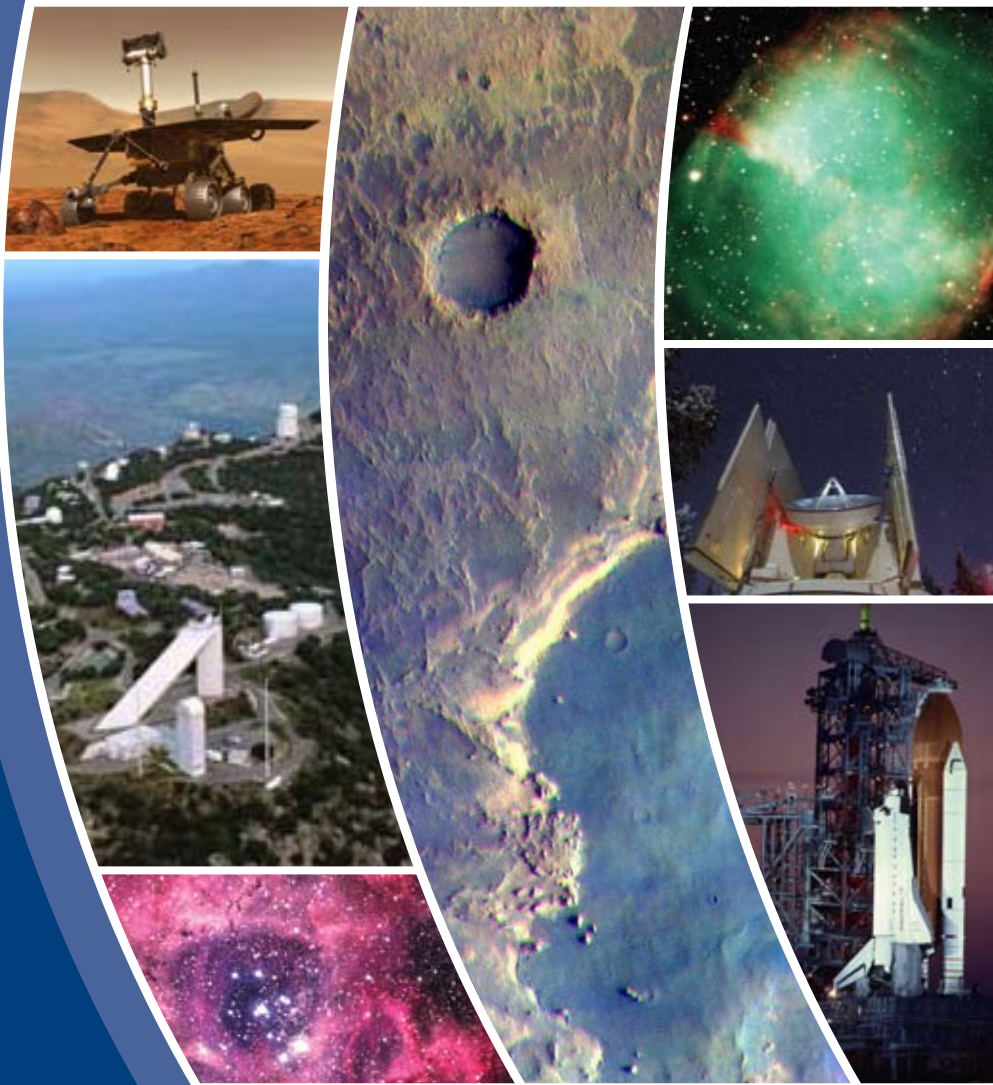


Astronomy, Planetary and Space Sciences Research in Arizona

AN ECONOMIC AND TAX REVENUE IMPACT STUDY



Prepared for
The Arizona Arts, Sciences and
Technology Academy

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CONTENTS

Acknowledgements	iii
Executive Summary	1
Introduction	5
Astronomy, planetary and space sciences research in Arizona	5
Purpose and objectives of this study	6
Study design	7
Participating organizations	7
Observatories and related research organizations	7
University departments and research centers	8
Characteristics of participating organizations	8
Framework for Analysis	9
Assessing the impacts of APSS organizations	9
Types of economic impacts	9
Concept of multiplier	11
Application of input-output mode	12
Tax revenue model	12
Data	13
Expenditures by category	13
Employee expenditures	14
Number of visitors and dollars spent	14
Economic impact of APSS organizations in FY 2006	15
Direct expenditures	15
Direct jobs	15
Indirect impacts	15
Induced impacts	17
Tax revenue impacts in FY 2006	18
Direct tax revenue impact	18
Induced tax revenue impact	19
Total tax revenue impact	19
Summary	20
Total monetary impact in FY 2006	20
Linkages with industry	21
Employment impact by sector	22
APSS multipliers for FY 2006	22
Conclusions and limitations of the study.	23
Bibliography	25

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LIST OF TABLES

Table 1.	Participating Organizations by Type	8
Table 2.	APSS Organizations and Related Expenditures, FY 2006 (\$)	15
Table 3.	Direct Impacts of APSS Organizations, FY 2006	16
Table 4.	Indirect Impacts of APSS Organizations, FY 2006	16
Table 5.	Induced Impacts of APSS Organizations, FY 2006	17
Table 6.	Direct Tax Revenue Impact of Astronomy-Related Expenditures, FY 2006 (\$)	18
Table 7.	Induced Tax Revenue Impact of Astronomy-Related Expenditures, FY 2006 (\$)	19
Table 8.	Total Tax Revenue Impact of Astronomy-Related Expenditures, FY 2006 (\$)	20
Table 9.	Total Economic Impacts (<i>Direct, Indirect and Induced</i>), FY 2006	20

LIST OF FIGURES

Figure 1.	Location of Major Observatories and Astronomy-Related Institutions in Arizona	6
Figure 2.	Economic Impact Flow Chart	10
Figure 3.	Linkages with Industry	21
Figure 4.	Employment Impact by Industry (<i>excluding direct employment in APSS organizations</i>)	22

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ASTRONOMY, PLANETARY AND SPACE SCIENCES RESEARCH IN ARIZONA: AN ECONOMIC AND TAX REVENUE IMPACT STUDY

EXECUTIVE SUMMARY

What is the main purpose of this study?

The purpose of the study is to provide quantitative measures of the importance of astronomy, planetary and space sciences research in Arizona's economy. The study provides measures of economic activity and associated impacts such as the number of jobs, wages and salaries, output and tax revenues.

How is the area of "Astronomy, Planetary and Space Sciences Research" defined for this study?

The scope of the study is limited to economic impacts associated with astronomy, planetary and space sciences research at Arizona's three universities, astronomical observatories and related research organizations, such as federal laboratories. Although a considerable number of companies in Arizona are involved in astronomy, planetary and space sciences related research, these have not been included in this study. *(For the defined area within the scope of the study, the abbreviation APSS will be used.)*

How is the economic "impact" defined in this study?

We define "impact" in its strict sense, which implies that a given economic activity generates jobs and wages and salaries. This impact occurs when money is brought into a region's economy either through exports of goods and services to markets

outside the region, or when visitors from elsewhere purchase the region's goods and services while staying in the region.

How does astronomy, planetary and space sciences research generate new jobs, wages and salaries, and output in the Arizona economy?

Astronomy, planetary and space sciences research activity has been funded mostly by federal institutions, such as the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF). By definition, these funds are injected into Arizona's economy and, thus, are capable of creating jobs, wages and salaries, and output. Direct impact occurs when observatories, related research organizations, and university departments and research centers hire professionals, faculty, staff and students and thus contribute to the overall employment in Arizona. Additional jobs in Arizona are generated through local purchases of equipment, office supplies, utilities and various professional and business services necessary for daily operations of these organizations. Furthermore, a significant number of jobs are created through spending by out-of-state visitors attracted to observatories and universities. The personal consumption by those employed in observatories, related research organizations, and university departments and research centers, as

well as by those employed in businesses that supply goods and services to these organizations and to their visitors, generates additional jobs.

How does astronomy, planetary and space sciences research generate tax revenues in Arizona?

Revenue impacts are generated when visitors, university departments/research centers, observatories and other entities make purchases and pay taxes to state and local governments (referred to as direct revenues). In addition, the employees whose jobs are generated by astronomy, planetary and space sciences research activity pay taxes to state and local governments in Arizona (referred to as induced revenues). Direct revenues include sales taxes paid to cities and the state; the state, in turn, shares some of the state revenues with cities and counties. Induced revenues to the state are derived from state sales and personal income taxes. Induced revenues to counties are collected from state-shared sales taxes, state-shared fuel/highway taxes and property taxes. Induced revenues to cities include proceeds from state-shared sales taxes, state-shared fuel/highway taxes and local sales taxes. Tax revenue also comes from expenditures by visitors attracted to the APSS activity, as visitors' purchases are subject to sales taxes, hotel taxes, taxes on restaurant meals and such.

What are the main sources of economic impacts identified in this study?

