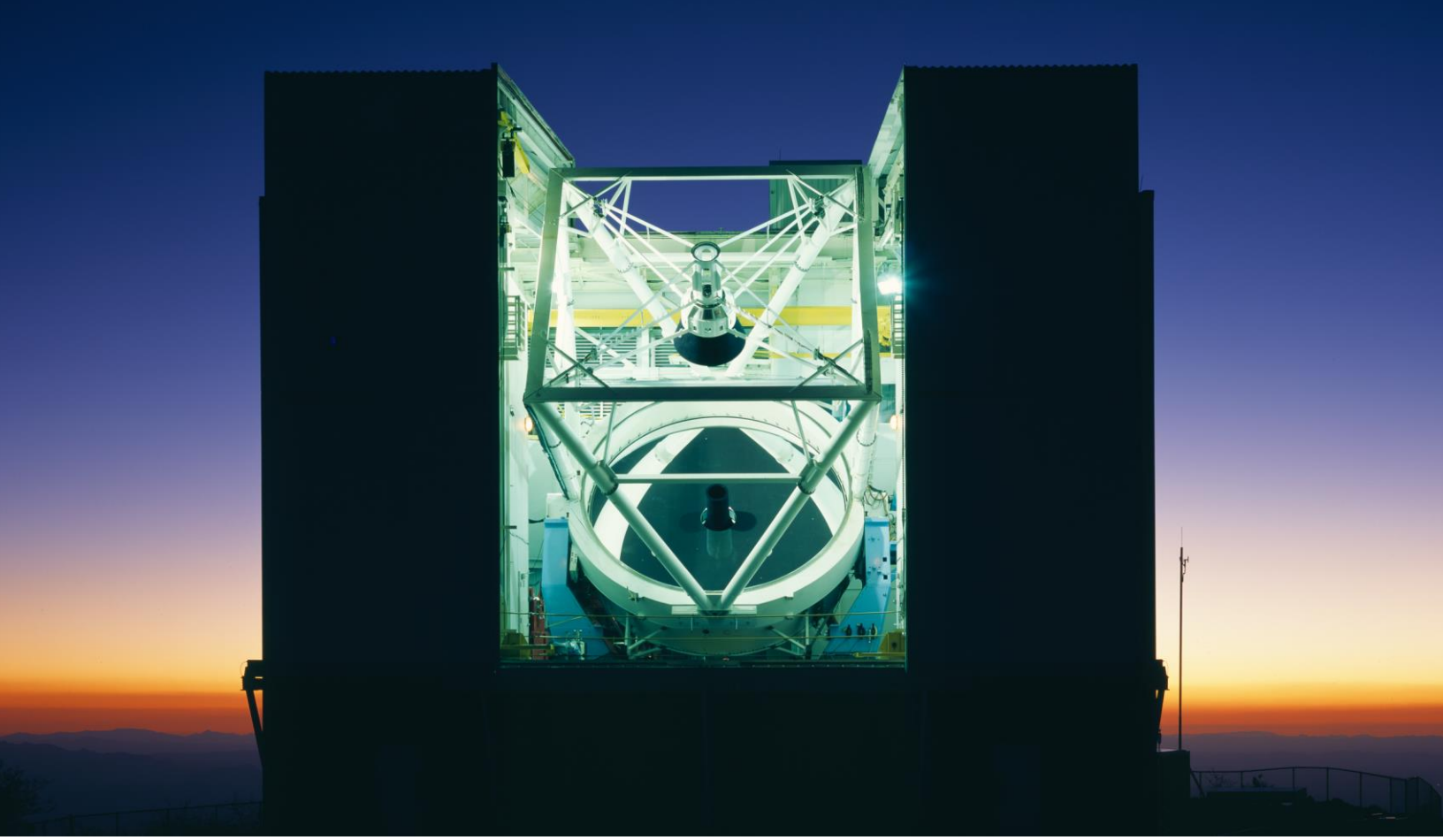


Photo Credit: Howard Lester, MMT Observatory, University of Arizona and Smithsonian Astrophysical Observatory.

The Economic Impact of UArizona Astronomy and Space Sciences Operations

December 2022

By: Rounds Consulting Group

4450 S. Rural Road, Suite C-220, Tempe, AZ 85282 | Phone: 480-508-4911 | www.roundsconsulting.com

Executive Summary

The following impact analysis, prepared for UArizona, quantifies the economic and fiscal benefits of the University's Astronomy and Space Sciences ("UA Space Sciences") operations.

