A History of the NASA Planetary Astronomy Program: 1958-2022

NASA Infrared Telescope Facility on Mauna Kea, Hawaii. Photo credit: NASA/Ernie Mastroianni

Abstract:

For decades, the public has been enraptured by popular high-resolution images and data taken of our multicolored planets by space-based telescopes. However, at the time NASA was established in October 1958, there was limited astronomical interest in planetary science with ground-based telescopes. Instead, stellar astronomy dominated most of the observing time at facilities, as astrophysics was considered the forefront of astronomical research. Once NASA determined that it wanted launch planetary missions to explore the solar system in detail, it became obvious that there were not enough high-quality solar system observations to lay the foundation for these missions. Therefore, the NASA Planetary Astronomy program (PAST) was established to fund ground-based research on solar system objects. This research covers the history of this important but little-known NASA program, which not only provided necessary support for planetary missions but also was responsible for rejuvenating astronomer interest in solar system research.

Key Words:

Ground-based Planetary Astronomy

NASA Ground-based Planetary Astronomy

NASA Planetary Astronomy Program (PAST)

NASA Infrared Telescope Facility (IRTF)

NASA Solar System Observation Program (SSO)

Ground-based Astronomy

NASA Planetary Science Division

NASA Headquarters

Solar System

NASA History

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Disclosure and Funding Acknowledgement: The author certifies that this is an original work. She acknowledges disclosed receipt of the following financial support for the research and authorship of this article: This work was supported by the Universities Space Research Association (USRA). Any views or opinions expressed are solely that of the author and not necessarily those of USRA, the National Aeronautics and Space Administration (NASA), or the George Washington University.

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"The United States' position of strength today in the discipline of planetary astronomy is almost totally due to the support that NASA has provided in the past, and NASA's continuing leadership and funding support are essential to the future health and productivity of the enterprise."

--NASA Planetary Astronomy Committee, 1989. *Other Worlds from Earth: The Future of Planetary Astronomy: A Report of the Planetary Astronomy Committee of the Solar System Exploration Division*. p.93.

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INTRODUCTION

The act of sending astronauts a quarter of a million miles from terra firma to promenade on the dusty ground of our neighboring silver sphere in the sky has dominated the fascination of space historians for decades. However, there are other NASA histories less explored, histories which speak of observations of asteroids hurling through the void at several thousands of miles per hour. Histories of fiery eruptions of volcanoes on the Jovian moon Io and the magnificent impact of comet fragments smashing into Jupiter. Histories of unprecedented solar system observations. This is a brief programmatic history of NASA's Planetary Astronomy program, a program which marked the rebirth of planetary astronomy in the United States and allowed intrepid scientists to study our solar system and provide crucial information for planetary spacecraft missions, predominantly through the funding of ground-based telescopes and research.

TERMINOLOGY

This paper shall focus on the activities of *Planetary Astronomy* as a research and analysis program, funded out of the Planetary Science Division and its predecessor organizations at NASA. Relevant mention to *planetary astronomy* as a discipline will also be provided. For clarity, the discipline of planetary astronomy comprises the observation of solar system bodies (besides Earth and the Sun) traditionally via ground-based telescopes, but also via space-based telescopes, balloons, or aircraft. "Planetary Astronomy," shown here in capital letters, refers to the specific NASA Headquarters (HQ) research and analysis program which solicits proposals for planetary astronomy research. Since 2014, the NASA Planetary Astronomy program has been called the Solar System Observations Program (SSO), but the author has chosen to title this work "A History of NASA's Planetary Astronomy program" instead of "A History of NASA's Solar System Observations Program," believing that the NASA Planetary Astronomy program, having been the name of the program for most of its existence, was more appropriate. Regardless of name, this program has funded research by ground-based telescopes and occasionally suborbital or space-based telescopes across frequencies ranging from ultraviolet to radio. Currently, SSO is funded out of the NASA Planetary Science Division of the Science Mission Directorate. The Planetary Astronomy program (PAST) also funded NASA's Infrared Telescope Facility located in Hawaii and supported the development of University of Texas, University of Arizona, and the University of Hawaii telescopes. However, while the NASA Planetary Astronomy (now SSO) program funds most of NASA's planetary astronomy activities, the NASA astrophysics division also provides notable support for some planetary astronomy research through its assets, such as the Hubble Space Telescope. The National Science Foundation (NSF) also provides some support for select planetary astronomy researchers (NASA, 1989: 33) as the more historic American agency for ground-based astronomy facilities and fundamental research, compared to NASA's support toward meeting its own agency objectives for exploration (NASA Office of the Administrator, 1967).

With the advent of space-based astronomical telescopes, some may question what role ground-based astronomy (as the primary medium of PAST research) still plays in planetary science and whether this medium of astronomy is still relevant today with the modern influx of higher resolution images and data we have gained through instruments on spacecraft sent to destinations in the solar system. Firstly, ground-based planetary astronomy has the unique ability to provide continuous observations over many decades of solar system bodies, unlike spacecrafts which may only be able to capture detailed snapshots of the bodies they visit in the solar system. Secondly, it is much less expensive to use an existing ground-based telescope for general observations not requiring a spacecraft, compared to the cost of designing and launching a spacecraft for similar planetary astronomy investigations—though spacecraft are required to meet many science objectives. Thirdly, and arguably best expressed in 1976 by JPL's Reinhard Beer, ground-based planetary astronomy plays a "vital role" preparing for planetary missions: "The design of instrumentation for spacecraft…cannot be undertaken in an intellectual vacuum—they must be based upon whatever knowledge is available" (Beer, 1976). Prior to the establishment of NASA, the preexisting knowledge of the solar system was too insufficient to immediately launch multi-million-dollar planetary missions. As will be discussed later, this knowledge-gap was due in part to the predominant interest of most astronomers to partake in more mainstream stellar astronomy compared to planetary research. To combat the knowledge gap, provide relatively inexpensive long-duration research, and to assist planetary missions, the majority of NASA Planetary Astronomy (SSO) funded research was and still is ground-based.

ACRONYMS

DART: The Double Asteroid Redirection Test flight mission facilitated by PDCO.

Discipline Scientist: There have been many titles for the leadership role of Planetary Astronomy at NASA including Program Chief, Program Officer, and Discipline Scientist. This paper will refer to the leadership position of NASA Planetary Astronomy as "Discipline Scientist" to alleviate confusion. If the other above terms are invoked, it will be with quotations to mark the specific title during the specified year.

Hubble: The Hubble Space Telescope

IGY: The International Geophysical Year

IRTF: NASA's Infrared Telescope Facility located on Mauna Kea on the Big Island of Hawaii

JPL: The Jet Propulsion Laboratory, a government funded laboratory run by the California Institute of Technology for NASA.

LPL: The Lunar and Planetary Laboratory at the University of Arizona

LPP: NASA's former Office of Lunar and Planetary Programs

NASA: the National Aeronautics and Space Administration

NASA HQ: NASA Headquarters, now the Mary W. Jackson Headquarters building located in Washington D.C.

NASM: The National Air and Space Museum

NEO: Near-Earth Object

NEOO: NASA's Near-Earth Object Observations Program

NRA: NASA Research Announcement

NSF: National Science Foundation

OSS(A): NASA's former Office of Space Science (and Applications)

PAST: NASA's Planetary Astronomy Program

PDCO: NASA's Planetary Defense Coordination Office

PI: Principal Investigator of a funded research activity or flight project

PSD: NASA's Planetary Science Division, under the administration of NASA's Science Mission Directorate

ROSES: Research Opportunities in Earth and Space Science omnibus solicitation

ROSS: Research Opportunities in Space Science omnibus solicitation

SSO: NASA's Solar System Observations Program, renamed in 2014 from the ROSES Planetary Astronomy program element, which now solicits for Planetary Astronomy research proposals

SMD: NASA's Science Mission Directorate

PLANETARY ASTRONOMY AT NASA BY THE DECADE

Pre-NASA to 1969

Politics and Interests of NASA From Origin to 1969

NASA's creation was mainly a direct response to the geopolitical tensions with the Soviet Union after the launch of the world's first artificial satellite, Sputnik on October 4, 1957. Sputnik served as a public demonstration of the advancement of Soviet rocket technology over the advancement of US rocket technology. The particular concern of the US was that this rocket technology was now presumed capable of delivering nuclear bombs to US soil. In July of 1958, the National Aeronautics and Space Administration was birthed in a period of high political tension between the two bilateral adversaries of the Cold War. The Soviet Union and the United States would both announce that they would attempt to launch a peaceful scientific satellite during the International Geophysical Year.

The International Geophysical Year (IGY) was an international year of scientific collaboration to investigate the physical sciences beginning in July of 1957 and lasting until December of 1958. The launch Sputnik and the creation of NASA both occurred during this period. NASA allowed for a continuation of IGY scientific research, particularly space studies. Before World War II, astronomical research was predominantly done by universities, privately funded, or by national observatories which were not as interested in planetary astronomy compared to astrophysics, stellar astronomy, timing and navigation (Schorn, 1998: 183). Famed French astronomer Gerard de Vaucouleurs explained in 1985 that the lack of interest in planetary astronomy during this period was primarily due to the pressure on astronomers to study what was "most interesting from the view of physics and astronomy," at the time. That was why astronomers would "look at the stars and galaxies," opposed to spending an equal amount of time looking inside the solar system (Tatarewicz, 1985: 96). Beginning in the early 1900s, the US led the world in observational astrophysics due to private investments in large telescopes and observatories which led to ground-breaking discoveries (National Academy of Sciences National Research Council, 1954: 3).

However, the establishment of NASA reinvigorated planetary space science by establishing partially government-funded telescopes and increasing the amount of research opportunities for universities and those in the astronomy profession. In the early 1960s, NASA's Space Science chief, Dr. Homer Newell, had the foresight to realize that space research in general "was not a passing fancy but would endure and prosper in future years," according to NASM historian Joseph Tatarewicz. For this reason, Newell thought it necessary to develop a "wide and strong base" in scientific communities outside of NASA, including universities (Tatarewicz, 1985: 104). Furthermore, in a June 1967 meeting between Dr. Newell, Dr. John Naugle, and others, the sentiment was expressed that NASA needed to "take astronomy seriously" In order to attract university commitment towards NASA astronomical research programs (NASA Office of the Administrator, 1967). According to the meeting memorandum, only after progress was "made towards substantive astronomical goals" would astronomers be interested in a NASA partnership and "bring with them de facto institutional commitment" to NASA. In the same meeting, there was also talk about how "meaningful long-range plans for astronomy" must include ground-based as well as space-based astronomy (NASA Office of the Administrator, 1967). A PAST research and investigation program was eventually established in the early 1960s. Historian and former NASA chief of Planetary Astronomy, Ronald Schorn, directly credits NASA and the space program for being the catalysts for "the rebirth of planetary astronomy" through the funding of research opportunities and astronomy programs across the country (Schorn, 1998: 183).

Once James Webb was appointed as the second NASA administrator in 1961, he reorganized NASA's structure to place science on an equal bureaucratic footing to the human spaceflight program (NASA, November 1, 1961 Organizational Chart). Notable NASA planetary science activities of the decade included the following: the first successful US flyby of the Moon via Pioneer 4 in 1959, the Ranger Program from 1961-1965 which took close-up photos of the Moon before impacting it, the Mariner Program from 1962-1975 which produced fly by missions of Venus and Mars, the Surveyor Program which successfully soft landed 5 of the 7 Surveyor spacecrafts on the Moon between 1966-1968, and the Lunar Orbiter Program in 1966 and 1967 which was tasked with lunar mapping and survey missions for the Apollo program. Despite these uncrewed planetary missions, human spaceflight was still the top priority of NASA in terms of funding and resource allocation for much of the 1960s with the Mercury, Gemini, and Apollo programs.

Overview of NASA Planetary Astronomy 1959-1969

Originally, there was no specific NASA Planetary Astronomy program until about 1963. However, there was a NASA Astronomy Program led first by Gerhardt Schilling and then by Dr. Nancy Grace Roman from 1960 to 1979. When she assumed the position of Chief of Astronomy in 1960, she was responsible for essentially everything "beyond the vicinity of the Earth," excluding "cold bodies in the Solar System," or in other words, non-planetary astronomy (Roman, 2019: 15). However, Dr. Nancy Grace Roman is worthy of mention because of the sad fact that the early working women of NASA have traditionally been left out of the historical narrative of the US space program, and she was a notable exception. Not only did she have a significant scientific leadership position very early in NASA history, but her strong advocacy for what would become Hubble Space Telescope has allowed us to revolutionize our understanding of the cosmos. The NASA Astronomy Program would also go on to partially fund ground-based facilities for stellar astronomy (Naugle, 1966), but on occasion, Dr. Roman would support NASA planetary astronomy. One instance of this was when she recommended partial-NASA funding for the University of Arizona 61-inch telescope to support the lunar and planetary work of the US space program (Roman, 1961).

Speaking of notable exceptions, the Jet Propulsion Laboratory (JPL) was one of the few research institutions interested in planetary science before the creation of NASA and was "already looking beyond the Moon," in 1958 (Tatarewicz, 1985: 98). When NASA and JPL eventually formed a partnership, JPL specifically wanted to be involved in lunar and planetary exploration, reportedly, "partly because 'nobody else wanted it' and partly for the challenge" (Tatarewicz, 1985: 98). JPL it had a significant role in stimulating what would become the NASA Planetary Astronomy program through its strong advocacy of a "supporting research" complimentary program to ground-based planetary astronomy which could in turn support space missions. This recommendation was given in a JPL five-year plan for lunar and planetary exploration, published in April 1959. The report would become the first comprehensive proposal for exploration of the solar system. It cited a consensus that supporting research which was less expensive than the cost of the total space research funding, "could well spell the difference between immediate success and a discouraging stretch-out in the overall space program," and advocated therefore for its funding (Tatarewicz, 1985: 99).