Astronomy, planetary and space sciences research in Arizona generates economic impacts through three main sources. These include (a) spending by employees in observatories, related research organizations, and university departments and research centers; (b) operations-related purchase of goods and services from Arizona businesses, and (c) spending by visitors such as visiting scholars, conference attendees, and general public attracted to observatories, planetariums and specialty museums.

How were data obtained on Arizona-based expenditures?

Because expenditure data are not readily available, a combination of methods was applied. Financial data from observatories and related research organizations were collected through a survey instrument designed to capture detailed data on those institutions' operations-related and capital-investment-related expenditures in Arizona. Data also included payroll, benefits and number of employees. For university departments and research centers, financial data on expenditures made in Arizona were obtained from respective central financial and procurement offices. University departments and research centers also received and responded to a survey instrument with additional questions.

Who participated in the study?

A total of 22 organizations responded to the survey. Thus, eleven observatories, three related research organizations, and eight university departments/centers/labs are included in the economic impact analysis. *(List of participant organizations appears in the Acknowledgements at the beginning of this report.)*

How much did Arizona's observatories and related research organizations spend in fiscal year (FY), ending June 30, 2006, and how much of that was spent in Arizona?

Arizona's eleven observatories and three related research organizations spent a total of \$135.4 million on operations, including payroll with benefits. An additional \$28.4 million was spent on capital investment/construction-related items. Thus, in FY 2006, total expenditures amounted to \$163.8 million. Of that amount, \$69.3 million was spent in Arizona.

How much did Arizona's university departments and research centers spend in Arizona during FY 2006?

Astronomy, planetary and space related departments and centers at the three universities spent a total of \$60.5 million (including payroll and benefits). Of that amount, \$33.9 million was spent in Arizona.

How many direct jobs and wages and salaries are related to astronomy, planetary and space sciences research in Arizona?

The participating APSS organizations – including observatories, university departments and related research centers – employed a total of 1,830 persons (including an estimated 168 jobs associated with overhead expenses), of which 320 were students. The total APSS payroll was \$84 million.

What is the impact of APSS employee spending in Arizona's economy?

Not all the wages and salaries paid in Arizona are available for spending in Arizona: payroll includes federal tax and non-tax payments such as contributions to Social Security and Medicare, all of which represent a leakage from the region. The amount of APSS payroll (excluding tax and non-tax payments) that was actually spent in Arizona was estimated at \$64.8 million in FY 2006. This spending generated 720 jobs and \$26.3 million in additional wages and salaries in Arizona.

How many jobs in Arizona do APSS organizations generate through purchases of operations-related goods and services?

The total direct operations-related spending (excluding payroll) of the participating organizations was \$21.4 million. This spending generated 274 jobs and \$10.8 million in wages and salaries. In addition, the capital-investment-related expenditures of \$11.8 million in FY 2006 generated 137 jobs and \$5.9 million in wages and salaries.

How many out-of state visitors were attracted to Arizona related to astronomy, planetary and space sciences research and how much did they spend?

In total, APSS organizations received more than 200,000 visitors in FY 2006, out of which close to 7,000 were professional visitors and 194,000 were public visitors. Of the public visitors, 22 percent were from outside Arizona. For the purpose of this study, only the economic activities of the professional visitors and those public visitors from outside Arizona were assessed to determine the effects of new money injected into Arizona's economy. Due to a pronounced collaborative nature of this research involving other national and international institutions, professional visitors were treated as out-of-state visitors.

How many jobs were generated through visitors' spending in Arizona?

Visitors from out-of-Arizona spent \$16.1 million dollars, generating an economic impact of \$25.7 million dollars in total. The out-of-state visitors' spending generated 286 jobs and \$8.1 million in wages and salaries in Arizona in FY 2006.

What is the impact of locally spent benefits?

Out of total benefits package, about \$5.2 million was spent locally on health services. This generated 81 jobs and \$3.5 million in wages and salaries.

What are the tax revenue impacts associated with Arizona's astronomy, planetary and space sciences research?

Astronomy, planetary and space-related observatories, centers, departments and research centers generate almost \$11.9 million dollars in revenues to state and local governments. Approximately \$2.6 million is attributable to the operations of university departments and research centers, \$5.9 million to observatories and similar organizations, and \$2.1 million to visitors. Capital investment in 2006 generated approximately \$1.2 million in tax revenues.

How are tax revenue impacts distributed among state and local governments?

The state of Arizona receives 57 percent of the revenues (\$6.8 million); Arizona counties receive 17 percent (\$2.0 million), and cities receive 26 percent (\$3.1 million).

What was the total monetary impact (output) of astronomy, planetary and space sciences research in Arizona's economy in FY 2006?

The total dollar impact (sales or output) in Arizona that was attributed to Arizona's astronomy, planetary and space sciences research was estimated at \$252.8 million in FY 2006. This includes \$138.6

million in wages and salaries and \$11.9 million in tax revenues.

What was the total employment impact of astronomy, planetary and space sciences research in Arizona's economy in FY 2006?

The economic activity of astronomy, planetary and space sciences research generated over 3,300 jobs. Of those, more than 1800 were employed in observatories, university departments and centers carrying out astronomy, planetary and space sciences research (APSS organizations), while close to 1,500 jobs or 45 percent were spread throughout all sectors of the state's economy.

Summary: Economic and Tax Revenue Impacts of Astronomy, Planetary and Space Sciences Research in Arizona, FY 2006

<u>Non-earnings expenditures (dollars in millions)</u>	
Operations-related expenditures in Arizona	\$21.4
Capital investment	\$11.8
Locally spent benefits	\$5.2
Out-of-state visitor spending	\$16.1
Total direct expenditures	\$54.5
<u>Earnings (dollars in millions)</u>	
Earnings in APSS organizations	\$84.0
Earnings outside APSS (including indirect and induced earnings)	\$54.6
Total earnings impact	\$138.6
<u>Tax revenues (dollars in millions)</u>	
State revenues	\$6.8
County revenues	\$2.0
City revenues	\$3.1
Total tax revenue impact	\$11.9
Additional value added	\$47.8
Total monetary impact	\$252.8 million
<u>Employment impact</u>	
Direct jobs in APSS organizations	1,830
Jobs outside APSS (including indirect and induced jobs)	1,498
Total employment impact	3,328

ASTRONOMY, PLANETARY AND SPACE SCIENCES RESEARCH IN ARIZONA: AN ECONOMIC AND TAX REVENUE IMPACT STUDY

INTRODUCTION

ASTRONOMY, PLANETARY AND SPACE SCIENCES RESEARCH IN ARIZONA

Since the early beginnings of Lowell Observatory in Flagstaff in 1896, Arizona has become home to a number of world-renowned observatories, state-of-the-art telescopes, and leading university departments and centers carrying out research in astronomy, planetary and space sciences.

Today Arizona has close to 30 observatories, with the state's largest and world's most visited cluster of telescopes located on Kitt Peak (Sage 2003). Each of the three state universities has at least one major department of astronomy, planetary and/or space sciences, with the largest number of academic and research centers at The University of Arizona (Figure 1).

"All three universities are engaged in very valuable basic science concerned with observations in our solar system and the emerging area of biochemistry to study materials on earth and other planets... The combination of astronomy and planetary sciences at UA and ASU makes the state a national leader in space science and engineering."

– Battelle Report, 2003.

A combination of factors has contributed to the development of astronomy, planetary and space sciences research in Arizona. Mountain peaks, dryness and wide-open skies have been and still are important factors for the location of telescopes. Arizona also benefited from the stimulus for space exploration and the attendant increases in federal government funding for astronomical research since the mid-1950s, mainly through the National Aeronautics and Space Administration (NASA) (Schnee 1977). Also significant has been the quality of researchers, enabling them to attract both funding and talent.

More than 350 scientists with doctoral degrees and another 600 professional and technical personnel conduct research and educational activities in Arizona's observatories and academic units. In addition, between 350 and 400 students annually work on different research projects carried out in observatories and academic units.

The actual number of people involved in astronomy, planetary and space sciences research in Arizona is higher than the number of employees in observatories and academic organizations whose research/educational activity is entirely or predominantly devoted to astronomy, planetary and space sciences; these employment numbers exclude collaborators from other disciplines and organizations in both the public and private sectors.

From 2002 to 2005, Arizona observatories and academic organizations carrying out astronomy,

planetary and space sciences research attracted more than \$600 million in grants and contracts.¹ The major funding organizations are NASA, NSF, and the U.S. Department of Defense. Needless to say, these grants are achieved in an increasingly competitive environment and, thus, in themselves attest to the quality and creativity of Arizona's scientific community.

