS	**Integrated Global Observing Strategy**
IMO	**International Maritime Organization**
IP	**Intellectual Property**
IPR	**Intellectual Property Rights**
IPT	**Integrated Product Team**
IR	**Infrared**
JSTOR	**Journal Storage Project**
JPL	**Jet Propulsion Laboratory**
MAPP	**Management Associates of Private Photogrammetric Surveyors**
MET	**Meteorological**
MGIC	**Montana Geographic Information Council**
MIT	**Massachusetts Institute of Technology**
MOU	**Memorandum of Understanding**
MTPE	**Mission to Planet Earth**

NACo	**National Association of Counties**
NASA	**National Aeronautics and Space Administration**
NBII	**National Biological Information Infrastructure**
NC CGIA	**North Carolina Center for Geographic Information and Analysis**
NDDB	**Natural Diversity Database**
NDI	**Non-Developmental Item**
NDVI	**Normalized Difference Vegetation Index**
NEMO	**Navy Earth Map Observer**
NERR	**National Estuarine Research Reserves**
NESDIS	**National Environmental Satellite Data Information Service**
NGO	**Nongovernmental organization**
NGS	**National Geodetic Survey**
NII	**National Information Infrastructure**
NIMA	**National Imagery and Mapping Agency**
NIST	**National Institute for Standards and Technology**
NMI	**NASA Management Instruction**
NOAA	**National Oceanic and Atmospheric Administration**
NOS	**National Ocean Service**
NRC	**National Research Council**
NRCS	**National Resources Conservation Service**
NRIS	**Natural Resource Information System**
NRO	**National Reconnaissance Office**
NSF	**National Science Foundation**
NSDI	**National Spatial Data Infrastructure**
NSPD	**National Security Presidential Directive**

NSTC	**National Science and Technology Council**
NTIA	**National Telecommunications and Information Administration**
NYS	**New York State**
OGC	**OpenGIS Consortium**
OGETA	**Open Geodata Consortium**
OGIS	**OpenGIS Specification**
OMB	**Office of Management and Budget**
ONHP	**Oregon Natural Heritage Program**
ONRC	**Olympic Natural Resources Center**
OSC	**Orbital Sciences Corporation**
OSTP	**Office of Science and Technology Policy**
P2	**Pollution prevention**
PASDA	**Pennsylvania Spatial Data Access**
PATH	**Partnership for Advancing Technology in Housing**
PI	**Principal Investigator**
PL	**Public Law**
PNDI	**Pennsylvania Natural Diversity Inventory**
PNGV	**Partnership for a New Generation of Vehicles**
POC	**Point of Contact**
PPP	**Public-Private Partnership**
R&D	**Research and Development**
R&T	**Research and Technology**
RAM	**Random Access Memory**
RGIS	**Resource Geographic Information System**
RNC	**Raster Nautical Chart**
RMSE	**Root Mean Space Error**

ROI	**Return on Investment**
RS	**Remote Sensing**
SAR	**Synthetic Aperture Radar**
SDB	**Science Data Buy**
SDPP	**Science Data Purchase Program**
SII	**Space Imaging, Inc. (U.S.)**
TNC	**The Nature Conservancy**
TNRIS	**Texas Natural Resources Information System**
USCAR	**United States Council for Automotive Research**
USDA	**U.S. Department of Agriculture**
USGCRP	**U.S. Global Change Research Program**
USGS	**U.S. Geological Survey**
VAD	**Value-Added Developers**
WISCLINC	**Wisconsin Land Information Clearinghouse**
WWW	**World Wide Web**

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RAND colleagues Liam Sarsfield, David Adamson, Kevin O'Connell, and John Baker were continual sources of thoughtful criticism and counsel that contributed to this work. We remain responsible, of course, for the contents of this briefing and any errors within it.

This is the final documented briefing of a study on public-private partnerships involving remote sensing data. The study was conducted by the RAND Science and Technology Policy Institute and contains information current as of March 2000.

Outline

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- Study Background, Motivation, and Approach
  - The NASA Science Data Buy
- Partnership categories
- Highlights from case studies
- Metrics for evaluating partnerships
- Options for NASA
- Conclusions

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STUDY BACKGROUND, MOTIVATION, AND APPROACH

This section discusses the background, motivation, and general approach of this study with an emphasis on the NASA Science Data Buy. We briefly cover the policy background of the SDB and our analytical approach for investigating the issues surrounding public-private partnerships.

Subsequent sections address the different types of partnerships and the results of case studies of a wide variety of public-private partnerships. We then identify metrics for evaluation and options for NASA in pursuing such partnerships, depending on the strategic goals of NASA's Earth Science Enterprise.

Study Sponsors

Science & Technology Policy Institute

- Project requested by the Office of Science and Technology Policy (OSTP)
  - Implementation oversight of National Space Policy
- Co-sponsorship funding provided by NASA
  - In cooperation with the Commercial Remote Sensing Program at the Stennis Space Center
- Conducted at the RAND Science & Technology Policy Institute
  - Study leaders Dave Frelinger and Scott Pace

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This study was commissioned by OSTP and NASA to examine issues surrounding the Science Data Buy (SDB). The SDB is an experimental effort to acquire Earth science data from commercial sources in support of NASA's Earth Science Enterprise (formerly known as Mission to Planet Earth). The study examines the effectiveness of alternative public-private partnerships with commercial remote sensing firms, as well as identifies useful metrics for evaluating those partnerships in achieving their objectives.

From an OSTP perspective, the study should assist in understanding issues relating to how public-private partnerships in R&D activities might be implemented and evaluated in support of National Space Policy. From NASA's perspective the study should assist the NASA Administrator in responding to the Commercial Space Act of 1998 requirement calling for a study of how NASA may assist commercial providers of remote sensing data to better meet the baseline scientific requirements of Earth Science Enterprise.

Dr. Scott Pace and David Frelinger of the RAND Science and Technology Policy Institute led the study. Study team members Beth Lachman, Mark Gabriele, and Arthur Brooks were responsible for the case studies and technical and economic analyses in this effort, respectively.

NASA's Earth Science Enterprise

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- NASA established its Mission to Planet Earth program in 1991 - building on earlier Earth science and applications research.
- In 1998, the program was renamed Earth Science Enterprise and focused on five areas:
  - Land-cover change and land-use change
  - Near-term climate variability and prediction
  - Long-term climate change
  - Natural hazards research
  - Atmospheric ozone research

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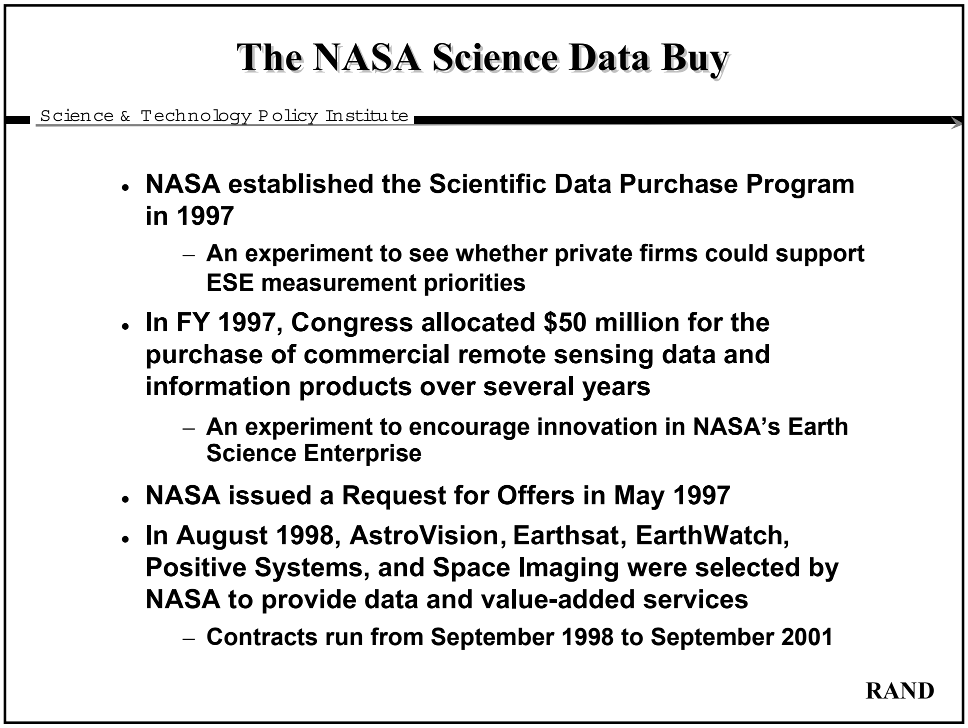
The United States, through the U.S. Global Change Research Program (USGCRP), along with other nations, is supporting research needed to characterize and understand interactions between localities and global change in the environment. The United States is pursuing several major initiatives, the largest single effort being under NASA's Earth Science Enterprise (ESE) for systems of satellites and ground networks known as the Earth Observing System (EOS). Data from diverse measurement sets are to be processed, distributed, and archived by a dedicated data information system known as EOSDIS.

Originally established in 1991 as Mission to Planet Earth, the effort led by NASA is perhaps the largest civil remote sensing effort in the world and will require continuity of data stretching over decades. As a subset of the broad research themes of the USGCRP, today's Earth Science Enterprise is focused on five major areas: (1) land-cover change and land-use change, (2) near-term climate variability and prediction, (3) long-term climate change, (4) natural hazards research, and (5) atmospheric ozone research.



The immediate motivating policy event for this study was the passage of the Commercial Space Act of 1998, and in particular the provisions calling upon NASA Administrator to acquire, when cost-effective, space-based and airborne Earth remote sensing data, services, distribution, and applications from commercial providers. The Congress had already allocated $50 million in 1997 to procure this mix of products and services, and NASA proceeded to implement this activity through the Commercial Remote Sensing Program (CRSP) office located at the NASA Stennis Space Center in Mississippi. The program, implemented under the aegis of the Science Data Purchase, provides NASA-supported scientists with data obtained from commercial providers.

The Science Data Purchase is not simply a procurement activity with industry. Indeed, one of the hallmarks of this activity is a very close relationship between NASA and the providers through the CRSP. The close arrangement between NASA and the providers leads to something much closer to a partnering arrangement than a simple purchasing of data. As we shall see later, the particular form in which this program has been initially implemented is significantly different from that of other organizations engaged in similar arrangements with other public-private partnerships.

Science Data Buy Program Expenditures

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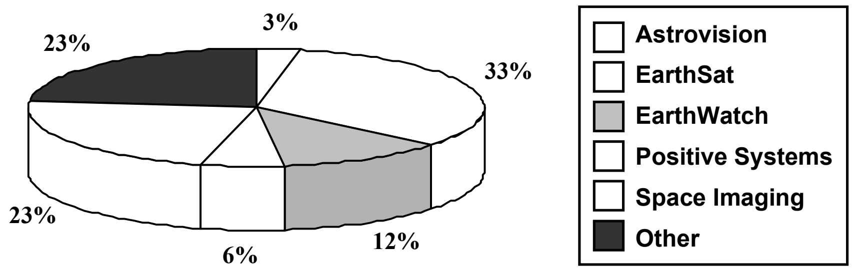

Total Expenditure = $50 million

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Five major firms were chosen in 1998 to provide data and value-added services to NASA via the Science Data Purchase Program: AstroVision, EarthSat, EarthWatch, Positive Systems, and Space Imaging. The figure illustrates the spending breakdown for the $50 million allocated to the program. "Other" consists of a number of smaller value-added firms, including airborne data suppliers.

A mixture of products and services was sought, including old data (e.g., Landsat) and new 1-meter commercial satellite imagery, using airborne and satellite platform, and operating in panchromatic, multispectral, and radar bands.

Science Data Buy Purchased Products and Services

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AstroVision	• Provide 7-kilometer and 600-meter resolution multispectral imagery of the Western Hemisphere. • Monitor tornadoes, thunderstorms, fires, volcanic eruptions, atmospheric grazing meteors, hurricanes, floods, night electric storms, and environmental degradation.
Earth Satellite Corporation	• Orthorectify Landsat imagery collected in the 1970s and 1990s.
EarthWatch	• Provide 2.5-meter resolution SAR imagery using the airborne Interferometric Synthetic Aperture Radar for Elevation (IFSARE) system. • Monitor land-use patterns, assess land-cover changes, and create digital elevation models of regions in the United States, Indonesia, and Central America.

RAND

This chart and the following one include brief descriptions of the products and services provided by the top five firms in the Science Data Purchase Program. Aerial and space remote sensing systems are represented, as are supplies of original data and value-added products. In the case of the Earth Satellite Corporation, earlier Landsat imagery was orthorectified, i.e., processed to correct for distortions caused by the curvature of the Earth when photographed from space. In the case of AstroVision and EarthWatch, some products are slated to come from prospective as opposed to current systems.

Science Data Buy Purchased Products and Services (cont.)

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Positive Systems	• Provide 1-meter multispectral imagery and image mosaics of different parts of the United States from the company's Airborne Data Acquisition and Registration (ADAR) 5500 sensor. • Monitor land-use patterns and assess land-cover changes.
Space Imaging	• Provide 1-meter panchromatic and 4-meter multispectral images and image mosaics using the data collected by the IKONOS satellite. • Provide digital elevation models (DEMs). • Monitor land-use patterns and assess land-cover changes.

RAND

These data purchases were not the first examples of NASA using space-based remote sensing data from commercial sources, but they are the first to be acquired under a program specifically designed for that purpose. A notable prior example is that of Orbital Sciences' SeaStar sensor which takes data of ocean color and circulation. In a cooperative arrangement with NASA, Orbital Sciences gets first and exclusive use of the ocean color data when they are of value to commercial users such as fishermen. After the exclusive period, the data are available to NASA for scientific research. In this case, NASA acquires data from a spacecraft owned by a private firm.

Near-Term Challenges for NASA

Science & Technology Policy Institute

Reporting as required by the Government Results and Performance Act (GPRA)

- **Research performance is difficult to measure**

Effective implementation of the SDB

- **Practical motivation to acquire data intelligently and efficiently**
- **Lack of institutional experience in purchasing data for scientific applications**
- **Uncertainty over most appropriate models for the acquisition and delivery of commercial data**
- **Questions of relevance to global change research needs**

RAND

NASA had a number of concerns motivating its interest in public-private partnerships in general, and the Science Data Purchase specifically. Like other federal agencies, NASA must use measures to track progress in attaining program goals under the Government Performance and Results Act of 1993 (GPRA). Choosing metrics for R&D activities has proven difficult for NASA and the scientific community at large. Many of the metrics attractive under GPRA, such as measures of efficiency and productivity, are somewhat awkward to apply to R&D activities.[5] In addition, many of the people and organizations charged with developing and using metrics to monitor R&D activities have little experience employing such techniques themselves. The combination of these two factors means that many of the metrics selected for monitoring the performance of these activities are less than helpful for both NASA and outside bodies in assessing its performance.

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[5] Measurements of the inputs such as dollars for the numerator are straightforward. The problem arises from selecting the right denominator and measuring its value. For instance in many scientific activities the output might be a paper. However, not all papers are of equal import and therefore some sort of weighted estimate is used to reflect quality. While established methods exist in the academic community to track such outputs, they have not seen wide-scale usage outside of academic circles.

In the case of the Commercial Remote Sensing Program, metrics have typically focused on measuring the number of partnerships rather than on outcomes of the partnerships themselves.[6] While monitoring the number of partnerships provides some data, it says little about the utility of the program itself in supporting either the broader efforts of the program, or more importantly, its support of the broader objectives of the Earth Science Enterprise. For instance, while commercial datasets might be less expensive, it is not clear that they are appropriate for the goals of the ESE or for the scientists themselves, unless some way is found to assess the utility of the datasets.

NASA recognizes that it lacks significant experience both in purchasing data and in designing optimal models for acquisition of data. The current structure of the program may not be the best possible structure for implementing its commercial strategy, and consequently NASA has an interest in seeing how other organizations have successfully implemented their public-private partnership programs. NASA might be better able to achieve its objectives in the future if it adopts some of the approaches successfully used by other organizations.

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[6] See NASA Performance Plan Fiscal Year 2000, April 1999, p. 37.

Other Stakeholder Challenges

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Scientific Community

- **Research portfolio balance, e.g., global circulation models vs. natural resource management**
- **Funding for research to use commercial data**

Industry

- **Integration of SDB data and products into the ESE data archive and distribution centers along with government data sources**
- **Potential divergence of government and industry data standards in remote sensing**
- **How will NASA make "build or buy" decisions for acquiring remote sensing data?**

RAND

Aside from NASA, there are several other stakeholders in the Science Data Purchase Program, notably the scientific community and industry. The scientific community is very diverse, with competing interests in the composition of the total research portfolio available to them—dominated in this instance by government funding. For example, global change research requires the development and testing of complex global circulation models for the oceans and atmosphere. In contrast, natural resource management research areas, such as forestry and land-use change, focuses on smaller-scale phenomena. While there is an increasing realization of common interests in research at multiple scale, these research communities have distinct data requirements.

Merely providing appropriate commercial data is not enough, however, as funding is also needed to analyze and use such data. When government funding pays scientists to do research, it usually provides data "free" from government systems. Thus the cost of research using government, as opposed to commercial, data may appear to be less, but this can be misleading since taxpayers pay for both government systems and research in the end. Commercial systems create options for government research that are not paid for by taxes, but exploiting those options usually requires government funds.

For industry, the utility of its products and services to Earth scientists requires that they be integrated into the Earth Science Enterprise archive and distribution centers alongside government data. This integration requires interoperable standards and common metadata information accessible to commercial and government users.[7] Because the needs of government-supported scientists and commercial applications can be quite different, the divergence between data standards developed for government and for industry must be addressed.

A further source of uncertainty for industry is whether and how NASA will make "build or buy" decisions for acquiring remote sensing data. That is, when is it more cost-effective for NASA to buy commercial data versus building a unique data acquisition system? The remote sensing industry, if not satellite builders, might prefer that government "buy" as much as possible. Scientists may not care about the source of data they use as long as they understand how it was acquired and what standards it conforms to, and that they are funded to analyze the data. Taxpayers, the Congress, and the Office of Management and Budget, however, are likely to care greatly about the *total* cost of meeting the research goals of the Earth Science Enterprise. Thus the public might be listed as the final and ultimate stakeholder in the use of commercial data for Earth science research.

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7 *Metadata* refers to data about data; that is, information about how data is structured, calibrated, and identified.

The Future of the Science Data Buy

Science & Technology Policy Institute

- SDB-provided data has met requirements, but NASA has not requested and the Congress has not allocated any additional funds for future data purchase agreements from commercial vendors.
- NASA says it "will purchase science data from commercial sources, rather than build new satellites, when these data sources meet ESE science requirements and are cost-effective."
- The SDB is an experiment - what next?

RAND

The Science Data Purchase Program, also commonly known as a Science Data Buy (SDB), has an uncertain future. In terms of commercial response and quality of products and services, the SDB has been an experimental success in meeting NASA-defined requirements—some observers were initially skeptical that industry could or would be able to respond in a useful way. (Success in this instance means data were delivered on or ahead of schedule, and its quality was verified.) However, as of this writing NASA has not requested and Congress has not allocated any additional funds for the program to continue.

The lack of ongoing funding for the SDB implies that the experimental period is over. NASA has said that it "will purchase science data from commercial sources, rather than build new satellites, when these data sources meet Earth Science Enterprise science requirements and are cost-effective."[8] This would seem to answer the policy question of "build or buy" but provides little guidance in terms of how and when cost-effectiveness would be determined.

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[8] NASA, "Mission to Planet Earth Commercial Strategy," Washington, DC, March 1997.

As we discuss in the next section, this study is aimed in part at providing a better sense of how NASA might utilize public-private partnerships in building on the experiences of the Science Data Buy.

Study Questions

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- What are public-private partnerships?
- What can be learned from past experiences?
- What metrics should be used to evaluate partnerships?
- What type of public-private partnerships are most appropriate in using commercial data for NASA's Earth Science Enterprise?
- What options are available for the future of NASA's Science Data Buy?

RAND

This study was organized to answer five major questions. Beginning with the definition of public-private partnerships and lessons from past experiences, we examined what metrics should be used to evaluate partnerships as well as what types of partnerships are most appropriate to the use of commercial data in NASA's Earth Science Enterprise. Finally, we address what options are available for the future of NASA's Science Data Buy.

A public-private partnership, broadly defined, is a productive relationship between a government entity and a private firm. The relationship is established—either through formal collaboration or simply via a market—in order to produce or distribute a particular good or service. In general, this good or service can be argued to possess some characteristics of a public good, such that while valuable, the private sector alone would not have sufficient incentive to produce it. Conversely, by partnering with the private sector, the government may produce public goods more efficiently and at less cost.

The discussion that follows develops and enhances this definition. We present several frameworks to categorize partnerships and offer real-world examples of partnerships in the production and dissemination of information goods. We use these frameworks to

examine critically the strengths and weaknesses of current partnering arrangements.

In addition to NASA's specific interests, the research team was interested in addressing the problem of public-private partnerships as they have been applied to scientific enterprises. To address these broader questions we needed to understand the dynamics of various types of relationships that have been used in the past, as well as the benefits and drawbacks of the approaches. We were also interested in how the public partner can operate most efficiently in these different relationships and in investigating measures of the success or failure of different approaches. Consequently, we devised a research approach that examined these issues across a wide range of partnerships that faced challenges akin to NASA's problem of supplying Earth observation data to the scientific community.

Study Approach

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- Conduct case studies of a wide range of existing public-private partnerships
- Apply theoretical economic analysis to the role of NASA with respect to commercial remote sensing
- Identify appropriate evaluation metrics for NASA partnerships using commercial data
- Develop alternative structures for future interactions between NASA and commercial data providers.

RAND

The study began with a broad focus on public-private partnership case studies and literature. Initially, we examined 50 examples of partnerships, collaborations, and data clearinghouse efforts that involve public-private partnerships or data distribution. Then the project focused on the most relevant "successful" examples.[9]

About 30 different case studies were examined in detail to understand the various models used in practice. We analyzed these partnerships' operations and organizational structures to understand key dimensions and the different approaches employed. We also compared and contrasted the cases to explore the differences and commonalties across many different approaches. In studying these cases, we conducted an extensive review of the literature as well as over 35 telephone and face-to-face interviews, lasting between 20 minutes and an hour. In some cases, follow-up interviews were conducted to gather additional documentation about the case study.

The second major phase of the research developed a quantitative model of partnerships to elucidate the economic consequences of various actions on the part of the public and private partners. The model

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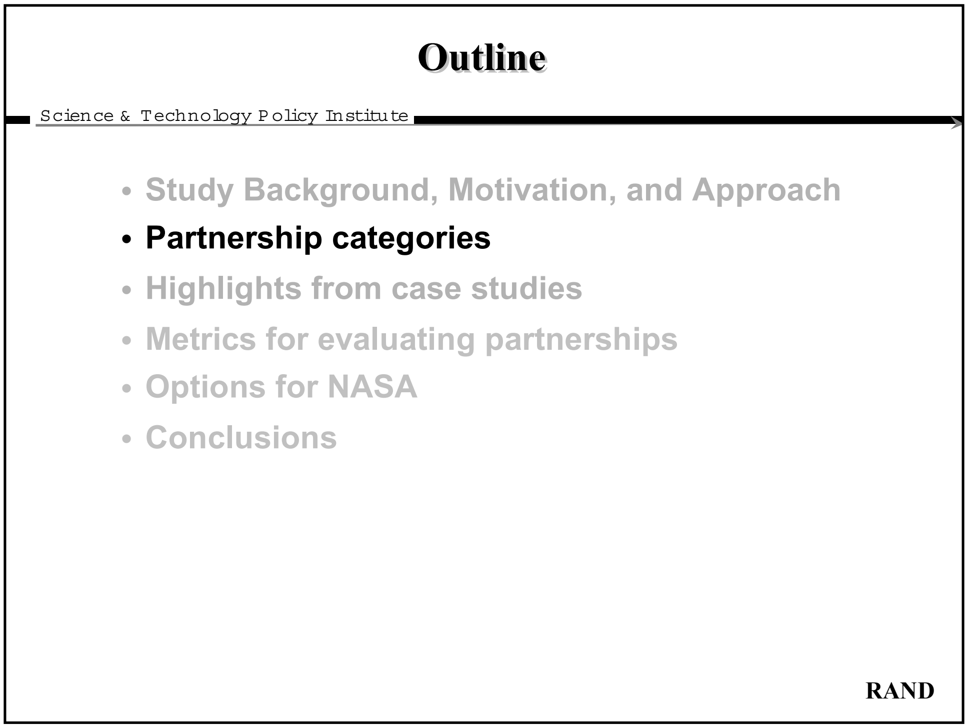
[9] Later in this document "successful" is more clearly defined.

helped to identify the general patterns of interaction in partnerships and to shed light on the parallels between very different kinds of partnering arrangements at the level of individual "agents" rather than viewing each arrangement as being a unique circumstance. The model also helped us obtain a clearer understanding of the key factors that public partners need to understand when interacting with markets and the potential consequences of not understanding them.

