A diversity, equity, and inclusion prospectus on a GNSS-embedded Artemis base camp: An empirical study

Ronald H. Freeman, PhD
Editor-in-Chief, Journal of Space Operations & Communicator
ronaldhoracefreeman@gmail.com

Introduction

Artemis missions, including activities at the Artemis Base Camp, will require robotic landers on the lunar surface prior to a human mission to the South Polar Region in 2024. By requiring accurate spacecraft position and velocity, ground operations teams compute position and velocity using ranging with telemetry, tracking and control (TT&C). The use of a GNSS spaceborne receivers capable of processing Earth GNSS signals and determination of position, velocity and time to satellite avionics systems enable the success for moon missions [1]. Both major space institutions and private entities across the globe will provide [2]:

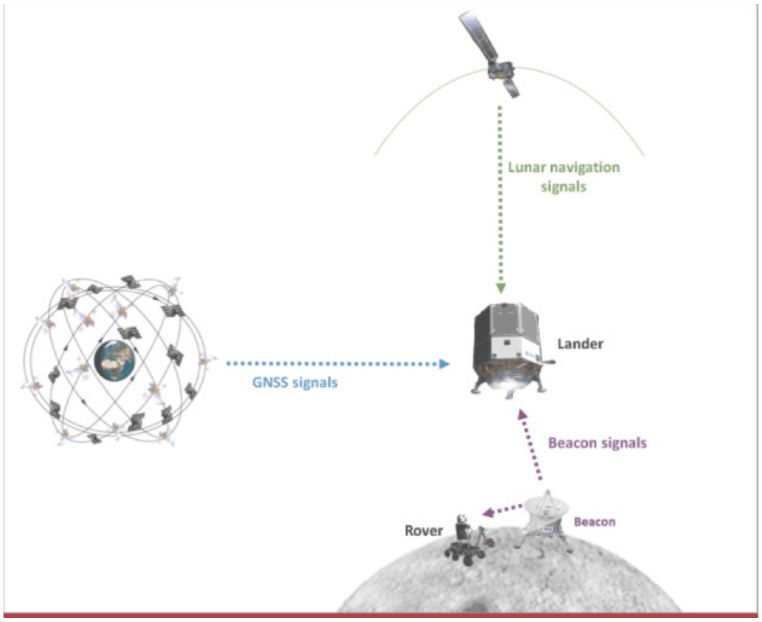
- The Artemis lunar spacecraft consisting of NASA's Orion crew module and the European Service Module.
- The space Gateway structure, to be launched by the partners of the International Space Station for assembly and operation in the vicinity of the moon, where it will move between different orbits.
- Both the European Large Logistic Lander (EL3) and NASA's Commercial Lunar Payload Services (CLPS) for cargo delivery of a radio telescope on the far side of the moon or a pilot plant for the production of oxygen from lunar regolith (the layer of unconsolidated rocky material covering bedrock) to lunar base camps.
- The Indian Lunar Exploration Programme and the Chinese Lunar Exploration Program that will provide lunar orbiters, impactors, soft landers and rover spacecraft.

Furthermore, on-board sensor redundancy will enable access to a dedicated navigation infrastructure of a joint dedicated Lunar Communication and Navigation System (LCNS) to support lunar in-situ resource utilization. The availability of GNSS-like services for an Artemis base camp will

- enable autonomous navigation, including more efficient and effective manouvers;
- reduce tracking and operational cost;
- provide back-up/redundant navigation for human safety;
- provide timing source for hosted payloads.