In September of 1959, just short of a month before NASA's first anniversary, the was a colloquium on lunar and planetary exploration for scientific community to discuss how the role of ground-based research programs, which had previously been "neglected" due to lack of funds and interest, could be expanded. NASA, among other US agencies, was interested in the colloquium because the young space agency was "looking for ways to give logical direction" to its space sciences programs (Tatarewicz, 1985: 94) The outcome of the colloquium was the general consensus summarized by meteorologist Stanley M. Greenfield of the RAND Corporation that if space exploration were to have a "logical approach," planetary missions would need "the full utilization of a parallel program of Earth-based research," which was relatively inexpensive in comparison (Tatarewicz, 1985: 97). Furthermore, it was discussed that limited budgets, the availability of instruments, and lack of qualified or interested astronomers were to blame for the absence of significant planetary observations up until that time (Tatarewicz, 1985: 96).

In the days following colloquium, the organizer of the Air Force lunar mapping project in Manchester England, Stanley M. Greenfield, noted from his research that much of the world's knowledge of the Solar System up until that time was outdated or inaccurate, citing how "much of the data on heights and locations of lunar craters and features had often been inaccurately copied and recopied from previous sources," and often those sources regarding topographical information on the Moon were from the 19th century (Tatarewicz, 1985: 96). Despite these revealing knowledge gaps and Kopal's plea "for doing everything possible from Earth before sending probes to the Moon," such a parallel space—ground-based astronomy program of NASA described by Greenfield would not come into being until 1963 (Tatarewicz, 1985: 96). Difficulties in creating a NASA Planetary Astronomy program at the time included defining the nature of planetary astronomy as either more geophysics or traditional astronomy for funding purposes, working out the position of a federally funded NASA planetary astronomy between the NSF (traditionally ground-based research) and NASA (traditionally space-based research), and determining how exactly a planetary astronomy program could assist space-based missions (Tatarewicz, 1985: 105).

Instead of NASA's Astronomy program, early Agency work in planetary astronomy was predominately facilitated by another office entirely. In 1960, NASA Administrator T. Keith Glennan reorganized the Office of Spaceflight Programs to include an office for Lunar and Planetary Programs (LPP). The Office for Lunar and Planetary Programs was directed by Edgar M. Cortright until 1961 (NASA; January 17, 1961 Organizational Chart).

It was also in 1960 that an all-day National Academy of Science Space Science Board, which was also an advisory board to NASA, met on June 24th to discuss planetary atmospheres and ended with recommendation that ground-based astronomy programs be funded by the government and "regarded as an integral part of the space program" (Tatarewicz, 1985: 102). Historian Joseph Tatarewicz credits this conference and the subsequent recommendation as the start of a "chain of events that ultimately led to" NASA's eventual adoption of a program similar to the one JPL proposed in its April 1959 report (Tatarewicz, 1985: 103). Homer Newell, the head of NASA's Office of Space Sciences was aware of the need and desire for a NASA Planetary Astronomy program, but he also believed that collaboration with universities and other non-NASA members of the scientific community was necessary for the discipline of planetary astronomy to flourish (Tatarewicz, 1985: 104).

In November of 1961, new NASA Administrator James Webb reorganized NASA HQ to clearly differentiate between space science and crewed spaceflight. Under this structure, Oran

Nicks took over as the director of the Lunar and Planetary Programs under the jurisdiction of the new Office of Space Sciences (NASA; November 1, 1961 Organizational Chart). According to Dr. Ronald Schorn, the first official Discipline Scientist of NASA Planetary Astronomy, it was under the management of Oran Nicks that the LPP took up a significant role in the effort to "rehabilitate" the discipline of planetary astronomy (Schorn, 1998, 215). In 1962, Nicks hired Roger C. Moore to head "ground and balloon based [planetary] astronomy" while effectively organizing what would later become NASA's Planetary Astronomy program (Schorn, 1998, 215). Despite his proficient work, Moore lacked a Ph.D. in astronomy, a degree desired by NASA for their head of Planetary Astronomy.

For this reason, Dr. Ronald A. Schorn was hired as NASA's first "Acting Program Chief" of Planetary Astronomy on detail from JPL in 1963. His hierarchical position was greater than what Moore's had been, despite having nearly identical intentions for the program (Schorn, 1998, 215). However, Schorn's newly appointed leadership position marked the official beginning of Planetary Astronomy at NASA. He served in the position until Dr. William Brunk took over in 1965, upon Schorn's return to JPL. In turn, Dr. Brunk held the position of discipline scientist for Planetary Astronomy for the rest of the 1960s up until the early 1980s (Brunk, 1983). In a draft 1964 NASA HQ document found in Brunk's archived files, the NASA Planetary Astronomy program had the following goals in that year:

1. "To obtain necessary background information in support of present and future spacecraft flights to the moon and planets.
2. To develop instrumentation for both ground-based and spacecraft planetary astronomy observations.
3. To perform laboratory analyses and theoretical studies to increase the understanding of planetary observations made either from the ground or from spacecraft" (NASA HQ, 1964).

Over the decades, these goals of the NASA PAST program would shift and evolve to include funding of an infrared telescope facility, solicit research proposals from universities, and go back and forth on whether space-based planetary astronomy research would be funded along with ground-based research. In terms of Supporting Research and Technology (SR&T), NASA PAST spent a total of $2,402,000 in 1964 on grants and contracts; $2,353,789 in 1965; $4,148,483 in 1966; $2,995,932 in 1967; and $1,767,000 in 1968. Between 1964 and 1968, NASA PAST funded between thirteen to twenty-two tasks per year spread between ten and fifteen universities (NASA HQ, 1967). By 1969, the NASA Planetary Astronomy program included the prioritization of planet observations through "ground-based observatories, aircraft, balloons, rockets, and Earth-orbiting satellites," with smaller bodies such as the Moon, asteroids, and comets being a secondary priority (NASA HQ, 1969: 1). In 1969, the NASA PAST program was implemented in coordination with the National Science Foundation predominantly where "major instrumentation and related support" was involved (NASA HQ, 1969: 2).

NASA's initial policy was to only support space-based astronomy, according to a 1969 memo from Homer Newell to then NASA Administrator, Dr. Thomas Paine, regarding NASA and NSF's support to astronomy (Newell, 1969: 1). However, "[t]he agency soon found…that due to lack of available instruments and people it was not possible to get adequate ground-based observational support to its planetary flight missions," according to Newell, and "[a]s a consequence, NASA decided to provide limited support to ground-based astronomy, to furnish both radio and optical instruments for planetary astronomy" (Newell, 1969: 1). This support would eventually include the establishment of a NASA Infrared Telescope Facility which would become a premier institution for ground-based planetary astronomy beginning the 1970s, and an asset of the NASA Planetary Defense Coordination Office for characterizing near-Earth asteroids decades later.

Significant NASA Planetary Astronomy Events/Developments 1959-1969

The three most significant program developments during NASA's first decade were the partial funding of the Lunar and Planetary Laboratory at the University of Arizona as well as the partial funding of three telescopes located at the Universities of Arizona, University of Texas, and the University of Hawaii. During the decade, NASA also began subsidizing and soliciting proposals for select graduate and postdoctoral research in planetary astronomy and provided funds and technical expertise to laboratories (NASA Solar System Exploration Division, 1989: 32). These actions, the partial funding of the telescope construction with the establishment of a research program, formed the foundation for the NASA Planetary Astronomy (PAST) research and analysis program of today (now called Solar System Observations). Overall, by officially establishing the PAST program, NASA inadvertently became the gold standard for federally funded planetary astronomy and almost single-handedly revived interest in the scientific discipline as previously mentioned (Schorn, 1998: 183).

a.) The University of Arizona Lunar and Planetary Laboratory

The creation of the Lunar and Planetary Laboratory (LPL) in 1960, significantly funded by NASA's Office of Lunar and Planetary Science, was a major component of what Schorn described as the "rebirth" of planetary astronomy during the decade (Schorn, 1998: 183). The LPL was the brainchild of famed "father of modern planetary science" astronomer Dr. Gerard P. Kuiper and allowed graduate and postdoctoral researchers the opportunity to investigate the solar system with top-of-the-line technology (NASA, "Gerard Kuiper (1905-1973)"). Located at the University of Arizona in Tucson, the LPL is in a desired location for astronomical observations thanks to the arid region's low humidity and consistently clear skies. In 1972 under the leadership of Dr. Elizabeth Roemer, the LPL began taking steps towards offering master's and doctoral degrees in planetary science. LPL has continued its partnership with NASA, heading both the Phoenix Mars mission launched in 2007 and the OSIRIS-REx sample return mission set to bring back samples of asteroid Bennu in 2023 (The University of Arizona, "A Brief History of LPL").

b.) The LPL 61-inch Kuiper Telescope

Prior to the construction of the LPL's 61-inch reflector, the University of Arizona already had a telescope, a 36-inch. However, this telescope was located at the Steward Observatory, not under the jurisdiction of LPL. Scheduling observing time was also difficult and Kuiper advocated for NASA to fund telescopes which could be used primarily for solar system observations which, at the time, was not a common practice of US observatories (Schorn, 1998: 216). In a June 1961 letter which advocated funding for an LPL telescope to NASA's Roger C. Moore of NASA's Lunar and Planetary Sciences, Gerard Kuiper made the case that such a telescope would be "a research tool especially designed for planetary and lunar studies…unlike any other telescope" in the world (Kuiper, 1961a). Furthermore, in the official proposal made to NASA for partial funding of the telescope, Gerard Kuiper specifically cited how elements of the US space program were "requiring an increasing volume of ground-based observations," for supporting research in space. Kuiper stops short of saying that this supporting research would be used for future planetary missions, but that is most likely what he meant. Kuiper also asserted that telescopic observations involving "problems of national interest" would be given "the highest priority" in telescope programming (Kuiper, 1961). Another argument for NASA's Office of Lunar and Planetary Programs to fund ground-based astronomy was that it would be a more cost-effective pathfinder to use before launching an expensive space-based observational system. Additionally, ground-based telescopes were more advantageous in the sense that they could observe planetary bodies from a semi-fixed position over a longer period compared to shorter-duration spacecraft flyby observations. Several decades later in 1989, a report by the NASA Planetary Astronomy Committee stated that planetary astronomy was an important method of "direct support for flight missions," providing data which could not obtained otherwise by space probes (NASA Solar System Exploration Division, 1989: 93). This report reiterated the 1960 argument for a planetary astronomy program. In 1965, NASA approved partial funding for an LPL 61-inch telescope. This action marked the first but not the last time NASA would help fund the construction of a ground-based telescope which would help advance planetary astronomy research and planetary exploration (Schorn, 1998, 216).

c.) The McDonald 107-inch Harlan J. Smith Telescope

Even before the approval of the LPL 61-inch reflector, NASA's Planetary Astronomy program, still led by Moore and Schorn, realized the importance of funding ground-based telescopes. Compared to the financing of the Apollo program, the Office of Space Science was receiving very little funding, and the Office Lunar and Planetary Programs was having a difficult time putting together funds for lunar and planetary missions. One of the only paths forward was to fund telescopes, whose cost "paled in comparison" to the cost of launching space probes, according to NASA's first chief of planetary astronomy, Ronald Schorn (Schorn, 1998: 216). However, US astronomers still preferred stellar astronomy to planetary astronomy (for the reasons mentioned previously) and did not have much enthusiasm to devote funds and resources to solar system exploration (Schorn, 1998, 217). However, the University of Texas did have interest and would focus on studying the Moon and planets, or, "features of extraordinary interest" which "tended to be overlooked in the drive toward the remotest and faintest objects in the universe," according to Dr. Harlen Smith, the University of Texas chairman of the astronomy department and later director of the McDonald Observatory (*New York Times*, 1968: 10). In return, NASA hoped that the planetary astronomy research done by the telescope would "help them design futures [sic] spacecraft to visit planets," according to a conversation between the *New York Times* and Dr. Brunk (*New York Times*, 1968: 10).

After negotiation between NASA and the University of Texas during 1963, a 1964 nine-page proposal for an 84-inch telescope (later increased to a 107-inch) was submitted to NASA by the University of Texas (Tatarewicz, 1985: 97). In his 1998 book on the history of planetary astronomy, Schorn (1998: 217) reflected that, in contrast, a modern funding proposal to NASA would be much longer and that simply a *request* by NASA for proposals could "easily" be thirty pages. However, NASA did accept the 107-inch telescope proposal. Schorn has also stated that this partially NASA-funded telescope became the reason that the University of Texas now has a "world renowned" astronomy program (Schorn, 1998: 217). Construction of the telescope began in the spring of 1966 and finished in fall of 1968 (The University of Texas, "2.7 M (107") Harlan J. Smith Telescope"). The 107-inch telescope began operation in 1969 with observations of Mars to assist the Mariner probes (Tatarewicz, 1985: 97). At the time of its dedication in November of 1968, the McDonald 107-inch telescope was the third largest telescope in the world, according to the *New York Times* (27 November 1968: 10).

d.) The University of Hawaii 88-inch telescope

When JPL canceled their 1963 request for a 60-inch reflector in Los Angeles, NASA had the ability to fund another telescope (Schorn, 1998: 218). While the construction of his 61-inch LPL telescope was still underway, Gerard Kuiper advocated the new telescope be placed on the mountain of Mauna Kea in Hawaii due to its superb location for astronomical observations. However, NASA did not want the new telescope under the jurisdiction of the LPL, which Kuiper still led, and instead suggested that the new telescope be under placed under the management of the University of Hawaii. After Schorn returned to JPL in 1964, Dr. William Brunk took over as head of the NASA Planetary Astronomy program and approved funding for construction of the 88-inch telescope in Hawaii (Brunk, 1983) The telescope was negotiated between 1964 and 1965, and began operating in 1969 with observations of Mars (Tatarewicz, 1985: 98).

1970-1979

Politics and Interests of NASA Between 1970-1979

In 1969, NASA had achieved President Kennedy's goal of landing an astronaut on the Moon and returning him safely to Earth. Besides the near disaster of the Apollo 13 mission, crewed lunar flights continued through December of 1972. The ending of the Apollo program signified the end of a decade where Congress was willing to grant large expenditures to NASA. President Nixon approved development of the costly and long-term Space Shuttle program and effectively turned NASA's mission into one of sustained presence in space instead of one of large undertakings to meet a specific deadline like with the 1960s moonshot. Nixon's initial space policy post-Apollo was publicly announced in March of 1970 (Nixon, 1970).