The third phase addressed the problem of selecting metrics for evaluating the partnerships. The study developed a general approach and a set of metrics for assessing the utility of science data purchases and similar programs. NASA should be able to test our proposed approach to evaluate its suitability for evaluating partnership activities and to provide a basis for developing more rigorous measures to assist in managing partnership programs and similar efforts.

In the following charts we establish a lexicon and framework for discussing partnerships that will be used throughout the report. We begin by examining the types of relationships within partnerships. Second, we discuss classifying partnerships according to the purpose of the partnership and the types of goods and activities being managed. Third, we define partnerships in terms of their outputs. Fourth, we look at the diverse organizational structures of partnerships. Finally, we categorize partnerships with respect to the sectors of the economy they represent, as well as their participation in free (or nongovernment) markets.



PARTNERSHIP CATEGORIES

This section discusses the classification of public-private partnerships. Because partnerships are multifaceted arrangements, we take several different cuts through those relationships. The schema used in our analysis focused on classifying partnerships according to type of partner relationship, output, and structure.

Defining Public-Private Partnership

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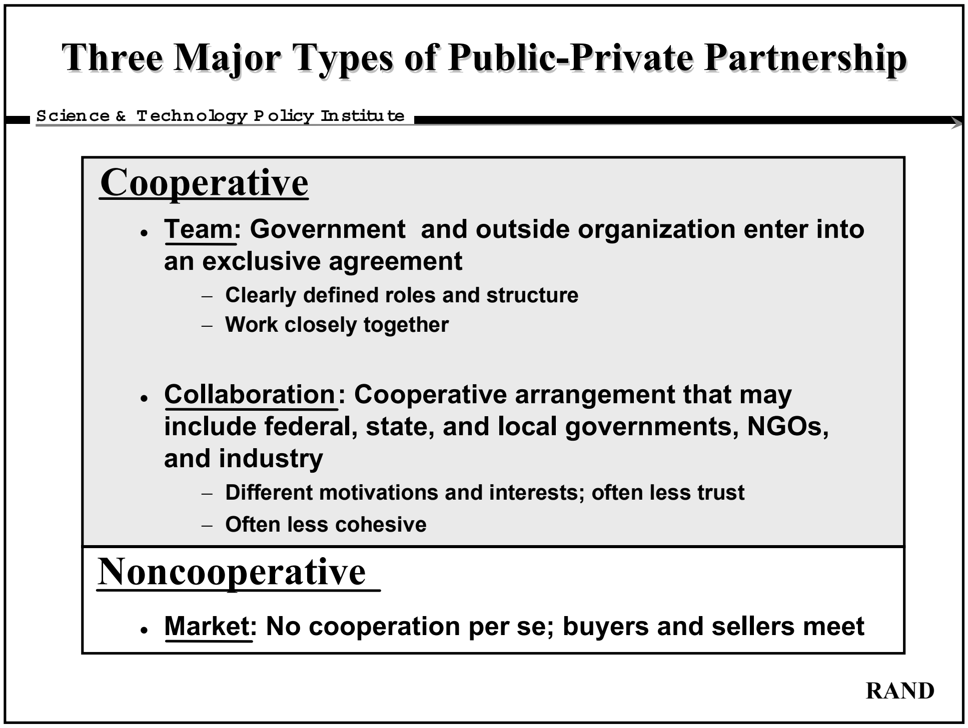
- <u>Public-Private Partnership:</u> Mechanism through which public agency provides a good or service jointly with private-sector firm.
- <u>Successful Partnership:</u>
  - *Darwinian* definition: Partnership persists over time.
  - *Effectiveness* definition:
    - Garners adequate funds
    - Produces good or service efficiently
    - Satisfies clients
    - Meets goals

RAND

The following charts refer to "successful" partnerships. "Success" can be defined in two ways. First, a Darwinian notion of successful partnerships (used implicitly earlier) simply refers to a partnership that survives over time and thereby demonstrates some sort of utility to the partners.

Later, we develop the definition of success to include the effectiveness of a partnership in several complementary dimensions: the ability to harness funds for investment, the efficiency of operations, the satisfaction of consumers, and the attainment of stated goals. These more complex definitions of success become useful when looking at partnerships that involve multiple projects.

Partnerships need not be co-equal in any particular aspect, such as levels of investment or risk, not do they imply jointly owned infrastructure or products. Partnerships also need not last any particular length of time and thus even short-lived partnerships may be successful.



The relationship between the different entities involved in a partnership is an important way to distinguish among different types of partnerships. In examining case studies of public-private partnerships, three distinguishing definitions were developed.

Team: A team partnership occurs when a government organization enters into an exclusive agreement with a different organization. Such an organization may be a for-profit company, a university, a nongovernmental organization (NGO, typically nonprofit), or even another government agency. For example, a federal agency may partner with a state agency. A team is characterized by a close working relationship between the two entities that includes a high level of shared risk, cost, and trust. Roles and structure are clearly defined in a team partnership. Many federal R&D partnerships are primarily teams.

Collaboration: A collaboration is a cooperative arrangement of multiple organizations, usually of different types. Such organizations may include federal, state, and local governments, foreign governments, for-profit firms, universities, and other NGOs. In this partnership, different entities, often with very different motivations and interests, come together for a common purpose and to share individual resources and strengths for shared benefits. Collaborations usually entail more complex interactions between the different entities in the partnership.

Because there are many different players with their own motivations and interests, a collaboration is often characterized by less trust and less cohesion than possessed by a team.

Both teams and collaborations are cooperative partnerships. A non-cooperative[10] of partnership is defined as a *market*. In a market, buyers and sellers meet and they are not trying to share anything; they do not need to really trust one another; rather they simply have a financial transaction. Many would not normally call a market a partnership and many government relationships that are referred to as partnerships are really markets. For example, some specific cases of a government agency contracting out a service have been called partnerships. In many ways as currently implemented, the SDB is more like a market broker than a collaboration or team, since NASA purchases the data from remote sensing companies and supplies it to scientists.

These definitions are not mutually exclusive and not always clear-cut. A partnership can include elements of all three types. More complex partnership efforts often consist of multiple partnerships of different types. An effort may involve a group of teams, collaborations, and markets, which will be illustrated later as specific cases are described.

Since these relationships are important to understanding partnership implementation, each case study was ranked on each of these partnership dimensions. Specifically, we classified each case as high, medium, low, or "does not apply" for each of the three partnership types. This relationship ranking helped us to understand the nature of these partnerships and identify which were the most relevant models for this study and the SDB.

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[10] Noncooperative does not mean uncooperative.

Classifying Public-Private Partnerships by Purpose

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<u>Rivalrous property partnership</u>: Physical property involved with exclusivity of use

<u>Service partnership</u>: Performance of a service, such as running a program for the government

<u>Nonrivalrous property partnership:</u> Intellectual property type of partnership, such as data that may or may not involve exclusivity

<u>Process partnership:</u> Intellectual property type of partnership, such as processing data via certain standards or procedures

RAND

We also classified public-private partnerships by the main purpose or function that the partnership provides. There are four classifications by purpose that the partnership performs for the government.

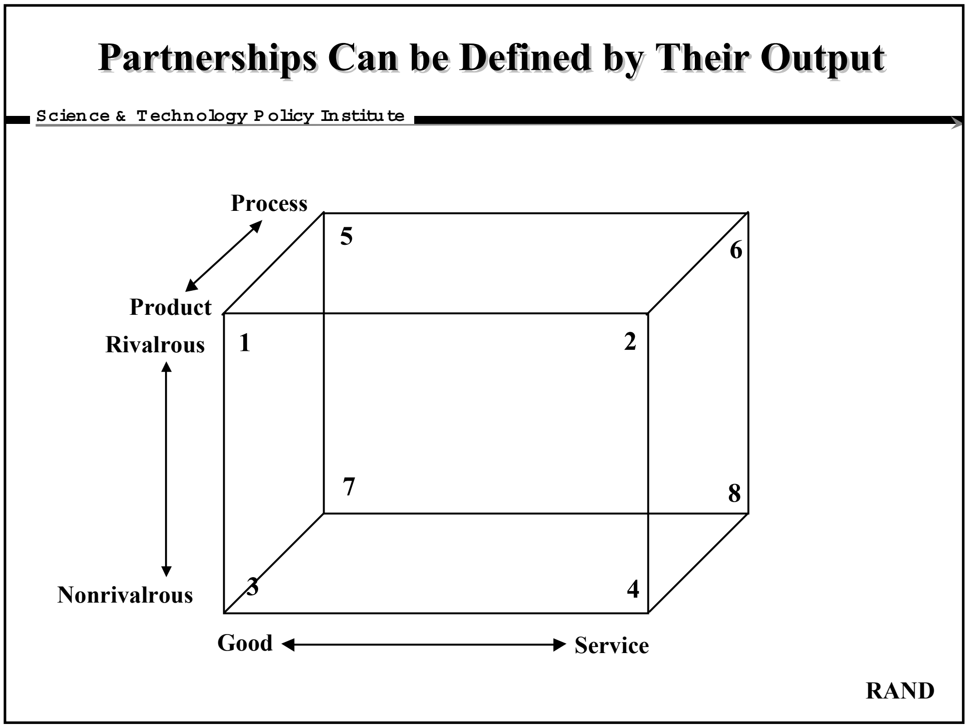
First, the partnership may mainly focus on sharing real property, i.e., physical property. For example, a public-private partnership is created so a company and government can share a facility or equipment, such as a university lab or special computer. This partnership is called a rivalrous property partnership.

Second, the partnership may be created so that the private company provides a service for the government agency, such as running a government program. This is called a service partnership.

Third, the public-private partnership may focus on providing data, such as a partnership to develop a database; called a nonrivalrous property partnership.

Fourth, the public-private partnership may focus on processing information, such as a partnership to conduct a research study together and provide scientific insights. This information processing partnership is called a process partnership.

The latter two partnership purposes involve intellectual property rights and related issues. Since the SDB consists of data and information and not physical property, nor providing a service, the nonrivalrous property and process partnerships are the most relevant forms. Initially, we focused on a range of partnerships, but then narrowed our focus to the latter two.



In general, public-private partnerships can be classified by their outputs. First, we distinguish between goods and services, or between tangible and intangible outputs. Examples are a computer compared to a task performed on that computer.

Second, products and processes are differentiated. That is, some outputs are primary products, whereas others serve as enhancements to these products. For example, raw data is a product, whereas the service of making it usable to a customer is a process.

Finally, there is a difference between rivalrous and nonrivalrous outputs. In the first case, one person's consumption of a physical output such as a computer precludes another's consumption of the same machine. A person's consumption of a nonrivalrous output—such as a song—does not rule out a second person from "consuming" it simultaneously.

Combining these distinctions gives us eight distinct types of outputs that partnerships can produce in information goods, summarized in the figure above. To illustrate the distinctions, here are some examples of each type of output:

1. Rivalrous product that is a good: Computer hardware

2. Rivalrous product that is a service: A firm-specific financial analysis

3. Nonrivalrous product that is a good: Water dam protecting a city

4. Nonrivalrous product that is a service: National defense

5. Rivalrous process that is a good: Additional memory added to a computer

6. Rivalrous process that is a service: Individual training to use the computer

7. Nonrivalrous process that is a good: Upgrades to a hurricane early warning system

8. Nonrivalrous process that is a service. Installation of upgrades to a hurricane early warning system

Public-Private Partnership Structures

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Traditional

- Government partners with one to a few companies
- Focus on clearly defined data, product, or service

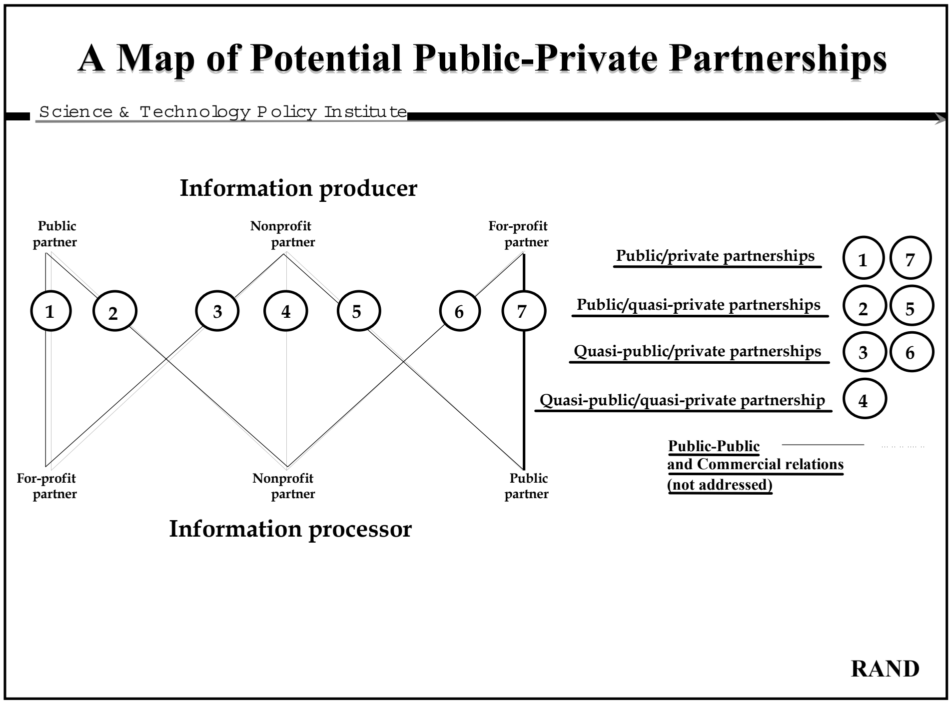
Nontraditional

- Government is one player in network of consumers and providers
  - Multiple products and services available
- If data are the product:
  - Multiple data sources may be combined into a single product
  - Pricing structures may be arbitrarily complex
  - Intellectual property issues can become a concern

RAND

A traditional public-private partnership involves a government organization pairing with one or a few private sector companies. It is usually a team partnership in which the partners' roles are clearly defined and there is a high level of shared risks, costs, and trust. The partnership is focused on providing a clearly defined and well-specified service, product, or data for the government entity. The source of the data is also clearly defined, usually from a single source, and typically the government or industry partner supplies it. Such partnership models are not as relevant for the NASA SDB; however, examining them provided some useful lessons about public-private partnerships that we will address later.

In nontraditional partnerships, the government is but one player in a larger network of consumers and providers. If the products of the partnership are data, multiple data sources may be combined into a single product (e.g., data from space, aerial, and ground-based sensors in a single geographic information system). Pricing structures may be arbitrarily complex in a nontraditional partnership and partly as a result of mixing public and private resources, intellectual property issues can also be complex.



To better understand the range of partnership models, we developed a map of the possible links between information producers and processors. Information partnerships are categorized with respect to (1) each partner's use of the information and (2) each partner's economic sector. The traditional partnership generally involves a government agency pairing with a for-profit firm. One side produces the data, while the other processes them. These are cases 1 and 7 above. Partnerships in information may also occur between different levels of government or two for-profit entities. The dashed lines denote these relationships.

It is useful to consider a more comprehensive taxonomy than just public-private partnerships, however. Nontraditional partnerships are frequent and include those featuring relationships between actors in other sectors or between partners in the same sector. For example, one or both entities may be quasi-public or quasi-private nonprofit organizations (cases 2-6). Nonprofit organizations receive these designations because, while they belong to the private sector, their function is religious, charitable, scientific, testing for public safety, literary, or educational under the U.S. tax code in order to receive exemptions from corporate taxation and (in some cases) tax-deductible contributions inside the United States. In other words, a nonprofit firm in a remote sensing partnership is quasi-private to the extent that it produces an (arguably) public good and quasi-public to the extent that it

receives indirect public subsidies through the tax code.

Outline

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- Study Background, Motivation, and Approach
- Partnership categories
- **Highlights from case studies**
- Metrics for evaluating partnerships
- Options for NASA
- Conclusions

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HIGHLIGHTS FROM CASE STUDIES

The following section discusses a few selected case studies in detail, the application of the general schema for classifying partnerships, and summarizes highlights derived from the case studies. A complete listing of the case studies examined can be found in Appendix 3.

Partial List of Public-Private Partnership Cases Examined

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Nontraditional:

- State Geospatial and Geographic Information Systems Centers
- NIMA Central Imagery Tasking Office
- National Spatial Data Infrastructure
- The Nature Conservancy Natural Heritage Program
- Center for International Earth Science Information Network
- Journal Storage Project
- EROS Data Center

Traditional:

- NOAA-Maptech CRADA
- EPA Environmental Technology Verification Program
- USGS/Microsoft TerraServer
- Partnership for a New Generation of Vehicles
- Partnership for Advancing Technology in Housing

RAND

This chart shows the main examples of traditional and nontraditional public-private partnerships examined in the study.[11] As we will show later, data clearinghouses and networks of clearinghouses were of particular interest. Data clearinghouse examples examined included the Earth Resources Observation Systems (EROS) Data Center, the Center for International Earth Science Information Network (CIESIN), the Journal Storage Project (JSTOR) and National Imagery and Mapping Agency's (NIMA's) Central Imagery Tasking Office (CITO).

Examples of clearinghouses networks included the FGDC National Spatial Data Infrastructure (NSDI) Nodes, State Geospatial and Geographic Information Systems (GIS) Centers, and The Nature Conservancy Natural Heritage Program. These groups are not mutually exclusive. For example, the Montana Natural Resource Information System (NRIS) runs the state GIS Clearinghouse, which is also an NSDI node. Montana NRIS also runs Montana's Natural Heritage Program.

In the next charts, we will discuss illustrative examples of traditional and nontraditional public-private partnerships and lessons learned from them.

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[11] Summary descriptions of the individual case studies can be found in Appendix 3.

Example of a Traditional Partnership: NOAA-Maptech CRADA

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- **Partnership to produce electronic nautical charts, formerly available only on paper from NOAA**
  - NOAA provides raw data exclusively to Maptech
  - Maptech adds value and sells the product
  - 100 Value-Added Developer (VAD) agreements to provide software to accompany electronic charts
- **Close working relationship that takes advantage of each partner's strengths**
  - Commercial sector's customer responsiveness, marketing, pricing, and deal-making flexibility
  - NOAA's R&D and nautical chart "brand name"

RAND

NOAA and the for-profit company, Maptech, partnered to produce electronic nautical charts. The NOAA-Maptech Cooperative Research and Development Agreement (CRADA) is a good example of a traditional public-private partnership that offers useful insights.[12] It matches private sector marketplace incentives and flexibility with government expertise and mission requirements.

A nautical chart is a map that shows information, such as water depths and traffic control schemes, that is critical to the safe and efficient use of the nation's waterways. NOAA is required by law to produce paper nautical charts. Certain high-risk and high-value vessels, such as vessels over 1600 tons, are required by maritime law to carry these nautical charts for safety reasons. It is important to note that 99% of the shipping and boating market is not required by law to carry these nautical charts because of the large number of small and noncommercial vessels. However, such vessels may choose to carry them for their usefulness and for safety reasons.

NOAA started requiring that its staff develop electronic versions of the nautical charts. However, the staff did not receive any additional

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[12] For more details about the NOAA-Maptech CRADA, see Appendix 2.

manpower or dollars for this new electronic chart production service, so they developed a public-private partnership to perform the function, which did not require any government funding. Using a CRADA mechanism, Maptech now produces and sells CD-ROMs containing electronic nautical charts that used to be available only in paper format from NOAA. Under the CRADA between NOAA and Maptech, the company has exclusive access to NOAA digital chart data and certain technology. In exchange for the exclusive rights, Maptech must produce all charts that meet NOAA standards (not just the profitable ones); issue new editions when NOAA does; provide an update service; make the results openly available to all at an affordable price; and do so in perpetuity.[13]

Maptech at its own risk and expense makes these official electronic charts in collaboration with NOAA and profits (or loses) in the marketplace based on their sales. The firm had to be more creative than the government would have been in order to make their electronic charts commercially viable. For example, they added value to the NOAA charts in their final product by including features and capabilities, such as place names, on the charts. They are in the process of adding digital orthophoto quadrangles (DOQs) to the charts to include visual reference aids.

Maptech developed a network of more than one hundred registered Value-Added Developers (VADs) to provide accompanying software for the electronic chart products. These VAD companies develop, produce, and sell special market navigation software that uses the chart databases. For instance, a VAD may create a special software system for kayakers or fishermen. Developing new specialty products enables the chart products to be sold in new niche markets. Maptech also provides special discounts to the official paper-chart agents.

Each partner brings unique strengths to the effort that benefits both parties. Maptech takes advantage of the NOAA "brand name" in marketing as well as NOAA R&D and data expertise. NOAA takes advantage of Maptech's ability to enhance the product, to widely market it, and to be creative and flexible in pricing and deal-making. For instance, Maptech makes frequent updates and upgrades of the product,

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[13] The NOAA-Maptech CRADA is a 4-year agreement that is automatically extended for another 4 years and so forth indefinitely, unless either party officially chooses to terminate the agreement when it comes up for renewal.

which increase demand and generate sales of the revised products to existing and new customers.

NOAA-Maptech CRADA Benefits & Drawbacks

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Benefits for the government (NOAA)

- Accomplish new mission of providing electronic charts without having to pay for it
- NOAA R&D enhanced by Maptech payments

Benefits for the public

- Wider availability of accurate, convenient charts at lower cost

Benefits for the private sector

- Expansion of markets and profits

Potential drawbacks

- Maptech competitors at an economic disadvantage
- Government not able to easily select another partner
- Government forgoes revenue if work was done in-house

RAND

Public-private partnerships convey very different kinds of benefits and potential costs to each partner. To understand these benefits and costs it is useful to examine them from three different perspectives: that of the government, that of the broader public, and finally that of the private sector.

Public Sector Benefits

The NOAA-Maptech CRADA has provided several benefits to the government and the public. NOAA is meeting its new mission requirement to provide electronic nautical charts without it costing NOAA or the taxpayer any additional funds. The electronic chart products are self-supported by sales. In fact, NOAA estimates it saves over $3 million per year and over 12 government employees (or full-time equivalents) that would have been needed to perform the same electronic chart production, marketing, and sales functions that Maptech does. On the other hand, NOAA and the government forgo the revenue they might otherwise gain from sales of electronic charts.

NOAA R&D programs benefit from R&D co-payment fees on all sales of the new products. NOAA receives 5% of the gross sales of all electronic chart products, which amounts to about $120,000 per year. These funds are used only to support NOAA R&D on electronic charting. NOAA researchers also benefit from real-world feedback from Maptech and its customers. Maptech points out instances where NOAA should gather additional data or process data in a different way in response to market demands.

The public benefits from access to a quality product at an affordable price. For example, the retail price for a Chartkit CD-ROM is $199.95 per region, and each CD contains about 55 charts per region; depending on the size of the region that works out to about $3.60 per chart. (NOAA negotiated a cap on the retail price of the electronic chart products.) To purchase an individual electronic chart on a disk costs $14.95 each. NOAA's plastic-coated paper charts cost about $15.65 each.

The partnership's product is self-supported by sales instead of taxpayer dollars. It also is an enhanced and more marketable product than NOAA would have likely provided by itself. For instance, Maptech suggested that NOAA provide Maptech with its electronic information about marine sanctuaries[14], because the general boating public would be interested. Maptech has incorporated this information into the product, which provides additional value to the product and helps NOAA in its educational mission to distribute information about the marine sanctuaries.

Paper chart sales have remained stable. However, as of summer 1999, the electronic charts were outselling paper charts 8 to 5, even though very large ships were still legally required to carry the paper charts for official navigational purposes. Given the increase in sales of the electronic charts compared to paper, the electronic charts are likely reaching new users, such as recreational boaters, and thereby, likely increasing public safety.