Operational activity of the UA Space Sciences drives a significant amount of economic activity and produces a 5 to 1 return from the $20M in state funding that brings in over $100M in grants, philanthropic donations, and contracts. This money circulates throughout the local economy and supports thousands of jobs statewide every year.

The following summarizes the key findings of the analysis. The impacts are categorized in terms of jobs, labor income (i.e., employee-earned wages and benefits), economic output (i.e., a measurement of economic volume similar to Gross Domestic Product), and tax revenues.

UArizona Astronomy and Space Sciences Annual Impacts on the Local Economy

$560.5M in Economic Output

3,300 Jobs

$193.9M in Labor Income

$100M+ in Grants/Contracts

$21.1M in Tax Revenues

THE UNIVERSITY OF ARIZONA

Key Findings – UA Space Sciences

- The UA Space Sciences departments, observatories, planetariums, and laboratories bring in over $100M in grants, donations, and contracts and directly employ over 900 persons (full- and part-time employees) throughout the state.
- However, the job impact goes beyond the 900+ individuals. In total, operations support approximately 3,300 full-time equivalent direct, indirect, and induced employees in Arizona.
- Operations of the UA Space Sciences produce a total of $193.9M in labor income (i.e., the aggregated direct, indirect, and induced employee-earned wages and benefits) annually.
- Each year approximately 80,000 individuals visit the Mt. Lemmon Sky Center, the Richard F. Caris Mirror Lab, and Flandrau Science Center and Planetarium, providing entertainment and education to the community.
- The UA Space Sciences produces approximately $560.5M in economic activity annually. This includes the activity generated by the departments' day-to-day operations and its vendors, grant awards, individuals visiting observatories, and employees spending their incomes throughout the local economy.

- Derived from employee wages, employee-owned property, spending on everyday items, and visitor spending, among others, operations of the UA Space Sciences generate approximately $21.1M in tax revenues each year. These revenues are collected on a state, county, and municipal level.

Note: The economic model utilized for this analysis estimates the direct impacts (i.e., the initial economic activity created by UA Space Sciences academic and non-academic operations, grant funding, contracts, philanthropic awards, and the impact of the 900+ direct employees) as well as the multiplier effects (or secondary impacts) associated with operations.

The multiplier effects capture the additional activity (i.e., indirect and induced jobs, labor income, economic activity, and tax revenues) created as one industry impacts other sectors and the activity generated by the cycle of spending and re-spending within the regional economy.

Impacts were calculated based on the UA Space Sciences job counts, personnel costs, operational expenditures/revenues, student counts, grant awards, and visitor activity. Actual impacts may vary, and some impacts may not materialize due to unanticipated events and changing circumstances. However, Rounds Consulting Group has made extensive efforts to confirm the accuracy of the information contained in this analysis.

Photo Credit: United Launch Alliance.

Table of Contents

Introduction

Rounds Consulting Group, Inc. ("RCG") was contracted by the University of Arizona to estimate the effects of the Astronomy and Space Sciences ("UArizona Space Sciences") operations on the local and regional economy. The University and UArizona Space Sciences play a vital role throughout Arizona's economy advancing the growth of the astronomy and space science industries.

Advanced fields such as aeronautics, engineering, optical sciences, and space sciences, among others, are of high concentration in the Tucson area due to UArizona's efforts and the tens of millions in federal grants, state resources, and donations that the UArizona Space Sciences bring in – leading the state in the development of new technologies, research, the creation of high-paying jobs, and exploring new frontiers.

On average, according to the university, the UArizona Space Sciences brings in approximately $100M in grants and awards as well as over $7M in philanthropic giving each year. Furthermore, the state provides approximately $20M in annual funding resources. According to the annual National Science Foundation Higher Education Research and Development survey, UArizona has spent more money on space research than any other university each year for more than three decades. The influx of money that circulates throughout the Arizona economy supports thousands of jobs and produces additional economic impacts.

University of Arizona Astronomy and Space Sciences

UArizona conducts space science related education, outreach, research, and development of new space technologies primarily within four units, the Steward Observatory, the Department of Astronomy, the Lunar and Planetary Laboratory, and the Department of Planetary Sciences, although at least half a dozen other units at the University have some activity in these areas.