Congress supported this position by Nixon but still allowed planetary science to have the "dominant portion" of NASA space science funding in the mid-1970s (Callahan, 2021: 42). Despite this fact, between 1974 and 1977 the NASA planetary science budget dropped by 60% when NASA was unable to convince Congress that solar system exploration was worth funding (Callahan, 2021: 57). The crewed US Skylab space station and development of what would become the Space Shuttle were also priorities of the Agency in the early 1970s.

The major focus of NASA planetary science during the 1970s was exploration with space probes, including visits to Mars and Venus, the two closest planets to Earth. On November 13, 1971, Mariner 9 became the first spacecraft to orbit Mars. Later that decade in 1976, the Viking program orbited two spacecraft and landed probes on Mars in 1976. Additionally, the Pioneer Venus Project sent two spacecrafts to orbit and land on Venus in 1978. It was also in the 1970s where NASA began to explore the Outer Solar System as well. Pioneer 10 and 11 launched toward Jupiter and the Outer Planets in 1972 and 1973. In 1965, a JPL graduate student discovered that the outer planets would be in a rare alignment in the late 1970s and subsequently there was calls to fund a multi-spacecraft "grand tour" of the outer solar system through this once in a 197-year occurrence. Unfortunately, the war in Vietnam and the development of the Space Shuttle kept Congress and the president from agreeing to fund the Grand Tour. Instead, the Voyager Program took the place of the Grand Tour, launching in 1977 (Callahan, 2021: 55).

Overview of NASA Planetary Astronomy 1970-1979

Even some NASA space scientists were not fully enthused about the concept of a Grand Tour if it meant diverting funds from the ground-based program towards the expensive space mission (Callahan, 2021: 54). According to National Aeronautics and Space Administration Budget Estimates for FY 1975, allocations to Planetary Astronomy averaged a little over $4 million dollars a year in funding in the mid-1970s. With the modest amount of money allocated to his program, Discipline Scientist William Brunk had his sights set upon building a new fully funded NASA astronomy facility in Hawaii by the end of the 1970s. This new facility which would later become the NASA Infrared Telescope Facility (IRTF), was created to give researchers awarded with a PAST stipend more planetary astronomy observing opportunities. Besides the IRTF, NASA Planetary Astronomy also funded and began using the planetary radar on the National Science Foundation's Arecibo radio telescope in Puerto Rico (NASA Solar System Exploration Division, 1989: 33). NASA even provided funding for a high-power radar system at Arecibo to increase planetary radar capability to "study the surface properties of several Jovian satellites" and "'map' the surfaces of Mercury, Venus, and Mars in considerably greater detail," compared to previous instrumentation (NASA HQ, 1972: 4).

During the entirety of the 1970s, William Brunk was Discipline Scientist for PAST. His method of soliciting for PAST research proposals was more of an informal process compared to that of today. One of his former employees, Jay Bergstralh, remembers Brunk sending out "dear colleague" letters outlining NASA interests and program changes to principal investigators (PIs) who he thought may be interested in doing research for NASA. Then, Brunk would receive research proposal letters back which would happen to align with NASA's planetary astronomy interests. Bergstralh had stated that he did not believe that principal investigators (PIs) were in any way pressured by NASA to conduct certain research, but he assumed that PIs could "read the handwriting on the wall very clearly," and most would "adjust their programs accordingly" for the best chance at funding (Bergstralh, 1983). William Brunk ceased his leadership of the Planetary Astronomy program in 1982 (Brunk, 1983a).

By 1972, NASA's Planetary Astronomy program still relied on ground, air, and space-based observations, in a similar fashion to the 1960s (NASA HQ, 1972: 1). Supported research ranged from "single investigator to large multifaceted research programs" located at the McDonald, Mauna Kea, Lowell, and Catalina observatories including laboratory and theoretical planetary studies. In the early 1970s, significant interest was shown for observing Mercury, Jupiter, Saturn, Uranus, Neptune, and Pluto while receiving additional information on Venus and Mars for planetary missions (NASA HQ, 1972: 3). However, Solar System planets were not the only focus of PAST in the 1970s. In 1973, NASA PAST funded the first major search for near-Earth asteroids via the Palomar Planet-Crossing Asteroid Survey (PCAS). The search was undertaken by Eleanor "Glo" Helin and Eugene Shoemaker of Caltech using the Palomar Observatory 18-inch Schmidt telescope. Helin and Shoemaker's observations were used to discover and categorize planet-crossing asteroids (Conway, Yeomans, and Rosenburg, 2022: 51). Today, NASA continues to fund the search for NEOs through the Near-Earth Observation Program of the Planetary Defense Coordination Office. This funding is part of a legacy of observations which were first made possible through Planetary Astronomy program.

Significant NASA Planetary Astronomy Events/Developments 1970-1979

a. The NASA Infrared Telescope Facility

The NASA Infrared Telescope Facility (IRTF) located on Mauna Kea on the Big Island of Hawaii is one of the most enduring legacies of the NASA Planetary Astronomy program. In the early 1970s, NASA desired a dedicated infrared planetary astronomy telescope which could support planetary missions like the Mariner mission to Jupiter and Saturn (NASA News, Release No. 75-209). At the time, infrared astronomy was "one of the newest and most rapidly expanding fields in astronomy" and NASA was responding to the large infrared demand on existing telescopes which had suffered from viewing locations and systems not suited to infrared astronomy (NASA News, 1974, Release No. 74-23). Given its desirable location at 13,600 ft. of elevation with minimal water vapor, the summit of Mauna Kea was the preferred site for NASA and one of the best in the world for ground-based observations for the same placement justification at the 88-inch telescope. NASA decided to fully-fund the construction of the three-meter telescope facility and contract with the University of Hawaii's Institute for Astronomy to operate and manage it (NASA, 1977: 7). On November 29, 1974, a sublease was created between the US government (NASA) and the University of Hawaii which will expire on December 31, 2033 (NASA, 1974). On July 6, 1979, the dedication ceremony for the newly constructed facility took place on the summit of Mauna Kea (Kroese, 1979: A-6) but the telescope was not fully operational until October of that year (NASA News, Release No. 79-66).

The initial priority of the IRTF was to support the two deep-space Voyager spacecrafts which launched in 1977 with their observations of Jupiter's "hot spots." This ground-based support was necessary because the spacecrafts could not determine the location of these hotspots on their own. Ground-based infrared telescopes on the other hand, "could locate the five-micron regions and provide information to the Voyager team for incorporation into the final encounter sequence" for the spacecraft's interferometer-infrared spectrometer (NASA News, Release No. 79-66). Under the leadership of Eric Becklin, the first director of the IRTF, the facility supported the Voyagers with complementary observations such as those of the active volcanoes of Jupiter's moon, Io when Voyager I flew by the celestial body in 1979. When it did so, the IRTF was in the unique position as the only ground-based telescope at the time to characterize the radiation of Io's volcanic eruptions (University of Hawaii Institute for Astronomy). With its infrared capability, the telescope has the ability to observe during daylight, which is a unique characteristic of a telescope, especially for its location. IRTF operations continued to be funded by NASA Planetary Astronomy until it was moved to NASA's Near-Earth Object Observations Program in 2014 (Fast, 2021). The entire astronomical community can apply for observing time, with about fifty percent of the time reserved for planetary science and fifty percent for astrophysics. From August of 2002 to the present, astronomers have had the option of remotely observing with the telescope from anywhere in world so long as they have reliable internet (The NASA Infrared Telescope Facility, About IRTF). Other notable observations made by the facility will be discussed in subsequent sections of this paper.

1980-1989

Politics and Interests of NASA Between 1980-1989

The 1980s was the first decade which saw the Space Shuttle regularly operational, but the decade was marred by the Space Shuttle Challenger disaster which killed all seven crewmembers. However, the decade is also known for space science accomplishments including the 1980 Solar Maximum mission to study the sun, development and launch of the Galileo orbiter which would travel to observe Jupiter, the Voyager 2 encounter with Uranus and Neptune between 1986 and 1989, and the 1989 launches of both the Magellan and Galileo missions which would visit Venus and Jupiter respectively. The development of the Hubble Space Telescope, and the "Apollo-like announcement" for an international space station by President Reagan in 1984 were also significant developments for NASA in the 1980s (NASA History Division, 2012).

The first significant crewed NASA mission of the decade was the April 12, 1981, launch of STS-1. Commander John Young and Pilot Bob Crippen became the first humans to be launched into space aboard the new Space Transportation System shuttle Columbia. This mission marked the beginning of a 30-year program, which by the time it ended in 2011, flew 135 shuttle missions. Crippen later called the STS-1 flight "a morale booster" for the United States at the time, marking the dawn of a new and exciting crewed program of reusable launch vehicles (Heiney, 2012). Unfortunately, five years later the dangers of space travel were harshly remembered.

On January 28, 1986, Space Shuttle Challenger blasted off from the Kennedy Space Center and broke apart 73 seconds into the flight due to a solid rocket booster O-ring which constricted in the cold temperatures and allowed hot gases from the solid rocket booster to ignite the main propellant tank. All seven crewmembers, Commander Francis Scobee, Pilot Michael Smith, Mission Specialists Judith Resnik, Ellison Onizuka, and Ronald McNair, and Payload Specialists Gregory Jarvis and Christa McAuliffe perished because of the disaster. Following the tragedy, all shuttle flights were grounded for the next two and a half years including the scheduled mission to deploy the Hubble Space Telescope.

While the Hubble was not under the administration of the NASA Planetary Astronomy program, it would go on to conduct astrophysics and planetary astronomy research. Similarly, the Galileo spacecraft, which was also under construction, was designed to be multi-disciplinary in the field of planetary science until the program was nearly cancelled by President Reagan. Only a last-minute rallying effort by NASA was able to save the Galileo mission and allow it to launch in 1989 (Callahan, 2021: 58). Due to technical setbacks and the Challenger investigation, Hubble's deployment into space was delayed from an initial launch year of 1983 until 1990. However, a reflective mirror manufacturing error in the multi-billion-dollar Hubble telescope caused a moment of great embarrassment for the space agency and necessitated a servicing mission a few years later. This was not the first time a NASA-funded telescope had mirror issues before telescope operation—in 1975 what was supposed to be the eight-ton mirror blank of the IRTF telescope cracked during polishing (*The Arizona Daily Star*, 1975: 1). The mirror was later replaced.

The 1980s have been called the "lost decade of planetary science" for falling behind the funding levels of astrophysics for the first time in the history of the Office of Space Science and Applications (Callahan, 2021: 42). The highest FY budget of the 1980s allocated to planetary science dipped to approximately $732 million (in 2010 dollars) compared to the high of $1.7 billion (2010 dollars) in the 1970s and $1.2 billion (2010 dollars) in the 1990s (Callahan, 2021: 81). President Reagan's science advisor, Jay Keyworth, famously disapproved of NASA's planetary science program and did not believe it could justify its expense (Callahan, 2021: 58). As a result, practically "every observatory" that received a grant from NASA or the NSF was "feeling the squeeze" of federal budget cuts by 1982, or nearly lost NASA funds altogether in the case of the IRTF. IRTF Scientists called the exclusion of funds "an enormous waste," and "unbelievable," given that the IRTF had been at the time, operational for just a few short years (Bloom, 1982). However, Congress eventually saved NASA funding of the IRTF through its 1983 appropriations to the Agency (US House of Representatives, 1982: 53).

Overview of NASA Planetary Astronomy 1980-1989

The main focus areas of NASA Planetary Astronomy in the 1980s were outer planets, satellites, comets, and asteroids (NASA Solar System Exploration Division, 1989: 36). In 1988, Planetary Astronomy had a budget of about $8 million with 2-3% of the funds going towards NASA HQ management and about 33% of the budget going towards the funding of observatory facilities at the NASA IRTF, University of Texas telescopes at McDonald, and the planetary radar on the Arecibo Radio Telescope of the National Science Foundation's National Astronomy and Ionosphere Center (NASA Solar System Exploration Division, 1989: 36). The NASA IRTF was supported by NASA Planetary Astronomy at a rate of about $2 million dollars a year by 1988 (NASA Solar System Exploration Division, 1989: 54). However, as a consequence of the declining Planetary Science budget during the decade, Planetary Astronomy funding also declined by 20% during the 1980s (NASA Solar System Exploration Division, 1989: 39). During FY 1982, the program was "extremely underfunded" and as a result "the serious need for instrumentation, especially for the IRTF" could not be met and research areas were eliminated as a result (NASA HQ, "Planetary Astronomy: Overview for FY 1982"). In a 1989 report by the NASA Planetary Astronomy Committee tasked with reviewing the PAST program, it was recommended that the NASA Solar System Exploration Division "reaffirm its commitment to Earth-based astronomy as an essential component of a balanced program of solar system exploration" (NASA Solar System Exploration Division, 1989: 93). It was estimated by NASA in 1989 that there were 200 active planetary astronomers in the United States, including those who were part-time observers. About half of these (100) were principal investigators (PIs) in the NASA Planetary Astronomy program (NASA Solar System Exploration Division, 1989: 34).

In terms of leadership, for the first time in almost twenty years, the NASA PAST program had a new Discipline Scientist starting in 1983. Dr. John Hillman served in the lead position for Planetary Astronomy from 1983 until 1985 (Chanover, 2007: 1065) and then again from 2002 (NASA, 2002) -2003 (NASA, 2003). Dr. Jürgen Rahe took over the program around 1986 (NASA Office of Space Science and Applications, 1986) and retained it until 1995 (NASA, 1995).

Significant NASA Planetary Astronomy Events/Developments 1980-1989

In the 1980s, the NASA Planetary Astronomy program no longer sought to develop new ground-based observatories. In fact, it was announced in March of 1982 that NASA would no longer fund the IRTF altogether. Due to budget cuts proposed by President Reagan in his FY 1983 budget proposal to NASA, the IRTF was facing elimination from the NASA budget and permanent closure (Akaka, 1982; and Sullivan, 1982). However, $1.7 million was set aside to still construct a facility halfway up Mauna Kea to support the IRTF and other Mauna Kea observatories (Sullivan, 1982). Despite the proposed elimination of funds, funding was re-established by Congress for both the IRTF and planned Mid-level Facility (US House of Representatives, 1982: 53. The following dates are select events and observations which did occur using facilities developed under the program or with PAST program funding:

[Approximately May] 1982: JPL astronomer Jerome Apt and University of Hawaii astronomer Robert Singer observe that Saturn's equatorial clouds reach 10 km higher into the atmosphere than clouds at other latitudes using the IRTF. Their observations complement Voyager's images of Saturn and "provide unique quantitative information on the altitude variations of the clouds" (NASA Daily Activity Report, 1982).