Private Sector Benefits

The NOAA-Maptech CRADA has also provided benefits for the private sector. Maptech has a healthy electronic chart business and as of summer 1999, over 30 VAD software products were on the market. These software developers produce navigation software in a less risky environment because they are guaranteed the availability of high-

[14] A marine sanctuary is like a national park in marine areas. Specifically, selected marine areas identified for their biodiversity, ecological integrity, and cultural legacy receive special protection through the National Marine Sanctuaries Program. Thirteen areas throughout the United States have been designated as marine sanctuaries. For more information about these sanctuaries see: http://www.sanctuaries.nos.noaa.gov/natprogram/natprogram.html

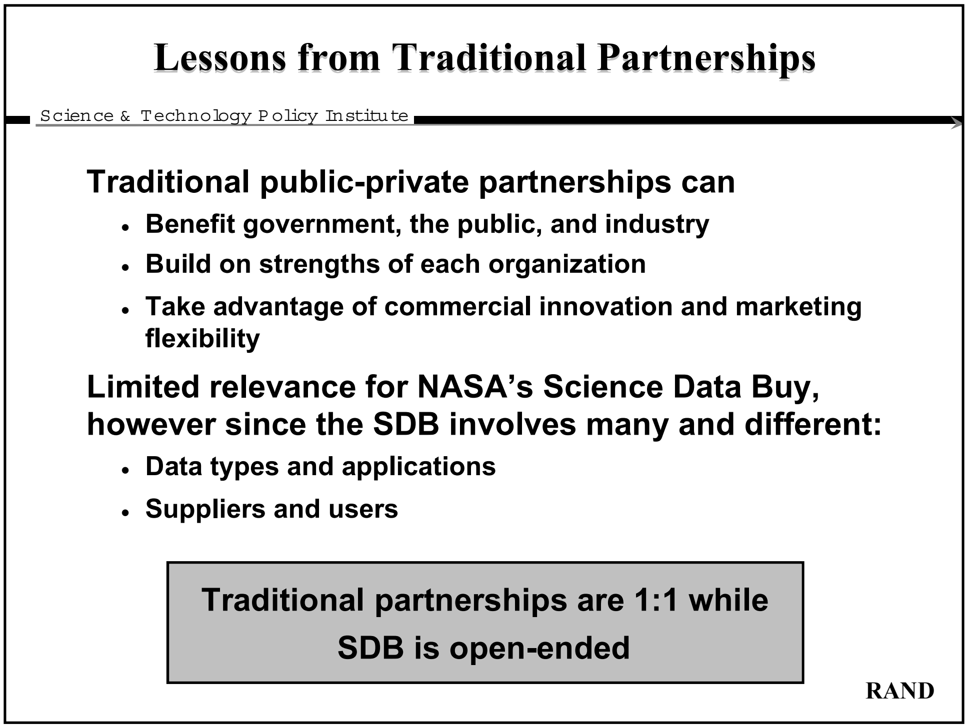
quality, affordable, consistent format, and official data through the CRADA. About 600 small retail sales agents are the official retailers of NOAA's paper charts. They now also sell Maptech's CD-ROMs and accompanying VAD software. These agents were originally opposed to the CRADA but now support it because they have benefited from the agreement—the CD-ROMs and accompanying software products sell at a higher profit than the paper charts.

Potential Negative Consequences

Despite the many benefits, there are always trade-offs in such arrangements. The CRADA gives Maptech a competitive advantage with the official NOAA brand name associated with the data in the product. This may hurt long-term market competition. Arguably, there is still competition since at least four other companies are producing electronic chart products beside Maptech. Other companies with innovative electronic charts can enter the market at any time, so it is not legally a monopoly. Given current technologies, such competitors can easily scan NOAA's paper charts to develop their own electronic data products.

An obvious question is whether the public may have benefited even more if there were greater market competition, which might occur if the partnership agreement had not granted Maptech exclusive rights to the data forever. For example, if the agreement stated that after 6 years the nautical chart data, even current data, would be available to anyone, then in 6 years competition in this marketplace might result in reduced prices and more availability of the products throughout the world. However, one can counterargue that a private sector company would not have been willing to enter such an agreement or else not invested so fully in the product under such conditions.

Finally, it can be argued that since NOAA has forgone the option of producing electronic charts in-house, it has given up potential revenues from those sales. It can be argued that government agencies should not perform tasks that can be done by industry, but the use of an exclusive agreement could be challenged if revenues were to grow so large as to seem disproportionate to Maptech's investments. In such a situation, NOAA could benefit from renegotiating the CRADA to find more favorable terms.



Important lessons can be learned from traditional public-private partnerships. First, if effectively implemented, they can provide benefits for government, companies, and the general public.

Second, successful public-private partnerships build on the strengths of each organization to do things that each organization would not do alone. Government and industry have very different cultures and incentives. Industry tends to have more flexibility while government has more restrictions on what it can do and how. For example, Maptech quickly changes its product to meet user's needs, which NOAA probably would not have done had it produced the electronic charts because it is less sensitive to market demands.

Third, the government can take advantage of commercial companies' flexibility in the marketplace. Since government has many restrictions on how it operates, the private sector partner usually can more fully exploit the commercial marketplace. For example, Maptech thought broadly about potential consumers, such as commercial and recreational boaters, in its product development plan. Maptech also recognized that the marketplace was fragmented and that to make chart production profitable, the marketing plan needed to allow for customized products for unique niche markets, which led to the VAD agreements.

Unfortunately, these lessons learned from traditional public-private partnerships may have limited relevance to the NASA SDB given their tight focus and close team partnership structures. The SDB involves many different data types and applications, data users and suppliers, and is more complex in terms of organizational involvement and interests.

Data Clearinghouses Are a More Relevant Partnership Model for the SDB

Science & Technology Policy Institute

Data Clearinghouses

- Distribute, acquire, maintain, or integrate data, and provide services for users
- May use teams, collaborations, and markets to perform its function
- Can deal with complex webs of suppliers and customers without imposing particular solutions
- Often a neutral organization takes the lead in operating the clearinghouse

RAND

Because of the differences between traditional public-private partnership (PPP) models and data-sharing situations like the SDB, we decided to focus on partnership cases that were most relevant to the SDB. What types of partnership models are most relevant? Given our initial analysis of the different types of partnerships, certain attributes seemed most important.[15]

- Partnerships involving data from many different suppliers and employed by many different users.
- Partnerships that mix or integrate data from many different sources.
- Partnerships that involve a combination of government, industry, and/or university scientists or other NGOs are more relevant than bilateral teaming arrangements.
- Partnerships that employ a diverse range of pricing and cost strategies, because of the desire for cost efficiency in partnership implementation.

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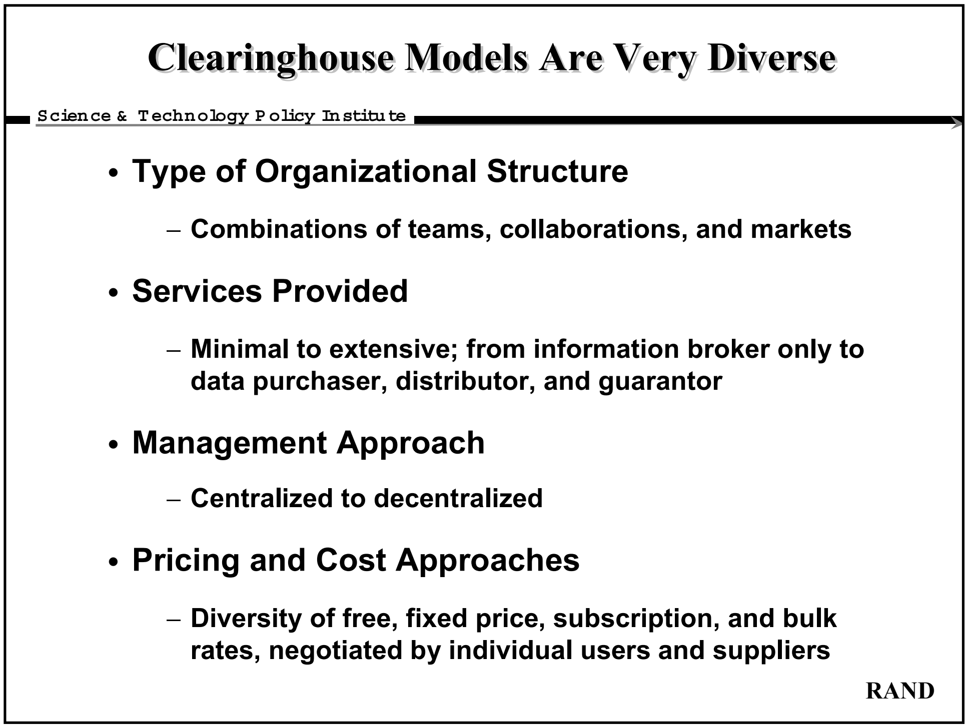
[15] This research analyzed relationships between entities and services provided as well as other key dimensions of PPPs to determine which PPP models would be most relevant.

- Partnerships involving intellectual property concerns, because such issues also arise when dealing with commercial remote sensing companies.
- Partnership arrangements that involve remote sensing or other geospatial data, which are more relevant because of the cost structures resulting from these technologies and their markets.

Not every partnership had to meet all these criteria. However, we tried to focus on cases that met most of them and at least met the first. Namely, the minimal requirement was that the partnership effort had to involve sharing data among many different users and suppliers. Using these criteria to identify partnership examples it became clear that one type of partnership model was most relevant. The partnership model that fits all these criteria is a data clearinghouse.

A data clearinghouse is not a traditional partnership; it is an entity designed to acquire, maintain, and distribute data or to provide informational services about data for many different data users. Such an organization may also integrate the data, generate data and metadata, or perform other types of data processing functions. It may employ many different types of partnerships to achieve its functions, including teams, collaborations, and markets. If collaboration is involved in conducting the clearinghouse, often a lead organization physically operates the data clearinghouse.



Data clearinghouses employ a wide range of implementation arrangements. We identified and examined four key implementation dimensions: organizational structure, services, management approach, and pricing and cost mechanisms.

In terms of organizational structure, the case studies included a diverse combination of teams, collaborations, and markets. Services provided by the clearinghouse case studies ranged from minimal to extensive. For instance, we looked at clearinghouses that were only information brokers, such as those providing only metadata, to clearinghouses whose activities included purchasing, creating, cleaning, maintaining, and distributing databases. Management approaches ranged from highly centralized to those that were highly decentralized and from strong management control to almost no management control.

A wide range of pricing and cost strategies was also examined. Some clearinghouses did not try to recover costs while others were full cost recovery operations. Some clearinghouses provided data for free, while others had fixed price, fee-for-service, or subscription fees. Some used bulk rates for data purchasing, or acquired data for free, at cost and/or market prices. Many negotiated different prices based on data sources. Such diverse pricing mechanisms applied for both data users and suppliers.

Example of a Data Clearinghouse: California Teale Data Center

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- Located within a state agency
- Self-supporting GIS Technology Center provides
  - Geographic information library
  - Data integration and consulting services
- Range of agreements to acquire and sell data to governments, universities, and the private sector
  - Data purchased from commercial vendors for state and local agency customers only
  - Partnerships to create data may require that data be placed in public domain; sell at cost of reproduction
  - Universities provided with data for research and education at cost

RAND

The Stephen P. Teale Data Center,[16] a California state department within the Business, Transportation and Housing Agency, was created more than 10 years ago to provide data and information services for state agencies. Teale has a GIS Solutions Group,[17] which serves as a geospatial data clearinghouse and service center for the state.

The GIS Solutions Group maintains a regional data library of over 50 widely used types of geographic information, containing themes such as roads, railroads, hydrography, vegetation, land ownership, public land survey, census, air basins, administrative and legislative boundaries, national wetlands inventory, and terrain. The Teale Center owns, maintains, and copyrights the data, licensing data to users with specific grants of use. The Center sells data licenses to anyone and has many private sector customers, though its main mission is to serve state and county agencies.

The GIS Solutions Group purchases most of its data, does some data processing, and then sells databases to users. Its data processing

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[16] For more detailed information about Stephen P. Teale Data Center, see: http://www.teale.ca.gov

[17] For more detailed information about the GIS Solutions Group, see their web site: http://www.gislab.teale.ca.gov/

typically involves combining a mosaic of datasets into a regional database at a scale and in a format of value to users. Datasets are acquired from federal and state agencies as well as the private sector. New datasets are also developed, often through individual data creation partnerships.

The GIS Solutions Group provides GIS consulting services, such as introductions to GIS technology, analyses of client needs for GIS technology, custom application design and development, integration of GIS with other data processing technologies, and application of GIS analytical tools. It also provides GIS training and education, database development, mapping and plotting, address matching, and customized user interfaces for GIS databases.

The California Teale Data Center has a wide range of agreements for acquiring and selling its data, based on the data sources, legal restrictions, and the deals it can make. The GIS library is available to clients by subscription at the county or state level and individual geographic themes can be licensed on a one-time basis. Data for individuals and organizations come with specific usage restrictions. Data are licensed to universities at cost with the stipulation that the data be used only for research and educational purposes. In addition, certain data can be sold only to government agencies. For instance, the Center has licenses to purchase commercial items, such as Environmental Systems Research Institute (ESRI) data products, which can be sold only to county and state agencies. The GIS Solutions Group negotiates deals with commercial providers, as well as state and local governments, to sell data through the Center. It seeks and often receives discounts for sales to state and county agencies.

If there are no maintenance or acquisition costs associated with the data, the Center sells the data at the cost of reproduction. One example is the soil database, which is sold at the cost of reproduction, since it comes from the U.S. Department of Agriculture (USDA) and does not require processing. In certain partnerships to create databases, such as the California watershed database, the data is considered in the public domain once it is created.

The Teale Data Center performs a middleman function among a diverse range of public and private sector suppliers and customers for specific types of data.

Another Clearinghouse Approach: NIMA Commercial Imagery Program (CIP)

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- Improve the tasking, storage, and dissemination of commercial imagery for defense and intelligence agencies
  - Enhance customers' ability to search for and access commercial imagery from imagery libraries and providers
  - Establish standards for metadata and interfaces
  - Familiarize and train endusers
  - Conduct utility assessments
- Provide flexible mechanisms and resource management for customer orders of commercial imagery
  - Enables multiple pricing and licensing levels for data
  - NIMA may purchase greater dissemination rights for selected data

RAND

In contrast to the California Teale Data Center, the National Imagery and Mapping Agency (NIMA) operates a much larger and more focused set of support activities that illustrates a somewhat different approach to partnership. The similarities and differences between the two programs and their user communities illustrate some important lessons for NASA.

NIMA operates a public-private partnership called the Commercial Imagery Program (CIP). The CIP allows NIMA to easily and efficiently purchase data from commercial providers for its own purposes, as well as for military and intelligence community clients. NIMA is using commercial imagery to satisfy select geospatial information requirements, fill gaps in its imagery collection, meet customer demands for unclassified data products, and to support unique and emerging applications. The program is similar to the NASA SDB except that it is operated exclusively for NIMA and its customers in the U.S. military and intelligence communities.

NIMA's Central Imagery Tasking Office (CITO) is the implementing organization for the CIP. The CITO also operates a national imagery clearinghouse system for its user communities.[18] As might be expected from the name, the Central Imagery Tasking Office directs the tasking and operation of national systems; and as an adjunct, the Commercial Imagery Program serves as the central tasking and ordering service of commercial imagery for U.S. military and intelligence communities. The CIP office has direct responsibility for receiving, processing, submitting, and monitoring satisfaction for all commercial requirements.

With the Commercial Imagery Program, NIMA uses a data clearinghouse to make commercial satellite imagery more readily available to the defense and intelligence communities. It is designed to improve timeliness of delivery and ease of dissemination of imagery to NIMA clients, while offering potential cost-savings or cost-sharing benefits through negotiated licensing agreements. CIP also enhances the ability of customers to search for and access commercial imagery within a Commercial Satellite Imagery Library (CSIL) and from commercial providers directly, by arranging for archiving commercial imagery metadata at its central facility and through direct "preferred customer" arrangements with commercial providers.

Within its data clearinghouse, NIMA has designed the system to allow flexibility in how customers can order commercial imagery. For example, users can place orders through classified or unclassified web sites, depending on the sensitivity of the request. NIMA is also developing a commercial imagery management tool that helps users search through existing imagery libraries, check order status, and plan new data collections where necessary. Toward that end, NIMA has contracts in place with Space Imaging, EarthWatch and OrbImage, whereby the CIP library will daily receive metadata on the most recent commercial imagery collections.

In addition to acting as an agent to facilitate purchases through the CIP clearinghouse, NIMA may itself purchase imagery data it chooses from commercial providers and make the data available to clients. These purchases are made under different types of licenses that regulate how that data may be used and how widely disseminated, thus allowing for greater efficiency in purchasing and distribution. For example, a license for a given image may cost $N as a product releasable to any one branch

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[18] National imagery refers to imagery collected by U.S. military and intelligence systems.

of the armed forces, but cost only 1.5 times $N for a license allowing distribution to all of the armed forces. In this instance, NIMA may pay the incremental cost to file the data in its library, available for use by all services. NIMA will also receive and post Landsat 7 metadata and other imagery data held by the EROS Data Center. NIMA establishes its own metadata standards for these data suppliers.

The NIMA CIP is an example of a federal agency providing a flexible system that allows specific types of clients to acquire commercial remote sensing data, as well as other remote sensing data and metadata, from its clearinghouse.

NASA and NIMA Use Commercial Data in Very Different Environments

Science & Technology Policy Institute

NIMA has clearly identified (statutorily defined) customers, who possess

- **Powerful constituencies**
- **An abundance of resources**
- **Clear chain of command that merges with NIMA's**

In contrast, NASA's customers for the SDB program

- **Are *chosen* by NASA and are always changing**
- **Have no official standing**
- **Have few resources**
- **Have virtually no constituency**

RAND

There are important differences between NIMA's commercial imagery program and NASA's Science Data Buy. Among its other duties, NIMA is responsible for providing the products from U.S. government imagery satellites (and their derived products, such as maps and terrain elevation charts) to all branches of the military and to the intelligence community. Any failure to provide these data threatens to impair the ability of NIMA's client organizations to accomplish their missions, which could result in harm to national security. Insofar as it enhances NIMA's ability to provide information required by the clients, the CIP serves as an organizational and logical extension to NIMA's operation.

NASA's relationship to the parties served by the Science Data Buy is rather different. Instead of a well-defined customer base, researchers receiving SDB data are chosen from a broad pool of applicants. These applicants rely on grants of money and data for their livelihood and must in effect use what is offered to them. While their need for data is not unlike that of any other researcher who relies on NASA, the difference lies in how the data are obtained. Most NASA data are collected by dedicated platforms owned and operated by NASA versus the SDB data that are purchased on the open market. This difference leads to substantial organizational consequences.

NASA and NIMA have Different Interests in Using Commercial Data

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NIMA's mission:

- Provide timely, relevant, and accurate imagery, imagery intelligence, and geospatial information in support of national security objectives

NIMA's institutional interests largely coincide with the interests of its users

- NIMA is effectively neutral with respect to the Commercial Imagery Program (CIP)
- The continuation of the CIP directly depends on the satisfaction of NIMA's customers

RAND

NIMA's customer base requires certain specific imagery and geospatial data products. Where commercial sources can provide those products more efficiently than NIMA assets, it is in the best interests of the clients for NIMA to acquire the data via CIP. Because the clients have their own powerful constituencies, there are strong incentives for NIMA to act in the clients' best interest. In addition, the Director of NIMA is a senior military officer (i.e., a two-star general), who presumably has incentives to ensure military organizations and operations are supported.

While NIMA may choose to acquire commercial imagery for the CIP with its own funds, any of its client agencies may choose to purchase specific data through the CIP. In this case, NIMA acts as a clearinghouse and provides advantages inherent in this type of partnership (e.g., greater buying power, preferred licensing arrangements, as discussed earlier). The funds used for any such purchase are transferred from the client organization through NIMA, which acts as the executive agent and handles processing and dissemination as requested by the client. Thus, clients must see CIP as adding value because if not, they can circumvent the CIP and purchase products from commercial providers directly, using those same funds.

Thus NIMA's organizational interests and the interests of its client organizations tend to be aligned, and the CIP avoids being undercut.

NASA and NIMA have Different Interests in Using Commercial Data (2)

Science & Technology Policy Institute

NASA's mission:

- Explore, use, and enable development of space for human enterprise
- Advance scientific knowledge and understanding of the Earth, the solar system and the universe, and use the environment of space for research
- Research, develop, verify, and transfer advanced aeronautics, space, and related technologies.

The SDB is not directly necessary to NASA exploration, research, or advanced technology - maintaining it requires continuous effort.

The SDB does not use a neutral party to mediate among the interests of involved communities.

RAND

The SDB is limited by being somewhat at odds with the stated mission of NASA and its corporate culture. While NASA's mission calls for "enabl[ing] the development of space for human enterprise," it does not require that NASA purchase the products of those enterprises. NASA's culture is that of a research organization, primarily one that builds and launches instruments that return scientific data. Purchasing data from commercial businesses, even for scientific purposes, is not the same.

Some members of industry fear that NASA has an organizational incentive to oppose the development of space-based commercial remote sensing systems since they could provide competitive data sources to NASA-owned systems. While there is no evidence to believe that NASA has ever operated with that intent, it is fair to say that NASA does not see the success of programs like the Science Data Buy as critical to meeting its science requirements.

NASA SDB clients, in contrast to NIMA clients, typically do not have the resources necessary to go to the commercial market directly and purchase products they require. Since most (if not all) SDB clients rely on research grants provided by NASA, they have virtually no leverage in the choice of data content or provider beyond the data requirements statement filed with their grant application. If their needs are not satisfied, they have no outside constituency to intercede on their behalf.

Indeed, they are SDB clients only by virtue of the fact that NASA has selected them for that position by way of a peer-review or other assessment process following the issuance of a NASA Request for Proposal or Announcement of Opportunity. A further incentive for a grant applicant to request only data known to be readily obtainable is that assurance of data availability is one of the criteria used for scoring the research applications.

Lessons from Nontraditional Partnerships: Successful Ones Evolve

Science & Technology Policy Institute

- Natural Heritage Program and Conservation Data Center Network
  - In-house standards development has become a collaborative process
  - New neutral organization (ABI) created to coordinate the program
  - Computerized technologies evolved for data collection, processing, and dissemination
- Center for International Earth Science Information Network
  - Adapted data access and distribution to latest web approaches
  - Transitioned from isolated organization to University Center
- California Teale Data Center
  - Originally subsidized by state but now in full cost recovery
  - Subscription and consulting services added

RAND

One consistent pattern we have seen in the partnerships is that they evolve over time in response to demands of their user communities, technological changes, and economic pressure. This chart illustrates three partnerships—The Natural Heritage Program and Conservation Data Center Network, CIESIN, and the California Teale Data Center—and highlights some key changes they have experienced over time.

The Natural Heritage Program and Conservation Data Center Network

The Natural Heritage Network[19] was originally started by a nonprofit group, The Nature Conservancy (TNC), over 20 years ago to collect, interpret, and disseminate information critical to conservation of the world's biodiversity. TNC worked in partnership with many independent public agencies and other organizations to develop individual state programs throughout the country. The U.S. Natural Heritage Program consists of separate programs in all 50 states. The effort has also expanded outside the United States.

Using a common, standards-based methodology, natural heritage programs collect and distribute information on endangered plants,

[19] For more information on the Natural Heritage Network see: http://www.heritage.tnc.org/

animals, and ecological communities that make up the planet's biodiversity. Collectively these programs and 85 biodiversity data centers throughout the Western Hemisphere are known as the Natural Heritage Network. Each center functions as a geospatial database clearinghouse.