Steward Observatory was established in 1916 upon the generous gift of $60,000 by Lavinia Steward to UArizona for the construction of the University's first research telescope. This telescope was formally dedicated on April 23, 1923. Over the following decades, the University leveraged Arizona's accessible mountain tops, dark skies, and clear weather to produce world-class astronomical observations. This opportunity, to be at the forefront of astronomical research, attracted talented students, staff, and faculty that helped sustain and grow the space science activities at the University. This led to the creation of the Department of Astronomy, the Lunar and Planetary Lab, and the Department of Planetary Sciences.

Today, Steward Observatory operates more than 20 telescopes at six sites in Arizona and is partnered in the operations of telescopes in Chile. Steward Observatory also includes multiple subunits, including the Richard F. Mirror Lab, the Arizona Radio Observatory, the MMT 6.5m telescope (partnered with the Smithsonian Astrophysical Observatory), the Mount Graham International Observatory, the Mount Lemmon Sky Center, Mount Lemmon Sky School, the Imaging Technology Lab, and many other significant research subunits. Steward Observatory also represents UArizona in multiple partnered (with other institutions) facilities. These include the Large Binocular Telescope Observatory on Mt. Graham, the Magellan 6.5m telescopes, the Event Horizon Telescope Collaboration, the LSST Corporation, and the Giant Magellan Telescope Organization.

In addition, Steward Observatory has been a partner/vendor with NASA for multiple missions, including producing instruments for NASA's Hubble Space Telescope, Spitzer Space Telescope, and James Webb Space Telescope. UArizona is the only university to have led more than one instrument for NASA's great observatories and the only university to lead instruments for JWST.

The UArizona Lunar and Planetary Laboratory (LPL, founded in 1960) and Department of Planetary Sciences (founded in 1973) were created to focus on the understanding of planets. Work produced by the LPL and the Department of Planetary Sciences involves high-tech research and operations utilizing telescopes, spacecrafts, and simulations of planetary conditions. LPL has had the Principal Investigators for two NASA planetary missions (the Phoenix Mars Lander and the OSIRIS-REx asteroid sample return), the only university that has directed more than one deep-space mission, and faculty and staff that have constructed many instruments aboard other NASA missions.

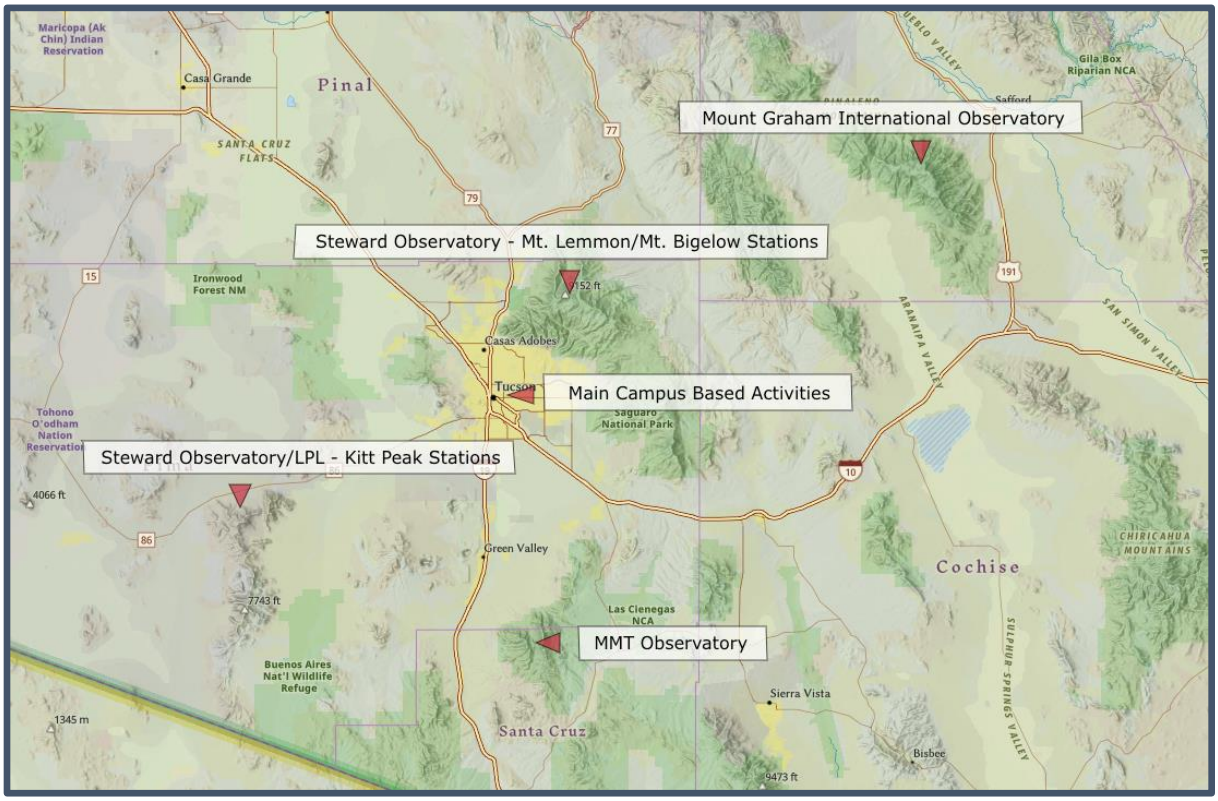
In addition to the primary space science units identified above, there are multiple centers and institutes at the University in the space sciences. These include the University of Arizona Space Institute (UASI), the Center for Astronomical Adaptive Optics (CAAO), the Earth Dynamics Observatory (EDO), and the Space Safety, Security and Sustainability Center (S4).