June 23, 1982: Three astronomers at the University of Hawaii using the NASA Infrared Telescope Facility with data from Voyager announced the first measurement of the size of four of the five major moons of Uranus (NASA Historical Staff, 1988).

March 8, 1985: NASA announces that efforts at JPL, the University of Hawaii, the University of Arizona, and University of Texas were being made to observe the once-in-124-year occurrence of eclipses between Pluto and its moon Charon. The oscillation between Pluto and Charon eclipsing each other relative to Earth allowed for measurements of mass, diameter, and density to be taken of the two bodies (NASA Historical Staff, 1990).

March 1986-June 1987: NASA's Infrared Telescope Facility monitors Comet Halley as part of its monitoring program for the comet's historic apparition. The program found indications that there was a change "in either the composition or particle size of the cometary dust, or both" of the comet (Tokunaga, Golisch, Griep, et al., 1988).

April 1989: K. Meech and Michael J.S. Belton observe CCD images of an extended coma on 2060 Chiron, showing that the previously thought asteroid was actually a comet (NASA, 1990).

1990-1999

Politics and Interest of NASA Between 1990-1999

The 1990s was a decade of regular use of the Space Shuttle, the finalization of the development plans of the International Space Station, the introduction of the NASA website, the launch of Hubble and many other significant accomplishments in the field of planetary science. The 1990s also marked the beginning of the post-Cold War period following the collapse of the Soviet Union in 1991. A new period of international cooperation in space was also birthed in this period, facilitated by shuttle mission STS-60 which included Russian cosmonaut Seregei K. Krikalev in 1994 and the signing of the International Space Station Agreement by the US and fourteen other nations in 1998 (NASA History Division, 2012). President George Bush Sr. also served as President of the United States in the early 1990s and asked chief executive of Martin Marietta, Norman Augustine, to lead an Advisory Committee on the “Future of the US Space Program.” Augustine’s recommendations specified the need for a balanced space program “within a tightly constrained budget” which included both crewed and uncrewed spaceflight objectives (NASA History Division, 2012).

The 1990s was an eventful decade for space science. One of the first major events to begin the decade for NASA began with the launch of the Hubble Space Telescope on April 24, 1990. Having gone through multiple servicing missions in the decades since it first launched including the correction of a manufacturing error in the telescope’s mirror, Hubble still continues to expand our understanding of the universe through its astronomical discoveries as of 2022. NASA describes Hubble as the first of the five long-duration “Great Observatories” put into space (Covey, 2012). The second was the launch of the Compton Gamma Ray Observatory on April 5, 1991, which at 17-tons was the heaviest payload flown to space at the time. The third Great Observatory, the Chandra X-ray Observatory was launched on July 23, 1999, to study black holes, supernovas, and dark matter. The fourth was the infrared Spitzer Space Telescope launched in 2003 and as of 2022, the James Webb Space Telescope has been the latest.

Regarding planetary science specifically, a combination of launches of new spacecraft and the encounters of already active planetary missions made the 1990s a semi-successful decade for planetary science. On September 25, 1992, the Mars Observer was launched on a mission to orbit Mars. Unfortunately, NASA permanently lost contact with the spacecraft days before it was scheduled to enter Mars orbit. Other mission failures included the 1999 loss of contact of the Mars Climate Orbiter launched in 1998, and the loss of both the Mars Polar Lander and Deep Space 2 in December of 1999. However, the successful US planetary missions of the 1990s include the NEAR (Near Earth Asteroid Rendezvous) Shoemaker launched in February of 1996, the Mars Global Surveyor launched in November of 1996, the Mars Pathfinder mission launched in December of 1996, the Saturn-bound Cassini mission launched in October of 1997, the Lunar Prospector launched in January of 1998, and Deep Space 1 launched in October of 1998.

However successful the NASA space science program was in the 1990s, the decade also marked trouble for US prestige in ground-based astronomy as European telescopes began to rival those of the United States in technology. The European Southern Observatory in Cerro Tololo, Chile, for example, was cited in 1992 as capturing images "up to six times more revealing" with its more advanced New Technology Telescope compared to those images from American telescopes, some also located at Cerro Tololo (Browne, 1992: C-1). This left a bitter taste in the mouths of American astronomers who had traditionally led the world in optical astronomy. One cause given for such a shift was the trend of new European observatories being built "by the relatively well-financed consortium" of eight European countries. As a result, there was some fear in American astronomers that preeminence in European observations would "dry up" grants extended to US universities (Browne, 1992: C-1).

However, American ground-based astronomy did expand during the 1990s to include the NASA Near-Earth Objects Observations (NEOO) Program of the Planetary Science Division which was established in 1998. The NEOO Program is tasked with tracking and characterizing near-earth asteroids, especially Potentially Hazardous Asteroids (PHAs) which due to size and proximity to Earth warrant continuous observation in case of Earth-impact. It is currently administered by NASA's Planetary Defense Coordination Office. The NEOO grew out of Planetary Astronomy, which first supported using ground-based telescopes to find and track NEOs.

In terms of NASA planetary science funding, of which Planetary Astronomy was a subset, the $940 million (2010 dollars) yearly average Planetary Science Budget from 1990-1999 was similar to the 1980s in the sense that it was still dwarfed by the NASA astrophysics budget at an average of $1.18 billion per year in 2010 dollars (Callahan, 2021: 81-2). However, this $940 million-dollar yearly average for the Planetary Science Budget was higher than the $565.96 million 1980-1989 yearly average allocated Planetary Science (in 2010 dollars) (Callahan, 2021: 81).

Overview of NASA Planetary Astronomy Program 1990-1999

The 1990s saw the introduction of the internet and internet-based Planetary Astronomy research solicitations. In a 1983 interview, William Brunk made the comment that because of a shortage of staff (including no secretary), a shortage of time, and the need to free-up storage space, at the time, many historical records from the Planetary Astronomy program were not properly documented or preserved (Brunk, 1983). That comment was made in the early 1980s which is a bleak reminder that some lesser-known aspects of NASA's history have not been well preserved over time. Nevertheless, this tangent is used to give value to records which have been saved due in part to the phenomenal work of the NASA HQ Historical Reference archivists combined with documented internet snapshots and the NASA Technical Report Server.

There was a gap in the 1990s between NASA's solicitation of paper research proposals in the beginning of the decade to NASA soliciting online proposals in the latter half of the decade. Because of this, the first year Jürgen Rahe was the Discipline Scientist of Planetary Astronomy is hard to pin down for reasons discussed in the "methodology" section of this paper. However, the 1986 NASA "Reports of Planetary Astronomy" and the 1995 NASA Research Announcement (NRA) for Planetary Astronomy list Rahe as the point of contact for the PAST program for solicitors, so it can be assumed that he held this position from 1986-1995 (NASA, 1995). Dr. Edwin Barker is listed in the same position in 1996 PAST NRA (NASA, 1996), Dr. Walter Huebner is listed in 1997 (NASA, 1997), and Dr. Thomas Morgan is listed in the NRAs from 1998 (NASA, 1998) until 2001 (NASA, 2001).

In terms of budget, in 1997, the estimated Planetary Astronomy budget was around $10 million dollars and was estimated that around 100-150 research investigations would be selected for funding that year. The scope of the PAST program that year incapsulated solely ground-based observations defined to support "understanding of the general properties and evolution of the planets and their satellites, and of comets and asteroids." However, data which supplemented current NASA missions like Galileo, NEAR, Mars Pathfinder, and Mars Global Surveyor were "encouraged." Observations relating to "Comparative Planetology" and "Earth Perspective" were also encouraged (NASA, 1997).

In 1998, the Planetary Astronomy program was only comprised of ground-based telescopic research relating to the same focus as the 1997 solicitation. Mission support for the Galileo Europa Mission and the Near-Earth Asteroid Rendezvous Mission were encouraged. $10.7 million was budgeted for 1998 with $3.5 million going towards facility support "principally the Infrared Telescope Facility" with the remain funds going toward around 100 investigations. However, one-third of those grants were expiring, putting $2.4 million up for grabs in new research (NASA, 1998).

The NASA Planetary Astronomy program in 1999 once again only solicited for ground-based research which could either support a NASA flight mission or was research which could not be conducted by current spacecraft missions. While the scope of the PAST program still included the study of comets, asteroids, planets, and natural satellites, the 1999 solicitation made it clear that observations of near-Earth objects (NEOs) would be supported separately through the new Near-Earth Object Observations Program, created in 1998. The 1999 PAST program was estimated to have $8.2 million at its disposal with $3.5 million of that amount allocated to facility support. One-third of grants were expiring so approximately $2 million was estimated to be available for selected research for 1999 (NASA, 1999).

Significant NASA Planetary Astronomy Events/Developments 1990-1999

The following list is comprised of select astronomical events and observations made through NASA Planetary Astronomy research investigations or partially/fully funded facilities:

June 7, 1991: NASA announced that radar astronomers funded by the Planetary Astronomy program identified a near-Earth metal asteroid (1986 DA) for the first time using the Arecibo Observatory (NASA Historical Staff, 2000: 84).

August 20, 1992: Astronomers David Jewitt and Jane Luu of the University of California observe a "planet-like object" past Pluto left mainly unchanged since the creation of the solar system which could be used to learn about how planets form (Sawyer, 1992: A9).

July 12-August 7, 1994: Observations are made of fragments of Comet Shoemaker-Levy 9 impacting Jupiter using the NASA Infrared Telescope Facility (IRTF) (NASA Historical Staff, 2000: 556).

March 2, 1995: Observers using NASA IRTF discover an instance of major volcanic activity on the Moon of Io (NASA Infrared Telescope Facility, IRTF's science highlights).

2000-2009

Politics and Interest of NASA Between 2000-2009

The 2000s was a decade of a new reorganization for NASA when the Office of Space Science merged with the Office of Earth Science to form the current Science Mission Directorate in 2004 (NASA, 2010a). Tragically, the decade also saw the loss of Space Shuttle Columbia and her crew; commander Rick Husband, mission specialist David Brown, mission specialist Laurel Clark, mission specialist Kalpana Chawla, mission specialist Michael Anderson, pilot William McCool, and Israeli payload specialist Ilan Ramond; upon reentry in 2003. The period between 2000 and 2009 also marked the first decade of the new millennium and the continuation of NASA's focus on the Space Shuttle Program and development of the International Space Station. On January 14, 2004, President Bush attempted to further promote the US crewed spaceflight program by proposing that the US send humans back to the Moon by 2015 and later to Mars (National Archives, 2016).

Despite the tragedy of Shuttle Columbia, NASA planetary science had a successful decade of new solar system discoveries. Notably, NASA's Planetary Science budget increased from its $940 million (2010 dollars) yearly average in the 1990s to an average yearly budget of $1.46 billion (2010 dollars) in the 2000s (Callahan, 2021: 82). In terms of flight missions, on February 12, 2001, NASA's NEAR spacecraft became the first to land on the surface of an asteroid. NASA's fourteen-year Galileo mission also ended in success with an intentional plunge into Jupiter's atmosphere on September 21, 2003. Additionally, the NASA's Stardust mission returned to Earth on January 15, 2006, carrying the first returned sample of dust from a comet. On May 25, 2008, the Phoenix Mars Lander successfully landed on the Red Planet; and on November 13, 2000, NASA announced that the Lunar Crater Observation and Sensing Satellite confirmed the discovery of a "significant amount" of ice in a crater on the Moon (National Archives, 2016).

Overview of the NASA Planetary Astronomy Program 2000-2009

From 2000 to 2009 there were four different Discipline Scientists of the NASA Planetary Astronomy program. To begin the decade, Dr. Thomas Morgan held this position from 1998 to 2001 (NASA, 2001). Taking over for him was Dr. John Hillman from 2002 (NASA, 2002) to 2003 (NASA, 2003). Former Air Force lieutenant colonel Lindley Johnson, who would later become NASA's first Planetary Defense Officer, held the position from 2004 (NASA, 2004) to 2006 (NASA, 2006). He would switch on and off as Discipline Scientist for the Planetary Astronomy program with Dr. Phillippe Crane; who held the position in 2007, 2009, and 2010; for the remainder of the decade (NASA, 2007, 2009, and 2010).

In 2000, $7.2 million dollars was budgeted for the PAST Program, $2.7 million of which was dedicated to facilities support. Around 80 investigations were being funded with the remaining budget. Approximately one-third of existing NASA grants were expiring leaving $1.5 million available for new funding research (NASA, 2000). The information in the 2001 PAST research solicitation was virtually the same as the year prior (NASA, 2001). Also in 2000, PAST Discipline Scientist, Tom Morgan organized a panel of experts including NEO-survey Principal Investigators and representation from JPL, MIT Lincoln Labs, and the Department of Defense to discuss the treat of near-Earth objects and how that hazard should be dealt with (Conway, Yeomans, Rosenburg 2022: 214-15). The result of this panel was the 2003 NEO Science Definition Team Report which reaffirmed NASA's "obligation and commitment" to understanding NEO threats to Earth (Near-Earth Object Science Definition Team, 2003: 132).

In 2002, research proposals were required to "contain an element of ground-based observing" and encouraged to support a NASA flight mission. A suggestion in the 2002 research solicitation included the study of Comet Encke which would be "extremely well placed" for ground-based observations from May through November 2003. Comet Encke was scheduled to be encountered by the CONTOUR spacecraft on November 12, 2003. Unfortunately, contact was lost with the Comet Nucleus TOUR (CONTOUR) six weeks after its July 3, 2002 launch. $7.2 million dollars was budgeted for the PAST Program, $2.7 million which was dedicated to facilities support. Around 80 investigations were being funded with the remaining budget, approximately one-third of which were ending leaving $1.5 million available for new funding research (NASA, 2002).