The Battelle (2003) report identified space sciences as one of the six core competencies critical for Arizona's position in research innovation. It identified leading areas of research activity and

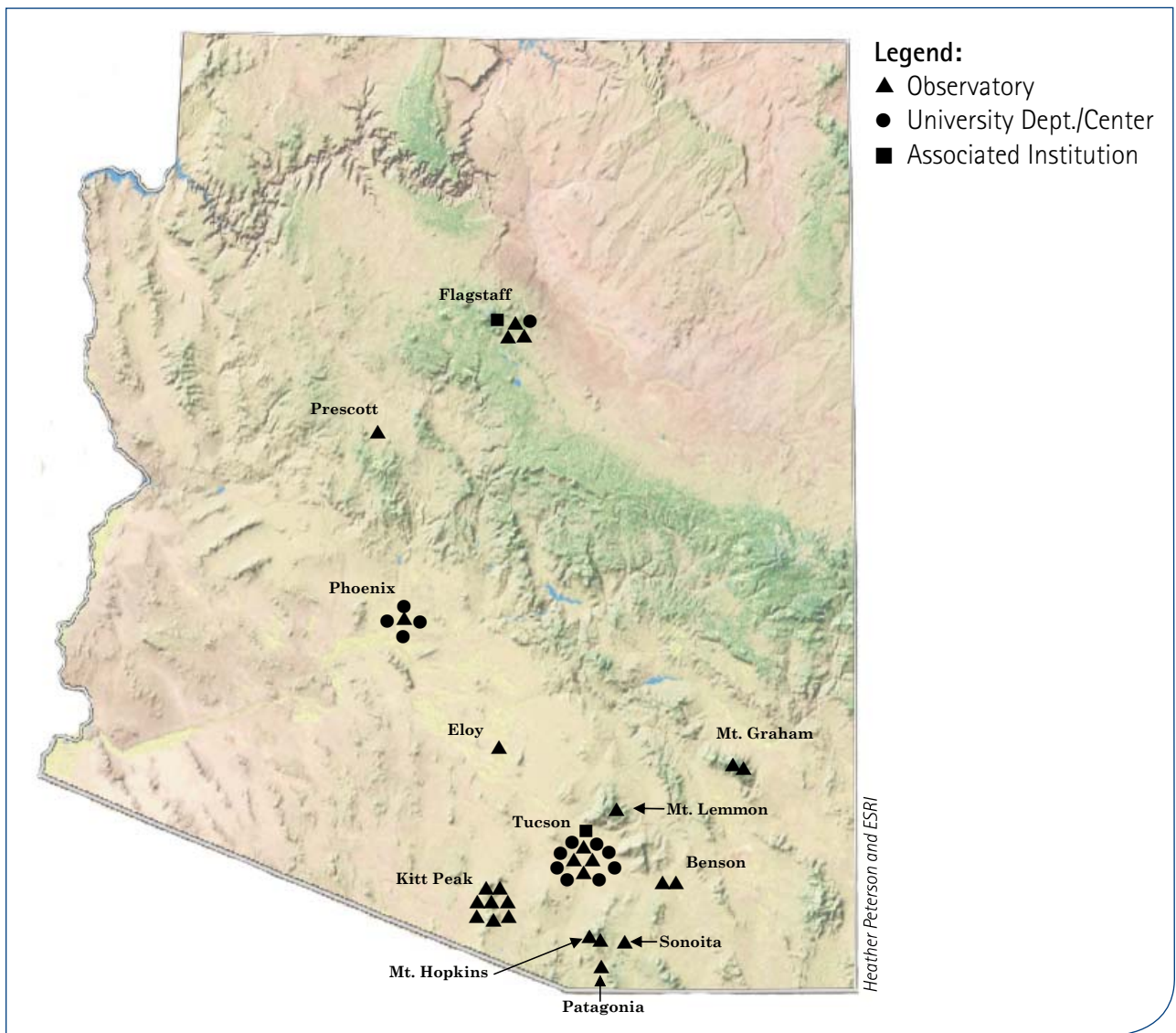
emphasized the importance of innovation in economic development of the state.

Building on the findings of Battelle's report, this study assesses astronomy, planetary and space sciences research as an economic activity and thus provides another perspective on the importance of such research in the state's economy.

PURPOSE AND OBJECTIVES OF THIS STUDY

The study was initiated by The Arizona Arts, Science and Technology Academy (AASTA) and overseen by a Project Planning Committee comprised of

Figure 1. Location of Major Observatories and Astronomy-Related Institutions in Arizona



¹ Based on data provided by surveyed organizations.

representatives of astronomy, planetary and space sciences organizations with the aim of assessing the economic impacts of astronomy, planetary and space sciences research on Arizona.

This is the first study in Arizona that identifies the monetary and employment impacts of the state's largest observatories, university departments and other research activity directly involved with astronomy, planetary and space sciences research.

By assessing the economic impact, that is, the impact that these institutions' activities have on the flow and level of spending in Arizona's economy, the study provides common benchmarks in terms of jobs, wages and salaries, tax revenues and output (sales). These benchmarks allow the public and policy-makers to gain a better understanding of the importance of these activities in Arizona's economy beyond their contribution to education and scientific knowledge.

STUDY DESIGN

A major task was to collect and collate financial and other data from astronomy-related organizations in order to develop a set of baseline data depicting the economic activity of these organizations in Arizona.

The project involved the following stages:

- Identification of a comprehensive list of organizations (observatories; university departments, centers and programs; other institutions) involved in astronomy, planetary and space sciences research and related activities;
- Design of a survey instrument to collect financial and other relevant data from observatories and related organizations (a copy of the questionnaire is available upon request);
- Collection of expenditure data from Arizona universities' financial and procurement offices pertinent to departments, centers and programs involved in astronomy, planetary and space sciences research and related activities;
- Modification of the observatory survey instrument to collect additional relevant data from university departments, centers and programs involved in astronomy, planetary and space sciences research;
- Preparation of survey and other financial data for estimation of economic impacts;
- Estimation of job, wage and salary, and output impacts using an Arizona input-output model;
- Estimation of tax revenue impacts using an Arizona-specific tax revenue model;
- Preparation of a summary report.

PARTICIPATING ORGANIZATIONS

OBSERVATORIES AND RELATED RESEARCH ORGANIZATIONS

An initial list of 21 organizations including observatories and other organizations carrying out astronomy, planetary and/or space sciences research in Arizona was compiled with assistance from AASTA. Cover letters explaining the purpose of the study and questionnaires requesting detailed expenditure

data in addition to general information were sent to all.

Of the targeted organizations, 14 responded to the survey and provided the requested information: Fred Lawrence Whipple Observatory, Large Binocular Telescope Observatory (LBTO), Lowell Observatory, MDM Observatory,² Multiple Mirror Telescope

² Consortium of University of Michigan, Dartmouth College, the Ohio State University, Columbia University and Ohio University.

Observatory (MMTO), National Optical Astronomy Observatory (NOAO), National Solar Observatory (NSO), Steward Observatory, Planetary Science Institute, Southern Association for Research in Astronomy (SARA), USGS Astrogeology Research Program, U.S. Naval Observatory, Vatican Observatory, and WIYN.³ After reviewing the response rate, the Project Planning Committee concluded that the participating organizations were the major players in this field and their combined expenditures were representative of approximately 90 percent of economic activity associated with the Arizona observatories.

UNIVERSITY DEPARTMENTS AND RESEARCH CENTERS

The research team identified departments and research centers involved with astronomy, planetary and space sciences research at each of the three Arizona state universities: Department of Physics and Astronomy at Northern Arizona University (NAU); the newly established School of Earth and Space Exploration at Arizona State University (ASU); and a total of six research centers at The University of Arizona – Department of Astronomy; Department of Planetary Sciences; Lunar and Planetary Lab; Optical Sciences Center (in the College of Optical Sciences); Arizona Remote Sensing Center (in the Arid Lands Studies), and the Flandrau Science Center.

A total of eight university departments/research centers participated in the study. Although there were several programs in other departments that were also related to astronomy, planetary and space sciences research, e.g., in hydrology, these units were not included because their fiscal year 2006 expenditures relevant for this study were negligible.

Expenditures data, by category, for all university departments and research centers were obtained from the financial and procurement service offices of each university. Additional data were collected through the questionnaire.

³ Consortium of the University of Wisconsin-Madison, Indiana University, Yale University and the National Optical Astronomy Observatory (NOAO).

The total number of participating survey organizations, including observatories, university departments and related research centers, was 22. This group of 22 organizations is referred to in the remainder of this report as APSS organizations.

CHARACTERISTICS OF PARTICIPATING ORGANIZATIONS

The majority of observatories are organized as research consortia, followed in number by those that are government laboratories and government-funded R&D centers, and then by independent research centers. University-based organizations include four major departments, four science research centers, and a laboratory (Table).

Table 1. Participating Organizations by Type

	Number
Research consortium	6
Government laboratory/Federally funded R&D center	5
Independent research organization	3
University department	4
University science center/lab	4
Total	22

Source: APSS survey 2007.

About half of the participating organizations were established before 1980, among them all the university departments.⁴ The majority of research consortia are relatively new organizations, established in the 1990s.

APSS organizations represent economic clusters in terms of their inter-organization collaborative efforts. Almost all APSS organizations reported having relationships with other similar organizations. These relationships are not only with out-of-Arizona organizations, but also with other in-state APSS organizations.

⁴ School of Earth and Space Exploration at the Arizona State University was established in 2006, but the departments and programs go back to the 1970s.