The Lunar GNSS project [3] went far beyond GEO, analyzing the feasibility and performance of a navigation solution based on GPS and Galileo for missions to the Moon (up to the descent and landing and surface operation phases). Its main objective was to investigate the use of weak GNSS signals for real-time position, navigation and timing (PNT) critical to such lunar assets including automated landers, rovers, orbiters, Earth-Moon transportation vehicles, and other in-situ navigation equipment[4]. Multiple studies were performed to assess GNSS signals for Earth-to-moon transfer orbits and lunar orbits. A satellite in an Earth to moon transit receiving GNSS signals mostly from side-lobes would be similar to that of NASA using GPS for the Lunar Gateway station. LCNS services (2025-2035) would enhance the transmission of additional ranging signals from moon orbit and from the moon surface, resulting in a lowered geometric dilution of precision but higher in-service availability. Alternatively, the present CubeSat constellation could be aimed for the positioning of landers and rovers on the far side of the Moon, as well as orbit determination of low-lunar-orbit (LLO) satellites. It is assumed that LLO satellites have GNSS-like receivers, and the orbit determination of an LLO satellite is based on the ranging and Doppler measurements with the CubeSat constellation [5].

Development of a Multi-spacecraft Autonomous Positioning System (MAPS) of beacons both in an orbital environment and fixed to the lunar surface will support precision surface navigation of local autonomous rovers [6]. Since frequencies on the order of several kilohertz have wavelengths long enough to maintain positive contact between visually disconnected beacons, the reception range subsequently becomes hundreds of kilometers, going well past the limits of the lunar horizon. During surface operations, different sorties may not be within line of sight of each other. Or, a sortie exploring the inside of a deep lava tube may have no guarantee of a MAPS satellite flying overhead, leading to little chance of maintaining contact with company assets. The solution is to set up a low frequency beacon infrastructure to ensure positive contact during non-line of sight (NLOS) situations. Low frequency beacons would complement higher frequency ones to provide a "lower-resolution" albeit efficient option for extensive surface operations [7].



Purpose
The purpose of this study was to retrospectively examine 1. if diversity in STEM workforce correlated to pivotal timeline milestones of GNSS development; and, 2. how STEM workforce diversity related to niche artifact designs progression to dominant artifact designs.

GNSS technology has an artifactual nature. The duality between (1) *technology as artifact* (e.g. a bundle of physical and/or conceptual features), juxtaposes (2) *technology-in-use*, (e.g. the patterned interactions of human agents with a particular technological artifact). Novel GPS/ GNSS technology artifacts, culminated over a 60-year timeline of development to include sensors, receivers, and transmitters, originate from concepts imagined through artifact designs. Their anthropocentric roots suggest critical review of relational diversity, equity, and inclusion (DEI) factors.

Method
This study referenced a historical timeline of developmental milestones in GNSS technology as stated in the United Nations Office of Outer Space Affairs publication wherein the International Committee on Global National Satellite Systems reported on "GNSS History". Selected technological time points of GPS/ GNSS development were referenced for comparative timepoints showing NASA demographic workforce statistics. A literature review of GNSS technology was chronicled to comprehensively represent innovations as well as technological gaps, referred to as technological transitions. NASA workforce statistics were then compositionally evaluated to discern demographic shifts to examine possible correlations with technological transitions.

Results and Discussion
The conceptual GPS niche in aerospace technology created in 1957 suggested social construction of their initial meanings and features. Accordingly, the ground-breaking contributions of certain African-American individuals were generally remembered 50 years later. Gladys West, who in 1956 was the second black woman ever hired and one of only four black employees hired at Naval Surface Warfare Center, worked in the development of computational techniques necessary for GPS precision. And, Harvey W. Banks, who in 1961 became the first Black American scientist to earn a doctorate in astronomy, pioneered in GPS technology, based on much of his dissertational work in geodesy. Other pioneer designers of GPS technology during the 1960s included Roger L. Easton of the Naval Research Lab, and Ivan A. Getting at Raytheon. Easton designed Mini track, a system for following different kinds of Earth-orbiting satellites with on-board clocks called Timation for Tme Navigation. And,

Getting, while at Raytheon (1951-60), oversaw the development of the first three-dimensional, time-difference-of-arrival position-finding system. An early designer and proponent of satellite-based navigation systems, Getting's work led to the development and deployment of the Global Positioning System (GPS).