In 2003, PAST PIs were encouraged to focus research in the areas of interest to NASA's Solar System Exploration program including studying the origin of the Solar System, figuring out what characteristics of our Solar System led to life, studying of how life begins and evolves, understanding the evolution of Mars, determining if life ever existed on Mars, or conduct research relating the future support of humans on the Red Planet. The 2004 PAST solicitation listed identical interests to the NASA Solar System Exploration Division. The 2003 PAST budget estimates were identical to those of the past three years (NASA, 2003).

In 2004, $8 million was budgeted for the Planetary Astronomy program with $3.5 million of that amount going towards facility support, mainly the IRTF. About 60 investigations were expected to be supported with the remaining funds. One-third of the PAST investigation at the time were expiring allowing research proposers to compete for the $1.5 million left available. From 2000 to 2004, the Planetary Astronomy program funded ground-based observations of planets, their satellites, and asteroids and comets using wavelengths from ultraviolet to radio. Funded research during this period needed to assist current flight missions or be research which could not be conducted by the current NASA flight missions (NASA, 2004).

In 2005, the NASA Research Announcement for Research Opportunities in Space Science (ROSS) was renamed to the NASA Research Announcement for Research Opportunities in Space and Earth Science (ROSES). The scope of the Planetary Astronomy program at this time was defined to support "investigation based on ground-based astronomical observations" between the ultraviolet to radio wavelengths. The Solar System, our planets and their satellites, and asteroids and comets were the areas of focus for the program. Specified in the 2005 solicitation was the requirement that the research proposal must include "an element of new observation" and must support NASA Solar System program objectives, active flight mission, or those which could not currently be met by flight missions in general. It was estimated that the NASA PAST program would have $2.1 million budgeted for the new awards. It was also estimated that twenty to twenty-five new research proposals would be funded (NASA, 2005).

In 2006, the scope of the PAST Program was the same as in 2005, but the solicitation recommended that proposers consider observing the 2007 Uranus equinox as part of their research. This equinox of Uranus was the first to occur since 1965, and the 2006 PAST solicitation suggested that the following phenomena be observed: "ring plane crossing, mutual Uranian satellite occultations, diurnally-driven auroral activity, and atmospheric radiative balance changes driven by rapidly varying insolation." Additionally, principal investigators wishing to use the Goldstone Planetary Radar of the Deep Space Network were told to contact the program officer of PAST, who was Lindley Johnson in 2006. $2.2 million was budgeted for the new awards of 2006 PAST program with an expected fifteen to twenty-five proposals to be granted funding (NASA, 2006). The scope and characteristics of the 2007 PAST program were virtually the same as 2006 (NASA, 2007).

2008 marked a change in program scope which returned solicitations to being both for ground and suborbital investigations involving sounding rockets or balloons. The Planetary Astronomy program would also fund construction, payload development, launch, instrument calibration, and data analysis. However, the scope of study toward solar system objects remained the same and PIs still had the opportunity to take advantage of the Goldstone Planetary Radar. The amount of funds budgeted for new 2008 Planetary Astronomy research investigations was once again $2.2 million for between fifteen to twenty-five new awards for research (NASA, 2008). The 2009 PAST ROSES solicitation was virtually identical despite having a more scaled-back budget with $1 million for an expected eight to twelve new investigations (NASA, 2009).

Significant NASA Planetary Astronomy Events/Developments 2000-2009

The following list is comprised of select astronomical events and observations made possible through NASA Planetary Astronomy funds or facilities between 2000 and 2009:

2001: The 40% NASA PAST-funded 1.8-meter Spacewatch II telescope on Kitt Peak sees first light. Spacewatch II was built to help determine the population of near-Earth asteroids. NASA PAST also funded the telescope's camera and provided partial support for salaries (Conway, Yeomans, Rosenburg 2022: 148).

October 2007: The NASA Infrared Telescope Facility detects water ice grains around the nucleus of the Comet 17P/Holmes (Tokunaga, 2009: 7).

July 20, 2009: The NASA IRTF captures an infrared photo of the cloud of debris from an object which exploded in Jupiter's upper atmosphere (Phillips, 2009).

January 15, 2009: NASA announces that a team of NASA and university scientists using the NASA IRTF and the W.M. Keck Observatory detected the presence of methane in the Martian atmosphere. The scientists' work was funded out of the NASA Planetary Astronomy program and the Astrobiology Institute at NASA Ames Research Center (WM Keck Observatory, 2009).

2010-2019

Politics and Interest of NASA between 2010-2019

The retirement of the Space Shuttle in 2011 marked the end of crewed US launches to space for the remainder of the decade. US astronauts instead needed to rely on Russian Soyuz capsules get to the International Space Station, completed also in 2011. During this decade, President Obama reoriented US space policy towards eventual crewed flights to an asteroid and Mars when he cancelled the crewed lunar Constellation program. When President Trump took office in 2017, the US space effort was once again focused on going back to the Moon and plans were scrapped for US astronauts to visit an asteroid. Under the Trump Administration in 2019, the Space Force was added as the 6th branch of the US armed services and new space policy directives were created encompassing topics such as space traffic management and space commercialization.

NASA Planetary Science was also eventful between 2010 and 2019. The Planetary Defense Coordination Office (PDCO) of NASA's Planetary Science Division was established in 2016 to continue to identify and track NEOs and work to coordinate mitigation efforts for planetary defense. The Near-Earth Object Observations Program was placed under PDCO funding starting in that year. In 2010, Deep Impact became the first spacecraft to fly by two comets when it visited Comet Hartley 2. Additionally, the Mars Odyssey mission released the first global map of Mars in 2010, the Messenger spacecraft entered orbit around Mercury in 2011, and the Juno spacecraft was launched towards Jupiter also in 2011. In 2012, the Curiosity rover landed successfully on Mars and the MAVEN mission was launched towards Mars in 2013. The Cassini spacecraft found signs of water geysers at Enceladus in 2014 and the New Horizons spacecraft flew by Pluto in 2015. Also in 2015, the Dawn spacecraft arrived at Ceres and in 2017 the Cassini spacecraft ended its mission by purposely flying into Saturn. In 2018, Voyager 2 exited the solar system, and the InSight spacecraft was launched towards Mars.

Overview of the NASA Planetary Astronomy Program 2010-2019

In 2014, The Planetary Science Division research and analysis programs underwent a large reorganization. The NASA Planetary Astronomy and Near-Earth Object Observation programs were combined to be jointly solicited as the Solar System Observation (SSO) Program. From this point onward, NASA Planetary Astronomy program funded research was now called NASA Solar System Observations Program funded research.

Dr. Phillippe Crane led the NASA Planetary Astronomy program at the beginning of the decade in 2010 (NASA, 2010). Taking over for him in 2011 was Dr. Kelly Fast who previously worked at the Goddard Space Flight Center and was a visiting astronomer to the NASA Infrared Telescope Facility. Dr. Fast held the position as Planetary Astronomy Discipline Scientist until 2018 (NASA 2011) with the exception of 2014 when the position was held again with Lindley Johnson (NASA, 2014). Currently, Dr. Fast runs the NASA Near Earth Object Observations Program in the PDCO and is the NASA Program Scientist for the NASA Infrared Telescope Facility. Doris Daou served as Planetary Astronomy Discipline Scientist with Dr. Fast in 2019 (NASA, 2019).

In 2010, the NASA Planetary Astronomy program continued to solicit for both ground-based observation as well as suborbital investigation which began in 2008. However, PIs did have the ability beginning in 2010 to propose research which could be conducted on the ISS. All other aspects of the program remained the same in 2010 besides the estimated funding for around ten to fourteen new proposals at $1.5 million (NASA, 2010). The 2011 program was virtually identical in all aspects to 2010 (NASA, 2011). 2012 was also very similar, but there was an estimated budget of $1.3 million dollars to be divided up for an expected eight to twelve new investigations (NASA, 2012). 2013 marked the last time that solicitations would be made under the "Planetary Astronomy" category of ROSES. The estimated budget for new research in 2013 was $1 million to fund an expected six to ten investigations (NASA, 2013).

2014 was the first year where Planetary Astronomy research proposals were solicited under SSO. According to PAST funding information given to me by Dr. Fast, funding for the NASA IRTF was also moved from the Planetary Astronomy component of SSO to the NEOO program portfolio. But regardless, in its first solicitation, Solar System Observations was defined to support "both ground-based astronomical observation and suborbital investigations" of solar system phenomena. Ground-based observations which could "supplement NASA missions" were "especially encouraged" (NASA, 2014). The 2015 SSO solicitation did not include an NEOO sub-element, nor did it include suborbital investigations (NASA, 2015). In 2016, the solicitation of an NEO sub-element resumed, but full suborbital investigations have not been included in solicitations since. The expected budget of Planetary Astronomy was $1 million to fund an expected eight to ten investigations (NASA, 2016). In 2017, the SSO solicitation was upfront about "primarily" supporting ground-based research and was "limited" in supporting airborne and space-based observations. In 2017, the PAST component had a $1 million expected budget to fund around eight to ten new investigations (NASA, 2017). 2018 had a nearly identical solicitation except it included a suggestion from the NASA Planetary Science Division that proposals include a focus on an aspect of the Moon. (NASA, 2018). In 2019, the NEOO-funded sub-element was split off from the SSO solicitation and separately solicited as Yearly Opportunities for Research in Planetary Defense (YORPD). Once again, $1 million was budgeted towards SSO new investigations which would number around eight to ten (NASA, 2019).

Significant NASA Planetary Astronomy Events/Developments 2010-2019

The following list is comprised of select astronomical events and observations made possible through NASA Planetary Astronomy funds or facilities:

May 29, 2012: The IRTF tracks asteroid 2012 KT42 as it makes sixth-closest asteroid encounter up until that time (Hand, 2012).

August 1, 2019: Scientists funded by NASA's Solar System Observations Program publish paper suggesting that a "key tracer" in determining how much atmosphere on Mars has been lost can vary depending on the time of day and surface temperature on the Red Planet (Livengood, Kostiuk, Hewagama, et. al, 2020).

December 2019: Astronomers funded by the NASA Solar System Observations Program observe an asteroid (6478 Gault) changing color for the first time (Chu, 2019).

2020-Present

Politics and Interest of NASA between 2020-Present

NASA was not immune from the mass-transfer of in-person work to telework due to the Coronavirus Pandemic in the spring of 2020. Virtual meetings became the primary medium of group communication and most NASA internships were made virtual. Regardless, the signing of the Artemis Accords for US-led international lunar exploration and commercial exploitation still occurred in December 2020. The US also began a partnership with SpaceX to launch American astronauts into space aboard the reusable Falcon 9 rocket, with the first manned test of the Crew Dragon capsule in May of 2020. When President Joe Biden took office in early 2021, he did not draft space policy to change the trajectory of US's Artemis Program mission to land astronauts on the Moon within the end of the decade.

The pandemic aside, planetary science still carried on at NASA. In February 2021, the Perseverance rover successfully landed on Mars. In October 2021, NASA's OSIRIS REx mission collected a sample from the asteroid Bennu which will return to Earth in 2023. Also in October, the Lucy mission was launched as the first mission to visit the Trojan asteroids. In November, the Double-Asteroid Redirection Test (DART) was launched on November 26, 2021, as NASA's first planetary defense mission to test the redirection abilities of a kinetic impactor spacecraft on an asteroid moonlet. NASA's largest and most technically advanced space telescope, the James Webb Space Telescope launched on Christmas Day 2021.

Overview of the NASA Planetary Astronomy (Solar System Observations) Program 2020-Present (2022)

Beginning in 2020, the jointly solicited PAST and NEOO Programs were once again divided into separate funding lines. The NEOO Program began soliciting under the Yearly Opportunities for Research in Planetary Defense. However, the Planetary Astronomy program continued to solicit under SSO. This is the status of the NASA Planetary Astronomy program which Dr. Lucas Paganini, ran as of 2022, currently runs having taken over as Discipline Scientist from Doris Daou and Kelly Fast in 2020 (NASA, 2020).

The 2020 SSO ROSES solicitation still budgeted approximately $1 million for eight to ten new investigations and included “primarily ground-based” but “limited” funded observations made from airborne and space-based technology (NASA, 2020). The 2021 SSO solicitation did not have a deadline, and proposals were evaluated throughout the ROSES 2021 solicitation year, with an expected $1 million budget to fund approximately eight to ten new investigations. Funded research would cover the range of wavelengths from ultraviolet to radio (NASA, 2021). In the 2022 solicitation for Solar System Observations, it was announced that SSO would begin accepting proposals “seeking analysis of archival data with Earth-based observatories” to better understand the developmental processes of atmospheres, exospheres, surfaces, motions, and interiors of solar system objects. Funded research could cover the range of wavelengths from X-ray to radio and expected funding was identical to the prior year (NASA, 2022).

Significant NASA Planetary Astronomy (Solar System Observations) Events/Developments 2020-Present (2022)

On August 4, 2021, NASA Solar System Observations Program funded scientists discovered that the reason areas of Jupiter's atmosphere are hotter than expected is because of the planet's powerful aurorae (O'Donoghue, 2021).

CONCLUSION

Ground-based solar system observations have "been fundamental" to scientific progress and how we view our "place in the universe," according to the American Institute of Aeronautics and Astronautics (1974). From our understanding of when to planet crops by measuring the length of the day to uncovering scientific proof that Earth is not flat through the observation of Earth's shadow on the moon during lunar eclipses, humanity has directly benefited from planetary astronomy. NASA revitalized the discipline of planetary astronomy and gave it modern applications to solar system research. Just as a ground-based observation investigations contributed to the success of planetary missions, so will continued observations have the opportunity to assist the future probes, landers, and humans who will explore other solar system bodies. That said, the documentation throughout time of the NASA PAST program is absolutely vital. Not only because it will become harder over time to document this important history as records get lost and data degrades, but because comprehensively understanding the successes, challenges, and impacts of any program helps inform policy makers as to whether such programs should be renewed or canceled. However, this is paper not an exhaustive history of the NASA Planetary Astronomy program. Rather, this work is a first step in documenting a lesser-known chapter of NASA's history compared to programs like Apollo or the Shuttle. Without adequate historical documentation, effective policy regarding existing programs cannot prevail and the significant legacies of such programs to American science and technology will also be, as such, degraded.