This program has adapted over time, especially with regard to its organizational structure. In 1994, a federation of more than 70 Natural Heritage Programs, Conservation Data Centers, and similar programs in the Western Hemisphere collaborated to form the Association for Biodiversity Information (ABI). ABI's mission is to unify, support, and represent the network of Natural Heritage Programs, Conservation Data Centers, and other cooperators in the mission of collecting, interpreting, and disseminating ecological information critical to conservation of the world's biological diversity. The Association helps independent data centers to meet local needs and operate as a network; share resources and expertise; cooperatively develop methods, protocols and systems; and make quality biodiversity information more accessible and useful. In summer 1999, the Association for Biodiversity Information officially took over coordination of the Heritage Network. [20]

ABI is a dedicated and "neutral" organization to support and represent the heritage network. ABI was created to overcome some of the difficulties that The Nature Conservancy had in running such a large collaboration of diverse interests and representation. Even though TNC is a highly respected and scientific environmental organization, it did not appear neutral enough in certain situations. For example, federal agencies can more easily work with a public-private collaboration like ABI, than they can with an environmental nonprofit such as TNC. It was also difficult for a national organization with other objectives to always appear and act neutral, when overseeing the collaboration of 50 independent state programs. Some state heritage programs felt TNC acted as a "big brother" with too much input into their individual programs. Another factor was that Heritage funds had to compete internally within TNC with other organizational needs, such as land acquisition. The ABI can solicit funds for its objectives without internal conflicts.

[20] For more information see ABI home page at: http://www.abi.org/AboutABI.cfm#Overview

The new arrangement solved problems encountered by the fragmented responsibilities of TNC and individual Network programs in developing, managing, and aggregating Network data. Most importantly to its supporters, the new arrangement places "leadership for the Network in the hands of an organization dedicated solely to furtherance of the Network and the application of Heritage data to biodiversity conservation."[21]

CIESIN (Center for International Earth Science Information Network)

The Center for International Earth Science Information Network (CIESIN)[22] was established in 1989 as a nongovernment organization (NGO) to provide information to help scientists, decision-makers, and public citizens better understand the changing world environment. CIESIN specializes in providing global and regional network development, science data management, decision support, and education and technical consultation services. A main part of its effort focuses on providing Internet tools for data sharing and forming partnerships to help create and make datasets available to their users. Formerly an independent organization based in Michigan, CIESIN is now associated with a research center at Columbia University in New York where it has access to more technical support.

CIESIN has evolved and adapted both organizationally and technically over time. For example, it moved from being a totally independent organization to being part of a university research center in order to gain the technical and labor infrastructure needed to support its work. The CIESIN Gateway was developed prior to the mass availability of the Internet, but adopted World Wide Web protocols when they became popular. Similarly, metadata for its datasets are all now compatible with common Federal Geographic Data Committee (FGDC), NASA Directory Interchange Format (DIF), and U.S. military geospatial metadata standards. CIESIN is also redesigning its system to be compatible with NASA's Open Archive Information System.

The CIESIN clearinghouse is an interesting example of an NGO that provides search and analysis tools, data access, and information through the Internet for specific applications. The organization's mission is to

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[21] Hilton, Jarel, ***Building a New Organization for the Heritage Network***, Alabama Natural Heritage Program, undated.

[22] For more information on CIESIN see the organization's web page at: http://www.ciesin.org/index_text.html

provide scientific information about earth resources to researchers using both public and private data sources. The shift to Columbia University helped provide the expertise and infrastructure needed to sustain the organization as it adapted to evolving user expectations (e.g., web access).

California Teale Data Center

As discussed earlier, the Stephen P. Teale Data Center was created to provide data and information services for state agencies. Clients are billed for costs such as staff time, data maintenance, and other infrastructure. Over the years, a pricing mechanism has been developed to accurately allocate fixed and variable costs for data and services. However, most of their revenue now comes from consulting services. Only about 30% of staff time is spent on the data library, the rest being spent on billable services. It is doubtful that the data library could be maintained by itself as a full cost recovery system.

The California Teale Data Center is a good example of a clearinghouse that provides a wide range of customer-oriented services. Besides distributing data, they act as a value-added reseller and provide consulting services. The clearinghouse has been able to achieve full cost recovery through creative consulting and data distribution deals. It closely resembles market partnership but also employs collaboration partnerships to create new datasets.

Successful Data Clearinghouses Share Several Elements

Science & Technology Policy Institute

- User communities help direct the partnership organization
- User demand drives the range of services provided
- Collaborations take advantage of technological and infrastructure advances
  - Relevant standards are adopted and used by the participants
  - Partnership organizations actively participate in relevant standards bodies and processes
- Dedicated "neutral" organization used for implementation
  - Centralized, decentralized, and mixed control management approaches used to lower transaction costs, gain collective action efficiencies, and promote greater data availability

RAND

We identified several elements that are shared by successful data clearinghouse arrangements.

Data clearinghouses maintain strong connections to users in many different ways. In some cases, the clearinghouse is run directly by the users or a subset of users (e.g., the Ohioview clearinghouse and the New York State GIS Data Sharing Cooperative). In other cases, the clearinghouse has a board of directors with users on it, as found in the Journal Storage Project. In the Montana and Texas NRIS clearinghouses, operational guidance comes from collaborative councils, consisting primarily of users. Other data clearinghouses are indirectly responsive to their customers by financially succeeding or failing based on customer usage. These clearinghouses, such as the California Teale Data Center, recover their full costs by charging users directly for products and services.

Even for the few clearinghouses that did not have full cost recovery or users running them, there was a strong connection to user interests. For example, the EROS Data Center solicits customer feedback in many ways and carefully tracks user statistics. Even though EROS Data Center is mainly a government-funded program, it feels it must be responsive to clearinghouse customer needs or its funding will eventually be in jeopardy.

Data clearinghouses take advantage of advances in technology to improve their operations. Most of the clearinghouses examined use a strong technology infrastructure to support their efforts and continually seek to upgrade their capabilities. The tremendous advances in information technologies over the last few decades have helped stimulate advances in geospatial technologies that have made geospatial data more affordable, easier to use, and easier to share. This in turn has led to wider use and higher demand for geospatial data and products. The Internet and web interfaces in particular make for easier data access and exchange mechanisms, enabling many-to-many interactions (as distinct from one-to-many broadcasting or one-to-one exchanges) to occur quickly and cheaply, which in turn stimulates new collaborations and partnerships.

The web fosters many-to-many relationships, and enables organizational structures with many different players, such as the 180 members of the NYS GIS Data Sharing Cooperative. Internet technologies also make self-service systems easier, where users control data information and acquisition themselves, as in the Olympic Natural Resources Center (ONRC), NIMA, and Pennsylvania Spatial Data Access (PASDA) clearinghouse efforts. It is also becoming easier to transfer large datasets through the Internet and on CD-ROM, as EROS Data Center does.

Technical standards play an important role in all clearinghouse efforts. As mentioned, standards are important for clearinghouses' quality assurance processes and shape cost and pricing strategies for data and value-added services. How standards are used varies from effort to effort, depending on the maturity of the clearinghouse operation. Some clearinghouses follow informal standards, especially in early stages before formal standards are approved. This occurred with several state GIS Centers, such as Montana's, before the state had official geospatial data standards.

Data clearinghouse efforts use parts of state or federal standards as well as customize formal standards for their own needs. For example, CIESIN uses Federal Geographic Data Committee (FGDC) standards. The California Natural Diversity Database (NDDB) uses a subset of the FGDC metadata standards, which is the state standard. The Olympic Natural Resources Center uses FGDC and National Biological Information Infrastructure (NBII) standards. The Oregon Natural Heritage Program (ONHP) and California NDDB both use the national Natural Heritage Program standards. The California Teale Data Center uses part of the FGDC standards that are customized for state needs.

Georgia GIS Data Clearinghouse cleans, documents, and converts acquired GIS data to comply with the state standards.

Many clearinghouses are active in the processes for making new standards.[23] Some of the early, innovative efforts helped create official and new standards, because their activities began before there were many geospatial standards. For example, the Montana NRIS GIS and Texas Natural Resource Information System (TNRIS) clearinghouses have both been involved in state standard development efforts for many years. Individual Natural Heritage Programs provide input to ABI in their standards development process. JSTOR was instrumental in developing library standards for reporting Internet usage statistics that are now spreading into wider global use.

An important means of enabling cooperation among diverse information producers and processors is the use of a dedicated neutral organization. This facilitates trust and cooperation for many different types of management approaches, whether centralized, decentralized, or mixed control. A neutral organization, apart from any individual partner, is typically used to advance the goals of the partnership itself, that is, to lower transaction costs (e.g., making desired data easier to locate), gain collective action efficiencies (e.g., by sharing overhead and increasing buying power), and promote greater data availability (e.g., improving the ease of use of data applications).

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[23] A special caveat about these observations: Since we looked at the more innovative organizations and ones that have been around a long time, they are more likely to be involved in standard making processes and to have customized standards for their own purposes. With more mature organizations and as such efforts become more common, such organizations may be less active in standard making processes and may be more likely to use existing standards without customizing them.

Successful Nontraditional Partnerships Share Several Elements (2)

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- Variety of pricing and data access arrangements
  - Flexibility in pricing and data delivery provides maximum accessibility to a wide variety of users
  - Technologies allow customization of data products
- Data quality assurance generally provided by the primary data collector
  - Clearinghouses normally provide assurance only for their own data processing services and products
- Critical mass of support and technical infrastructure

RAND

We found a wide range of pricing and access deals across and within different clearinghouses. There was variety in what different clearinghouses paid for datasets and what they charged for datasets as well as significant variation in data purchasing costs and selling prices within the clearinghouse itself. This variation depended on where the data came from and where they were going.

Some clearinghouses distinguished access based on the user's purpose or organization, with government agencies and NGOs being treated differently than commercial companies. Data usage and access also depended on purchasing and licensing agreements for individual datasets. We briefly illustrate some of these different arrangements.

When a data clearinghouse acquires an individual dataset, it can distribute it in different ways based on the licensing agreement or other terms and restrictions that come with the data. First, some datasets, such as many federal databases, are in the public domain so anyone can use, freely distribute, and access them. The same is true for many states, such as Texas, in which data created by state funds must be in the public domain, so TNRIS distributes their state-funded databases freely. At the California Teale Data Center, the watershed database is distributed at cost of reproduction to anyone because the data partnership that created it required the database to be in the public domain.

Second, clearinghouse members can use some databases only for their own purposes. For example, New York State (NYS) GIS Cooperative members can use other members' clearinghouse datasets only for their own purposes and cannot distribute or sell other members' datasets. In Ohioview, only university members can use Ohioview data. In addition, since a nonprofit, academic status was used for acquisition of Landsat 4 and 5 data, it cannot be used for any commercial purposes. However, their member scientists can use the data to help governments and in research.

Third, some data acquisition agreements state that the clearinghouse can only distribute products derived from the purchased dataset and/or limits access to parts of the purchased dataset. For example, CIESIN cannot freely distribute the World Bank's Socio-Economic database, but it can distribute a derived product using this database or allow users to view pieces of the original database.

Fourth, some datasets can be distributed only for noncommercial use or to noncommercial clients. For example, the California Teale Data Center can sell ESRI data products only to state and local government agencies. Some CIESIN data can be used only for science and educational purposes.

How a clearinghouse chooses to price datasets varies. Organizational mission and legal restrictions usually drive this variation. Some clearinghouses are required to have full cost recovery, like the California Teale Data Center. Other clearinghouses, like the California NDDB, are required to charge minimal prices for data. Some distribute data for free or at the cost of distribution only, such as TNRIS and Georgia GISDC. Access charges can also be based on the sources of the data and the associated licensing agreements.

Some clearinghouses charge fee-for-service and/or have special subscription rates for their entire databases. The California Teale Data Center GIS library is available to clients by subscription at the county or state level and individual geographic themes can be licensed on a one-time basis. The California Natural Diversity Database and ONHP both offer fee-for-service and entire database subscription services. In addition, California NDDB prices vary by user type. For example, the cost of the statewide database is $1,250 for government agencies and NGOs, and $2,500 for commercial companies.

Clearinghouses employ agreements and licenses that are similar to those of software vendors. For example, a clearinghouse may provide password access only for selected individuals, site licenses, or limited group licenses such as any five people can use the data at one time. Some clearinghouses charge a flat rate regardless of organization size and access while others may charge by total number of users accessing the database. For example, JSTOR charges by organization size based on four classes: large, medium, small, and very small research institutions.

Despite the many differences in data pricing and access approaches, one similarity stood out across most of the clearinghouses: Most clearinghouses exploit creative pricing and access approaches based on their legal limits. The clearinghouses were aggressive and creative in their deal-making approaches given their mission and operational restrictions.

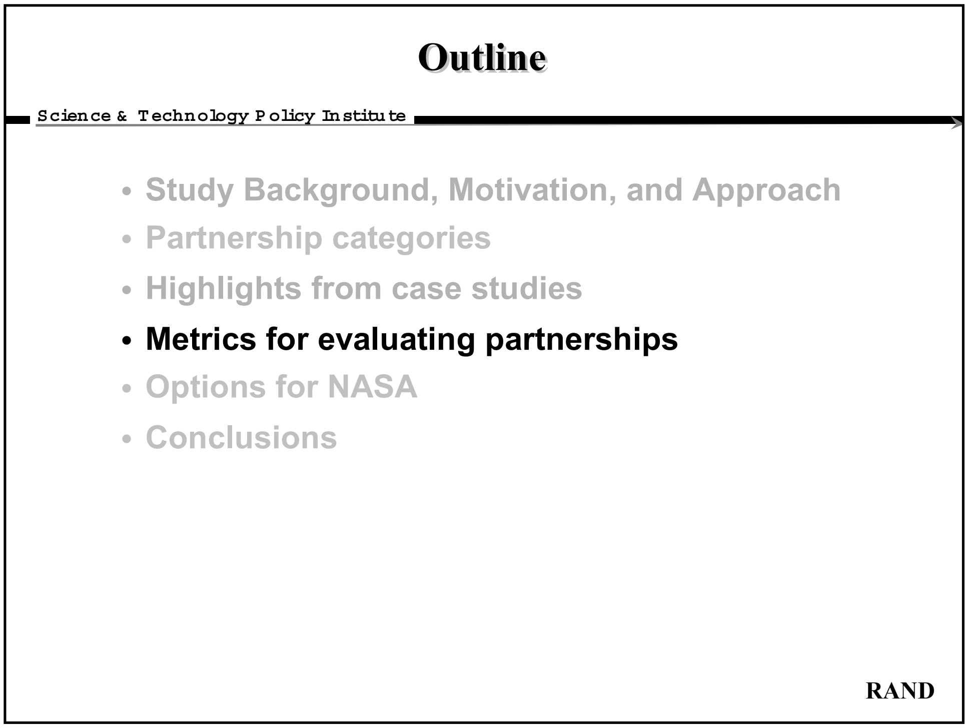
Data quality approaches also varied for different clearinghouse efforts. For some clearinghouses, such as ONRC, the original data producer or owner is responsible for the data quality. In other cases the collaboration's members are jointly responsible for quality control. In the New York clearinghouse effort, members have signed the NYS GIS Data Sharing Cooperative and agree to share data quality responsibility. Primary data creators are responsible for maintaining their own datasets, but data users agree to report any revisions or corrections to the dataset creators, so that the original data creators can make necessary changes.

Some data clearinghouses perform data quality control functions internally, ranging from the minimal, such as minor data cleaning and checking, to high level, such as being fully responsible for quality control when creating new datasets. For example, the California Natural Diversity Database relies mostly on the data supplier for quality control, except that the clearinghouse reviews data survey forms to check some of the basic data and who verified the data. The California Teale Data Center performs minimal quality control when it mosaics datasets together. However, California Teale Data Center, CIESIN, and JSTOR maintain full responsibility for quality assurance when they actually create the datasets.

Many use different quality controls based on the data source. If the clearinghouse purchased the dataset, then the original data producer is responsible for quality. If the clearinghouse created or added value to the dataset, then the clearinghouse itself is responsible for quality control of its work. For example, at the California Teale Data Center, the USDA is responsible for the data quality of the soil database while the Center is responsible for the quality of data processing services and products using that basic database.

Metadata information about who created the data is an important part of quality assurance. Data clearinghouses use metadata and metadata standards for quality assurance and to inform their users about the data. For example, when Texas NRIS contracts database creation work to private sector vendors, the vendors must meet Texas NRIS standards. Other standards, such as the Natural Heritage Program national standards for the ONHP and California NDDB efforts, are commonly used for quality assurance.

Successful clearinghouses are able to secure a critical mass of support and technical infrastructure that enables them to sustain their efforts. Such support includes having sufficient leadership, funding, technological expertise, and other resources. For example, CIESIN moved from being a totally independent organization to part of a university research center because they needed low cost, state-of-the-art computer support and other technical expertise provided by university researchers.



METRICS FOR EVALUATING PARTNERSHIPS

Having discussed partnership case studies in some detail, we now examine what kinds of metrics are appropriate for evaluating public-private partnerships.

Current Effectiveness Measures

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- **Sample current metric:**
  - **"The Science Data Purchase is underway, processing 83 tasking requests for over 30 sites."**
- **NASA measures inputs and outputs, but**
  - **Outputs such as simple counts are unrelated to client satisfaction and only indirectly related to goal attainment**
- **Criteria for resource acquisition and efficiency are common in business**
  - **Similar criteria or proxies are possible for NASA**
  - **However, NASA must choose what kind of buyer it will be for commercial data and products**

RAND

Current measures of effectiveness for the Science Data Purchase Program (SDPP) tend to be simple counts, such as numbers of data requests made or fulfilled. These measures of inputs and outputs are important to know but are not themselves indicative of higher-order measures of effectiveness such as client satisfaction or attainment of public policy goals.

Performance criteria for some aspects of public-private partnerships, such as attracting resources and efficiency in using those resources, are common in business. Similar proxy measures for them can be developed for NASA in its efforts to acquire commercial remote sensing products and services. However, NASA must first understand its relationship to the market and choose what type of buyer it will be. That is, does NASA act as just another commercial buyer among many or does it dominate the market as the primary or even sole customer for remote sensing data. The economic importance of this choice is treated in detail in Appendix 1. If NASA misreads the market it may find itself paying too much for data or deterring suppliers from entering the market by paying too little.

In the next few charts, we suggest a comprehensive approach to measuring the effectiveness of public-private partnerships. In particular, we show how this approach could be adapted and

implemented by NASA for efforts such as the Science Data Buy.

General Measures of Partnership Effectiveness (Cooperative and Noncooperative)

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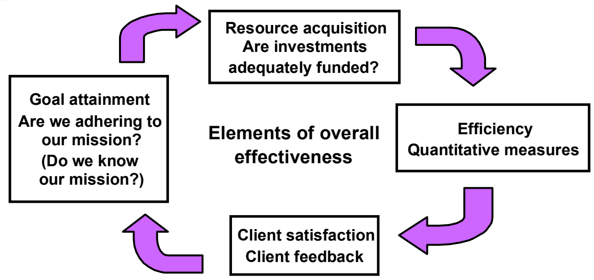

Effectiveness component	Measurement device
Resource acquisition	• Profit margin • Capital investment as a percentage of total revenues
Efficiency	• Costs as a percentage of revenues • Per-unit average production cost
Client satisfaction	• Client interviews • Percentage of return clients
Goal attainment	• Measurement is a 3-step process 1. Identify organizational mission (example: maximize share value) 2. Identify goals that are compatible with the mission (example: maximize long-run profit stream) 3. Measure attainment of these goals (example: gauge 5-year discounted moving average of profits)

RAND

Performance measurement has been at the forefront of much research of late in both the public and nonprofit sectors.[24] Based on reviews of existing literature, multiple criteria and perspectives are helpful in measuring the effectiveness of public-private partnerships. One approach we found to apply to the diverse forms of partnership examined in this study divides "effectiveness" into several interrelated categories:[25]

- Resource acquisition effectiveness (or having the means to invest adequately)
- Efficiency of operations
- Consumer satisfaction
- Attainment of partnership goals

Assessing effectiveness in a multidimensional way can help uncover areas of partnership weakness that might otherwise surface in unexpected and more damaging ways. For example, a public-private

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[24] See, for example, Brooks (2000), Kravchuk and Schack (1996), GASB (1993, 1994).

[25] Kushner and Poole (1996).

partnership may be functioning adequately from the viewpoint of its clients, but it could be underinvesting in capital for future projects because of resource constraints on one or more of the partners. In the medium term, ineffectiveness in resource acquisition can result in inefficient operations that can adversely affect consumer satisfaction and thus attainment of partnership goals in the long term.

This chart describes some common measurement methods of effectiveness. Resource acquisition effectiveness can be measured via the profit margin of an enterprise or (in the case of a public partnership) capital investment as a percentage of total revenues. Efficiency is the most familiar effectiveness dimension and already has well-known metrics, including cost as a percentage of revenues and per-unit average production costs. Client satisfaction can be measured in a number of ways, including the direct solicitation of client feedback as well as the percentage of clients who return within a particular period. Satisfaction can naturally consist of multiple aspects, such as ease of product use, price, timeliness of delivery.

While resource acquisition effectiveness, efficiency, and client satisfaction are largely quantitative questions, understanding goal attainment requires a multi-step process. First, the partnership must identify its organizational mission, for example, maximizing the public accessibility of remote sensing data. As obvious as this may be, many partnerships will likely find this a challenge, having been formed without a clearly defined mission in the first place. Next, the partnership must identify goals that are compatible with that mission, such as a specified annual increase in public consumption of data. Finally, progress toward attaining these intermediate goals must be measured.

The following charts describe processes to measure user client satisfaction with the SDB and to measure goal attainment by quantifying research quality before and after the SDB.

Example Metric: Assessing Client Satisfaction

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Measurement Approach: Survey community

- **Step 1: Collect background data requirements and preferences**
  - From scientists and research proposals
- **Step 2: Design short, two-part survey**
  - E-mail / web and telephone portions
  - Focus on data requirements and ability to obtain data under the SDB
- **Step 3: Collect and analyze survey data**
  - Demonstrate specific preferences & needs
  - Ideally, attach relative weights to the importance of different data properties

RAND

In theory, a good way to provide data that meet the needs of the Earth Science Enterprise (ESE) research community would be to ask its members to specifically identify the data they need and then obtain exactly that data. Unfortunately, that is difficult for a variety of reasons: The ESE research community is constantly changing, many researchers have very different data requirements, and articulating data requirements is difficult when working on scientific problems whose solutions are by definition unknown.

Social science research methods have been developed to obtain useful information regarding individual and group preferences in circumstances such as these. Given appropriate resources, such an approach would be effective and useful to NASA in assessing client satisfaction with data provided under the SDB.

Even given limited time and funding, it would be possible to conduct a brief but useful survey-based study to collect baseline data about researchers' data requirements and preferences. Such a study would have both a quantitative and a qualitative component and could be targeted at specific groups, such as those researchers currently funded by the SDB and those researchers who sent qualified proposals but did not receive funding. Central to the success of such a survey would have to be a clear understanding by researchers that their grant status with

respect to the ESE would not be affected in any way by their participation.

The quantitative aspect of the study would consist of a brief questionnaire inquiring as to the specific characteristics of the data required to support their research, what data is currently used to meet those requirements, the availability of that data (limitations on area coverage, temporal coverage, or spectral coverage).

The qualitative aspects, which could be addressed in a follow-up telephone interview, would focus on any deficiencies that the researcher had identified in the first part of the survey and try to ascertain what modifications to that data might enhance the research opportunities available, and in what ways (e.g., more predictive power, better model fidelity).

The objective of the survey would be to demonstrate specific data preferences and needs that are unmet under current SDB data acquisition strategies. If the sample size were sufficiently large, it would be possible to assign weights to the relative importance of different data properties and select data for acquisition according to those criteria.

Example Metric: Goal Attainment

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Examine work from researchers who:

- **Received government data before and commercial data after the act creating the SDB**
- **Received government data before and after the act**

$$c_{ijt} = \alpha + \beta_1 d_t + \beta_2 d_j + \beta_3 d_{tj} + X_{ijt}\gamma + \varepsilon_{ijt}$$

c_{ijt} = performance measure of researcher or institution *i* at time *t*
d_t = dummy to denote time
d_j = dummy to denote treatment
d_{tj} = dummy variable denoting time and treatment
X_{ijt} = research type, institution type, etc.

Typical outcome measures for experimentation on research

- **Research quality (e.g., weighted citations, weighted citations/grant size, review panel)**
- **Cost-effectiveness (published papers, publications/grant size, weighted citations/grant size)**

RAND

The goals for the SDB will be several, arising from the statement of its mission. Here we present a metric for measuring performance on two typical goals: maintenance of research quality and cost-effectiveness.

While greater use of commercial resources through the SDB might improve the efficiency of data collection, the resulting research products might be degraded in terms of quantity and quality if data are not transferable between scientific and commercial uses. Impartial assessments of the effectiveness of data products cannot proceed from simple observations of what is produced after a new program or law is implemented. Doing so would give a biased picture of improvement, because there may be confounding changes in research funding, varying uses of data (civil or military), and technological improvements over time. A better approach to answering such questions is to use an experimental design.