The Navy Navigation Satellite System (NNSS), also known as the Transit system, was an invention that evolved from an Applied Physics Laboratory (APL) team discovering that the Doppler shift on the signal broadcast from the Soviet Sputnik satellite in 1957 could be used to predict when the satellite would be in view from APL. Precision navigation for the Navy's strategic system submarines began in 1958, and the system became operational in 1964. In 1967, the Transit system was released to industry and became available to civilian ships of all nations [8].

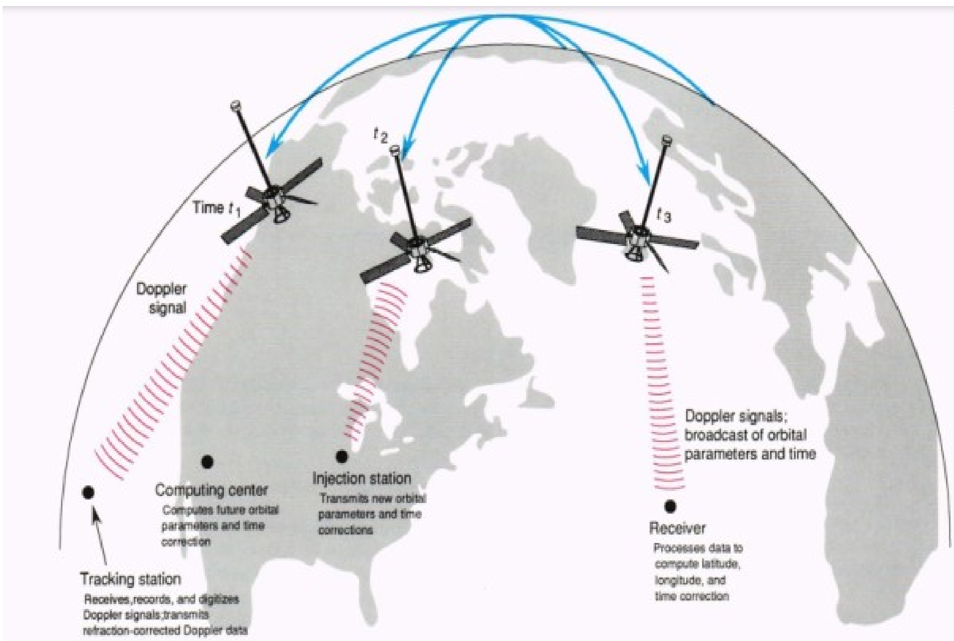


Figure. The Transit concept in the early 1960s.

Using dozens of Transit fixes to provide sub-meter accuracy, surveyors were able to locate remote benchmarks. Integrating this idea with a number of other classified engineering design studies from the 1960s, the Global Positioning System (GPS) project was developed in 1973. It was created by the U.S. Department of Defense. The experimental Block-I GPS satellite was first launched in 1978, but in order to validate the concept, ten more experimental satellites were launched by 1985. The Timation satellites were conceived, developed, and launched by the United States Naval Research Laboratory beginning in 1964. The concept of Timation was to broadcast an accurate time reference for use as a ranging signal to receivers on the ground. On 31 May 1967, the Timation-1 satellite was launched. This was followed by the Timation-2 satellite launch in 1969. The results of this program and Air Force Project 621B formed the basis for the Global Positioning System (GPS). Bradford Parkinson assigned to US Air Force's 621 B Project during 1970s developed new satellite-based navigation system which included Atomic clocks intended for high orbits. [9].

In the niche-analytic level (MLP), relevant experimental and demonstration projects allowed niche engineers to learn about innovation in real-world circumstances. Such was the case with the experimental development of Transit and Timation Receiver whereby GPS Block I satellites of the 1970s and 1980s would be operational. In the socio-technical regime-level (MLP), an important factor was the alignment of existing technologies, policies, regulations and infrastructure. Novelties competed with technologies that benefited from these developed systems. The final analytical level, the socio-technical landscape (MLP), was the wider context that influenced both niche and regime dynamics [10].

Integrating designs from multiple GPS niche pioneers during the 1960s, the GPS project was developed in 1973. To explain the analytical framework in developing GPS, a multi-level perspective (MLP) of three-level realignment—

the niche, the regime, and the landscape— scheme described the socio-technical transition [11]. Although technology innovations emerged from a GPS niche, the niche did show diversity and inclusion.