That said, there are two distinguished legacies of the NASA Planetary Astronomy program: the creation of the NASA Infrared Telescope Facility and the revitalization of planetary astronomy because of NASA's interest in Solar System exploration. The NASA IRTF was the first fully funded NASA ground-based telescope that was operated as a national facility. The facility is located at one of the best locations in the world for observations due to its location at 13,600 ft and minimal water vapor at that altitude. Since its establishment in 1979, the IRTF has supported NASA planetary science flight missions through ground-based observations. Lastly, the IRTF offers remote observations world-wide, allowing astronomers to use the telescope via the internet from any location in the world**.** This observation option proved to be beneficial during the lock-down of the COVID-19 pandemic. In 2014, funding for the IRTF was transitioned to the Near-Earth Object Observations program. Although the NASA IRTF is no longer funded by what is now the NASA Solar System Observation Program, it still is an enduring legacy of NASA planetary science made possible by the NASA Planetary Astronomy program.

The other lasting legacy of NASA Planetary Astronomy is the overall impact it has had on the discipline of planetary astronomy. Through the various funding and construction of planetary science telescopes for universities, the funding of research proposals, and the construction of a dedicated planetary astronomy telescope, NASA has been directly responsible for the current success of planetary astronomy in America if not the world. From a program that officially began nearly sixty-years ago which endured multiple reorganizations and eventual name change to Solar System Observations, NASA's Planetary Astronomy program continues to play a strong role in facilitating humanity's understanding of our Solar System and providing significant support to high-profile NASA space missions.

ACKNOWLDEGEMENTS

This research paper would not be possible without the assistance of some very stellar people. Firstly, my gratitude goes to my internship supervisor, Dr. Kelly Fast, program manager of the NASA PDCO Near Earth Object Observations Program. She was extremely helpful throughout my entire internship in the Planetary Defense Coordination Office, and I really learned a lot from her regarding everything from near-Earth objects to the recent history of NASA Planetary Astronomy program. From the bottom of my heart, I thank her for her enthusiasm, encouragement, and assistance in providing me with records for this project.

Next, I have Steve Garber of the NASA History Division to thank for his assistance in this project. This is probably the largest and most complicated research project I have done so far, and I could not have done nearly as much as I did without his support, guidance, and referrals. Both he and Dr. Fast also reviewed and made edit suggestions to this paper, and for that I am grateful.

Additionally, I must thank current (as of spring 2022) NASA head of Planetary Astronomy (Solar System Observations) Dr. Lucas Paganini and former NASA Planetary Astronomy Discipline Scientist Mr. Lindley Johnson. I informally interviewed both of them to gain valuable background information of the program and how it has evolved to the present.

Rick Spencer and Claudia Jones of the NASA Headquarters Library were extremely helpful in getting me hard copies of books and old NASA records. I truly thank them for their interest and assistance in this project.

KarShelia Kinard of the NASA Science Mission Directorate gave me access to the list of those NASA accessions to the Federal Records Center relating to planetary astronomy. Although the FRC was not able at the time to grant me access to the records, I was able to compile a list of accessions which can be assessed in the future for further research on the NASA Planetary Astronomy program (see "Methodology" section below).

In the fall of 2021, Sarah LeClaire from NASA Archives gave me temporary access to the NASA phone records from 1963 which was helpful for me to confirm who worked in for NASA and when they were employed by the Agency. During my summer 2022 internship, she and Sarah Jenkins were very helpful in helping me look for NASA archive records and pulled between twenty and thirty boxes in total for me to sort through. Without their help, my paper would not have been as detailed, so I thank both Sarah and Sarah for all their help.

Dr. Alan Tokunaga, former director of the IRTF kindly took time out of his busy schedule to proofread sections related to the IRTF.

Lastly, I would like to give a special shout-out to the NASA Planetary Defense Coordination Office for being so welcoming and kind to me as I began my first internship at NASA for the Fall of 2021 and through my subsequent internships at NASA HQ. Overall, I have been so proud to have had the opportunity to work at the PDCO this past year, and I am greatly appreciative of all the guidance and support I received from virtually everyone in the office.

METHODOLOGY

Conducting research for this project felt like putting together a puzzle without an image to reference and not knowing if you had all the pieces. In part, this is because there are no comprehensive reports such as timeline of personnel or budget information spanning multiple decades concerning the NASA Planetary Astronomy program, at least to my knowledge. That said, this paper uses a variety of resources including interviews, consultations with NASA historians, historical astronomical publications, NASA technical memorandums, newspapers, yearly research proposals, letters, memos, obituaries, informal oral interviews, NASA organizational charts, former Planetary Astronomy budget allocations, past Agency phone directories, and former NASA webpages documented by Internet Archive. However, there were several difficulties involved in uncovering the information in this paper over the six-month period of research.

Firstly, the Coronavirus pandemic restrictions put in place for public safety made it impossible to access records from the institutions like the National Air and Space Museum and Federal Records Center (FRC) during the fall of 2021 when I wrote and researched the most for this paper. Additionally, all NASA Headquarters internships that semester were virtual for the same reason, so access to the NASA HQ library and archives was difficult. Most research was completed through access to the internet, the NASA Technical Report Server (NTRS), the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES), and the other methods mentioned above during my fall 2021 internship. I returned to PDCO for a summer 2022 internship a few months later to continuing working on this history project and helping with policy and administrative aspects of PDCO. However, the NASA archives reopened during this time, and I was finally able to access the majority of the primary source documents cited in this work.

A second obstacle was the search for NASA records of solicited proposals and Planetary Astronomy lead personnel throughout the decades, especially pre-internet. The NASA Technical Report Server only lists research proposals from post-2004, making records before that period very difficult to access if they still exist. Additionally, the NASA HQ archives did not have the complete collection either. For example, former PAST Discipline Scientist Dr. Jürgen Rahe is listed in many of his online obituaries including one from the American Astronomical Society as coming to NASA Headquarters in 1989 to lead the NASA PAST Program (Pilcher, 1997: 1482-1483). However, a NASA technical memorandum from 1986 states that Dr. Rahe was already in the Planetary Astronomy Discipline Scientist position when the document was published (NASA Office of Space Science and Application, 1986). Without having access to the information of the pre-1995 PAST solicitations, I used an educated guess to determine which years Dr. Rahe was Discipline Scientist for PAST in this paper's timeline located in the appendix. This paper also assumes that all PAST POCs listed on solicitations were the PAST Discipline Scientists that year based on this action being the modern trend. However, it is possible that some of the start years of the Discipline Scientists listed in the appendix are slightly off if there was a leadership transition after the yearly PAST solicitations were publicized that year. This is because I listed the Discipline Scientist of that year to be the one listed in the yearly solicitation and did not have the records to verify they were the PAST Discipline Scientist for the remainder of the year.

The following list of documents are currently inaccessible at present because they either cannot be located or the facility, they are housed in is temporarily restricting access. However, any future research focusing on the Planetary Astronomy program at NASA should make use of these documents when they are accessible:

NASA record accessions to the Federal Records Center:

255-0672: Records of the Solar System Exploration Division, Planetary Astronomy Office. D. J. Rahe Grants to Principal Investigators FY 1983.

255-06-0658: NASA Research Announcements and Announcements of Opportunity from 1989 through 2000.

Box 1: 1989-1992 NRA 90-OSSA-8 Planetary Astronomy program and Planetary Atmospheres Program

Box 2: 1993-1994: NRA 94-OSS-01 Research in Planetary Astronomy and Planetary Atmospheres

Box 3: 1995: NRA 95-OSS-05 Research in Planetary Astronomy and Planetary Atmospheres

Box 4: 1996-1997: NRA 96-OSS-05 Research in Planetary Atmospheres

255-71A3941: Reports from research grants from the Planetary Astronomy program 1963-1969.

255-93-0629: 1960 thru 1991, Box 6, Astronomy Ground Based, '66, '69, '70, '71.

255-70A4785: 1962-1964 Research grants from the Planetary Astronomy program

255-91-0601: 1990 Records of the Office of Space Science and Applications Solar System Exploration Division,

Box 1: 4151.00 Beebe R/Planetary Astronomy FY90 NGL-32-003-001

255-72A3069: 1963-1969 Reports from the research grants from the Planetary Astronomy program.

255-80-0608: 1975 Files of the Administrator 1961-1977, Box 4, "Astronomy 3 ground-based"

255-70A2509: 1968-1969 NASA astronomy program and planetary program, program options & issues for decision.

APPENDIX

Timeline of Personnel

Below is the list of NASA Headquarters personnel who either ran the Planetary Astronomy program at NASA or had a significant influence with planetary astronomy activities at NASA. The timeline is of my creation from available records:

1958: John F. Clark is Planetary Science Program Chief under Assistant Director of Space Sciences, Homer Newell, jr. until 1960.

1959: Dr. Nancy Grace Roman is made head of Observational Astronomy at NASA, under Homer E. Newell, jr. Director of Space Sciences. She served as Chief of NASA Astronomy from 1960-1979.

1959: Edgar M. Cortright forms and heads the NASA Lunar and Planetary Programs Division.

1960: Oran Nicks becomes Director of Lunar and Planetary Programs Division.

1962: Roger C. Moore is put in charge of Ground and Balloon Based Planetary Astronomy by Oran Nicks, Director of Lunar and Planetary Programs.

1963-1964:[1] Dr. Ronald A. Schorn is selected as NASA Acting Program Chief of Planetary Astronomy, the first person at NASA specifically selected to lead Planetary Astronomy.

1964-1982: Dr. William Brunk takes over from Schorn as NASA Program Chief of Planetary Astronomy (Discipline scientist for Planetary Astronomy).

1983-1985: Dr. John Hillman is Discipline Scientist for Planetary Astronomy.

1986(?)-1995:[2] Dr. Jürgen Rahe is Discipline Scientist for Planetary Astronomy.

1996: Dr. Edwin Barker is Discipline Scientist for Planetary Astronomy.

1997: Dr. Walter Huebner is Discipline Scientist for Planetary Astronomy.

1998-2001: Dr. Thomas Morgan is Discipline Scientist for Planetary Astronomy.

2002-2003: Dr. John Hillman is Discipline Scientist for Planetary Astronomy.

2004-2006: Lindley Johnson is Discipline Scientist for Planetary Astronomy.

2007: Dr. Phillippe Crane is Discipline Scientist for Planetary Astronomy.

2008: Lindley Johnson is Discipline Scientist for Planetary Astronomy.

2009-2010: Dr. Phillippe Crane is Discipline Scientist for Planetary Astronomy.

2011-2013: Dr. Kelly Fast is Discipline Scientist for Planetary Astronomy.

2014: Lindley Johnson and Dr. Kelly Fast are Program Officers for Solar System Observations. Planetary Astronomy is now funded as Solar System Observations (SSO)

2015-2018: Dr. Kelly Fast is Planetary Astronomy Discipline Scientist under SSO.

2019: Doris Daou and Dr. Kelly Fast are Planetary Astronomy Discipline Scientists under SSO.

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[1] Dr. Ronald A. Schorn was the first official Program Officer of NASA Planetary Astronomy.

[2] This date range was best estimate using the information I had access to at the time. The actual time period could not be verified at time of publication by records.

2020-Present (Spring 2022): Dr. Lucas Paganini is Planetary Astronomy Discipline Scientist under SSO.

NASA Planetary Astronomy-Related Photographs

Figure 1 *Aerial photo of construction of the NASA Infrared Telescope Facility. Photo credit: NASA HQ Archives.*

Figure 2. *NASA Infrared Telescope Facility atop Mauna Kea, Hawaii. Copyright NASA/Ernie Mastroianni.*

Figure 3 *The IRTF on a snow-covered Mauna Kea. Photo credit: NASA HQ Archives.*

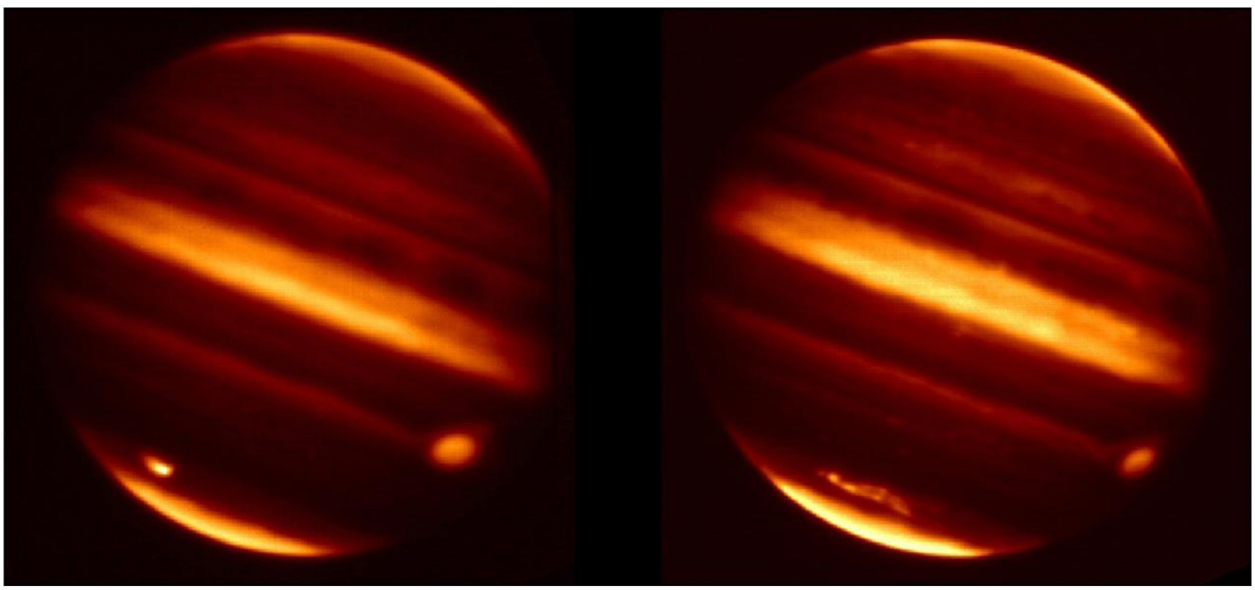

Figure 4. *Jupiter Scar in Infrared: These infrared images obtained from NASA Infrared telescope facility in Mauna Kea, Hawaii, show before and aftereffects from particle debris in Jupiter atmosphere after an object hurtled into the atmosphere on July 19, 2009. Copyright NASA/IRTF/JPL-Caltech/University of Oxford.*