Graduates of the Departments of Astronomy and of Planetary Science have become international leaders in the field, working, often in leadership roles, at many different observatories and academic institutions around the world, as well as large government organizations such as the National Aeronautics and Space Administration (NASA), the National Science Foundation, and many National Labs, including the NSF's National Optical Infrared Laboratory (NOIRLab) in Tucson, Arizona, the only FFRDC in the state of Arizona. Astronomy and Physics graduate Brian Schmidt won the 2011 Nobel Prize for Physics.

The four primary space science units (Steward Observatory, Department of Astronomy, Lunar and Planetary Laboratory, and the Department of Planetary Sciences) are headquartered in Tucson but also have operations and employees at remote (out of Tucson) locations. Flandrau Science Center and Planetarium, and Richard F. Caris Mirror Laboratory are located on campus in Tucson. LBTO, Steward Observatory, and LPL operations outside of Tucson are located at or near the summits of Mt. Lemmon, Mt. Bigelow, Mt. Hopkins, Kitt Peak, Mt. Graham, and in Chile.

Photo Credit: University of Arizona.

UArizona Astronomy and Space Sciences Facility Locations



Additional Information & Model Assumptions

To estimate the full extent of the economic and fiscal impacts of the UArizona Astronomy and Space Sciences operations, data and information pertaining to the operations of key facilities were utilized. The assumptions applied in this analysis are based on the UArizona Space Sciences job counts, personnel costs, operational expenditures/revenues, grant awards, and visitor activity as of fiscal year 2021 ("FY 21").

Over the previous four years (FY 18 to FY 21), the UArizona Space Sciences departments were awarded approximately $100M in grants, over $7M in philanthropic donations, and received $20M in state funding per year on average. The data provided by the University was adjusted for effects related to the COVID-19 pandemic.

The student impact (including more than 100 graduate students) and use of state resources by the UArizona Astronomy and Space Sciences is not included as part of this analysis and, therefore, the impacts can be considered conservative. Moreover, this study includes only activities at the University of Arizona and does not include the federal NSF NOIRLab (which operates the Kitt Peak National Observatory), the private non-profit Planetary Sciences Institute, or any commercial aerospace companies in the Tucson area.

The detailed descriptions of the facilities are as follows.

Steward Observatory (including MMT, Richard F. Caris Mirror Lab, and other subunits) and the Department of Astronomy: Headquartered on the UArizona campus, Steward Observatory and the Department of Astronomy conducts observational and theoretical research, technological development, student education, and public outreach. Although UArizona astronomers use telescopes all over the world, much of the observing is performed at telescopes throughout southern and eastern Arizona that are operated by Steward Observatory or with partners of Steward Observatory.

Notably, the MMT Observatory is a large telescope, 6.5m primary mirror, located at the 8,500-foot summit of Mt. Hopkins in southern Arizona focusing on astronomical research and education. Operations of the facility include engineers, technicians, scientists, astronomers, and staff from UArizona supported by funding secured by UArizona and the Smithsonian Astrophysical Observatory.

Including those working at the MMT and other mountaintop observatories, Steward Observatory and the Department of Astronomy had 335 full-time equivalent employees as of FY 21.