In many real-world scenarios like this one, conditions for a ***randomized experiment*** cannot be met, but we can argue that randomization has occurred to some degree naturally, and we can design what is called a ***natural experiment.***

Measuring outcomes in an experiment can be difficult, because the concept of "outcomes" is so amorphous.[26] Outcomes of policy experiments are generally designed to capture some concept of effectiveness (in contrast to simple quantitative measures such as inputs or outputs). An experiment to capture the effects of the Commercial Space Act's provision on the use of commercial remote sensing data presents no exception to the performance measurement challenge.

The volume of published papers and research reports produced as a result of the data used is a useful metric of research output—and one that is easy to measure. However, this measure does not provide much useful information about cost because it does not consider project size; for example, a $1 million grant will probably not be comparable in output to a $300,000 grant. To correct for this, an input-output ratio such as the number of publications a project produces over a set period of time divided by the research grant size (indicating the publications per grant dollar) might seem appropriate. This metric is still difficult to interpret because it does not control for research quality or impact on the scientific community.

Another measure of research output that incorporates quality is the weighted number of ***citations*** to the research in the natural sciences scholarly literature (measured after a certain period of time has passed, usually 2 to 4 years), where the weighting depends on the journal's importance.[27] This sort of accounting is standard practice for rating scholarly journals.[28] The disadvantage of using this type of measure, naturally, is the time lag in calculating it. Alternatively, a score based on journal impact as measured by the Science Citation Index (weighted by article length) would produce an immediate metric.[29]

Traditionally, research quality is evaluated through various peer-review mechanisms. We might generate data for this measure through an internal or external review of ESE research grants. The problem with this approach is that the results might change with the policy intervention itself; that is, it might be difficult to maintain a constant "political climate" for both applicants and evaluators participating. In addition, such review can be costly and time-consuming.

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[26] Joyce (1993).

[27] Stephan (1996)

[28] Janke (1973), Weisheit and Regoli (1984)

[29] Levin and Stephan (1991)

Better solution relies on citations in peer-reviewed professional journals or weighted journal impact, corrected to account for grant size. Thus we can use the same measure for both cost-effectiveness ***and*** research quality.

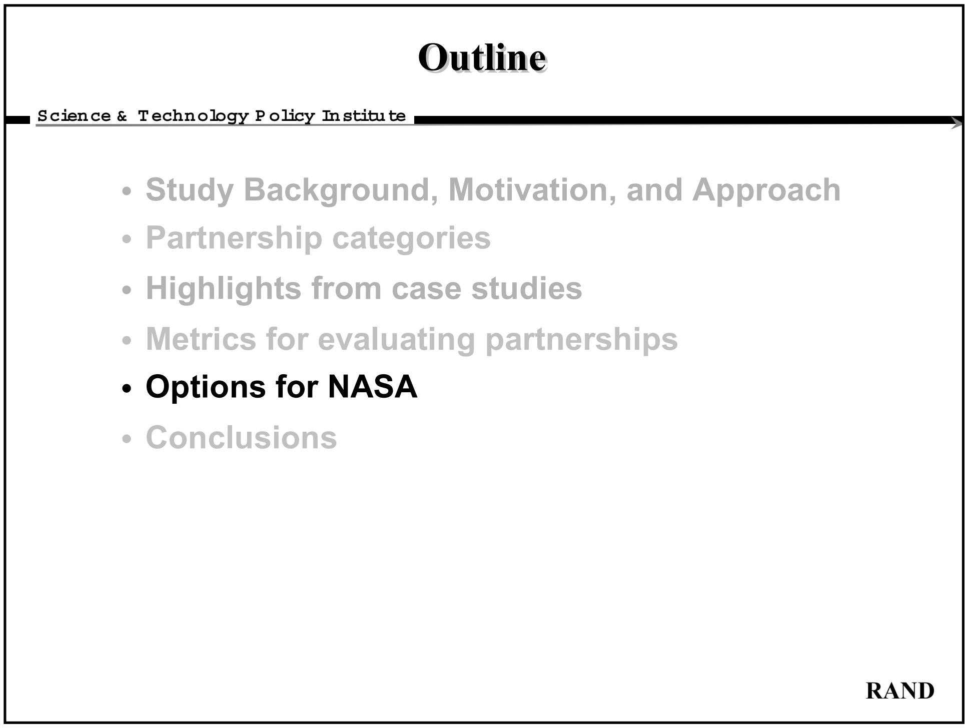
Next, we turned to the design of the experiment to gauge the cost-effectiveness and quality of research carried out with commercial, as opposed to government, data. An experiment in which subjects are randomly assigned to groups that are or are not subjected to the policy intervention would be the most effective design because it removes systematic differences between the groups.[30] In this case, researchers would be randomly assigned data from government or commercial sources, thus precluding systematic co-variation between time (t) and treatment (j). Ideally, neither the researchers nor those conducting the test would know which group had which data. Assuming that any interaction between j and t were due to attributes of individual research proposals, randomization neutralizes this effect by (theoretically) spreading out all attributes across both the treated and untreated groups. Unfortunately, this truly randomized design is problematic for NASA research for two reasons. First, researchers tend to formulate their proposals based on specific, known datasets; researchers self-select into a particular data environment. Second, data sources are usually obvious, since government satellites produce different kinds of data than do commercial providers.

The most basic experiment requires observing researchers and institutions both before and after the mandate by which they are given government data beforehand and commercial data afterward. To help control for phenomena occurring simultaneously with the SDB (but which are unrelated), we need add an untreated control group that is also evaluated pre-test and post-test. Specifically, we incorporate researchers into the sample who continue to use government data after the mandate. This experimental design is called an "untreated control group design with pre-test and post-test," or "difference in differences." The mathematical mechanics are shown in this chart.

This experimental design is not perfect, as there may be interactions between the mandate and the treatment group itself (that is, between $j = 1$, $t = 1$). A change coinciding with the mandate might affect the treatment more than the control group; for example, a stronger private-sector orientation at NASA that comes with passage of the Commercial

30 Acland (1979).

Space Act might favor research proposals that use commercial data. The vector *X* in the equation in this chart is intended to net out as much of this contamination as possible; however, it is almost certain that some unexplained variance will remain in the data. As a practical matter, however, this design offers NASA a realistic means of measuring the attainment of SDB goals.



OPTIONS FOR NASA

The following section discusses options for NASA to consider in using public-private partnerships to support Earth science research with commercial data sources and products.

Creating Partnerships

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- Deciding to create a partnership means a willingness or necessity to depend on others
- The choice between market solutions and a partnership arrangement depends on several factors
  - Clear statutory authority
  - User community acceptance and comfort level
  - Ability to manage transactions
- In partnerships, structure is less important than other factors:
  - Active and powerful user community to direct organization
  - Dedicated "neutral" organization for implementation
  - Ability to adapt and evolve over time
  - Adequate funding, technology, and infrastructure support

RAND

Creating a partnership of any sort, especially across the very different cultures of the public and private sectors, implies a necessity or willingness to depend on others. Choosing among various cooperative and market-based approaches depends on several factors.

For the public sector, a primary requirement is clear statutory authority to engage in partnerships that may involve use of public resources. The user or client community to be served should have some level of acceptance or willingness to consider the potential products or services offered—e.g., they do not have a prohibition against using private (or public) sector data. Finally, both parties need to be able to manage transactions, such as administering contracts, tracking sales, and allocating costs.

Specific partnering structures are less important than other factors in determining whether a partnership succeeds or even survives. An active and strong user community that can direct or provide clear feedback serves as a proxy for the market response to a purely commercial firm. A neutral implementing organization is key to maintaining trust among users and partners, again, this is important in lieu of purely commercial relations among the public and private participants.

As mentioned earlier, the ability to adapt and evolve over time in meeting client needs is important for partnerships as with any other market-driven organization. Finally, the ability to meet client needs depends on having adequate infrastructure and capital to service those needs, including skilled workers and appropriate technology. These resources can be deployed in a variety of organizational structures, but without them, a partnership, however well intentioned, is unlikely to survive.

Unique Challenges for NASA's Science Data Buy

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- Earth science community lacks information about and ability to control SDB program
  - SDB products not part of mainline ESE data management systems such as EOSDIS
- Legislative intent for the SDB seems to conflict with NASA's institutional interests
  - Uncertain statutory authority for NASA to pursue data clearinghouse arrangements
- Mission conflicts for NASA in being a funding source, an operating entity, and a user
  - In analogy, NASA contains aspects of NRO, NIMA, and end users of remote sensing imagery

RAND

There are some unique challenges in creating public-private sector partnerships with NASA in Earth remote sensing.

Much of the Earth science community is largely unaware of the Science Data Buy and does not have a direct role in its operation. In part, this situation reflects a lack of integration between research efforts using commercial as opposed to government data. More fundamentally, many of the scientific user communities for remote sensing data are closely tied to NASA and NASA funding. Unlike other user communities in the successful partnering arrangements we examined, the Earth science community is unable to exert significant direct pressure on NASA.[31] This community is obviously influential in defining scientific priorities and their work provides a fundamental rationale for NASA's Earth Science Enterprise. However, members do not provide direct feedback in ways that determine NASA's immediate behavior in the same way that a commercial firm would respond to a market. While this may be appropriate for a government agency, lack of user community control over programs such as the SDB makes it more difficult to respond rapidly to user needs and priorities.

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[31] The science community can, however, exert considerable indirect pressure through means such as congressional testimony and reports by the National Research Council.

A second challenge involves statutory authority for partnerships. The Commercial Space Act of 1998 encourages use of commercial remote sensing data and NASA's original 1958 authorizing legislation allows for innovative cooperative agreements using Space Act agreements. However, these agreements need to be specifically negotiated and approved as exceptions to standard organizational practice. In general, it is not clear that NASA has the proper statutory authority to pursue innovative data clearinghouse arrangements. For example, partnering agreements may require NASA to operate in ways that do not conform to federal acquisition regulations or to meet nongovernmental requirements.[32] It may be possible for NASA to use a nongovernmental entity as an intermediary, but the effort necessary to understand the scope of allowable involvement, direct and indirect, creates uncertainty and thus partnership barriers.

The third major challenge stems from intrinsic tensions inside NASA. NASA is at once a funding source for scientific research and an R&D organization responsible for the design, launch, and operation of spacecraft for data acquisition. As a funding agency, its goal is to advance scientific understanding through the findings of specific research programs. As an R&D organization, it maintains a large physical infrastructure and cadre of trained personnel necessary to support space missions. Attempts to procure commercial data can easily conflict with other agency activities, e.g., by competing for funds that might otherwise be spent on research using government data, or the development of advanced sensors and spacecraft to acquire new and unique datasets.

This last issue is a subtle one. The legislative intent behind the Science Data Buy seems to be in conflict with NASA's traditional institutional interests. Buying or outsourcing data acquisition inevitably conflicts with NASA's primary mission as an exploration and development agency. Few incentives are now in place for NASA to succeed in outsourcing data acquisition in comparison with the incentives to succeed in funding research and flying missions. In rough analogy to the intelligence community, NASA contains aspects of the National Reconnaissance Office (NRO) and the end-users of information gathered from NRO systems, but does not have an intermediary

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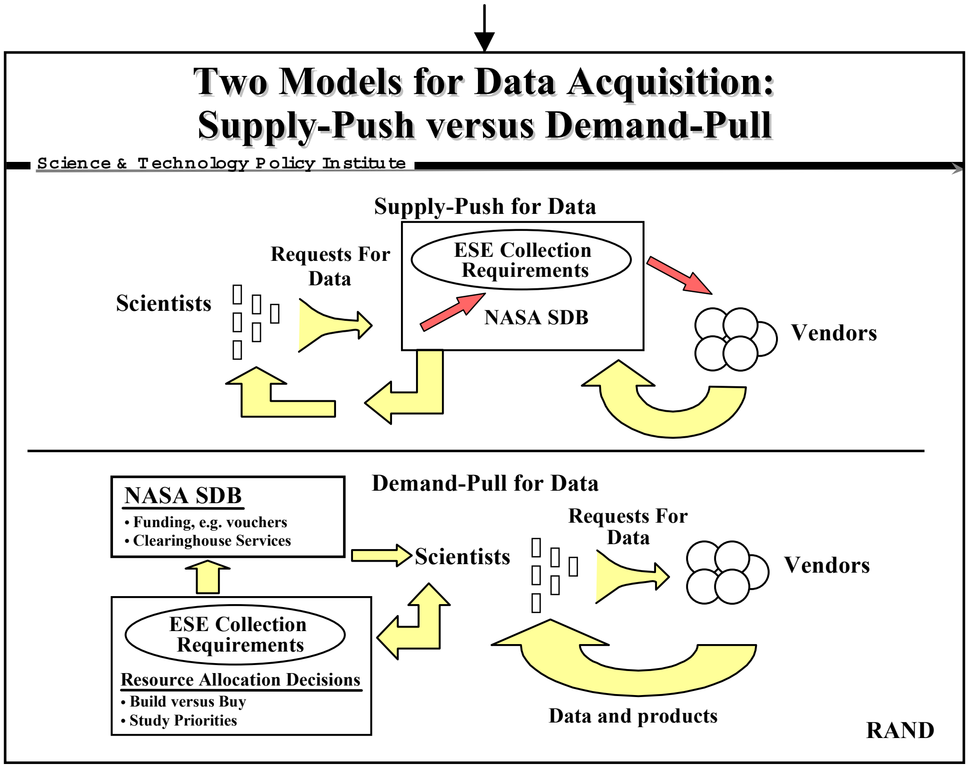
[32] As a specific example, the concept of "anchor tenancy" (42 USC, Chapter 26, Section 2459d) may be a problem in using the data buy as a routine solicitation approach. The government cannot commit to being an anchor tenant or make minimum order commitments for space hardware or services without congressional approval.

function such as that performed by the National Imagery and Mapping Agency (NIMA).



As the case studies show, there are a wide variety of structures for organizing a partnership. In examining NASA's options with respect to the process of the Science Data Buy, two critical choices are the centrality of NASA's role as an intermediary and whose utility is to be maximized. The above schematic illustrates two exemplar roles for NASA. The first can be termed a "supply-push" approach and the second a "demand-pull" approach.

In the supply-push case, which approximates the current Science Data Purchase Program, NASA is in the middle of transactions between data providers and the scientific community. NASA essentially picks and chooses the data it will procure based on selecting datasets that both match the requests coming into NASA from affiliated scientists and are consistent with NASA's perspective on strategic collection requirements and priorities. While the original scientific requirements for the Earth Science Enterprise might approximate the priorities of the research community, in many cases the strategic directions of NASA and the community at large are probably very different. The Earth science research community, or at least parts of the community, can change its research interests far more quickly than NASA can change strategic directions underpinning development programs spanning many years.

The demand-pull case illustrates a different approach in which NASA adopts a less central role and acts primarily as a neutral intermediary to facilitate data acquisition. Control over the choice of data in this case is pushed to the periphery as users pick and choose the data they need. This creates a more direct line of feedback between data suppliers and vendors and the end-use customers, namely the scientists. As in other commercial sectors serving the scientific community, such as biomedical technology, private firms will have incentives to meet customer needs when those customers have clear purchase authority.

NASA exercises oversight through the control and allocation of funding to research areas and leaves most decision-making to the scientists themselves. Thus research priorities for the use of public funds are still the responsibility of a public agency, but the implementation of those priorities is decentralized. NASA can capture data it believes is useful, but not in immediate demand, through a mechanism similar to NIMA's upgrading of data licenses via funds reserved for broader community use. This mechanism is similar to decisions made by many data clearinghouses in supporting both immediate and long-term anticipated demands.

Three Alternative Partnership Strategies

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- NASA as the central actor
  - Example emphasis: Focus on traditional/core scientific missions, e.g., global change research
- Focus on the larger scientific community while maintaining NASA as an intermediary
  - Example emphasis: global change plus applications research communities, including state and local government and nongovernmental organizations
- Facilitate the interaction of the scientific and commercial remote sensing communities
  - Example emphasis: Provide a mechanism for the scientific community to gain buying power, and efficiencies with minimal strategic direction

RAND

The following charts illustrate three alternative partnership strategies. The first strategy maintains NASA as the central decision-maker and actor in SDB with an emphasis on satisfying NASA's own strategic objectives. The focus of research would be on traditional scientific missions such as global change research that do not have direct practical applications.

The second case illustrates a role for NASA as an active intermediary but with a less central role. The emphasis on global change research would continue, but with a broader focus to include applications research of interest to state and local governments as well as nongovernmental organizations.

Finally, the third case has NASA acting in the role of a data clearinghouse. In this case, scientists would have more direct influence and buying power. Presumably, many would continue existing lines of research, but with more flexibility to change directions and create new cooperative efforts outside of the federal government.

There are many variations on the three approaches described here. However, the decision as to which approach should be taken is predicated on a thorough understanding of NASA's real mission, who is to benefit, and what is likely to be feasible in implementation.

The NASA-Centered Option

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- NASA and ESE scientists determine which data are most needed
  - NASA makes the "build or buy" decision on whether to use government or commercial systems
- NASA operates as a sophisticated consumer in the marketplace to meet its needs
  - Does NASA have market power?
  - How much?
  - How can it be used to greatest advantage?
- Goal is improved efficiency for meeting needs of the Earth Science Enterprise

RAND

The NASA-centered option is to view the Earth Science Enterprise itself as the customer for commercial data purchases. In this approach ESE strategic collection plans drive the data purchase plans. Since the strategic plans are a direct reflection of NASA's own articulated needs, the goal is simply to improve efficiency of data acquisition operations. NASA would not alter its purchasing decisions or the development of government systems in response to non-NASA affiliated researchers.

The first task would be to identify what areas of the ESE strategic plan can best be satisfied by commercial remote sensing data. For instance, if atmospheric chemistry data are needed and can be supplied by commercial sources, NASA would need to clearly signal industry of its interest and be willing to consider commercial options on a par with traditional NASA development programs.

Should a commercial source of the data appear feasible, NASA must next understand its relative position in the marketplace and how its actions may impact the market. That is, NASA should correctly determine its market power and whether or not it has the ability to influence general price levels. It is possible for NASA to pay too much as well as too little for data (thus discouraging supply). Similarly, if NASA "underbuys" data, it forgoes benefits from using the data in research; if it "overbuys," it also suffers a loss by paying for data it does

not need.[33] A significant problem for NASA is acting optimally in the face of institutional pressures that favor internal development efforts, as well as external political and private interest in using what the remote sensing community has to offer immediately.[34]

Another question is how best to use the collected commercial data. Should NASA's strategy be one of "gap filling" in using commercial data to cover areas not requiring specialized, cutting-edge efforts, or should it baseline its plans on the commercial market and only selectively add more exotic collection capabilities as required (or as funding is available)? The option of commercial data acquisition could be used to provide competitive pressures on the development costs of NASA systems. One could imagine issuing a request for proposals to supply data for the Earth Science Enterprise as a whole. NASA would contract to build a government system only after not receiving any responsive proposals to supply data.

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33 See Appendix 1 for a discussion of these issues.

34 The current NASA data acquisition process is frequently driven by the research interests of scientists who have significant intellectual interests in research areas requiring cutting-edge instruments whose construction is in itself a major undertaking. While not a bad thing in itself, it does create conditions unfavorable to using commercial remote sensing data firms, which must take less technical and financial risk in their collection.

Broaden Scope of Earth Science Enterprise

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- Broaden scope of Earth Science research to include more applications (e.g., environmental management) as well as global change science
  - Federal civil agencies, e.g., Interior, USDA, EPA
  - State and local governments
  - Nongovernmental organizations
- NASA operates as a sophisticated consumer in the marketplace
  - For NASA and non-NASA data needs
- Goal is improved efficiency and broader rationale for the Earth Science Enterprise

RAND

A second option broadens the scope of the Earth Science Enterprise to include more application research. This would in turn affect the mission and customers for programs such as the Science Data Purchase Program. In addition to global change research, NASA-supported research would seek to address the needs of other federal agencies using remote sensing data, state and local governments, and even nongovernmental organizations as well as global change studies.

In this approach, NASA would seek to become a sophisticated consumer in the commercial remote sensing market and acquire data that is also of value to non-NASA public agencies. As in the case of NIMA, NASA would compete for government (and possibly nonprofit) clients by adding value in acquisition functions. For example, NASA could secure more favorable licensing arrangements, lowering the transaction costs of dealing with commercial suppliers, and providing technical support to enhance the utility of acquired data and products. NASA could offer data validation and verification services for those agencies not capable of performing these functions in-house.

The ultimate goals of this option are to create a broader rationale for and improved efficiency in the Earth Science Enterprise by using a wider range of remote sensing data sources and products to meet a

wider set of public needs (including, but not limited to, global change research).

Empower Earth Scientists

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- **Facilitate direct interactions of Earth scientists and commercial communities**
  - Enable scientists to gain buying power and efficiencies with minimal strategic (i.e., by NASA) direction
- **Allow scientists to collaboratively determine their data requirements**
  - Ascertain their wants and needs via direct inquiry
  - Acquire data based on previous patterns of demand and usage by the scientific community
  - Establish tracking system for research based on data acquired through SDB to facilitate future planning and purchases

RAND

The last option emphasizes NASA's position as a facilitator and de-emphasizes its role as an intermediary in the process. In this demand-pull approach, it's recognized that centralized organizations often have difficulty establishing the true demand for specific items in a responsive fashion. Consequently this approach attempts to decentralize as much of the decision-making process as possible, while at the same time retaining some centralized control over funding priorities and strategy. NASA would act both as an agent for the Earth science community in terms of obtaining data, while at the same time retaining control of broad directions of research through the control of grants covering research activities.

The scientific community would collaboratively determine their scientific requirements through quasi-market mechanisms or through the direct survey of representative samples of the community—as distinct from asking committees of "representative" scientists what the requirements should be. Funding for data collection would be based on community choices, but NASA would retain an intermediary role in data verification and validation and would provide publicly accountable program management.

Rather than using a centralized approach where NASA attempts to lead the scientific community, NASA would enable scientists to actively

select the data required. Like the second option discussed in the preceding chart, NASA would seek to be effectively neutral in the overall data acquisition process. However, in this option it considers the possibility of being nothing more than a mechanism through which the Earth science community resolves differences, and provides a convenient focal point to facilitate procurement of data. NASA might acquire databases based on broad patterns of demand and usage by other government agencies and NGOs, rather than using just its own agenda for data acquisition. This would require establishing tracking systems to facilitate future data purchase plans. By tracking how data is used, and by whom, NASA would also be in a better position to assess the utility of the SDB program.

Collaborative Options for Data Acquisition

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Quasi-Market Solutions

- Data catalog
  - Lower information costs, potential for quality control standards
  - Creates potential barriers to entry, menu costs
- Vouchers
  - Lower transaction costs, economically efficient
  - Depends on market existence, vendor quality control, information costs, divergence from NASA mission

Cooperatives

- Clearinghouse
  - Depends on vendor quality control
  - Lower information costs, ease of access
- Buying cooperatives
  - Depends on vendor quality control, may exclude some sources
  - Greater market power for buyers

RAND

For the last two options, in which NASA's role becomes less central, there are several specific implementation mechanisms to choose from. One set of mechanisms emphasizes quasi-market solutions and the second emphasizes cooperatives.

As a result of lessons from economics research and the case studies involving public-private partnerships in databases, we identified two candidate quasi-market mechanisms. The first is a data catalog that allows purchasers to order data conveniently from vetted providers. A catalog lowers the transaction costs for buyers and sellers and provides some assurance of data quality by virtue of being selected for inclusion. However, the ability to deny inclusion in the catalog creates a barrier to entry that may result in higher costs by restricting competition. In addition, it may not be necessary or appropriate for NASA to bear responsibility regarding the quality and usefulness of data to knowledgeable end users (e.g., scientists).

The second mechanism is vouchers. These could be issued to affiliated scientists (e.g., those receiving research grants or conducting research of interest to the NASA Earth Science Enterprise) and would be redeemable for remote sensing data and/or value-added products. Thus scientists would directly choose what data they wanted, just as they would purchase other forms of technical hardware and software.

Vendors would be able to redeem the vouchers for cash from NASA or other government agencies. The traditional management role of the principal investigator (PI) would seem particularly suited to the use of vouchers in that the PI would continue to have responsibility for acquiring data, albeit on a larger scale.