Figure 5: *The top images of Fragment R of comet Shoemaker-Levy 9 impacting Jupiter were taken by Dr. Yongha Kim, Dr. Beth Clark, and Dr. William Cochran using the ROKCAM infrared camera on the McDonald 107-inch telescope. Photo credit: NASA HQ Archives.*

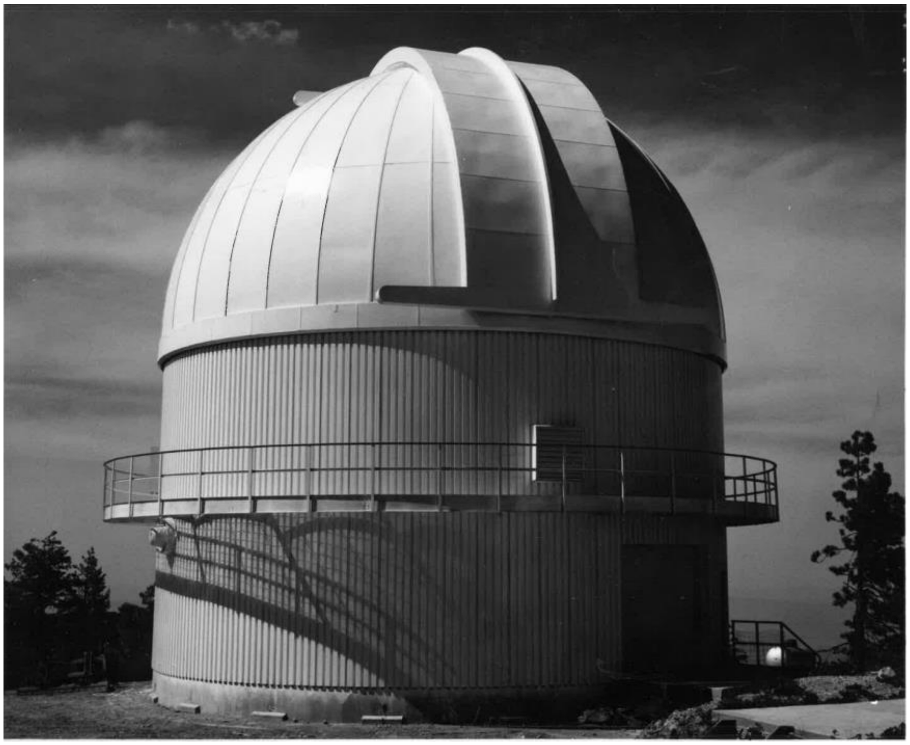

Figure 6 *The University of Arizona 61-inch Kuiper telescope (outside). Photo credit: NASA HQ Archives.*

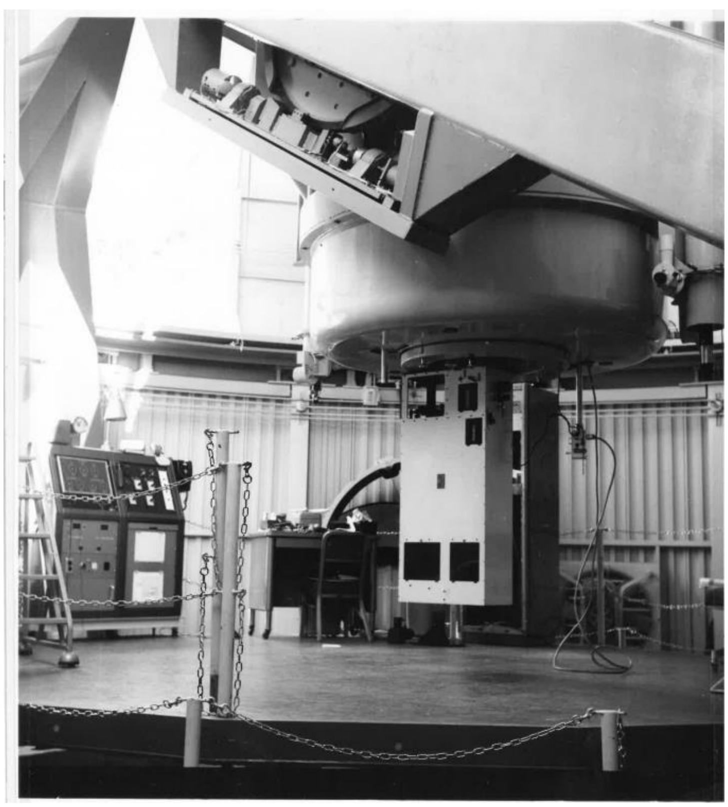

Figure 7 *The University of Arizona 61-inch Kuiper Telescope. Photo credit: NASA HQ Archives.*

Figure 8 *The University of Arizona 61-inch Kuiper Telescope. Photo credit: NASA HQ Archives.*

Figure 9. *S74-17688 (11 Jan. 1974)--- This color photograph of the comet Kohoutek was taken by members of the Lunar and Planetary Laboratory photographic team from the University of Arizona, at the Catalina Observatory with a 35mm camera on January 11, 1974. Photo credit: NASA*

Figure 10 *The summit of Mauna Kea. The IRTF is featured in the bottom right of the photo. Photo credit: NASA HQ Archives*

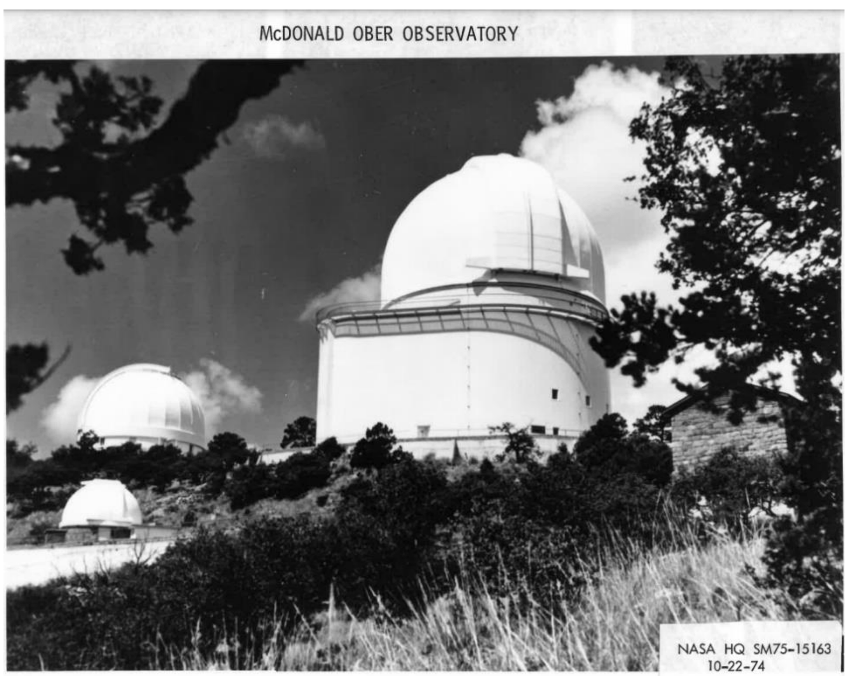

Figure 11 *The 107-inch Harlen J. Smith Telescope at the University of Texas. Photo credit: NASA HQ Archives*

Figure 12 *NASA The Planetary Defense Coordination Office sticker. The PDCO uses ground-based telescopes to spot Near-Earth Asteroids partially funded in the past by the NASA Planetary Astronomy program, like the IRTF. Photo credit: Alyse Beauchemin/NASA*

REFERENCES

Akaka DK (1982) Letter to James M. Beggs concerning NASA's possible elimination of funding for the IRTF. 29 October. Provided to author by Dr. Alan Tokunaga.

American Institute of Aeronautics and Astronautics (1974) Exploration of the solar system: an AIAA review. 28 February., NASA HQ Archives.

Arizona Daily Star (1975) Kitt Peak finds crack in mirror: Hawaiian scope part cost $500,000. 13 September, Section B—pg. 1. NASA HQ Archives.

Beer R (1976) Letter to IS Rasool concerning the necessity of the Hawaii Infrared Telescope, 17 March. Available at: NASA HQ Archives.

Bergstralh JT (1983) Interviewed by Joseph N Tatarewicz, Neils Bohr Library & Archives Oral Histories. American Institute of Physics, College Park, MD USA, 13 July. Available at: www.aip.org/history-programs/niels-bohr-library/oral-histories/28194.

Bloom B (1982) No stars in their eyes: US budget cutters telescope spending for astronomers. *The Christian Science Monitor*, 19 March, np. NASA HQ Archives.

Browne MW (1992) Europe's New Telescopes Rival U.S.'s. *The New York Times*, 4 February 4, c1. NASA HQ Archives.

Brunk W (1975) Memo to NASA Director of Lunar and Planetary Programs regarding significant planetary astronomy events of FY1975, 4 December, 1. Available at: NASA HQ Archvies.

Brunk W (1983) Interviewed by Joseph N Tatarewicz, Session I & II, Neils Bohr Library and Archives Oral Histories. American Institute of Physics, College Park, MD USA. Available at: www.aip.org/history-programs/niels-bohr-library/oral-histories/28198-1.

Brunk W (1983a) Biographical/Historical Note of "Interview of William Brunk by Joseph N. Tatarewicz on 1983 July 21." Niels Bohr Library & Archives, American Institute of Physics, https://libserv.aip.org/ipac20/ipac.jsp?uri=full=3100001~!28198!0&profile=rev-icos.

Callahan JW (2021) Funding Planetary Science: History and Political Economy. In: Billings L (ed) *50 Years of Solar System Exploration: Historical Perspectives*. Washington D.C.: NASA Office of Communications, pp.35-88.

Chanover N (2007) Obituary: John J. Hillman, 1938-2006. *Bulletin of the American Astronomical Society* 39 (4): 1065. Available at: https://ui.adsabs.harvard.edu/abs/2007BAAS...39.1065C/abstract.

Chu J (2019) For the First Time, Astronomers Catch Asteroid in the Act of Changing Color. *MIT News*, 29 August. https://news.mit.edu/2019/asteroid-changing-color-first-0830.

Conway EM, Yeomans DK, Rosenburg M (2022) *A history of near-Earth objects research.* Washington DC: NASA SP-2022-4235.

Covey S (2012) 1990s: International Flair and Understanding the Solar System. NASA Kennedy Space Center. (accessed 20 December, 2021). Available at: https://www.nasa.gov/centers/kennedy/about/history/timeline/90s-decade.html.

Fast K (2021) NASA HQ Planetary Science Division view of ground-based facilities for small bodies science. NASA Presentation 31 March. Available at: Nationalacademies.org,

Hand E (2012) Astronomers catch video of near-miss asteroid. *Nature News*, 20 June. Available at: https://doi.org/10.1038/nature.2012.10873.

Heiney A (2012) 1980s: All eyes focus on Space Shuttle. Kennedy Space Center: Historical Timeline, June 29. (Accessed 20 December 2021) Available at: https://www.nasa.gov/centers/kennedy/about/history/timeline/80s-decade.html.

Kroese R (1979) Newest telescope in use in Big Isle. *Honolulu Advertiser*, 7 July, A-6. NASA Headquarters HQ Archives.

Kuiper GP (1961) Proposal to National Aeronautics and Space Administration for partial support of a 60-inch lunar and planetary telescope. 29 March. NASA HQ Archives.

Kuiper GP (1961a) Letter to Roger C. Moore concerning Kuiper's 29 March proposal to NASA "for partial support of a 60-inch lunar and planetary telescope." 9 June. Available at: NASA HQ Archives.

Livengood TA, Kostiuk T, Hewagama T, Smith RL, Fast KE, Annen JN, and Delgado JD (2020) Evidence for diurnally varying enrichment of heavy oxygen in Mars atmosphere. *Icarus* 335, 1 January, 113387, Elsevier: Science Direct. Available at: https://doi.org/10.1016/j.icarus.2019.113387.

NASA (1974) Infrared Telescope Facility sublease agreement between the University of Hawaii and the US government (NASA), signed November 29. Sublease provided to author by Alan Tokunaga.

NASA (1977) Management plan for the operation of the NASA Infrared Telescope Facility on Mauna Kea, Hawaii, appendix b. October, p. 7. NASA HQ Archives.

NASA (1990) Technical Memorandum 4205: Reports of Planetary Astronomy—1990. July, 151. NASA HQ Archives.

NASA (1995) Research in planetary astronomy and planetary atmospheres. 1995 NASA Research Announcement NRA95-OSS-05, OMB Approval No. 2700-0042.

NASA (1996) Research in planetary astronomy and planetary atmospheres. 1996 NASA Research Announcement NRA96-OSS-05, OMB Approval No. 2700-0087.

NASA (1997) Exploration of the solar system: research in planetary science. 1997 NASA Research Announcement NRA 97-OSS-04, OMB Approval no. 2700-0087. Available at: https://web.archive.org/web/20030703093913/http://research.hq.nasa.gov/code_s/nra/current/NRA-97-OSS-04/planet.pdf.

NASA (1998) A.3.2: Planetary Astronomy program. Research Opportunities in Space Science-1998 (ROSS-98). NRA 98-OSS-03, OMB Approval No. 2700-0087. Available at: https://web.archive.org/web/20030930180603/http://research.hq.nasa.gov/code_s/nra/current/NRA-98-OSS-03/A32.pdf.

NASA (1999) A.3.2: Planetary Astronomy program. Research Opportunities in Space Science-1999 (ROSS-99) NRA 99-OSS-01. Available at: https://web.archive.org/web/20030710160135/http://research.hq.nasa.gov/code_s/nra/current/NRA-99-OSS-01/A.3.2.htm.