Lunar and Planetary Laboratory: The UArizona Lunar and Planetary Laboratory and Department of Planetary Science, located on the UArizona campus in Tucson, focuses on the areas of planets, theoretical astrophysics, planetary surfaces, and orbital dynamics, among various others. As well as laboratories and research facilities, LPL has housed the operations of the science teams of many spacecraft missions and instruments. In FY 21, the program employed 165 full-time equivalent individuals.

Large Binocular Telescope Observatory: The Large Binocular Telescope Observatory is currently the largest telescope in the world, located on the 10,500-foot summit of Emerald Peak in the Pinaleno mountain range. The binocular design of the Large Binocular Telescope (LBT) has two identical 8.4m (27ft) telescopes mounted side-by-side for a combined collecting area of a single 11.8m telescope. Operations of the facilities employed 66 individuals (as of FY 21). These staff are located in Tucson and Safford, Arizona.

Richard F. Caris Mirror Lab: A subunit of Steward Observatory, RFCML (Richard F. Caris Mirror Lab) is located under the east wing of the UArizona football stadium. It was created by Roger Angel and colleagues as a collaboration of scientists and engineers to construct giant lightweight mirrors for use in optical telescopes. The Mirror Lab has produced many of the largest telescope mirrors ever made. The lab is currently casting mirrors for the Giant Magellan Telescope, which once complete will be the most advanced earth-based telescope in the world. The Mirror Lab also draws approximately 4,700 visitors per year for tours.

Mt. Lemmon Sky Center: A subunit of Steward Observatory, the activities of the MLSC (Mount Lemmon Sky Center) occur on the 9,200-foot summit of Mt. Lemmon near the Tucson metro area. The Mt. Lemmon Sky Center was developed to strengthen the astronomical research performed at UArizona. As of current, nine telescopes are located on the summit of Mt. Lemmon. Given the observatory's proximity to Tucson, public tours of the facilities are common.

Sky Nights is a nighttime observation program open to the public that explores the astronomical phenomenon of the southwest skies. The programs are offered throughout the entire year and include activities such as lectures, a dinner, and a guided navigation of the sky at the Mt. Lemmon Observatory. The Sky Center supported 18 full-time equivalent employees as of FY 21 and draws approximately 7,000 visitors in a typical year.

Flandrau Science Center and Planetarium: Located at the UArizona campus, the Flandrau Science Center and Planetarium offers exhibits for the public to explore UArizona scientists' research and learn about topics such as biology, energy, and optics. As of FY 21, there were 7 full-time equivalent employees at the facility. The facility attracts approximately 68,000 visitors annually.

Select Assumptions of UArizona Astronomy and Space Sciences Facilities		
Facility	**FTEs [1)]**	**Visitors [2)]**
Steward Observatory, Astronomy, and MMT Observatory	335	NA
Lunar and Planetary Laboratory	165	NA
Large Binocular Telescope Observatory	66	~ 500
Richard F. Caris Mirror Lab	27	~ 4,700
Mt. Lemmon Sky Center	18	~ 7,000
Flandrau Science Center and Planetarium	7	~ 68,000

1) Full-time equivalent jobs as of FY 21.
2) Number of visitors during a typical year prior to the COVID-19 pandemic.
Source: UArizona Astronomy and Space Sciences

Photo Credit: Thomas Folkers, Steward Observatory, University of Arizona.