Vouchers offer the possibility of efficient transactions, though they depend heavily on the existence of a true market and well-informed consumers. Just as with direct government purchases, it is important for NASA to understand its relative power in the market for remote sensing data and related product prior to proceeding with implementing any specific voucher scheme.

Cooperatives could be created among the potential user communities for remote sensing data. One of the most prominent forms of cooperative is the data clearinghouse. A clearinghouse can lower the transaction costs of matching buyers and sellers of data and lower prices by enhancing buyer market power. Such an organization typically uses a neutral organization for its operation and may depend on the quality control of vendors if it cannot sustain its own validation and verification program.

Buyer cooperatives can similarly lower prices for participants but need not require a neutral organization for its operation. However, the cooperative may have little incentive to acquire data that is not of immediate interest to members; potentially useful sources can be easily overlooked; and coordinating purchases for a very diverse set of clients (such as Earth scientists) can be complex and costly in itself.

Outline

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- Study Background, Motivation, and Approach
- Partnership categories
- Highlights from case studies
- Metrics for evaluating partnerships
- Options for NASA
- **Conclusions**

RAND

CONCLUSIONS

This final section reviews the study approach, highlights the key conclusions, and discusses some policy implications of those conclusions for NASA, the Administration, and Congress.

Review of Study Approach

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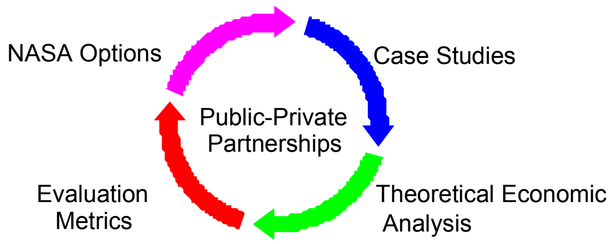

- **Case studies based on literature and interviews**
- **Theoretical economic analysis of cases and NASA's potential market role**
- **Evaluation metrics based on literature, theory, and interviews**
- **Alternative options based on all the above**

RAND

To briefly review, the approach taken in this study was an iterative one. The selection of evaluation metrics and the most appropriate form of public-private partnerships for NASA's Earth Science Enterprise did not result from a single step, but a series of steps.

We began with case studies of a wide variety of public-private partnerships based on literature searches and interviews. The case study phase was followed by theoretical economic analysis of incentives and disincentives for partnerships and the implications of NASA decisions on how it behaves in commercial markets.

Evaluation metrics for partnerships were identified based on existing literature and theory, as well as interviews conducted for the case studies. Alternative options for NASA were developed based on literature, theory, and interviews with scientists and commercial firms involved in the Science Data Buy and the Earth Science Enterprise.

Review of Main Study Questions

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- **What metrics should be used to evaluate partnerships?**
  - *Resource Acquisition, Efficiency, Client Satisfaction, and Goal Attainment*
  - *Effective metric methods are feasible and available*
- **What type of public-private partnerships are most appropriate in using commercial data for NASA's Earth Science Enterprise?**
  - *Quasi-market solutions and Cooperatives*
- **What options are available for the future of NASA's Science Data Buy?**
  - *Depends on defining the customer and mission*

RAND

Returning to the original questions, we have defined and classified public-private partnerships and reviewed several examples selected from the larger set of case studies reviewed. These examples were chosen for the potential applicability of "lessons learned" to NASA's Science Data Buy.

Turning to more specific questions, we found four general metrics that can be used to comprehensively evaluate specific partnerships: Resource acquisition, Efficiency, Client satisfaction, and Goal attainment. Common business and nonprofit metrics are already available for Resource acquisition and Efficiency. We then suggested feasible means of determining Client satisfaction and Goal attainment via simple survey techniques and review of the citation frequency of scientific papers produced using commercial data sources. It should be noted that the use of citation frequencies is appropriate only for the goal of scientific research. If commercial data sources were used for more practical applications, such as natural resource management by federal agencies, other metrics applicable to the goals of those agencies would have to be added. Such metrics would ideally already be in place to respond to the oversight requirements of GPRA.

If public-private partnerships in commercial data and value-added products are to be sought by NASA's Earth Science Enterprise, several

implementing mechanisms can be used. The most promising from the standpoint of efficiency and ability to accommodate diverse interests are quasi-market solutions and cooperatives. These include data catalogs, vouchers, buyer cooperatives, and data clearinghouses.

Finally, we suggest three notional options for the future of the Science Data Buy. The first option retains a tight focus on NASA needs, especially those of global change research within the Earth Science Enterprise. The second option involves expanding the orientation of the SDB to include practical applications, such as supporting the Earth science needs of other federal agencies, as well as basic scientific research. The third option displaces NASA from the center of the SDB process and seeks to place more responsibility and authority with Earth science researchers to secure the data they needed from commercial or government sources.

Choosing among these three options, or many possible variations, depends on defining the mission of the SDB and its intended customers. The choice thus depends on policy considerations and not solely on technical or economic factors.

Who is the Customer?

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- **Current SDB driven by Congress**
  - Depends on committed people within NASA
- **Who are the real customers for the SDB?**
  - NASA, global change scientists, Earth scientists?
  - Public, other civil agencies?
  - Commercial remote sensing industry?
- **NASA has limited flexibility to respond to a dynamic market and changing user needs**
  - May need a nongovernmental organization (e.g., the Space Telescope Institute) as an intermediary
  - Uncertain NASA market position hinders appropriate evaluation metrics

RAND

The Science Data Purchase Program and related legislation contained in the Commercial Space Act indicate that Congress drives current efforts. The program is not a "natural fit" within NASA, as evidenced in part by the lack of widespread awareness of the program within the NASA Earth science community.[35] Implementation of the SDB as an experimental effort has depended on a small number of committed people within NASA.

The SDB has demonstrated that commercial firms are able to provide scientific data and products of value to global change research and the Earth Science Enterprise. However, the policy question remains as to who the real customers are. Is it just global change scientists, Earth scientists in general, or even the public? Is the customer organization NASA, the federal government (including other civil agencies), or organizations of Earth science researchers such as universities and NGOs? To what extent is commercial remote sensing itself a "customer" in the sense that SDB purchases help stimulate and grow this industry? Should the U.S. government seek to help primarily U.S.-based firms and how would that be defined?

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[35] Pace (1999), p. 219.

One of the major economic questions for NASA is ascertaining its relative market power, both overall and in specific sectors of remote sensing. The selection of evaluation metrics for factors such as efficiency and goal attainment depends on knowing whether NASA is a dominant or minor player in the market. (Appendix 1 treats this point in more detail.)

A fundamental organizational challenge for NASA is its limited flexibility in responding to dynamic markets and rapidly changing customer needs for remote sensing. Should NASA decide to expand the range of customers it serves with the SDB program, it may need to create a nongovernment intermediary organization. NASA has already done this in the case of the Space Telescope Institute to manage competing demands for that facility. As with data clearinghouses, it was decided that an organization outside the traditional field centers was needed to assure users of neutrality and fairness. Similarly, consideration is being given to creating a nongovernment intermediary for operation of the International Space Station. A nongovernment intermediary could be created to operate a clearinghouse for data and products from public and private remote sensing sources.

What is the Mission?

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- **NASA needs to clarify the purpose of SDB**
  - Is the mission limited to NASA science requirements for global change research or does it include broader needs of the Earth science community?
- **If the SDB mission is limited, then a supply-push approach may continue to be appropriate**
- **If the SDB mission is broad, then a demand-pull approach may be more appropriate**
  - NASA enables and facilitates but does not control data acquisition via partnerships and quasi-market mechanisms

RAND

The preceding questions on customers, markets, and organization lead to perhaps our most significant observation: NASA needs to clearly articulate the mission of the SDB. Defining the mission makes the treatment of secondary issues on how to best acquire data much easier. If, for instance, NASA identifies its Earth Science Enterprise collection objectives as the primary mission, it might make the most sense to continue with its current supply-push approach. On the other hand, if NASA sees its primary objective as supporting the Earth science community and public in general, then demand-pull strategies and partnering arrangements would be more effective.

Many possible solutions are available to NASA in terms of public-private partnering arrangements. The structure of the arrangements themselves is not critical to success. Rather, the critical factors appear to be having an active, informed user community, mechanisms for that community to signal its preferences to the controlling bodies, neutrality of the management organization, an ability and willingness to adapt over time, and adequate funding and material support.

In actual implementation, the structure of any partnering arrangement is likely to be driven by three main factors. The first is the existence of clear legal authorities for the public partner to enter into contractual relationships. The second is the ability of the partnership organization

to efficiently manage transactions between parties in a cost-effective manner. Finally, the user community must be willing to accept the partnership as equitable, and one that protects their interests over the long term. Of these factors, the last one may be the most challenging issue for NASA and its user community, since it shifts responsibility and authority away from NASA and to the end users. NASA thus becomes an organization that more accurately "enables and facilitates" research as opposed to "conducts and leads" research in the Earth sciences.

Policy Implications

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NASA

Whether the science mission is limited or broad, the ESE requires a complex portfolio of activities:

- **A mix of "doing" science and "enabling" science**
- **Balancing the development of new capabilities versus ensuring the continuity of observations at multiple scales in time and space**

After determining market position, deciding how and when to "build vs. buy" capabilities is the most crucial question:

- **Deciding to use information products and standards used by others outside of the ESE**
- **Deciding to "demonstrate and transition" versus "operate" remote sensing capabilities**

RAND

Both the emergence of commercial remote sensing data and value-added products and the debates over the future of the Science Data Buy have policy implications for NASA and the Earth Science Enterprise in particular. The decision to engage in public-private partnerships and the choice of evaluation metrics depend on strategic choices made for the Earth Science Enterprise as a whole.

Scientifically, the ESE already requires complex measurements that are made at multiple scales and differing time periods. Thus the ESE requires a complex portfolio of activities whether its mission is defined in limited or broad terms. The ESE already deals with difficult questions on balancing the development of new scientific capabilities versus ensuring the continuity and quality of existing observations. Similarly, the ESE also confronts decisions on how it should balance "doing" science via development and operation of unique systems, and "enabling" science via grants and research support to scientists themselves.

With respect to using commercial sources of data and products in the ESE, NASA needs to first understand its market position in areas where use of commercial sources may be usable. Next, NASA should make explicit "build or buy" decisions on developing government-unique systems versus buying from commercial sources. The decision to use data and products from outside the ESE may be difficult for many reasons, such as incompatible standards, lack of research support to use commercial data, or uncertain data validity and calibration. However, these difficulties need to also be balanced against the cost of building and maintaining government-unique systems. A dollar spent on building a spacecraft is not available for data analysis or application.

Unlike NOAA or NIMA, NASA is culturally not an operating agency but rather an R&D agency. In many other areas of the agency, NASA is attempting to shed operational responsibilities in order to focus on R&D and exploration activities.[36] Thus it would seem that a focus on demonstrating and transitioning new remote sensing capabilities would be more in keeping with the future of the agency than operating remote sensing systems for long periods of time.

[36] A private contractor, United Space Alliance, operates the Space Shuttle and NASA is debating whether a private organization should manage commercial uses of the International Space Station.

Policy Implications (2)

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Congress and the Administration

- **Consistent with current national policy and law, a wide variety of options are available**
  - Maintain or modify NASA's role in global change research
  - Create a data clearinghouse as an NGO outside NASA
  - Shift the SDB to other agencies with a more operational culture, e.g., NOAA, NIMA
  - Shift the SDB to agencies with broader user communities, e.g., USGS, NSF
- **The current SDB was a successful experiment in demonstrating the capabilities of commercial vendors**
  - However, continuing the SDB depends on answers to questions about its mission and customers in and outside the Earth Science Enterprise

RAND

The Congress and the Administration will likely need to answer the same questions about the focus of the Earth Science Enterprise, the future of Science Data Buy efforts, and the use and evaluation of public-private sector partnerships.

Within both current national policy and law, many options are available for the Science Data Buy. Assuming NASA's role in global change research remains unchanged, the simplest next step would be to create a nongovernmental data clearinghouse with NASA as one partner. The clearinghouse could offer data catalogs, organize buyer cooperatives, and possibly serve as a vehicle for experimentation with data vouchers.

Alternatively, the SDB effort could be continued, but with more of a focus on immediate public sector applications, not basic science. This might then involve shifting the SDB to agencies with more of an "operational" culture such as NOAA or NIMA. NIMA may be particularly promising as it already has a large effort underway in the Commercial Imagery Program. The needs of civil agencies such as the Department of the Interior and the Environmental Protection Agency might be met through cooperation with NIMA or NOAA-sponsored data clearinghouse. NIMA is experienced in practical applications of remote sensing while NOAA has had a great deal of experience in working with civil and commercial users of remote sensing data for meteorological and environmental research purposes.

The SDB might also be continued at agencies that serve very broad user communities, such as the U.S. Geological Survey or the National Science Foundation. In this case, the focus would be on serving the needs of end users, scientists in the public or private sectors, without much in the way of central direction. The SDB would be wholly "market driven" rather than directed to serve a specific set of government missions. Unfortunately, the relatively small budgets of these agencies would likely make it difficult to accommodate a major new initiative focused on remote sensing applications.

The current SDB has been a successful experiment in demonstrating the capabilities of commercial remote sensing vendors. The policy frameworks, structural mechanism, and evaluation tools are available to pursue further public-private partnerships. However, the continuation of the SDB depends on answering strategic questions about its mission and customers inside and outside the Earth Science Enterprise.

Afterword

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Significant events since the study was completed:

- **Stennis Space Center designated Lead Center for Earth Science Enterprise Applications**
  - June 30, 2000
- **USGS Business Partners Program**
  - Firms agree to purchase a minimum of $50K of Landsat imagery over 2 years and improve or distribute the data
  - 15 companies listed on USGS website - August 2000
- **FY01-02 NASA authorization creates a $25 million per year Earth Science Data Buy program**
  - NASA can opt out if 5% of EOS and Pathfinder funds are already used for data purchases
  - Passed by Congress in September 2000

RAND

Since this study was completed in March 2000 and its publication, there have been some significant events related to the purchase of science data. First, the Stennis Space Center, where the Science Data Buy is managed, was designated the lead NASA center for Earth Science Enterprise applications. Applications in this instance mean practical uses of ESE data for commercial and civil government purposes (e.g., natural resource management, disaster management, and urban planning). This may encourage more links between NASA and other civil government agencies that use remote sensing data.

Second, the U.S. Geological Survey formed a Business Partners Program to include firms that agree to purchase a minimum of $50,000 of Landsat 7 data over 2 years and agree to improve and/or distribute the data more widely. In return, participating firms are listed on the USGS web site and provided one-on-one staff assistance from USGS. As of August 2000, about fifteen companies from the United States and overseas were part of the program. This program may be considered a type of buyer cooperative where the firms seek to leverage their buying power with the USGS in terms of greater attention from USGS staff and potential customers as opposed to getting more favorable prices. In this case, government regulations limit prices to the marginal cost of reproduction and dissemination with limited freedom to negotiate.

Lastly, the Congress included a report provision in the Fiscal Year 2001–02 NASA authorization bill that creates a $25 million per year commercial data buy program for the Earth Science Enterprise. NASA can opt out of doing this if it can show that it is already spending at least 5% of its budget on purchasing data for its Earth Observing System and Pathfinder missions. For fiscal years 2001–02, that sum would be about $25 million per year as well. The Congress passed the NASA authorization in September 2000 as H.R. 1654. This provision was contained in Section 125 of the accompanying conference report. While this is an indication of the continuing interest of the Congress in purchasing science data, the mission and customers for such data purchases within the Earth Science Enterprise remain unresolved.

APPENDIX 1: THE VALUE OF UNDERSTANDING NASA«S MARKET POSITION

Ascertaining NASA's Market Position

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Data over 2-3 years needed to test market position

- **Information required:**
  - Quantities of data purchased
  - Grants awarded
  - Other research inputs acquired
  - Total amount spent on research by NASA

Regression model

- **Total research budget regressed on costs and data**
- **Look for significance of squared data term**

$$TC_t = \alpha + \beta_1 Q_t + \beta_2 Q_t^2 + X_t \gamma + : \varepsilon_t$$

RAND

This chart outlines an empirical method for ascertaining NASA's market position as a buyer of remote sensing data. This appendix discusses the development and significance of this approach to NASA purchases of commercial remote sensing data.

Why NASA«s Market Position Matters

The rationale for the model, as well as the technical details for its form, is presented below. In the market for remote sensing products, NASA is either:

(A) a small customer in a self-sustaining commercial market, or

(B) a majority (or sole) customer.

There are two possible dangers here. First, NASA may think (or want to pretend) it is a small player while in reality it is the major customer.

Second, it may think it is the major player when in reality the market is competitive among buyers.

Analysis

We can model the ill effects of such misunderstandings by assuming that NASA has some sort of a value function ***V(Q)***, where ***Q*** is the amount of remote sensing data it purchases. This function has two parts: the benefits from more information, ***f(Q)***, and the cost, ***P·Q*** (that is, the price it pays per unit times the amount it purchases). We may assume that NASA experiences diminishing marginal value in ***Q***—that ***f*** increases at a decreasing rate—so $f' > 0$ and $f'' \leq 0$ for all values of ***Q***.[37]

Readers may complain at this point that this framework in which there is just one input to production (data) is unrealistically simple. In reality, there are many inputs to the benefits ***f***(***Q***). Further, the different inputs react with each other such that the derivatives of the benefit function with respect to one input depend not only on that input, but on the value of the others as well. For example, we may require both data ***and*** processing equipment, and increasing one without the other will not increase the overall level of benefit. The note at the end of this appendix explains how this circumstance does not affect the outcomes predicted by the simple model.

The value function can be written as:

(1) $$V(Q) = f(Q) - PQ,$$

And hence NASA's problem is defined as:

(2) $$\max_{Q}\{V(Q)\}.$$

The form of the first-order condition depends on whether NASA is large or small. If it is small, then it cannot affect the market price by its actions. Hence, $P = P_m$, a constant (from NASA's point of view). The first-order condition is then:

(3) $$\frac{dV}{dQ} = f'(Q) - P_m = 0,$$ and NASA's maximum value is

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[37] These assumptions provide for quasi-concavity of the benefit function and a unique global optimum.

(4) $V_S^* = f(Q_S^*) - f'(Q_S^*)Q_A^*$.

If NASA is large, then its actions will affect the market price—greater purchases will push up the price (i.e., it has some monopsony power), so $P = P(Q)$, where $P' > 0$. Its first-order condition is therefore:

(5) $\frac{dV}{dQ} = f'(Q) - P'(Q)Q - P(Q) = 0$, and NASA's maximum value is

(6) $V_L^* = f(Q_L^*) - Q_L^*\left[f'(Q_L^*) - Q_L^* P'(Q_L^*)\right]$.

Comparing (4) and (6), we can see that at any value of Q, situation (B) always dominates (A) in value for NASA. Thus it's good to be big. However, this is in no way meant to imply that NASA's optimal strategy should be to prevent the development of a market on the demand side. First, to try to do so would likely be an exercise in futility. If the natural demand-side market were a large one in which NASA were small but tried to distort it such that other buyers were excluded (via restrictive contracts, for example), the lost profits would likely lead sellers' simply to ignore or exclude NASA. And if it created economic incentives for firms not to exclude it under these circumstances, this would have to take the form of a potentially huge voluntary overpayment for remote sensing products, thus negating the monopsonistic gains in the first place. Second, if NASA were able—through legal means—to prevent the formation of the naturally large market, NASA's relative smallness as a customer—even in the absence of other buyers—would probably make production of these products infeasible by sellers (in the absence of large voluntary overpayments), meaning that no market would develop at all. In other words, being a monopsonist is advantageous—indeed, much better than being a small, competitive customer—but only when it occurs exogenously. NASA's policy objective is properly ***not*** to try to bring this about, therefore, but rather to ascertain its naturally occurring market position and to act optimally with respect to that position.

The problem arises when NASA is confused about its market position; when it consumes Q as if it were small while it is really large, or vice versa. Making one more mild assumption about the behavior of price, $P'' < 0$, we can prove that it will never attain its maximal value and may even accrue a loss. This point becomes apparent when we note that $V_S(Q_S^*)$ and $V_L(Q_L^*)$ are global maxima from the positive values of the

second derivatives of (3) and (5), so $V_L(Q_L^*)$ > $V_L(Q_S^*)$ and $V_S(Q_S^*)$ > $V_S(Q_L^*)$.

To demonstrate this, assume the plausible functional forms $f(Q) = Q^\alpha$ where α <= 1[38], and $P(Q) = Q^\beta$ where β > 0. Then, substituting into eq. (1):

(7) $$V(Q) = Q^\alpha - P_m Q$$

if NASA is small, or

(8) $$V(Q) = Q^\alpha - Q^\beta Q$$

if NASA is large.

The first-order condition for (7) yields:

(9) $$Q_S^* = \left(\frac{P_m}{\alpha}\right)^{\frac{1}{\alpha-1}}.$$

The first-order condition for (8) yields:

(10) $$Q_L^* = \left(\frac{\alpha}{\beta+1}\right)^{\frac{1}{\beta-\alpha+1}}.$$

Results

If NASA thinks it is in A (a big market exists) while it is actually in B (it is a monopsonistic buyer), then the equilibrium value will be attained when (9) is (inappropriately) combined with (8) and :

(11) $$V_L(Q_S^*) = \left(\frac{1}{\alpha}\right)^{\frac{\alpha}{\alpha-1-\beta}} - \left(\frac{1}{\alpha}\right)^{\frac{\beta+1}{\alpha-1-\beta}}.$$

On the other hand, if it had correctly assessed its situation and consumed Q_L^*, it would attain value

(12) $$V_L(Q_L^*) = \left(\frac{\alpha}{\beta+1}\right)^{\frac{\alpha}{\beta-\alpha+1}} - \left(\frac{\alpha}{\beta+1}\right)^{\frac{\beta+1}{\beta-\alpha+1}}.$$

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[38] This parameter value range maintains the assumption that preferences are convex.

If NASA thinks it is large (no outside market exists) while it is actually small (there are many buyers in competition), then the equilibrium value will be attained when (10) is combined with (7):

$$(13)\qquad V_S\left(Q_L^*\right)=\left(\frac{\alpha}{\beta+1}\right)^{\frac{\alpha}{\beta-\alpha+1}}-P_m\left(\frac{\alpha}{\beta+1}\right)^{\frac{1}{\beta-\alpha+1}}.$$

On the other hand, if it had correctly assessed its situation and consumed Q_S^*, it would attain value

$$(14)\qquad V_S\left(Q_S^*\right)=\left(\frac{P_m}{\alpha}\right)^{\frac{\alpha}{\alpha-1}}-P_m\left(\frac{P_m}{\alpha}\right)^{\frac{\beta}{\alpha-1}}.$$

It is easily proven that for all values of α, β, and P_m, $V_L\left(Q_L^*\right) > V_L\left(Q_S^*\right)$ and $V_S\left(Q_S^*\right) > V_S\left(Q_L^*\right)$. Figures 1 and 2 explore the value space with respect to these parameters.