Most commonly, APSS organizations collaborate in joint research projects. APSS organizations frequently share development and engineering resources, which is also a characteristic of economic clusters. Four of the responding APSS organizations

reported purchasing inputs from out-of-state APSS organizations and three purchased inputs from in-state organizations. In some instances, an APSS organization subcontracted to or received a subcontract from another unit or participated in a coordinated research and development project.

FRAMEWORK FOR ANALYSIS

ASSESSING THE IMPACT OF APSS ORGANIZATIONS

Economic impact studies have most often been used in situations where a change in economic activity is being planned, such as opening of a new company, expansion of an existing industry, or shutting down a military base. They have also been used in assessing the economic impact of various cultural and sports events, as these tend to attract visitors and increase economic activity. As noted by Ilze Groves (2005) in her study of worldwide science centers, institutions with an ongoing presence and year-round activities in a region are increasingly carrying out economic impact studies to assess and demonstrate the contribution that their activities make to their local economies.

In general, the economic contribution of APSS organizations to their local communities can be assessed through the flow and level of spending. These organizations pay their employees, purchase supplies, contract for services, and acquire assets within the local community. They also attract out-of-area visitors. These activities, in turn, support local jobs, create household income and generate tax revenues to their local and state governments (Groves 2005, Americans for the Arts 2004).

The concept of "impact" in its strict sense implies that a given economic activity generates new output and associated jobs and earnings. This occurs when new money is injected into a region's economy either through exports of goods and services to

- markets outside the region, or when outside visitors purchase region's goods and services while staying in the region. This type of economic activity is also referred to as "basic" as opposed to economic activities that serve the needs of local population (such as retail and housing construction).

Because the activity of APSS organizations is largely (and in many cases exclusively) supported by out-of-state grants and contracts, their activity fits the definition of an economic impact-generating activity. This kind of research is funded, predominantly, by federal and international funds and, thus, brings new money into the state. By definition, it is a basic (export) activity. It is, therefore, appropriate to measure its impact on the creation of new jobs and associated earnings and expenditures (sales).

TYPES OF ECONOMIC IMPACTS

Economic impact is comprised of direct, indirect and induced impacts. The direct impact is also referred to as the primary impact, while indirect and induced impacts combined are referred to as secondary impacts.

In this study, direct impact refers to the expenditures made by APSS organizations, including payroll to APSS's employees and purchases of goods and services from local suppliers. Spending by out-of-state visitors is also a direct impact. Associated with these direct expenditures are jobs in APSS organizations and jobs in supplying businesses, referred to as direct jobs in this report.

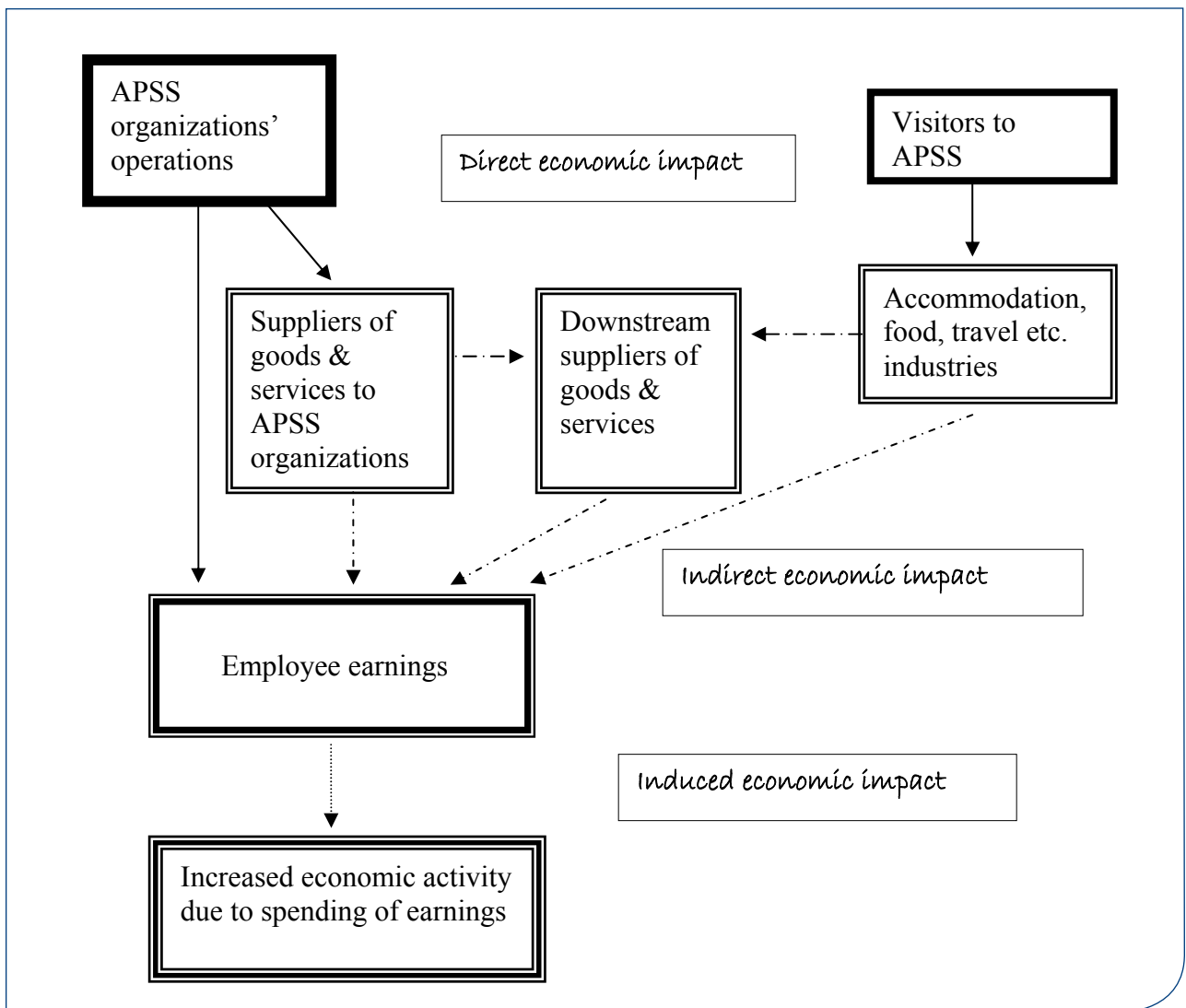
Indirect jobs are generated as the first-round of expenditures are spent purchasing goods and services from various other businesses in the local economy. They are also called inter-industry purchases as businesses respond to the new demands of the directly affected establishments. Wages and salaries paid to employees in these supporting businesses are called indirect earnings, and by analogy, the output (sales) generated through the monetary transactions of these supporting businesses, are called the indirect output (sales). The magnitude of these indirect impacts depends upon the percentage of goods and services purchased and/or produced

locally. The more locally produced goods and services used, the larger the indirect impacts.

Induced jobs result from spending by APSS employees and those in supplying (*i.e.*, economically-linked) businesses. This spending generates additional jobs and associated earnings (*i.e.*, induced earnings). Typically, most induced jobs are generated in retail and services sectors, reflecting households' consumption patterns.

Total economic impacts represent the sum of direct, indirect and induced impacts. Figure 2 illustrates economic impact by showing the flow of money from APSS organizations into the regional economy.

Figure 2. Economic Impact Flow Chart



Framework for Analysis. Adapted from Groves (2005).

Tax revenue impact refers to changes in government revenues associated with changes in the economy due to APSS organizations. When APSS organizations make purchases in the state (or in some instances purchase equipment from out of state), they pay taxes. They pay contracting taxes (a component of sales taxes) when they build new or modify existing facilities. Taxes paid by the APSS organizations are referred to as direct revenues. Direct tax revenues accrue to both state and local (county and city) governments.

When employees of APSS organizations and of firms that are economically-linked to APSS spend money, they generate additional revenues as they pay sales, fuel, motor vehicle, and a wide variety of other taxes. The revenues generated to state and local governments due to employee spending are referred to as induced revenues.

CONCEPT OF MULTIPLIER

The term multiplier is used to describe the total impacts associated with a unit change in a particular economic activity. The definition of a multiplier is total impact (direct plus indirect plus induced) divided by the direct impact. Although the definition is a simple mathematical formula, multipliers actually represent the sum of an infinite number of economic impacts as the direct economic activity iterates through the economy.

When APSS organizations make local purchases, the industries making the sales have to hire additional workers, pay additional wages and salaries and, in turn, will themselves make additional purchases locally. When those first-round impacted firms make additional purchases locally, another round of hiring, wages and salaries, and local purchases is initiated. Indirect impacts incorporate an infinite number of these iterations; however, the impact in each round is not of equal magnitude. Later rounds of purchases result in ever-lesser impacts, because leakages occur at each iteration, as some purchases are made out of the local area. To calculate the impacts, the first round and the subsequent

iterations must be included.