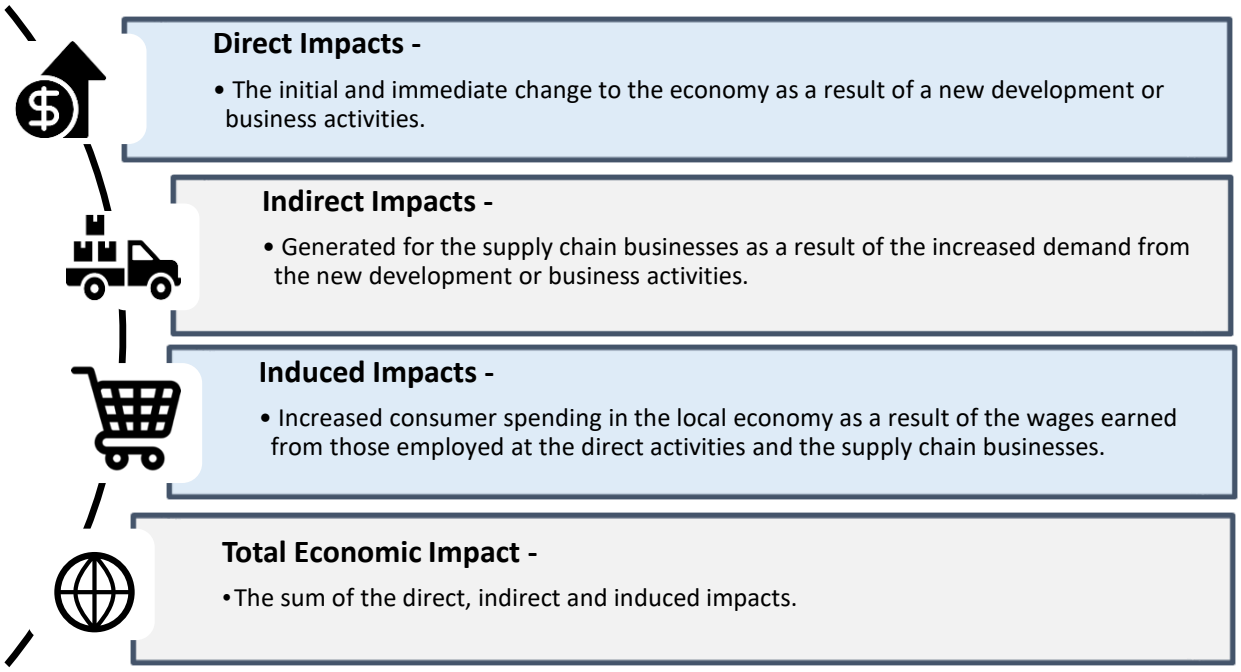
Model Methodology

Economic and fiscal impact models are an effective way to demonstrate the regional implications of a particular project, policy, business, development, or other activity in a given area. The study area can range from a single neighborhood or city to an entire state or country. Typically, the level of effects resulting from the activity is estimated in terms of *output*, *labor income*, *employment*, and *tax revenues*.

For this analysis, RCG developed an economic and fiscal impact model to analyze the effects resulting from the operations at UArizona Astronomy and Space Sciences facilities. The custom model employs an input-output methodology commonly used by economists to determine impacts. This method was used to estimate the "multiplier" or "ripple" effects caused by the activities being analyzed.

The basis for multiplier effects is the interdependencies between industries, how one industry impacts other sectors, and the cycle of spending and re-spending within the regional economy. These multipliers quantify relationships among industries and estimate the extent that the area being analyzed can capture sales, earnings, and job impacts within the region.

Input-output models measure impacts based on their source. *Direct* effects are the result of the initial activity being analyzed. The multiplier effects, or secondary effects, are measured as either *indirect* or *induced*. These are defined as:



Direct economic impacts are derived from UArizona Astronomy and Space Sciences operations including the employment of scientists, engineers, professors, office administrators, and other staff at the UArizona campus and various research stations throughout Arizona.

These direct impacts create additional indirect and induced impacts as the UArizona Astronomy and Space Sciences departments, observatories, and laboratories utilize supplier businesses for goods and services (i.e., the indirect impacts), and as employees spend their incomes at local businesses (i.e., induced impacts).

Additional economic development considerations also exist that enhance the economic impact of the UArizona Astronomy and Space Sciences operations. For example, the departments bring in tens of millions in federal grants and philanthropic donations for research and development purposes. This money is spent and re-spent locally, creating additional jobs, income, economic activity, and tax revenues. The impact of the money that is spent and remains in Arizona is significant and quantified as part of this analysis.

Note: Each year state resources are provided to the UArizona Astronomy and Space Sciences operations. State resources are not included in the model exercises to reduce the likelihood of overestimating the impacts by double counting on an annual basis.

Economic Impact Methodology

An economic impact model provides a quantifiable method to estimate the economic activity of a particular activity in a given area. Impacts can be used to measure existing activity and to measure potential expansions/contractions of an area's economy resulting from changes in economic activity. Typically, the level of economic effects resulting from the activity is estimated in terms of *output*, *labor income*, and *employment*.

> ***Output*** *captures the broader level of economic activity, or the total value of goods and services produced in the region similar to how statistics like Gross Domestic Product ("GDP") capture economic volume in individual states and across the country.*
>
> ***Labor income****, a component of output, represents employee-earned wages and benefits. The earnings component is used to measure the total change in income throughout the economy due to economic or business activity.*
>
> ***Employment*** *is the total number of full-time (or equivalent) jobs created in the economy on an annualized basis.*

A common input-output model used to generate economic multipliers is IMPLAN (short for "impact analysis for planning"). Originally developed by the U.S. Forest Service in the 1970s, the responsibility for developing IMPLAN data sets shifted to the University of Minnesota as demand grew for regional models. Now, IMPLAN runs as a private organization and is the leading provider of nationwide economic impact data and analytical software.