Figure 1. NASA is a small buyer: Value changes as P_m changes

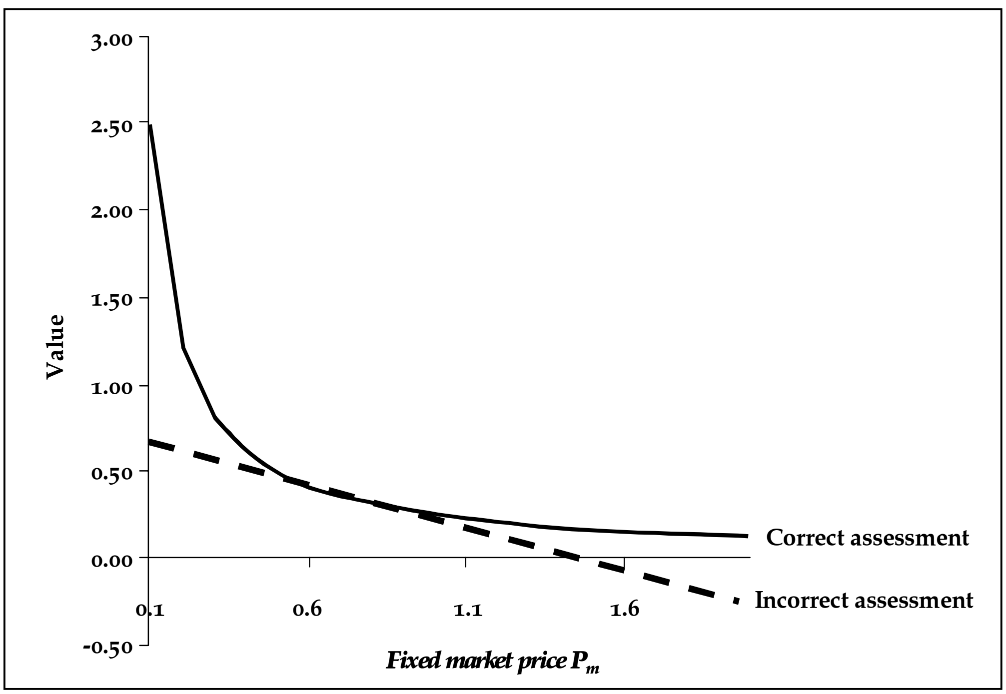
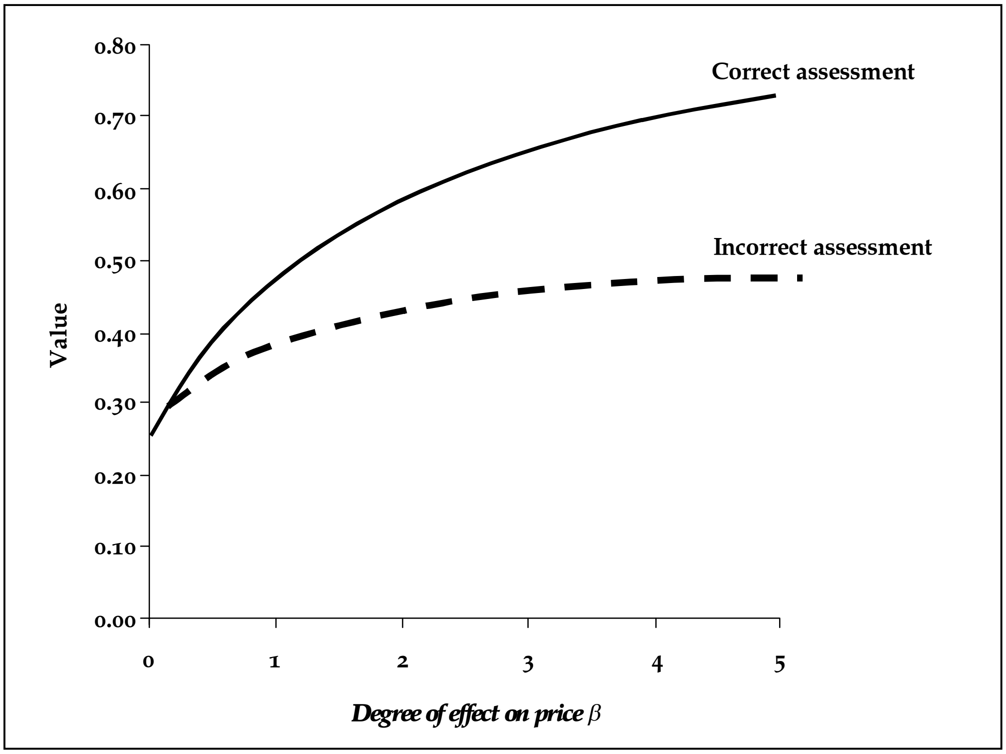


Figure 2. NASA is a small buyer: Value changes as α changes



Testing

Having established the need for NASA to understand its true market position, we now describe the data needed and necessary tests for finding this out.

The data needed consist of monthly time series of information on quantities of data purchased, grants awarded, and other inputs acquired over 2-3 years, as well as the total amount spent on research by NASA.

The following regression should indicate whether NASA's purchases of data have an effect on the price of data:

(15) $TC_t = \alpha + \beta_1 Q_t + \beta_2 Q_t^2 + X_t \gamma + \varepsilon_t$, where

TC_t = the total amount spent on research in period t

Q_t = the quantity of data purchased in t

Q_z^2 = a quadratic term for data purchased

X_t = vector of characteristics of grants awarded and other inputs purchased at t.

The interpretation of (15) is straightforward. We can plausibly assume that total cost will rise with the quantity of data purchased, so we expect $\beta_1 > 0$. However, the effect that NASA's purchases have on the price will be reflected in β_2. If this coefficient is significant and positive, we may interpret this as saying that as NASA purchases more data, TC rises at an increasing rate, meaning that price is being bid up. On the other hand, if β_2 is insignificantly different from zero, we may reasonably conclude that NASA is not affecting price with its purchases.

Conclusions

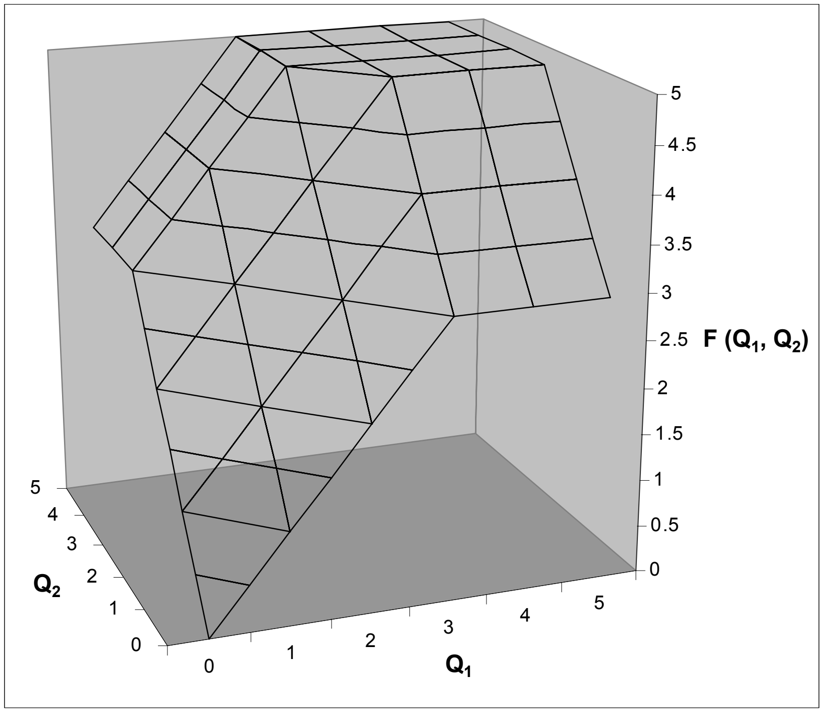
The point of this analysis is that given a plausible metric for valuing remote sensing data—one that follows standard microeconomic principles and makes a minimum of restrictive assumptions—we can see that NASA *always* has an interest in assessing its buying position accurately. Not doing so will inevitably lead to a loss, and under certain parameter values this loss can be huge.

Note on the effects of adding multiple, related inputs to the model

In reality, the benefits NASA gets from increasing remote sensing data are not a smooth, increasing function as in the example used above. Rather, there are several inputs to this benefit, and their individual contribution to the total benefit almost certainly depends on the value of the other inputs. For example, we might expand the simple model to say the inputs are data (Q_1) and processing capability (Q_2), and that at certain levels, data acquisition can be increased without any positive impact on benefit at all if processing ability is not increased. This situation is depicted in Figure 3.

There is a simple reason why this plausible complication to the model does not affect the results: All we assumed was that the first derivative of the benefit function with respect to the inputs was *nonnegative*, $f'(\cdot) \geq 0$. Thus, if we are comfortable with the assumption that, while adding data might add to cost, it will never decrement benefit (as in the example above), we have not posed anything troublesome for our central results.

Figure 3. A ƒclumpy≈ or multi-benefit function



APPENDIX 2: THE NOAA-MAPTECH CRADA

This appendix contains a detailed case study of a successful and evolving partnership, the NOAA-Maptech Cooperative Research and Development Agreement (CRADA), that offers useful lessons for NASA ESE's science data buy (SDB). We include it to illustrate the many different factors that go into creating a public-private partnership involving geographic data and analyses.

NOAA and Maptech have an innovative partnership to produce electronic nautical charts. Using a CRADA mechanism, the private company Maptech now produces and sells CD-ROMs containing electronic nautical charts, which used to be available only in paper format through NOAA. This CRADA offers useful insights about public-private partnerships because it has combined the incentives of the marketplace with government expertise and requirements to provide a better service to the public as well as benefits to industry.

Nautical Charts

A nautical chart is a fundamental tool of marine navigation. Such a chart shows water depths, aids to navigation, obstructions, traffic control schemes, and other information critical to the safe and efficient use of the nation's waterways. NOAA is required to produce such charts. The Office of Coast Survey, National Ocean Service (NOS) in Silver Spring, Maryland, produces nautical charts. This office has been tasked with the compilation and maintenance of charts for the safety of marine navigation and to support marine commerce in the United States. Certain high-risk and high-value vessels, such as large vessels over 1600 tons, are required by maritime law to carry these nautical charts for safety reasons. More specifically, these official charts ensure that mariners have the best available information and that vessels sharing restricted waterways have the same information when they make critical navigation decisions. Most of the shipping and boating marketplace, 99%, is not required by any law to carry these nautical charts because of the large number of smaller and noncommercial vessels. However, many of these vessels also carry them because of their usefulness and safety benefits.

Electronic charting systems are revolutionizing marine navigation and improving safety. For instance, electronic charting allows for faster updates than traditional paper charting methods. NOAA pioneered the

development of standards for the Electronic Navigational Chart (ENC) and the Raster Nautical Chart (RNC). The ENC is a database of charted items while the RNC is an electronic picture of an existing paper chart. Private companies started making electronic versions of NOAA paper charts for the 99% of the unregulated marketplace. NOAA wanted to develop ENCs and RNCs and considered many different mechanisms, including contracting, free distribution of data to anyone wanting to make a product, and certifying private products. However, NOAA's NOS didn't receive any additional manpower or dollars to provide this new electronic chart production service. Due to concerns about the costs associated with providing this additional service, NOAA examined public-private partnership options and decided to implement a unique Cooperative Research and Development Agreement (CRADA), which would essentially cost the government nothing. The CRADA was selected because it offered the greatest flexibility to meet evolving needs at the lowest risk and cost to the taxpayer. It also was the first CRADA at NOAA.

How the Partnership Works

Under the CRADA between NOAA and Maptech, the company has exclusive access to NOAA digital chart data and certain technology, such as patented image compression processes for updating raster charts. A CRADA protects selected data, including government data, from the Freedom of Information Act (FOIA) and this enables the private sector to collaborate with government in R&D and earn a fair profit from their efforts.[39] In exchange for such exclusive rights, Maptech must produce all charts that meet NOAA standards (not just the profitable ones); issue new editions when NOAA does; provide an update service; make the results openly available to all at an affordable price; and must do so in perpetuity.[40] Maptech produces and sells CD-ROMs of the electronic charts called Chartkits. Maptech, at its own risk and expense, makes these official ENCs and RNCs in collaboration with NOAA and profits or loses in the marketplace based on sales. In marketing the Chartkits, Maptech effectively takes advantage of the

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39 Under a CRADA, the data are protected from FOIA for 5 years. Therefore, any NOAA nautical chart data that are 5 years or older can be accessed by any U.S. citizen through an FOIA request.

40 The NOAA-Maptech is a 4-year agreement that is automatically extended for another 4 years and so forth indefinitely unless either party officially chooses to terminate the agreement when it comes up for renewal.

NOAA brand name. However, the current legal requirement for ships is still the NOAA paper charts. The legal acceptance and official standards for electronic charts have not yet been established and is subject to international negotiations at the International Maritime Organization (IMO).

NOAA has negotiated a cap on the retail price of the electronic chart products. NOAA also receives an R&D co-payment from all sales of these products. These R&D co-payments are used only to fund NOAA R&D on electronic charting. NOAA receives 5% of the gross sales of all electronic chart products, which amounts to about $120,000 per year.

Maptech had to be more creative than the government would have been to make electronic chart production commercially viable. Therefore, Maptech has expanded the functional value of and the commercial market for the electronic charts. First, Maptech has added value to the NOAA charts in the final product by adding additional features and capabilities, such as place names on the charts, and is in the process of adding digital orthophoto quadrangles (DOQs) to the charts to include visual reference. A DOQ is a computer-generated image of an aerial photograph in which displacements caused by camera orientation and terrain have been removed. A DOQ's visual image is combined with the nautical chart to make a more useful chart product. Second, Maptech creates frequent updates and upgrades of the product that increases demand and generates sales of the revised products to existing as well as new customers. Weekly chart updates are available through the Internet. Third, Maptech has developed a network of over 100 registered Value-Added Developers (VADs) to provide software to go with the electronic chart products. These VAD companies develop, produce, and sell special market navigation software that uses the chart databases. For instance, a VAD may create a special software system using the charts for the kayaking or fishing market. By developing such new specialty products the chart products are being sold in new niche markets. VADs are partners in technology development and have equal access to chart products. As of summer 1999 over 30 VAD products were on the market. These software developers are able to produce navigation software in a less risky environment because they are guaranteed the availability of high-quality, affordable, consistent format and official data coming from the CRADA.

The retail price for a Chartkit CD-ROM is $199.95 per region, and each CD contains about 55 charts per region depending on the size of the region, which works out to a price of about $3.60 per chart. The charts cover coastal and oceanic regions throughout the world. For instance, the U.S. East Coast is covered by 5 CD-ROMs, and the Chesapeake Bay, Delmarva Peninsula area is a CD-ROM consisting of over 50 charts. An individual electronic chart on a disk costs $14.95 each. NOAA's paper charts cost about $15.65 each. Paper chart sales have remained steady. However, as of summer 1999, the electronic charts were outselling paper charts 8 to 5, even though very large ships were still legally required to carry the paper charts for official navigational purposes. Given the increase in sales of the electronic charts compared to paper, the electronic charts are likely reaching new users, such as recreational boaters, and thereby, likely increasing public safety. Another reason ships find the electronic charts more useful is because they provide electronic positioning on electronic chart capability. Mariners can use the electronic charts with a GPS receiver to plot exactly where they are on the electronic chart in real time. With the paper charts and a GPS receiver they have to plot their location on the nautical chart by hand.

Hundreds of small retail chart sales agents are the official retailers of NOAA's paper charts. They receive the paper charts at a 40% discount and also now sell Maptech's CD-ROMS and the accompanying VAD software. For these CD-ROMs they receive a 35% discount or more, depending on what sort of deal they work out in the flexible commercial marketplace with Maptech. Some of these agents also give discounts to consumers, such as offering a 10% discount so that a CD sells for around $180. These agents were originally opposed to the CRADA but now generally support it because they have also benefited from the agreement. They have additional products to sell—the CD-ROMs and the accompanying software products—that have a higher profit margin than the paper charts.

This CRADA represents a collaborative process that has improved NOAA's R&D and enhanced the technology transfer of government R&D. In this partnership, the government (NOAA) performs fundamental research while the commercial sector (Maptech) performs process research and development. Namely, NOAA performs the applied research (by NSF definition) while Maptech performs the process engineering and development to make the product marketable. An example of this collaboration is the development and use of a process for updating the digital files electronically. NOAA had developed an algorithm and format by which old digital files can be compared pixel by pixel with new ones and then electronically updated, along with developing the compression technology by which this process can easily be distributed. Maptech made this pixel by pixel comparison process commercially viable. With this enhanced process, mariners can easily update their own data files. NOAA and two other organizations had developed basic formats and algorithms for this process. Maptech tested these three methods with their VADs and clients to choose the best format for the marketplace. NOAA's format was chosen and Maptech validated it and made it into a useful product. NOAA has a patent pending for this algorithm and compression process that will be licensed to Maptech.

Maptech gives ongoing market and demand feedback to NOAA that its researchers use in R&D. For example, Maptech keeps NOAA informed about the need to gather additional data or process the data in a different way given the market demand. In addition, Maptech suggests different information that NOAA could provide to incorporate into the chart products. For instance, Maptech suggested NOAA provide Maptech with its electronic information about marine sanctuaries because the general boating public would be interested in this information. Maptech has incorporated marine sanctuary information into the product, which provides additional value and helps NOAA in its educational mission to distribute information about the marine sanctuaries. A similar example is Maptech's request for the electronic Coast Guard "light list" from NOAA. This database contains all the Coast Guard information about buoys, range lights, etc. Maptech incorporated this database into the chart product, which enhances the product by providing additional safety information. We should note that NOAA would provide this electronic database to anyone requesting it, because it is not protected under the NOAA-Maptech CRADA from FOIA.

Impact on Federal Agencies and Other Interests

NOAA's paper charts have always been sold to other federal agencies at a discount rate. Federal purchasers include the Navy, the Coast Guard, and the Army Corps of Engineers. They still receive the paper and the electronic charts at discount prices, and all parts of NOAA receive paper charts free from the Office of Coast Survey NOS. However, all parts of NOAA, except for the Office of Coast Survey, which produces the paper charts, must now pay for the electronic charts. Some NOAA program managers were initially upset about having to pay for the electronic charts. However, they have recognized the efficiency in having the cost of the charts transferred to the users, i.e., user fees, rather than being subsidized by the Office of Coast Survey. In addition, NOAA saves a significant amount of money because it does not have to produce the electronic charts. NOAA estimates it saves more than $3 million per year and more than 12 government full-time equivalents (FTEs), which would have been needed to perform the same electronic chart production, marketing, and sales functions that Maptech performs. This estimate is based on the amount that the private company spent during the first year to develop, manufacture, and market this product.

Because of the unique military requirements regarding navigation, NIMA and the Navy have always made their own paper charts and they now make their own digital charts. However, Navy ships purchase the NOAA paper charts and Maptech CD-ROMs for planning purposes.

NOAA considered many different options to produce the digital charts before deciding on a CRADA. For instance, it looked at producing the digital charts and making them available free over the Internet. However, this service would have cost the government a significant amount and other data producers objected to free NOAA data because free data would put them out of business and the retail chart agents did not want to lose their chart product sales. The CRADA seemed the best option to balance many different interests. However, a few companies have objected to this CRADA on the grounds that it established a monopoly. It certainly gives Maptech a competitive advantage with the official NOAA brand name associated with the data in its products. However, there are four producers of raster charts and four producers of vector charts beside Maptech. Other companies with innovative electronic charts can enter the market at any time so it is not legally a monopoly. Given current technologies, such competitors can easily scan NOAA's paper charts to develop their own electronic data products. In addition, with over 100 VAD licensees and 600 retailers, many different companies are participating in and benefiting from this agreement.

There are clearly benefits to this agreement, but often such agreements involve some trade-offs and disadvantages, even if minor ones. In this case, the question arises whether the public may have benefited even more if this partnership agreement did not grant Maptech exclusive rights to the data forever. For example, if the agreement stated that after 6 years the nautical chart data, even current data, would be available to anyone, then in 6 years competition might result in reduced prices and more availability of the products throughout the world. However, one can counterargue that a private sector company would not have been willing to enter such an agreement or else not invested so fully in the product under such conditions.

One company, Delorme, did sue under FOIA, in Maine, in an attempt to get the electronic chart data from NOAA. This company makes maps and atlases, wanted to get into the nautical charting business, and felt it should be entitled to the same electronic NOAA data that Maptech was using. However, this company lost its suit, and the court upheld the CRADA giving exclusivity to Maptech for the use and distribution of the NOAA electronic chart nautical data. In addition, two Italian companies that make a digital nautical charting product have been directly lobbying in the U.S. government and indirectly through the International Maritime Organization against the NOAA-Maptech CRADA because they seem to want the elimination of this U.S. competitor.

As part of their ongoing R&D process, NOAA has developed electronic nautical chart standards in cooperation with other government charting agencies. These standards are used throughout the NOAA-Maptech partnership process. The IMO has adopted these NOAA standards for digital nautical charting. After standards are developed by the IMO, the International Electro-Technical Committee (IEC) provides testing for such standards. Once the IEC finishes this testing development process, then the U.S. Coast Guard will most likely change the National Chart Carriage regulations so that the digital charts produced to this standard, such as the Maptech products, will become legally acceptable on ships for navigation. Namely, the electronic charts will be accepted under maritime law for navigational purposes in place of the paper charts.

Differences between Government and Industry

Government and industry have very different cultures and incentives, which can make it difficult to develop effective public-private partnerships that benefit both sides. Culturally, industry has more flexibility while government has more restrictions on what it can do and how. In addition, government's timelines to complete tasks often are slowed by bureaucratic requirements while acting quickly to gain competitive advantage in the marketplace is key within industry.

NOAA's measure of success regarding navigation charts is meeting mission requirements to produce a quality product that focuses on maximum distribution and inclusiveness, while Maptech's measure of success focuses on profitable sales of products. The NOAA-Maptech CRADA was able to overcome such differences to meet both government and industry's success criteria. In addition, both were able to structure their partnership agreement in a way that took advantage of the different strengths of their individual organizations and cultures. For instance, NOAA's cultural orientation was to target coastal managers and scientists and fulfill its mission requirement of producing charts and making them widely available. NOAA did not at first consider other parties' interests or unique needs for such charts, while Maptech thought more broadly about potential consumers and the marketplace, such as targeting commercial and recreational boaters in its product development plan. Maptech recognized that the marketplace was fragmented and that to make the chart production profitable, the marketing plan must enable customization for the unique niche markets, which led to the VAD agreements. Maptech also quickly changes the product to meet user's needs, which NOAA would not have likely done had it produced the electronic charts. Thereby, the charts are most likely reaching a wider audience and more quickly than they would have if NOAA had produced the charts without industry help, and Maptech has a profitable product.

Summary of Benefits

This partnership has produced a range of benefits for industry, the government, and the public, including:

1. The raster charts are widely available, of high quality and affordably priced.

2. Value has been added to government data, namely, government data has been turned into more useful and widely available information.

3. The nautical chart product is self-supported from sales rather than being taxpayer subsidized.

4. The collaboration process has enhanced NOAA R&D. This enhancement includes both the real-world feedback from Maptech and the additional funding from this R&D co-payment from product sales.

5. The sale of charts has increased, which has probably resulted in a wider use of the navigation charts and most likely increased public safety.

6. The commercial production of the electronic chart products and the accompanying VAD software has resulted in increased commercial sales for a number of different commercial firms.

The partnership has achieved its mission and been a success[41] both for government and the private sector. To summarize the main outcomes:

- Government meets its important safety-driven regulatory functions, namely, NOAA's charting mission requirements.
- The private sector adds value and makes a profit at the same time, namely, Maptech meets its business mission.
- The CRADA has fulfilled its mission to advance technology.
- New VAD software development is financed.

Lessons Learned/Insights for NASA Commercial Partnership Efforts

The NOAA-Maptech partnership focused on creating a useful information product, not exclusively on data or technology. It is important for those involved in the NASA ESE Science Data Buy, both government and industry, to recognize that possible products are not just data, but also information. Turning remote sensing data into useful information is what ultimately matters to scientists as well as other potential users and purchasers of such data. Focusing on useful information rather than data opens the door for a wider range of approaches and possibilities in selling and using such data.

In the NOAA-Maptech CRADA, the commercial sector made sure the CRADA was focused on creating information useful to as broad a marketplace as possible. Maptech recognized the many special niche markets and set up the VAD agreements to help target them. The NASA Science Data Buy, also has wide range of potentially useful niche markets. A critical question is how could the NASA Science Data Buy partnerships be structured to help take advantage of them?

Understanding the different incentives and cultures of government and industry and how to take advantage of them was key in the NOAA-Maptech partnership. Among the questions for NASA and the SDB are:

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[41] Success here refers to the numerous beneficial outcomes from this agreement for the public, government, and the private sector. It does not mean that the agreement necessarily maximizes public good. The public certainly benefits in many different ways. However, theoretically the public may have benefited even more if an agreement had been reached that helped foster more competition in the private sector, namely, an agreement that did not give Maptech exclusive access to the NOAA data forever.

- **What are the different cultures and incentives of NASA, commercial companies, and the scientists in the SDB?**
- **How might the SDB evolve to accommodate and take advantage of the different organizational strengths and interests?**

APPENDIX 3: PARTNERSHIP CASE STUDIES

The following summary descriptions cover each of the case studies. Figure 4 (on p. 137) shows how many case studies were examined for each general type of partnership.

Four key implementation dimensions were examined in each of the partnership cases: organizational structure (e.g., combinations of teams, collaborations, and markets), services provided, management approach (e.g., centralized or decentralized), and price and cost mechanisms employed (e.g., free, fixed price, subscription, bulk rates).