Induced effects, like indirect effects, also represent the sum of an infinite number of rounds of spending. As employees of the direct and indirect sectors spend money locally, those impacted industries experience higher sales, increased employment and added wages and salaries. Again, the wages and salaries of those new employees are spent locally and the money continues to circulate through the local economy. The size of the impact diminishes each round as workers purchase some goods and services out of the area or buy some products that are not made locally.

Multipliers can be calculated using several different economic measures as the direct economic stimulus, e.g., jobs, earnings, and sales. It is important to note, however, that a multiplier calculated for one measure, e.g., earnings, cannot be used to assess the impact of another measure, such as jobs or sales.

By definition, multipliers are greater than or equal to one. In application, the direct effect is multiplied by the "multiplier" to get total economic impacts. The resulting estimate of total economic impacts *includes* the direct effect. For example, suppose the jobs multiplier for a particular exporting activity is 1.4 and 100 new jobs are added to the local economy in that sector. The total local impact of those jobs is 140 jobs, a figure that includes the 100 direct jobs plus 40 additional jobs that represent the multiplier or so-called "ripple" effect. The 40 additional jobs include both indirect (economically-linked) and induced (employee spending) jobs.⁵

⁵ In general, multipliers should only be calculated for and applied to basic or export activities. Activities that sell to persons living in or businesses located in the region, such as most retailing, many services, etc., tend to be part of the ripple effect and do not create their own set of iterative impacts. There are exceptions to this general rule, particularly in rural areas. In a rural area, the entry of a new retailer may increase the amount of goods purchased within the region. In this situation, the new retailer increases the amount of money that stays within the community.

APPLICATION OF INPUT-OUTPUT MODEL

Input-output methodology is one of the most common approaches in estimating economic impacts. Input-output (I-O) models are based on inter-industry relationships in a given region and trace transactions between industry sectors that are caused by changes (increase or decrease) in demand for goods and services.

The choice of "local economy" or "region" can affect both the absolute and relative size of the estimated economic impact. Thus, geographic boundaries have important effects on the analysis (Siegfried, Sanderson and McHenry 2006).

As the geographic area expands, multipliers grow. Smaller regions, such as counties, have considerably more leakage out of the area than larger regions, such as states. A state economy is relatively more diversified so it tends to have fewer leakages than a county economy. As a result, relatively higher shares of purchases made and related production are retained within a state than a county. Thus, the economic impact of a given amount of spending will be higher using the state as the analysis "region" instead of a county. The same amount of expenditure will generate higher total impacts when analyzed at state level compared to a county level.

On the other hand, the relative size of a given impact will be larger for smaller regions. Thus, the impact of a particular industry will be assessed as more "important" if measured relative to a small region than a large one.

The selection of a state-based analysis in this study was dictated by the principal purpose of the study – to assess the impact on the state's economy. Although largely concentrated within Pima County, there are APSS activities spread throughout the state of Arizona so the state is the geographical area used in this study.

The IMPLAN⁶ I-O model of Arizona applied in this study provides a portrait of the state's economy in

terms of 509 industry sectors, including government and households.

Specifically, the IMPLAN model was used in this study to estimate the following impacts on Arizona's economy:

- Number of jobs, wages and salaries, and output generated through APSS organizations' spending on goods and services in Arizona;
- Number of jobs, wages and salaries, and output generated through spending of APSS organizations' employees;
- Number of jobs, wages and salaries, and output generated through out-of-state visitors associated with APSS organizations, and
- One-time impact (jobs, wages and salaries, and output) generated through capital investment and construction activity associated with APSS organizations.

The results of the I-O model are used to calculate job, earnings and output multipliers.

TAX REVENUE MODEL

The revenue impact model estimates state, county and city tax revenues associated with changes in business activity. The model is designed to be used in conjunction with other economic assessment information, e.g., the wage impact results obtained from the input-output model and other specific information about changes in business activity.

Two types of input data are required to run the model. The first type of data consists of community and tax information, such as county, city and state property tax rates, net assessed valuations, taxable sales, county and incorporated city population.

The second type of input is project-specific information. The required input consists of the following types of data inputs: total wage impact of the project or activity obtained from the input-output model (direct, indirect and induced impacts), taxable expenditures, by category, construction costs and, for retail sales, the portion of sales spent in cities, counties, the state and outside the state. In some instances, in order to take into account the different

⁶ Developed and maintained by Minnesota IMPLAN Group, Inc., the IMPLAN I-O models are widely used in academic and applied research.

tax levels and regimes of different taxing jurisdictions within the state, assumptions are made to distribute sales geographically within the state.

Direct tax revenues are those associated with direct expenditures, e.g., APSS organizations' or visitor purchases. Thus, when a visitor makes purchases locally, a portion of those purchases is taxable, and those taxes accrue to state and local governments. Direct tax revenue impacts reported for the state in this report are revenues retained by the State of Arizona following distribution to cities, towns and counties.

Induced tax revenues are revenues that accrue to the state or local governments due to the spending of employees in the affected industries. When visitors spend money in a restaurant, more workers are required in the restaurant industry and when those workers spend their earnings, they generate induced tax revenues. The same is true when university employees and observatory employees spend locally.

Note that the revenue impact model does not estimate revenues that will be distributed to special districts or school districts. However, it should be recognized that these governmental organizations will receive induced tax revenues.

DATA

For the purpose of estimating the economic impacts of APSS organizations on Arizona's economy, the following types of data were collected:

EXPENDITURES BY CATEGORY

For observatories and related research organizations (*i.e.*, non-university organizations), we used a questionnaire to gather data on (a) payroll, (b) operations-related expenditures in Arizona (such as professional services, professional development expenses, facility expenses, equipment, materials and supplies), and (c) capital expenditures (such as remodeling/construction and equipment).

For university departments and research centers, we obtained data on expenditures by object code from their respective financial services offices. The UA Financial Services Office's data provided detailed expenditures, including employee payroll. However, these data included expenditures both in Arizona and outside Arizona, so additional data – expenditures by object code and zip code – were obtained from the UA Procurement and Contracting Services

Office. Although these two data series did not match perfectly, the latter provided the best estimate of what was spent in Arizona. Financial services offices at ASU and NAU provided less detail than UA, but were able to provide Arizona-only expenditures.

Because a large portion of the expenditures made by APSS organizations at universities is derived from grants, it is necessary to assess the impact of both the expenditures made by research centers/departments using those funds and the overhead-related dollars that are spent elsewhere in the university. Specifically, at universities, grant budgets include not only the direct costs of completing the requirements of the grant (*e.g.*, wages and salaries, benefits, travel, and supplies) but also an "indirect charge," which is designed to cover the overhead costs of administering the grant and to pay for university operating expenses related to fulfilling grant requirements, such as utilities, laboratory expenses, and administrative support. Since the indirect charges on federal grants can be 50 percent of the direct costs, assessing the impacts of these charges is important.

Only Arizona expenditures were entered into the IMPLAN I-O model.

EMPLOYEE EXPENDITURES

Data on wages and salaries paid to employees in APSS organizations and the amount of employee benefits were collected through the survey or from university financial services offices as described above. Student wages and associated benefits were treated separately from other employee wages and salaries because the expenditure patterns of these two groups differ.

To estimate the impact of local (Arizona) spending, we first estimated disposable income by applying the Arizona's disposable income factor of 76 percent to wages and salaries of regular employees, and an estimated 85.2 percent to student wages. This means, that about 24 and 14.8 percent respectively leak out of state in the form of federal tax, FICA and other non-tax contributions.

Survey-based expenditure patterns for university employees and students obtained in a recent University of Arizona impact study (Pavlakovich-Kochi and Charney 2005) were used to estimate categories of spending in this study.

A portion of employee benefits that is spent on health insurance and services, estimated at 24.4 percent of wages and salaries, was added to the local expenditures associated with the employee impacts.

NUMBER OF VISITORS AND DOLLARS SPENT

The survey confirmed that the APSS organizations have been an important attraction for visitors to Arizona.

Information on number of visitors and average spending in FY 2006 in Arizona was obtained from questionnaires; separate questions were asked about professional visitors and public visitors. Estimates of average daily expenditures were requested only for professional visitors, while in regard to public visitors, secondary sources were used to estimate the number of days/nights spent and average daily expenditures.

Since the questionnaire asked only basic questions, the expenditure breakdowns and spending characteristics for each type of visitor were obtained from other sources, most notably the Travel and Tourism Satellite Accounts (TTSA), published by the U.S. Bureau of Economic Analysis, and the Arizona Tourism Statistical report.

Estimates of average daily spending of public visitors were based on domestic overnight non-resident leisure visitors' spending in Arizona, as reported in the Arizona Tourism Statistical report (2006). A detailed breakdown by spending category for both, the professional and public visitors, was obtained by using the TTSA breakdown of non-resident visitors' spending by 24 commodities.⁷ These estimated volumes of spending by category were entered in Arizona I-O model to estimate impact on jobs, earnings and output.

⁷ For a more detailed account of methodology, please contact the authors.