The RCG custom economic impact model employs this input-output model methodology and uses Arizona-specific IMPLAN multipliers. However, the model is further customized to capture dynamic economic impacts that typical input-output models do not capture.

Fiscal Impact Methodology

Fiscal impact models provide estimates for the government revenues that are generated by a particular project, policy, business, development, or activity in a given area. Typically, fiscal impacts examine revenues that are likely to result from a project or activity and are determined by the study area's tax structure.

In general, the types of government taxes analyzed include sales taxes, excise taxes, lease taxes, income taxes, and property taxes. The type of activities subject to these taxes includes payroll, retail sales, utility use, and leases, to name a few.

Fiscal impacts are categorized similarly to economic impacts and are broken down at the direct, indirect, and induced levels in which they are created.

In general, direct revenues can be estimated by definable sources such as the sales taxes generated by the UArizona Astronomy and Space Sciences facility expenditures and direct employees' retail purchases. Direct revenues additionally include those direct employee taxes such as personal income and residential property taxes, among others.

Indirect and induced revenues are generated by the wages, residency, and spending of those indirect and induced employees who are supported by the direct activity.

The RCG fiscal impact model employs this methodology. The model was designed to produce revenue information under Arizona state and local governments' tax structures. The tax revenue impacts include the tax revenues generated throughout Arizona in the state's various counties and municipalities.

Disclosure

The data and assumptions used in this report are subject to marginal uncertainty and variation. Therefore, actual impacts may vary, and some impacts may not materialize due to unanticipated events and changing circumstances. However, RCG has made extensive efforts to confirm the accuracy of the information contained in this analysis.

Economic and Fiscal Impacts

Operations of the UArizona Astronomy and Space Sciences departments are significant economic drivers in the state and specifically the Tucson metro area.

The operations of the departments provide key scientific research across astrophysics, planets, astronomy, and cosmochemistry, and have led to discoveries such as assisting in the first photographing of a black hole and the creation of revolutionary technologies such as mirrors for the Giant Magellan Telescope.

In addition to academic endeavors, the University runs observatories and planetariums such as the Mt. Lemmon Sky Center that draws in thousands of visitors each year, producing additional economic activity. The federal grants and philanthropic money that flows through UArizona Space Sciences further increase the University's impact on the local economy as the money circulates throughout the region and is re-spent in the economy.

The annual economic and fiscal impacts produced by the UArizona Astronomy and Space Sciences operations are summarized in this section.

Economic Impacts

Each year, the UArizona Astronomy and Space Sciences operations support 1,176 direct jobs in Arizona. This includes those 900+ individuals employed within the departments and consists of students, scientists, professors, education professionals, and operations personnel at observatories, planetariums, the University, and other related facilities. This also includes direct subcontractors, the direct jobs supported by federal grants and philanthropic donations, and the direct jobs supported by visitor spending.

The total direct labor income (i.e., the employee-earned wages) produced by UArizona Space Sciences in FY 21 aggregated to $88.3M. This equates to an average wage of over $75,000 per employee. The annual economic output generated by UArizona Space Sciences' direct operations totaled $252.9M.

The annual operations of UArizona Space Sciences create additional demand for supplier businesses that provide goods and services to the University and its contracted entities. This activity supports an additional 1,104 indirect jobs with $57.4M in combined wages. The indirect activity generates $158.8M in economic output annually.

As the 1,176 direct and 1,104 indirect workers spend their wages at local businesses (i.e., grocery stores, movie theaters, restaurants, etc.) an additional 996 induced jobs are created in Arizona. These induced jobs earn a combined $48.1M in wages each year and generate $148.8M in economic output.

In total, the direct, indirect, and induced activity supported by the UArizona Astronomy and Space Sciences operations support 3,276 full-time equivalent jobs, $193.9M in labor income, and generate $560.5M in economic output each year.

Annual Economic Impacts – UArizona Astronomy and Space Sciences Operations

Impact Type	Jobs [1)]	Labor Income [2)]	Economic Output [3)]
Direct Impact	1,176	$88,366,100	$252,917,500
Indirect Impact	1,104	$57,438,600	$158,758,500
Induced Impact	996	$48,064,100	$148,782,100
Total Impact	**3,276**	**$193,868,800**	**$560,458,300**

[1)] Full-time equivalent jobs.
[2)] Sum of all employee-earned wages and benefits.
[3)] Total economic activity.
Note: May not sum to total due to rounding. As of FY 21.
Source: UArizona Space Sciences; IMPLAN; Rounds Consulting Group, Inc.