Partnership Name	Summary Description
ABI	In summer 1999, the Association for Biodiversity Information (ABI) officially started supporting and representing the Natural Heritage Network. ABI is a new international conservation organization created by a collaboration of more than 70 Natural Heritage Programs, Conservation Data Centers, and similar programs spanning the Western Hemisphere. ABI's mission is to unify, support, and represent the network of Natural Heritage Programs, Conservation Data Centers, and other cooperators in the mission of collecting, interpreting, and disseminating ecological information critical to the conservation of the world's biological diversity. The Association helps the independent data centers to meet local needs and to operate as a network; to share resources and expertise; to cooperatively develop methods, protocols, and systems; and to make quality biodiversity information more accessible and useful. For more information see http://www.abi.org/AboutABI.cfm#Overview
Allegheny GIS Consortium	Allegheny GIS Consortium is an NSDI 1997 Cooperative Agreement Program project. The project goal was to identify a source for GIS information and a forum for GIS communication in western Pennsylvania.

CA NDDB	The California Natural Diversity Database (CA NDDB) is the State Heritage Program for the state of California. The Wildlife and Habitat Data Analysis Branch, Habitat Conservation Division, in the California Department of Fish and Game runs the database. The Natural Diversity Database (NDDB) is a statewide inventory of the locations and condition of the state's rarest species and natural communities. For more information see http://www.dfg.ca.gov/whdab/
California Teale Data Center	The Stephen P. Teale Data Center, a California state department within the Business, Transportation and Housing Agency, was created more than 10 years ago to provide data and information services for state agencies. California Teale Data Center has a GIS Solutions Group, which serves as a geospatial data clearinghouse for the state. For more information see http://www.gislab.teale.ca.gov/
CIESIN	The Center for International Earth Science Information Network (CIESIN) was established in 1989 as an NGO to provide Earth science information to scientists, decision-makers, and public citizens. Now CIESIN is associated with a research center at Columbia University. CIESIN provides global and regional network development, science data management, decision support, and education and technical consultation services. For more information on CIESIN see http://www.ciesin.org/index_text.html
Cornell University Geospatial Information Repository (CUGIR)	Cornell University Geospatial Information Repository (CUGIR) is a geospatial clearinghouse for New York State that specializes in providing environmental information.
Environmental Technology Verification (ETV) Program	The U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program consists of twelve different public-private partnership pilots that are designed to verify the performance of innovative technical solutions to problems that threaten human health or the environment. For more information see http://www.epa.gov/etv/

EROS Data Center	The Earth Resources Observation Systems (EROS) Data Center is a data management, systems development, and research field center for USGS National Mapping Division. EROS Data Center's main clearinghouse function is to store, process, and distribute a variety of data, mostly federally funded remote sensing land datasets. For more information on EROS Data Center see http://edcwww.cr.usgs.gov/eros-home.html
ETV: Advanced Monitoring Systems pilot	The Advanced Monitoring Systems pilot is an Environmental Technology Verification (ETV) Program partnership between the U.S. Environmental Protection Agency and Battelle (an NGO). Initially it focused on verifying commercially-ready advanced air emissions and water monitoring systems including both on-site and remote monitors.
ETV: Air Pollution Control Technologies	The Environmental Technology Verification (ETV) Program Air Pollution Control Technologies pilot is a partnership between the U.S. Environmental Protection Agency and the Research Triangle Institute (an NGO). This partnership is focused on verifying commercially-ready air pollution control technologies with an initial focus on NOx, fine particulates, and volatile and semivolatile organics.
ETV: Drinking Water Systems	The Drinking Water Systems pilot is an Environmental Technology Verification (ETV) Program partnership between the U.S. Environmental Protection Agency and NSF International (an NGO). This pilot is verifying commercially-ready packaged drinking water systems for small community water supplies. These systems include membrane, disinfection, and other mechanical filtration technologies; and chemical-physical processes technologies.

ETV: EvTEC Pilot	**EvTEC is the independent private sector approach to verification for the Environmental Technology Verification (ETV) Program. It is a partnership between the Civil Engineering Research Foundation (an NGO), and the U.S. Environmental Protection Agency. Technology focus varies and includes everything from de-icing technologies to a new treatment process for wastewater sludge.**
ETV: Greenhouse Gas Technology	**The Greenhouse Gas Technology pilot is an Environmental Technology Verification (ETV) Program partnership between the U.S. Environmental Protection Agency and Southern Research Institute (an NGO). Its purpose is to verify commercially-ready air pollution control technologies that prevent and control greenhouse gas emissions, such as a fuel cell technology.**
ETV: Indoor Air Products	**The Environmental Technology Verification (ETV) Program Indoor Air Products pilot is a partnership between the U.S. Environmental Protection Agency and Research Triangle Institute (an NGO). In this pilot, indoor-air related products are tested to verify pollution prevention claims of low impact on indoor air quality with a focus on office furniture and air filtration units.**
ETV: Pollution Prevention Innovative Coatings and Coatings Equipment Pilot	**The Pollution Prevention Innovative Coatings and Coatings Equipment is an ETV Program partnership to verify commercially-ready, lower-polluting innovative coatings and coating application techniques for metals and plastics. It is a partnership between CTC, a for-profit company, and the U.S. Environmental Protection Agency.**
ETV: Pollution Prevention Metal Finishing Technologies	**The Pollution Prevention Metal Finishing Technologies ETV pilot is a partnership between CTC, a for-profit company, and the U.S. Environmental Protection Agency. This pilot verifies commercially-ready metal finishing technologies that reduce hazardous air pollutants and prevent discharge of heavy metals from metal finishing facilities.**

ETV: Pollution Prevention, Recycling and Waste Treatment Systems	**The Pollution Prevention, Recycling and Waste Treatment Systems pilot is a partnership between the State of California and the U.S. Environmental Protection Agency. This federal and this state agency have partnered in verifying commercially-ready pollution prevention (P2), recycling, and waste treatment technologies. Technology areas include hazardous waste related ones, such as aerosol can treatment, and P2 technologies, such as alternative cleaning for printed circuit boards and rechargeable batteries.**
ETV: Site Characterization and Monitoring Technologies	**The Environmental Technology Verification (ETV) Program Site Characterization and Monitoring Technologies pilot is a partnership between the U.S. Environmental Protection Agency, Sandia National Labs, and Oak Ridge National Labs. It focuses on verifying commercially-ready technologies for on-site identification and characterization of contaminants in air, water, and soil for public/private remediation sites, such as brownfield applications.**
ETV: Source Water Protection Technologies	**The Source Water Protection Technologies pilot is an Environmental Technology Verification (ETV) Program partnership between the U.S. Environmental Protection Agency and NSF International (an NGO). This pilot is trying to prevent risks to sources of drinking water supplies by verifying commercially-ready source water protection technologies including on-site disposal systems, septic tanks, and water distribution systems.**

ETV: Wet Weather Flow Technologies	The Wet Weather Flow Technologies ETV pilot is an Environmental Technology Verification (ETV) Program partnership between the U.S. Environmental Protection Agency and NSF International (an NGO). This pilot is verifying commercially-ready urban area wet weather flow control technologies, including storm inlet devices (i.e., inserts for catch basins or storm inlets) and advanced high-rate treatment technologies (i.e., sedimentation, micro- and fine-mesh screening, biological processes, and disinfection).
Georgia GIS Data Clearinghouse (GISDC)	Georgia GIS Data Clearinghouse (GISDC) is a consortium of state agencies and Georgia universities. The purpose of the Clearinghouse is to collect, document, format, and publish GIS information collected by multiple agencies of Georgia state government. For more information about the Georgia GIS Data Clearinghouse see http://www.gis.state.ga.us/clearinghouse/clearinghouse.html
Georgia GISCC	The GIS Coordinating Committee (GISCC) is a public-private consortium that directs Georgia GIS activities and resources. It consists of nine members, including GA Department of Transportation, Department of Natural Resources, Department of Health, Bell South, and Georgia Power. GISCC has developed a business plan to help promote the long-term development and use of a Georgia Spatial Data Infrastructure, modeled after the NSDI. For more information see http://www.gis.state.ga.us/Coordination/GISCC/giscc.html
Integrated K–12 GIS	An NSDI Cooperative Agreement Program project to develop a prototype application for building an educational GIS. This project is developing a GIS software environment and curriculum materials for K–12 education. University of California, Berkeley, private sector companies, and government agencies have partnered in this effort.

JSTOR	The Journal Storage Project (JSTOR) is a nonprofit organization established in August 1995 to help save researcher time and library storage space. JSTOR produces and provides an electronic database of back issues of academic journals that researchers can quickly search and access through the Internet. For more information see http://www.jstor.org/about/
Metadata Software Development	Metadata Software Development is an NSDI Cooperative Agreement Program (CAP) effort with several Illinois state agencies to develop and implement software for viewing metadata. Specifically, this effort is implementing a graphic metadata viewer on a National Geospatial Data Clearinghouse Node in Illinois.
MetroGIS	MetroGIS is a clearinghouse to help local governments and other organizations share geospatial data in the seven-county Twin Cities Area of Minnesota. The Metropolitan Council, a regional government organization, started the MetroGIS concept in 1995. For more information on MetroGIS see http://www.metrogis.org/
Montana Geographic Information Council (MGIC)	The Montana Geographic Information Council (MGIC) was created by executive order by the governor in September 1997. The purpose of MGIC is to provide policy level direction and promote efficient and effective use of geographical information. MGIC may also establish priorities for statewide needs, help in developing plans to meet those needs, simplify cost sharing, encourage collaboration and cooperation to develop databases and applications, and promote coordination of programs, policies, and technologies. MGIC is comprised of fourteen members appointed from the private sector; local, state, and federal government; the university system; and the Native American community.

Montana NRIS	**The Montana Natural Resource Information System (NRIS) Geographic Information System (GIS), run by the Montana State Library, acts as a clearinghouse for GIS databases. Montana NRIS also provides services to state, federal, private, NGO, and public groups or individuals needing access to GIS technology. For more information see http://nris.state.mt.us/gis/gis.html**
NACo/Intergraph GIS starter kits	**This partnership between the National Association of Counties (NACo) and Intergraph Corporation will develop a GIS "Starter Kit" that will be provided free to qualified NACo member counties. The offer includes Intergraph's GIS software package (Geomedia), specialized GIS interfaces, data specific to member counties, initial software training, and ongoing service support.**
NatureServe	**NatureServe is a new effort by the Association for Biodiversity Information (ABI) to provide geospatial biodiversity data through the web. Biological and conservation data will be available for more than 50,000 North American species, aggregated into a searchable database. For more information see http://www.abi.org/NatureServe.cfm**
New Mexico RGIS	**The New Mexico Resource Geographic Information System (RGIS) is a cooperative Program between the University of New Mexico and the State of New Mexico General Services Department. The Program is dedicated to advancing applications of GIS technology within New Mexico's state agencies, local government, and private industry. For more information see http://rgis.unm.edu/**
NIMA	**The National Imagery and Mapping Agency (NIMA) also runs a geospatial and imagery clearinghouse system for their user communities. NIMA's customers are the U.S. military and intelligence communities.**

NOAA-MAPTECH Nautical chart CRADA	**The NOAA-Maptech Cooperative Research and Development Agreement (CRADA) is an R&D partnership. NOAA and the for-profit company, Maptech, have partnered to produce electronic nautical charts.**
North Carolina Center for Geographic Information and Analysis (NC CGIA)	**The North Carolina Center for Geographic Information and Analysis (NC CGIA) is a geospatial clearinghouse with a mission to enhance, facilitate, and promote the efficient, cost-effective development and use of geographic information in North Carolina. For more information see http://cgia.cgia.state.nc.us/**
NSDI Community Demonstration Projects	**NSDI has been sponsoring six Community Demonstration Projects to support the use of geographic data for decision-making in local areas. These projects are being coordinated with the FGDC and are being implemented in partnership with cities, counties, and communities to illustrate the use of geographic information. Each project addresses different issues, such as crime prevention and reduction, watershed and water quality management, disaster preparedness and recovery, and urban growth and land use planning. The six communities are: Dane County, Wisconsin; Gallatin County, Montana; Tillamook County, Oregon; the Susquehanna-Lackawanna River region in central and northeastern Pennsylvania; the Tijuana River Watershed; and Baltimore, Maryland. For more information see http://www.fgdc.gov/nsdi/docs/cdpproj.html**
NYS GIS Clearinghouse/ Data sharing Cooperative	**New York State Geographic Information Systems (GIS) Clearinghouse is operated by the New York State Library to disseminate information about New York's Statewide GIS Coordination Program and to provide access to the New York State GIS Metadata Repository. The Cooperative is a group of governmental and not-for-profit entities that have executed Data Sharing Agreements for the purpose of improving access to GIS data among members. For more information see their web site at http://www.nysgis.state.ny.us/index.html**

OGETA	**Open Geodata Consortium (OGETA) is a public-private partnership to advance the use of shared geospatial information in the Greater Atlanta Metropolitan area. OGETA's objective is to develop and run a spatial information utility for the Greater Atlanta Metropolitan area, which will give users remote access to multiple spatial / geographic databases with a single query. For more information on OGETA see http://www.ogeta.com/**
Ohioview	**Ohioview, an NSDI clearinghouse node, is a complex collaboration partnership designed to acquire and provide datasets for Ohio University scientists. Ohioview's mission is to promote the low-cost distribution of U.S. Government civilian satellite data for public use in Ohio. The idea is to create a public library for sharing remote sensing data on Ohio, which will be used for science and government purposes to promote the public good. The current focus of the consortium is to make Landsat 4, 5, and 7 data available for their members. Currently, Ohioview's members are university researchers and scientists. For more information see: http://www.ohioview.org/**
ONRC Clearinghouse	**Olympic Natural Resources Center (ONRC) Clearinghouse is an NSDI clearinghouse node for the Olympic Peninsula. The ONRC clearinghouse is a metadata archive of Olympic Peninsula geospatial and biological data. The ONRC clearinghouse is a partnership between the USGS Forest and Rangeland Ecosystem Science Center, the University of Washington Field Station, and the Olympic Natural Resources Center. For more detailed information about ONRC see http://cathedral.cfr.washington.edu/~chouse/**

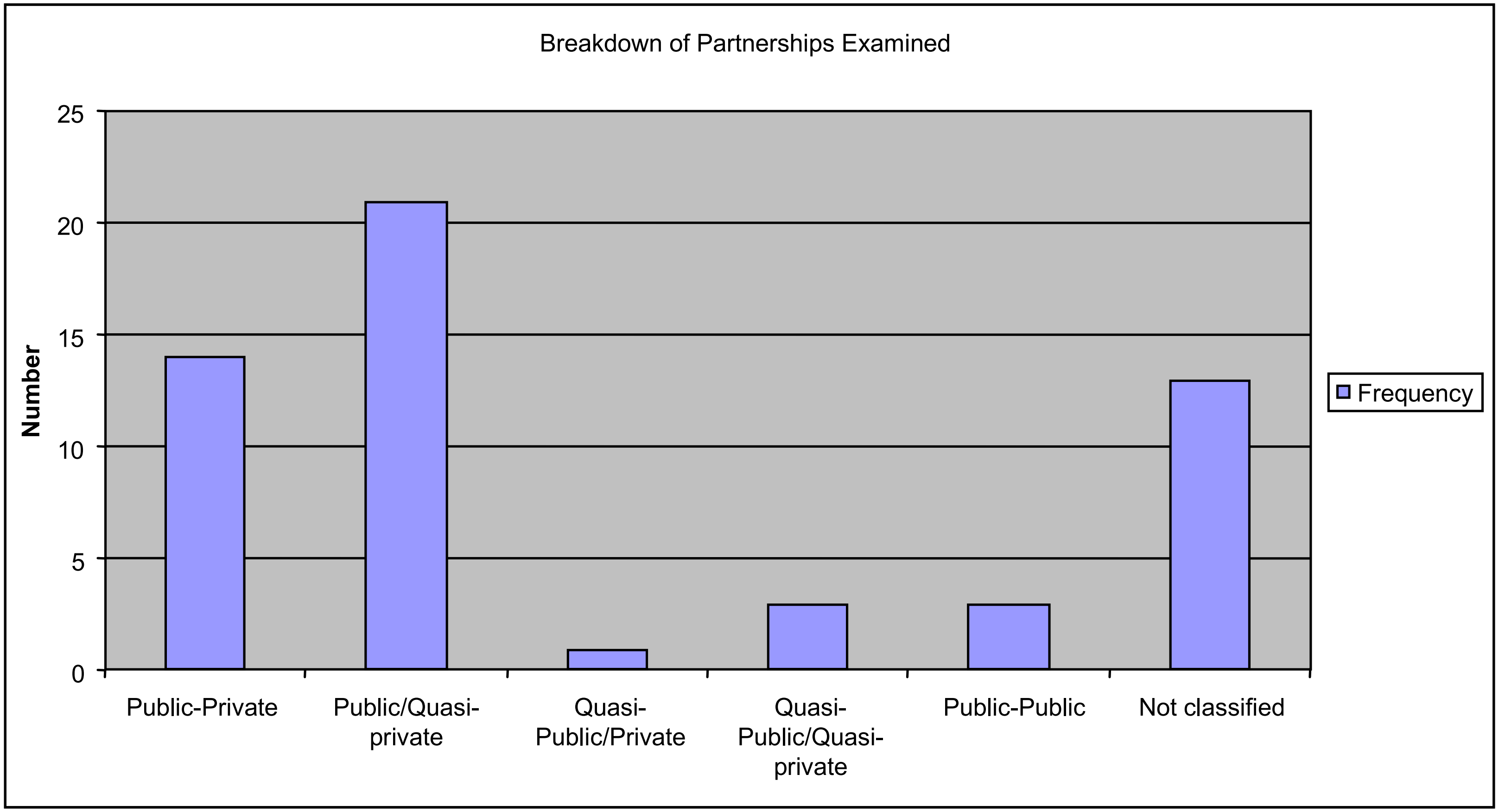
Oregon Natural Heritage Program (ONHP)	**Oregon Natural Heritage Program (ONHP) is the state's Natural Heritage Program. The Nature Conservancy in cooperation with the State of Oregon manages ONHP. As a state heritage program TNC develops, acquires, maintains, and distributes data about the state's rarest plants, animals, and natural communities. For more information see http://www.heritage.tnc.org/nhp/us/or/**
Partnership for Advancing Technology in Housing (PATH)	**The Partnership for Advancing Technology in Housing (PATH) is a voluntary program that seeks to accelerate the creation and widespread use of advanced technologies to radically improve the quality, durability, environmental performance, energy efficiency, and affordability of U.S. housing. PATH links federal agencies with home building, product manufacturing, insurance, financial and regulatory communities in a partnership focused on technological innovation in the American housing industry. For more information see http://www.pathnet.org/**
PASDA	**The Pennsylvania Spatial Data Access system (PASDA) is Pennsylvania's official geospatial information clearinghouse and the state's node on the NSDI. Started in 1995, PASDA was developed to provide Pennsylvania citizens with free access to geospatial information and metadata, contributing to the knowledge of the state and wise use of its resources. For more information, see the clearinghouse web site: http://www.pasda.psu.edu/**
Pennsylvania Natural Diversity Inventory (PNDI)	**Pennsylvania Natural Diversity Inventory (PNDI) is the state's Natural Heritage Program. PNDI is a partnership between the Western Pennsylvania Conservancy, the Pennsylvania Bureau of Forestry, and The Nature Conservancy. It conducts inventories and collects data to identify and describe the Commonwealth's rarest and most significant ecological features. For more information see http://www.dcnr.state.pa.us/forestry/pndi/index.htm**

PNGV	The Partnership for a New Generation of Vehicles (PNGV) is a public-private R&D partnership between the U.S. federal government and the U.S. automotive industry to establish technical leadership in the development and production of affordable, fuel-efficient, low-emission automobiles. PNGV, established in 1993, draws on the resources of seven federal agencies, universities, suppliers, and the United States Council for Automotive Research (USCAR), a cooperative, pre-competitive research effort between DaimlerChrysler Corp., Ford Motor Co., and General Motors Corp. For more information see Chapman (1998) and http://www.uscar.org/pngv/index.htm
SEMATECH	International SEMATECH is a consortium of 13 semiconductor manufacturing companies from seven countries. This consortium strives to influence semiconductor manufacturing technology development. For more information see http://www.sematech.org/public/
Texas Geographic Information Council	The Texas Geographic Information Council is a geographic data planning and coordination group serving state and regional government agencies in the State of Texas. The Texas Geographic Information Council partnership provides the operational guidance and oversight for the state's GIS clearinghouse, TNRIS. For more information see http://www.tgic.state.tx.us/
Texas Natural Resources Information System (TNRIS)	The Texas Natural Resources Information System (TNRIS) is the state's clearinghouse for natural resources and other geospatial data. TNRIS is an operational division of the Texas Water Development Board and is managed by this state agency. For more information see http://www.tnris.state.tx.us/about.htm

The Natural Heritage Network	**The Natural Heritage Network was originally started by The Nature Conservancy (TNC) more than 20 years ago to collect, interpret, and disseminate information critical to conservation of the world's biodiversity. TNC worked in partnership with many independent public agencies and other organizations to develop individual state programs throughout the country. The U.S. Natural Heritage Program consists of separate programs in all 50 states. The effort has also expanded outside the United States. Collectively, these programs are known as the Natural Heritage Network. The Natural Heritage Network comprises 85 biodiversity data centers throughout the Western Hemisphere. Each of these centers functions as a geospatial database clearinghouse. For information on each state program see http://www.heritage.tnc.org/nhp/us/usmap.html The Network and ABI overlap, however, since ABI is new, both are included for completeness.**
Tools for Network access to DOQs	**An NSDI Cooperative Agreement Program effort with the Massachusetts Institute of Technology (MIT) and Massachusetts state agencies to improve tools for utilizing and viewing Digital Orthophoto metadata and data through the web.**
USGS National Mapping Division Business Partners (BPs)	**The USGS's National Mapping Division has a program, called Business Partners (BPs), in which private organizations distribute its products. The Business Partner Program includes published products, digital cartographic data, aerial photographs, and satellite imagery (Landsat 7) product lines. For more information see http://mapping.usgs.gov/www/partners/bpmain.html**
USGS/ Microsoft TerraServer CRADA	**The USGS/Microsoft TerraServer Cooperative Research and Development Agreement (CRADA) is an R&D partnership that focuses on providing seamless digital orthophoto quadrangles (DOQs) through the web. For more information on the USGS/Microsoft TerraServer CRADA see http://terraserver.microsoft.com/about.asp**

Virginia Natural Heritage Program	**Virginia Department of Conservation and Recreation operates the Virginia Natural Heritage Program, part of the Natural Heritage Network. Its mission is conserving Virginia's biodiversity through inventory, protection, and stewardship. The Natural Heritage Program represents a comprehensive effort to inventory and preserve the animal, plant, and natural community resources of the Commonwealth of Virginia. For more information see http://www.state.va.us/~dcr/vaher.html**
Web Mapping Testbed	**The Open GIS Consortium, Inc.'s (OGC's) effort to develop and implement an open interface for using geospatial data through the web. OGC's Web Mapping Testbed makes it easier to map and use geospatial data through the web. For more information see http://www.opengis.org/wmt/**
West Virginia Natural Heritage Program	**The West Virginia Natural Heritage Program, founded in 1975, conducts an ongoing statewide ecological inventory of rare plant and animal species, wetlands, and other biological communities. The program identifies unique natural areas and serves as a clearinghouse for general information on the state's natural history. This program operates as part of the WV Division of Natural Resources, Wildlife Resources Section, and is part of the Natural Heritage Network. For more information see http://www.heritage.tnc.org/nhp/us/wv/**
WISCLINC	**The Wisconsin Land Information Clearinghouse (WISCLINC) is a state clearinghouse for geospatial data and metadata, related land and reference information, and the Wisconsin agencies that produce or maintain these items. WISCLINC is also a registered node in the web of NSDI clearinghouses. For more information see http://wisclinc.state.wi.us/**
Wyoming Natural Diversity Database	**Wyoming Natural Diversity Database is the state Natural Heritage Program for the state of Wyoming. The University of Wyoming runs this clearinghouse. For more information see http://uwadmnweb.uwyo.edu/wyndd/**

Figure 4 - Classification of Partnerships Examined



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