ECONOMIC IMPACT OF APSS ORGANIZATIONS IN FY 2006

DIRECT EXPENDITURES

The direct economic impact in this study includes: payroll of APSS employees, additional payroll at universities associated with grant overhead expenses, APSS operations-related expenditures for goods and services purchased in Arizona (including overhead expenses); locally spent benefits; and direct spending of out-of-state visitors. Also included is FY 2006 capital investment, *i.e.*, expenditures in Arizona for equipment, remodeling & construction (Table 2).

Table 2. APSS Organizations and Related Expenditures, FY 2006 (\$)

APSS employee payroll <i>(including students)</i>	75,560,152
Additional payroll at universities <i>(overhead)</i>	8,418,297
APSS operation-related expenditures <i>(including overhead)</i>	21,413,158
Benefits	5,181,620
Total APSS	110,573,227
Visitor Spending	16,078,009
One-time capital investment (APSS)	11,799,784
Total direct impact (output)	138,451,020

Source: APSS survey 2007; university FSOs.

The APSS organizations contributed to the economy of Arizona \$84.0 million in direct wages and salaries, and spent \$21.4 million on operations-related goods and services purchased from Arizona businesses. In addition, \$5.2 million worth of employee benefits was spent locally, mostly in the health services sector.

Out-of-state visitors attracted to APSS organizations for either professional reasons, such as conferences and research, or as the general public, spent an estimated \$16.1 million in Arizona. Assuming that FY 2006 is representative of on-going annual expenditures, APSS organizations contribute annually over \$126.6 million directly to the Arizona economy.

In FY 2006, APSS organizations spent an additional \$11.8 million in Arizona for equipment, remodeling and construction. Thus, the total direct impact on the state's economy was \$138.5 million.

DIRECT JOBS

APSS organizations employed 1,830 persons (including 168 jobs associated with overhead charges), of which 320 were graduate and undergraduate students. Operations-related local purchases supported an additional 156 direct jobs in local businesses, and 44 jobs through a portion of locally spent benefits. Visitor spending generated an additional 202 direct jobs. Thus, 2,232 jobs in Arizona are directly related to APSS organizations every year. In FY 2006, due to capital investment, an additional 78 direct jobs were generated in the state increasing the number of direct jobs associated with APSS economic activity to 2,310.

INDIRECT IMPACTS

The indirect impact in this study includes: expenditures for goods and services in the local economy triggered by the initial direct expenditures of APSS organizations and visitor spending. Because every initial dollar is spent and re-spent, the impact on output, jobs and earnings is felt throughout the economy. It usually takes at least a year for the last cent to be spent locally.

These inter-industry impacts are generated through increases in economic activity (output, jobs and earn-

Table 3. Direct Impacts of APSS Organizations, FY 2006

	Jobs	Wages & Salaries (\$)	Other Value Added (incl. taxes) (\$)	Output (\$)
Employees in APSS (including students)	1,662	75,560,152	-	75,560,152
Additional employees at universities (overhead)	168	8,418,297	-	8,418,297
APSS operation-related expenditures	156	6,300,803	15,112,354	21,413,157
Benefits	44	2,524,834	2,656,786	5,181,620
APSS direct impact	2,030	92,804,086	17,769,140	110,573,226
Visitor spending	202	4,993,291	11,084,718	16,078,009
One-time capital investment (APSS)	78	3,514,971	8,284,813	11,799,784
Total direct impact	2,310	101,312,348	37,138,671	138,451,019

Source: APSS survey 2007; IMPLAN I-O.

Table 4. Indirect Impacts of APSS Organizations, FY 2006

	Jobs	Wages & Salaries (\$)	Other Value Added (incl. taxes) (\$)	Output (\$)
APSS employee spending	-	-	-	-
Additional university employees' spending	-	-	-	-
APSS operation-related expenditures	57	2,270,537	3,956,438	6,226,975
Benefits	14	405,219	1,226,887	1,632,106
APSS indirect impact	71	2,675,756	5,183,325	7,859,081
Visitor spending	37	1,467,406	3,075,760	4,543,166
One-time capital investment (APSS)	25	1,161,919	2,103,419	3,265,338
Total indirect impact	133	5,305,081	10,362,504	15,667,585

Source: IMPLAN.

ings) associated with each initial dollar of local purchases. The magnitude of indirect impacts depends upon diversity of the state economy and intensity of transactions between in-state industries. The more in-state industries buy from each other, the higher the multiplier and the resulting indirect impact.

Based on FY 2006 expenditures, it was estimated that APSS organizations generated 71 indirect jobs and \$2.7 million in indirect wages and salaries in Arizona on an annual basis. Visitors to these organizations indirectly created 37 jobs and \$1.5 million in wages and salaries. Adding these impacts to the

indirect impact of capital investment, the combined number of indirect jobs in FY 2006 was 133 with \$5.3 million in wages and salaries (Table 4).

Indirect output, including wages and salaries, taxes and other value added, was \$15.7 million. This includes the one-time impact of capital investment in FY 2006.

INDUCED IMPACTS

Induced impacts include jobs, earnings and output that are being generated as employee earnings are re-spent in the local economy.

The combined induced impact of APSS organizations' operations and employee spending was 804 jobs and \$29.1 million in earnings. In addition, spending by employees in jobs generated by visitor spending represented the addition of another 47 jobs and \$1.7 million in earnings. Thus, 851 induced jobs and \$30.8 million in earnings are generated annually through APSS related economic activity.

In FY 2006, capital investment generated an additional 34 induced jobs and \$1.2 million in earnings. The combined induced impact in FY 2006 was 885 jobs and \$32.0 million in earnings (Table 5).

Table 5. Induced Impacts of APSS Organizations, FY 2006

	Jobs	Wages & Salaries (\$)	Other Value Added (incl. taxes) (\$)	Output (\$)
APSS employee spending	636	23,486,688	45,877,818	69,364,506
Additional university employees' spending	84	2,821,716	8,400,980	11,222,696
APSS operation-related expenditures	61	2,219,847	4,568,788	6,788,635
Benefits	23	551,278	1,933,880	2,485,158
APSS induced impact	804	29,079,529	60,781,466	89,860,995
Visitor spending	47	1,662,423	3,400,138	5,062,561
One-time capital investment (APSS)	34	1,219,266	2,494,184	3,713,450
Total induced impact	885	31,961,218	66,675,788	98,637,006

Source: IMPLAN.

TAX REVENUE IMPACTS IN FY 2006

Tax revenue impacts are estimated for different levels of government. In Arizona, several major sources of city and county government revenues are state-shared revenues. These are taxes imposed by the state, collected by the state and partially redistributed by the state to cities and counties according to legislated formulas. The primary state-shared taxes are:

- State-shared sales tax revenues, which are distributions of state sales taxes;
- Highway User Revenue Fund revenues, which are fuel tax collections, use fuel (primarily diesel) tax collections, truck fees and a variety of other highway-related tax and fee collections that are shared with counties and incorporated cities and towns; and
- Urban Revenue Funds, which are portions of the state income tax distributed to incorporated cities and towns.

Other local tax revenue sources include city sales taxes and city and county property taxes

DIRECT TAX REVENUE IMPACT

Direct tax revenue impacts, as shown in Table 6, are those paid concurrently as expenditures are made. For example, an observatory pays a contracting tax (a component of sales taxes) on its construction activity, a retail tax for supplies purchased locally, and use taxes on certain equipment purchased from out of state. Astronomy-related spending by universities and observatories (excluding capital spending) generated a total of \$1.7 million dollars to state, county and city governments. Astronomy-related visitor spending is estimated to have generated \$1.6 million in revenues to various levels of governments, and capital expenditures generated \$0.9 million in revenues.

Table 6. Direct Tax Revenue Impact of Astronomy-Related Expenditures, FY 2006 (\$)

	University Spending	Observatory Spending	Visitor Spending	Capital Spending	
State of Arizona					
Privilege Taxes Retained by State	151,165	701,230	714,145	435,388	
Privilege Tax Revenues Dedicated to Education	21,394	108,378	96,358	70,799	
Motor Fuel and HURF Revenues	-	15,133	13,486	-	
Direct State Tax Revenues	172,559	824,741	823,989	506,187	2,327,476
Counties in Arizona					
State-shared Privilege Tax Revenues	22,681	144,686	166,735	95,602	
State-shared Motor Fuel and HURF Revenues	-	1,349	5,806	-	
Transient Occupancy Taxes	2,086	28,533	39,446	-	
Direct County Tax Revenues	24,767	174,568	211,986	95,602	506,923
Cities in Arizona					
City Privilege Taxes	64,301	327,023	289,075	212,396	
Transient Occupancy Tax	8,345	27,974	157,782	-	
State-shared Privilege Tax Revenues	13,997	89,290	102,898	58,999	
State-shared Motor Fuel and HURF Revenues	-	2,165	9,319	-	
Direct City Tax Revenues	89,643	446,452	559,074	271,395	1,363,564
Total Direct Tax Revenues	283,969	1,445,761	1,595,049	873,184	4,197,963