NASA (2000) A.5.1: Planetary Astronomy program. Research Opportunities in Space Science-2000 (ROSS-00) NRA 00-OSS-01. Available at: https://web.archive.org/web/20030927112239/http://research.hq.nasa.gov/code_s/nra/current/NRA-00-OSS-01/A.5.1.html.

NASA (2001) A.5.1: Planetary Astronomy program. Research Opportunities in Space Science-2001 (ROSS-01) NRA 01-OSS-01. Available at: https://web.archive.org/web/20030910131754/http://research.hq.nasa.gov/code_s/nra/current/nra-01-oss-01/append5.html#A_5_1.

NASA (2002) A.5.1: Planetary Astronomy program. Research Opportunities in Space Science-2002 (ROSS-02) NRA 02-OSS-01. Available at: https://web.archive.org/web/20030910130754/http://research.hq.nasa.gov/code_s/nra/current/NRA-02-OSS-01/appendA2.html#A.2.7.

NASA (2003) A.2.7: Planetary Astronomy program. Research Opportunities in Space Science-2003 (ROSS-03) NRA 03-OSS-01, Available at: https://web.archive.org/web/20061012092253/http://research.hq.nasa.gov/code_s/nra/current/nra-03-oss-01/appendA2.html#A.2.7.

NASA (2004) B.7 Planetary Astronomy. Research Opportunities in Space Science-2004 (ROSS-2004) NRA Soliciting Basic Research Proposals. Available at: https://web.archive.org/web/20061007084106/http://research.hq.nasa.gov/code_s/nra/current/NNH04ZSS001N-PAST/index.html.

NASA (2005) B.8 Planetary Astronomy. Research Opportunities in Space and Earth Science-2005 (ROSES-2005), NSPIRES. Available at: https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=225/solicit ationId=%7BCA1A2C91-4339-9A34-1BDE-F118E7FC124F%7D/viewSolicitationDocument=1/ROSES_2005.pdf.

NASA (2006) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2006 (ROSES-2006), NSPIRES. Available at: https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=32176/solicitationId=%7B2C17F0F7-121E-6204-AC8D-C46B342C02BD%7D/viewSolicitationDocument=1/C.05_Planetary_Astronomy.pdf.

NASA (2007) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2007 (ROSES-2007), NSPIRES. Available at: https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=77552/solicitationId=%7B9F3968C5-CD1A-9263-05E3-F4CB26E43303%7D/viewSolicitationDocument=1/C.05%20Planetary%20Astronomy%20Program.pdf.

NASA (2008) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2008 (ROSES-2008), NSPIRES. Available at: https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=128954/solicitationId=%7BFBE07DDA-B0BD-1838-C649-E77B8C6B129E%7D/viewSolicitationDocument=1/C.5%20Planetary%20Astronomy.pdf.

NASA (2009) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2009 (ROSES-2009), NSPIRES. Available at: https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=176884/solicitationId=%7B40121960-DA38-AF7D-D9C4-5277F79549EE%7D/viewSolicitationDocument=1/C.5%20PAST.pdf.

NASA (2010) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2010 (ROSES-2010), NSPIRES. Available at: file:///C:/Users/student/Downloads/C+5+PAST+Amend+11.pdf.

NASA (2010a) Explanatory guide to the NASA Science Mission Directorate education & public outreach evaluation factors, Version 3.1. Available at: file:///C:/Users/student/Downloads/SMD_MissionGuideV3_1_508.pdf.

NASA (2011) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2011 (ROSES-2011), NSPIRES. Available at: file:///C:/Users/student/Downloads/C+5+PAST+corrected.pdf.

NASA (2012) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2012 (ROSES-2012), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.5+PAST+Final.pdf.

NASA (2013) C.5 Planetary Astronomy. Research Opportunities in Space and Earth Science-2013 (ROSES-2013), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.5+PAST%20(1).pdf

NASA (2014) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2014. (ROSES-2014), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO+clarified+022714%20(1).pdf.

NASA (2015) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2015 (ROSES-2015), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO.pdf.

NASA (2016) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2016 (ROSES-2016), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO%20(1).pdf.

NASA (2017) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2017 (ROSES-2017), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO%20(2).pdf.

NASA (2018) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2018 (ROSES-2018), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO+Lunar+notice.pdf

NASA (2019) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2019. (ROSES-2019), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO%20(5).pdf.

NASA (2020) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2020 (ROSES-2020), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO+NOT+clarified+June+22%20(1).pdf.

NASA (2021) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2021 (ROSES-2021), NSPIRES. Available at: file:///C:/Users/student/Downloads/C.6+SSO%20(4).pdf.

NASA (2022) C.6: Solar System Observations. Research Opportunities in Space and Earth Science-2022 (ROSES-2022), NSPIRES. Available at: https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=734149/solicitationId=%7B48600C7F-C3C8-D052-DD1D-C2AE0D27A9DF%7D/viewSolicitationDocument=1/C.6%20SSO%20NOT%20clarified%20June%2022.pdf.

NASA Daily Activity Report (1982) LH-14, “Planetary Astronomy,” May 11, 1982. NASA HQ Archives.

NASA History Division (2012) Celebrating NASA's fortieth anniversary 1958-1998: A Chronology of Defining Events in NASA History, 1958-1998. Accessed December 19, 2021. Available at: https://history.nasa.gov/40thann/define.htm.

NASA Historical Staff (1967) *Astronautics and Aeronautics, 1966*. Chronology of Science, Technology, and Policy, P-4007. Washington D.C.

NASA Historical Staff (1988) *Astronautics and Aeronautics, 1979-1984.* Chronology of Science, Technology, and Policy, P-4024. Washington D.C.

NASA Historical Staff (1990) *Astronautics and Aeronautics, 1985.* Chronology of Science, Technology, and Policy, P-4025. Washington D.C.

NASA Historical Staff (2000) *Astronautics and Aeronautics, 1991-1995, A Chronology*, SP-2000-4028. Washington D.C.

NASA HQ (1964) Draft: Planetary Astronomy. November 23, William Brunk Files, NASA HQ Archives.

NASA HQ (1967) Planetary Astronomy: university grants & contracts. William Brunk Files, NASA HQ Archives.

NASA HQ (1972) Attachment 196 to Planetary Exploration PAD. December, NASA HQ Brunk Files, NASA HQ Archives.

NASA HQ (nd) Planetary Astronomy: overview for FY 1982. NASA HQ Brunk Files, NASA HQ Archives.

NASA Infrared Telescope Facility (nd) About IRTF. Available at: http://irtfweb.ifa.hawaii.edu/information/about.php (accessed 22 July 2022).

NASA Infrared Telescope Facility (nd) IRTF's science highlights: major volcanic eruption on Io discovered at IRTF. IRTF's Gallery of Images, *Institute for Astronomy, University of Hawaii.* Available at: http://irtfweb.ifa.hawaii.edu/research/science/GalleryOfImages/Io.html.

NASA (nd) December 29, 1959 NASA Organizational Chart. NASA History Division. Available at: https://history.nasa.gov/orgcharts.html (accessed 22 July 2022).

NASA (nd) "Gerard Kuiper (1905-1973)". Available at: https://solarsystem.nasa.gov/people/720/gerard-kuiper-1905-1973/ (accessed December 1, 2021).

NASA (nd) January 16, 1961 NASA Organizational Chart. NASA History Division. Available at: https://history.nasa.gov/orgcharts.html (accessed 22 July 2022).

NASA (nd) Mars Exploration Program: Mars Pathfinder. Available at: https://mars.nasa.gov/mars-exploration/missions/pathfinder/ (accessed 20 December 2021).

NASA (nd) November 1, 1961 NASA Organizational Chart. NASA History Division. Available at: https://history.nasa.gov/orgcharts.html (accessed 20 December 2021).

NASA Solar System Exploration (nd) "Gerard Kuiper (1905-1973)". Available at: https://solarsystem.nasa.gov/people/720/gerard-kuiper-1905-1973/ (accessed December 1, 2021).

NASA News (1974) Release No. 74-23. Site chosen for large infrared telescope. Feb. 1. NASA HQ Archives.

NASA News (nd) Release No.: 79-66. Infrared telescope begins operations in Hawaii. NASA HQ Archives.

NASA News (nd) Release No.: 75-209. NASA Awards $5.5 Million Contract for Large Infrared Telescope." NASA HQ Archives.

NASA Office of the Administrator (1967) Memorandum for record. Subject: June 23 meeting of astronomers to discuss STAR proposal of the Ramsey Committee. Meeting between Dr. Newell, Dr. Naugle, Dr. Goldberg, Dr. Schwarzschild, and Mr. Close. June 27. NASA HQ Archives.

NASA Office of Space Science and Application (1986) Technical Memorandum 89189: Reports of Planetary Astronomy—1985. NASA Technical Reports Server: Washington D.C.

NASA Solar System Exploration Division (1989) *Other worlds from Earth: the future of planetary astronomy: a report of the Planetary Astronomy Committee of the Solar System Exploration Division*. Washington D.C.: NASA.

National Academy of Sciences National Research Council (1954) Ground-based astronomy a ten-year program. A report prepared by the panel on astronomical facilities for the committee on science and public policy of the National Academy of Sciences, pg.3. NASA HQ Archives.

National Archives (2016) Space exploration: timeline. Available at: https://www.archives.gov/research/alic/reference/space-timeline.html#time (accessed 21 December 2021).

Naugle JE (1966) Letter to Geoffrey Keller of the National Science Foundation discussing Dr. Roman's review of ground-based astronomy, May. Available at: NASA HQ Archives.

Near-Earth Object Science Definition Team (2003) Study to determine the feasibility of extending the search for near-Earth objects to smaller limiting diameters. 22 August, available at: https://www.nasa.gov/sites/default/files/atoms/files/pdco-neoreport030825.pdf (accessed 4 August 2022).

New York Times (1968) 3d largest telescope dedicated on foggy day in Texas. November 27, 10. NASA HQ Archives.

Newell H (1969) Memo to NASA Administrator Thomas Paine regarding NSF/NASA support to astronomy, 7 November. Available at: NASA HQ Archives.

Nixon R (1970) Statement by President Nixon on the space program March 7, 1970. In *Beyond the Atmosphere: Early Years of Space Science*, by Newell H. The NASA History Series, appendix J. Washington, DC: NASA History Office, 2004. Available at: https://history.nasa.gov/SP-4211/appen-j.htm.

Arizona Daily Star (1975) Kitt Peak finds crack in mirror: Hawaiian scope part cost $500,000. 13 September, Section B—pg. 1. NASA HQ Archives.

O'Donoghue J, Moore L, Bhakyapaibul T, Melin H, Stallard T, Connerney JEP, and Tao C. (2021) Global upper-atmospheric heating on Jupiter by the polar aurorae. *Nature* 596**,** 54–57. Available at: https://doi.org/10.1038/s41586-021-03706-w.

Phillips T (2009). What hit Jupiter? NASA Science. Available at: https://science.nasa.gov/science-news/science-at-nasa/2009/03aug_whathitjupiter/.

Pilcher C (1997) Obituary: Jurgen H. Rahe, 1937-1997. *Bulletin if the Astronomical Society* 29(4): 1482-1483. Available at: https://ui.adsabs.harvard.edu/abs/1997BAAS...29.1482P.

Roman NG (1961) Subject: research proposal #BG-2053 from the University of Arizona. Memorandum for Mr. Roger Moore, Planetary Sciences. May 3. NASA HQ Archives.

Roman NG (1980) Interviewed by David DeVorkin, Neils Bohr Library and Archives Oral Histories. American Institute of Physics, College Park, MD USA, 19 August. Available at: www.aip.org/history-programs/niels-bohr-library/oral-histories/4846.

Roman NG (2019) Autobiography: Nancy Grace Roman and the dawn of space astronomy. *Annual Review of Astronomy and Astrophysics*, 57:1-34. Available at: https://doi.org/10.1146/annurev-astro-091918-104446.

Sawyer K (1992) Planet-like object seen beyond Pluto may provide clues to origin of comets. *The Washington Post*, 16 September, p. A9, NASA HQ Archives.

Schorn RA (1998) *Planetary Astronomy: From Ancient Times to the Third Millennium*. Texas A&M University Press: College Station.

Sullivan W (1982) Budget squeeze may halt use of Hawaii telescope. *New York Times*, Mar. 14. NASA HQ Archives.

NASA Infrared Telescope Facility (nd) IRTF's science highlights: major volcanic eruption on Io discovered at IRTF. IRTF's Gallery of Images, *Institute for Astronomy, University of Hawaii.* Available at: http://irtfweb.ifa.hawaii.edu/research/science/GalleryOfImages/Io.html.

The University of Arizona (nd) A brief history of LPL. Available at: https://www.lpl.arizona.edu/about/history/overview (accessed 1 December 2021).

The University of Texas at Austin McDonald Observatory (nd) 2.7 M (107") Harlan J. Smith Telescope. Available at: https://mcdonald.utexas.edu/for-researchers/research-facilities/2-7-m-107-harlan-j-smith-telescope (accessed 1 December, 2021).

Tatarewicz JN (1985) 'A strange plea'—the campaign for planetary astronomy in support of solar system exploration, 1959-1962. NASM Research Report, pp. 91-109. NASA HQ Archives.

Tokunaga AT, Golisch WF, Griep DM, Kaminski CD, and Hanner MS (1988). NASA Infrared Telescope Facility Comet Halley monitoring program II postperihelion results. United States. Available at: https://doi.org/10.1086/114945.

University of Hawaii Institute for Astronomy (nd) Eric Becklin—Infrared trailblazer. Available at: https://about.ifa.hawaii.edu/history/eric-becklin-infrared-trailblazer/ (accessed 2 December 2021).

US House of Representatives (1982) Joint explanatory statement of the committee of conference. In 97th Congress 2d session, conference report No. 97-897, making appropriations for the National Aeronautics and Space Administration, September 29, 1983, p.53. In NASA Chronological History, Fiscal Year 1983. Available at: https://www.nasa.gov/sites/default/files/atoms/files/o45128943_1983.pdf.

W.M. Keck Observatory (2009) Discovery of methane reveals Mars is not a dead planet. Available at: https://keckobservatory.org/discovery_of_methane_reveals_mars_is_not_a_dead_planet/.