Fiscal Impacts

In the same fashion as economic impacts, tax revenues are generated by direct, indirect, and induced activity. Direct tax revenues include the taxes paid by the direct employees and the UArizona Space Sciences departments as well as the tax revenues paid by the annual 80,000+ visitors to the UArizona facilities.

Indirect tax revenues include the taxes paid by indirect employees and businesses – whereas induced tax revenues include the taxes paid by induced employees and businesses. These tax revenues are collected as sales, personal incomes, and property to name a few. Tax revenues are further broken down at the state, county, and municipal level.

A total of $11.2M in tax revenues are generated each year by the UArizona Space Sciences direct operations. This includes $5.4M in state tax revenues, $2.7M in county tax revenues, and $3.1M in municipal tax revenues. These tax revenues originate from sales taxes on employee/visitor/business purchases and residential property taxes on employee-owned real estate, among others.

Furthermore, $5.4M and $4.6M in tax revenues are generated by indirect and induced activity, respectively, each year. This includes the tax revenues generated by sales taxes on employee purchases, taxes levied on motor vehicles, and various tax monies earned for the distribution among counties and cities. Among these revenues, $5.1M is collected at the state level, $2.2M at the county level, and $2.6M across the various cities and towns.

In total, $10.5M is generated for the state, $4.9M is generated for counties, and $5.7M is generated for the cities and towns throughout Arizona each year – for a total of $21.1M.

Fiscal Impacts – UArizona Astronomy and Space Sciences Operations

	State [7]	County [8]	City [9]	Total
Direct	**$5,376,000**	**$2,663,200**	**$3,123,800**	**$11,163,000**
Sales Tax [1]	$1,934,300	$264,000	$1,511,000	**$3,709,300**
Bed Tax [2]	$66,900	$9,500	$104,000	**$180,400**
Property Tax [3]	$ -	$1,788,800	$511,700	**$2,300,500**
Income & Payroll Taxes [4]	$3,169,500	$ -	$ -	**$3,169,500**
Vehicle Taxes & Fees [5]	$205,300	$ -	$ -	**$205,300**
State Shared Revenues [6]	$ -	$600,900	$997,100	**$1,598,000**
Indirect	**$2,786,700**	**$1,164,600**	**$1,402,600**	**$5,353,900**
Sales Tax [1]	$843,900	$96,800	$619,000	**$1,559,700**
Property Tax [3]	$ -	$687,700	$177,300	**$865,000**
Income & Payroll Taxes [4]	$1,750,200	$ -	$ -	**$1,750,200**
Vehicle Taxes & Fees [5]	$192,600	$ -	$ -	**$192,600**
State Shared Revenues [6]	$ -	$380,100	$606,300	**$986,400**
Induced	**$2,339,200**	**$1,041,800**	**$1,215,700**	**$4,596,700**
Sales Tax [1]	$730,300	$83,900	$537,800	**$1,352,000**
Property Tax [3]	$ -	$620,700	$159,900	**$780,600**
Income & Payroll Taxes [4]	$1,435,000	$ -	$ -	**$1,435,000**
Vehicle Taxes & Fees [5]	$173,900	$ -	$ -	**$173,900**
State Shared Revenues [6]	$ -	$337,200	$518,000	**$855,200**
Total	**$10,501,900**	**$4,869,600**	**$5,742,100**	**$21,113,600**

In 2022 dollars. May not sum to total due to rounding.
Sources: IMPLAN; Arizona Department of Revenue; UArizona Space Sciences; Rounds Consulting Group, Inc.
[1] Sales taxes levied on employee/visitor/business retail, food/beverage, and utility expenditures.
[2] Bed taxes levied on visitor hotel lodging.
[3] Property tax revenues collected from employee- and private business-owned real estate property.
[4] State personal income taxes and unemployment insurance taxes.
[5] Taxes and fees levied on motor fuel, vehicle registrations, etc.
[6] State income taxes, sales taxes, and other tax monies distributed to counties and cities (based on their population).
[7] Revenues generated for the State of Arizona.
[8] Revenues generated for counties in Arizona.
[9] Revenues generated for cities and towns in Arizona.