Table 7. Induced Tax Revenue Impact of Astronomy-Related Expenditures, FY 2006 (\$)

	University Spending	Observatory Spending	Visitor Spending	Capital Spending	
State of Arizona					
Income Tax	474,969	900,838	96,227	69,846	
Privilege Tax Retained <i>(excludes Prop. 301 0.6% Tax)</i>	691,235	1,311,013	140,041	101,679	
Privilege Tax Retained Dedicated to Education	106,492	201,976	21,575	15,660	
Motor Fuel and HURF Revenues <i>(State Highway Fund)</i>	94,365	178,976	19,118	13,877	
Induced State Tax Revenues	1,367,061	2,592,803	276,961	201,961	4,437,857
Counties in Arizona					
State-shared Privilege Tax	122,904	233,102	24,900	18,073	
State-shared Motor Fuel Tax and HURF	40,622	77,045	8,230	5,974	
Vehicle License Tax for General Fund	33,922	64,338	6,873	4,988	
State-shared Vehicle License Tax for Highways	7,860	14,908	1,592	1,156	
Property Tax <i>(excludes personal property taxes)*</i>	240,360	455,873	48,696	35,346	
Induced County Tax Revenues	445,668	845,266	90,291	65,537	1,446,762
Cities in Arizona					
Urban Revenue Sharing**	83,818	158,971	16,981	12,326	
State-shared Privilege Tax	75,848	143,855	15,366	11,154	
State-shared Motor Fuel Tax and HURF	65,209	123,678	13,211	9,589	
State-shared Vehicle License Tax	33,922	64,338	6,873	4,988	
Property Tax <i>(excludes personal property taxes)</i>	29,729	56,385	6,023	4,372	
City Privilege Tax <i>(excludes transient occupancy)</i>	258,329	489,952	52,336	37,988	
Transient Occupancy Tax	1,183	2,244	240	174	
Induced City Tax Revenues	548,038	1,039,423	111,030	80,591	1,779,082
Total Induced Tax Revenues	2,360,767	4,477,492	478,282	347,160	7,663,701

*Amounts for property taxes represent long-term impact associated with real property improvements (i.e., amounts excludes taxes on personal property). Revenues will increase over time to amounts shown in table.

**Impact associated with Urban Revenue Sharing will have 2 year lag.

INDUCED TAX REVENUE IMPACT

Not only do operations of observatories and universities generate revenues, employees at these institutions and economically-related industries (via indirect and induced economic impacts) generate tax revenues as they spend their income within the state. In addition, the spending of employees in visitor-related industries, such as restaurants and hotels, generate revenues. Tax revenues created by employees spending their income are referred to as induced revenues in this study and are shown in Table 7.

Spending by employees at observatories and universities, by employees in economically-linked sectors, and employees associated with astronomy-related visitors generated \$4.4 million to the state, \$1.4 million to counties, and \$1.8 million to city governments. The combined induced tax revenue derived from all earnings was \$7.7 million to state, county and city governments.

TOTAL TAX REVENUE IMPACT

Total revenue impacts are summarized in Table 8. The state of Arizona received \$6.8 million and cities and counties received another \$5.1 million.

Table 8. Total Tax Revenue Impact of Astronomy-Related Expenditures, FY 2006 (\$)

	University Spending	Observatory Spending	Visitor Spending	Capital Spending	Total
State of Arizona	1,539,620	3,417,544	1,100,950	707,219	6,765,333
Counties in Arizona	470,435	1,019,834	302,277	161,139	1,953,685
Cities in Arizona	634,681	1,485,875	670,104	351,986	3,142,646
Total Tax Revenues	2,644,736	5,923,253	2,073,331	1,220,344	11,861,664*

Source for Tables 6, 7 and 8: The Economic and Business Research Center revenue model.

SUMMARY

TOTAL MONETARY IMPACT IN FY 2006

The total monetary impact of APSS organizations' economic activity in Arizona in FY 2006 was an estimated \$252.8 million (Table 9). This includes total earnings impact of \$138.6 million and other value added of \$114.2 million, which includes the

\$11.9 million in tax revenues. Value added includes proprietary income, e.g., income to business owners and other self-employed work; benefits such as retirement payments and health insurance; and indirect business taxes.

Table 9. Total Economic Impacts (Direct, Indirect and Induced), FY 2006

	Jobs	Wages & Salaries (\$)	Other Value Added (incl. taxes) (\$)	Output (\$)
Employees in APSS (including students)	1,662	75,560,152	-	75,560,152
Additional employees at universities (overhead)	168	8,418,295	-	8,418,295
APSS employee spending	720	26,308,404	54,278,798	80,587,202
APSS operation-related expenditures	274	10,791,187	23,637,580	34,428,767
Benefits	81	3,481,331	5,817,553	9,298,884
APSS total impact	2,905	124,559,369	83,733,931	208,293,300
Visitor spending	286	8,123,120	17,560,616	25,683,736
One-time capital investment (APSS)	137	5,896,156	12,882,416	18,778,572
Total impact	3,328	138,578,645	114,176,963	252,755,608

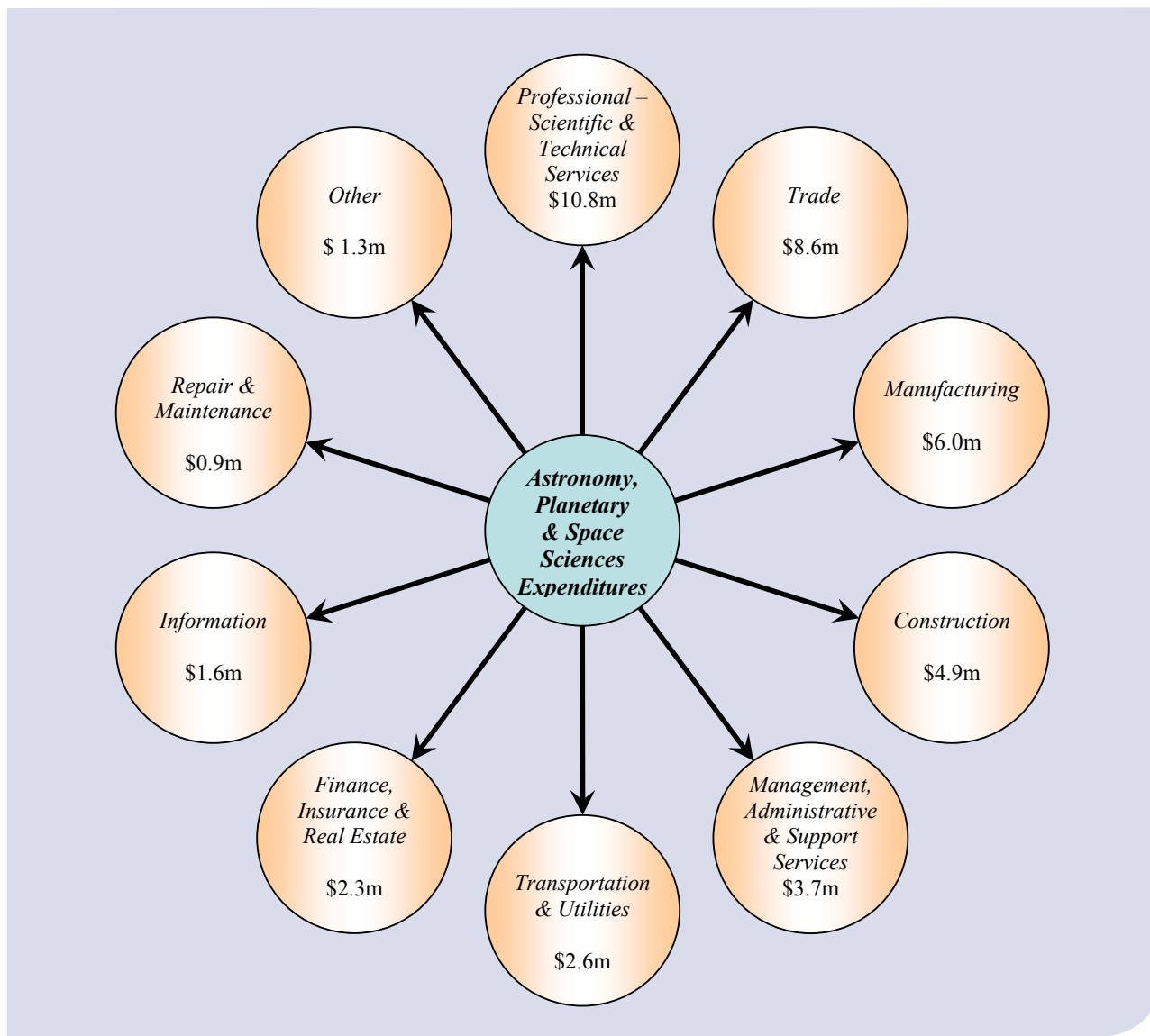
Source: IMPLAN.

LINKAGES WITH INDUSTRY

Figure 3 portrays economic linkages between APSS organizations and industry sectors in the regional economy. It shows indirect output in various industry sectors as a result of direct expenditures for goods and services by APSS organizations (including capital investment). Practically, every industry sector has been affected, with the largest economic benefit accruing to professional, scientific and technical services (\$10.8 million), followed by trade (combined wholesale and retail, \$8.6 million), manufacturing

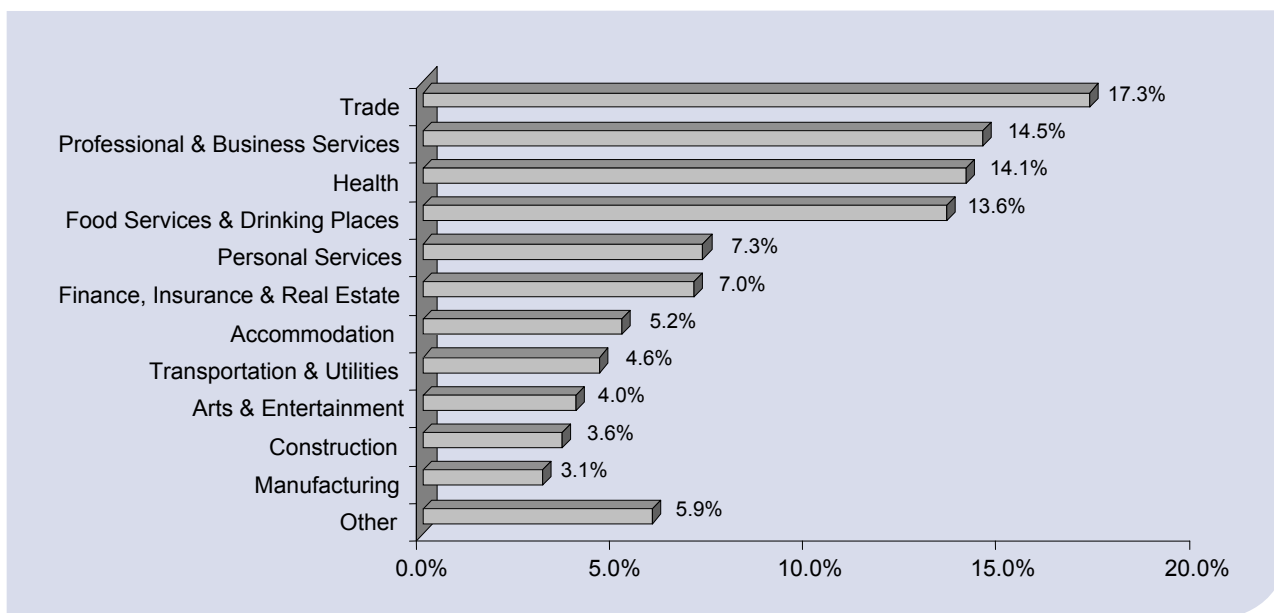
(\$6.0 million), construction sector (\$4.9 million), and administrative, support and waste management services (\$3.7 million). Other sectors benefit as well, such as transportation and utilities (\$2.6 million), finance, insurance and real estate services (\$2.3 million), information services (\$1.6 million), and repair and maintenance (\$0.9 million). The remaining \$1.3 million is spread over other sectors, such as accommodation and food services, and government services.

Figure 3. Linkages with Industry



Source: IMPLAN I-O for Arizona. Inter-industry impacts measure the direct and indirect interaction of the Astronomy, Planetary and Space Sciences organizations with other industries as well as interaction among industries. "Other" includes: food and accommodation, government, art and entertainment, education, health, agriculture and mining industries.

Figure 4. Employment Impact by Industry (excluding direct employment in APSS organizations)



Employment impact includes jobs generated by APSS organizations' employee and visitors' spending and spending by employees in affected businesses (indirect wages). Direct employment in APSS organizations is excluded. The category "other" includes education services, publishing, postal services, government, agriculture and mining.

EMPLOYMENT IMPACT BY SECTOR

Figure 4 shows employment impact by industry sector associated with the economic activity of APSS organizations, including visitor impact, but excluding direct employment in APSS organizations. As reported above, close to 1,500 jobs in FY 2006 were generated outside APSS organizations. The distribution of these jobs by industry sector reflects a significant contribution of APSS payroll being spent locally as well as the impact of visitors' spending. Of all indirect and induced jobs, 17.3 percent were generated in trade (retail trade and wholesale), another 14.5 percent in professional and business services, 14.1 percent in health services, and 13.6 percent in food services and drinking places. These four industries accounted for close to 60 percent of all indirect and induced jobs. Other jobs were generated in personal services (7.3 percent), finance, insurance and real estate (7.0 percent), accommodation industry (5.2 percent), transportation and utilities (4.6 percent), arts and entertainment (4.0 percent), construction (3.6 percent), and manufacturing (3.1 percent). The remaining 5.9 percent jobs

were in other services such as education, publishing, postal services, government, as well as agriculture and mining.

APSS MULTIPLIERS FOR FY 2006

Composite multipliers reflect the ripple effect of the economic activity associated with the APSS organizations, including purchases made by those organizations, spending by employees, visitor spending, and 2006 construction activity. The composite job multiplier is 1.6, which means that for every 10 direct jobs in the APSS organizations, another 6 jobs are generated in the Arizona economy. For every dollar of direct wages and salaries, another 50 cents in earnings are generated throughout the economy (wage and salary multiplier of 1.5). When tax revenues and other value are added, an additional \$1.30 dollars in sales is created by every dollar of direct expenditures (output multiplier of 2.3).⁸

⁸ Reported multipliers are calculated by dividing the total impact (bottom row in Table 9) by APSS direct impact (fifth row in Table 3).

CONCLUSIONS AND LIMITATIONS OF THE STUDY

As mentioned in the introduction, this is the first study conducted to assess the economic impact of the astronomy, planetary and space sciences research on the economy of Arizona.

Impacts of university departments and research centers have been regularly included in the overall impacts of the three Arizona universities, but they were merged with economic activities of other departments and programs.

Certain observatories provide selected information on their websites about their economic activity, such as the number of scientists and students, visitors, cost of telescopes, or even estimates of total monetary contribution to the local area.

Other states with comparable importance of astronomy, planetary and space sciences research are Hawaii and New Mexico. The University of Hawaii Institute for Astronomy conducted a study of APSS impact on the state's economy in 2001 and, since then, provides annual updates.⁹

However, without the accessibility to full reports and detailed methodology, any comparison becomes meaningless. As noted in many economic impact studies, only if exactly the same analytic methodology is used, can estimated values from different reports be compared (ARA Group 1999).

While this study is the first one to present the most comprehensive assessment of the economic activity of Arizona's astronomy, planetary and space sciences research, the scope of the study was limited to "measurable" impacts. This study only traces money associated with APSS organizations in Arizona and visitors to those organizations.

An important segment of APSS-related activity in the state is not measured, specifically manufacturers and other industries that are the result of APSS activity in the state. This study measures the impact

on the private sector only if APSS organizations purchase goods or services from them or if employees make purchases from them. But there are many more private sector impacts associated with astronomy, planetary and space sciences research. In some instances, entire economic sectors, e.g., the optics industry, are the direct result of the strong presence of APSS organizations in Arizona. In other instances, parts of certain Arizona industries, such as missiles, electronics and computers, scientific instruments, engineering services, and robotics have close connections to astronomy, planetary and space sciences. Sometimes the connections are due to graduates in these scientific fields working in the private sector. Skills learned in these sciences are surprisingly transferable to the private sector.¹⁰ Sometimes the relationships involve APSS scientists working with private sector companies.

In addition, this study does not capture all the broad benefits that the APSS organizations bring to the state of Arizona. For many years, these organizations have increased the visibility of the state to the rest of the country and the world. It is not possible to place a monetary value on the role APSS has played in helping to establish Arizona as a center of research and technology.

Nor can this study measure the economic impact or benefits that are derived from innovations and inventions associated with APSS organizations. And certainly this study cannot put a value on the new knowledge about the world and universe that these organizations are creating.

Astronomy, planetary and space sciences research has been an important economic cluster in Arizona for decades. This is the first study that attempts to assess the state-wide economic impact of these

⁹ Kudritzki, Rolf-Peter and Bob Joseph. 2003. Update to 2001 Self-Study report. (http://www.ifa.hawaii.edu/publications/self-study/Self-Study_Update-Oct03.pdf) on 5/13/2007.

¹⁰ ARA Group. 1999. A Division of KPMG Consulting LP. Estimation of the Economic Impacts of Canadian Astronomy. Report prepared for the National Research Council. Accessed at <http://www.casca.ca/lrp/vol2/economic/Economic.htm> on 2/6/2006.

organizations. Despite the limitations and narrow focus of this study, the measured economic impacts are substantial, with astronomy, planetary and space sciences research activities directly or indirectly contributing over 3,300 jobs to the Arizona economy, \$138.6 million in earnings, and \$114.2 million in other value added, including \$11.9 million in taxes. Combined, astronomy, planetary and space sciences research contributes over a quarter of a billion dollars in output (sales) to the local community.

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