1957	1960	1964	1968
Sputnik I Launched By monitoring Sputnik-1 radio transmissions, within hours realized that, the Doppler effect could pinpoint where the satellite was along its orbit.	First Successful TRANSIT Experimental GPS Satellite (1B) were concept validation satellites and reflected various stages of system development, used in Block II	Transit Became Operational	World's First Portable Satellite Doppler Geodetic Surveyor AN/PRR-14 Geoceiver, operates from a variety of power sources including portable gasoline generators weighing less than 100 Ibs. The receiver automatically searches in frequency for satellite signals and, when locked on, initiates measurements and ~unches the teletype tape containing the observations.
NASA Black Workforce	.Not Available	Not Available	Not Available
NASA Black/Hispanic/Asian Workforce	Not Available	Not Available	Not Available

NASA workforce demographic statistics during 1960s was not available. However, during the same time period, "Hidden Figures" of Apollo 11 in 1969 contributed to NASA successful first lunar landing and return mission. Katherine G. Johnson in 1953 joined the all-woman NASA pool of women performing data reduction calculations, known as "computers." Her greatest contribution to space exploration, she stated, was the calculations that helped synchronize Project Apollo's Lunar Lander with the moon-orbiting Command and Service Module.

1971	1975	1978
First Timation Receiver for the Naval Research Lab (NRL)	First Concept Validation GPS Navigator, the GPS X-Set	The first experimental Block-I GPS satellite was launched in February 1978.
NASA Black Workforce— 3.1%	4.6%	5.8%
NASA Total- B/H/A 3.1%/ 0.7% / 0.7% Workforce—4.6%	Science & Eng. –4.4% 4.6%/ 1.2%/ 0.8%	5.7% 5.8%/ 1.7% /1.2%

Subsequent to the technological transition of three-dimensional, time-difference-of-arrival position-finding system, came the socio-technical transition of increased minority STEM workforce engagement---diversity and inclusion. Due to an improved reporting system in the 1970s (particularly since 1972), NASA workforce statistics of minorities and women became available. Between 1972 and 1978, the total number of minority employees increased from 1,290 (4.7 percent of NASA's total permanent in-house work force) to 2,061 (8.9 percent of the total). Growth in minority employment at NASA was spread uniformly over every minority category--Black, Hispanic, Asian (B/H/A), and American Indian. The most significant growth occurred among employees in the professional administrative branch of NASA, where the minority share rose from 3.0 percent in 1972 to 9.8 percent in 1978. Although the overall permanent NASA work force shrank considerably between 1972 and 1978, the percentage of minorities among technical support and clerical personnel doubled, and increased from 3.4 percent to 5.7 percent among scientists and engineers [12].

DEI enhances creativity and impact of scientific investigation [13]. With a growing DEI sector of the aerospace community, efforts were needed not just to diversify membership and leadership, but to identify and mitigate racism and unconscious bias within [14]. Minorities, women, persons with disabilities, and other underrepresented groups had been identified as a rich, yet underutilized source of STEM workforce capacity, leading to questions of broader inclusion and concerns about increasing participation. The science of broadening participation (SoBP) was necessary to inform a comprehensive understanding of what the pertinent issues were, why they occurred, and how various organizations created pathways toward more DEI entities. The interactive and affective roles enacted in DEI impacted the socio-technical processes of strategic leadership [15].

The Multi-Level Perspective (MLP) evaluates descriptively a framework of the socio-technical processes for which minorities increasingly became part of. To explain socio-technical transitions progressing towards technology sustainability, technology transitions occurred whenever innovation enacted a change by way of realigning the levels—the niche, the regime, and the landscape-- from the niche level innovation. The socio-technical regime-level consisted of engineers and their activities that maintained socio-technical system (STS) linkages. The socio-technical landscape consisted of elements such as cultural values or material arrangements [16].Therefore, the DEI-embedded (SoBP) additionally impacted the emergent processes of dominant designs, mostly at the regime level.

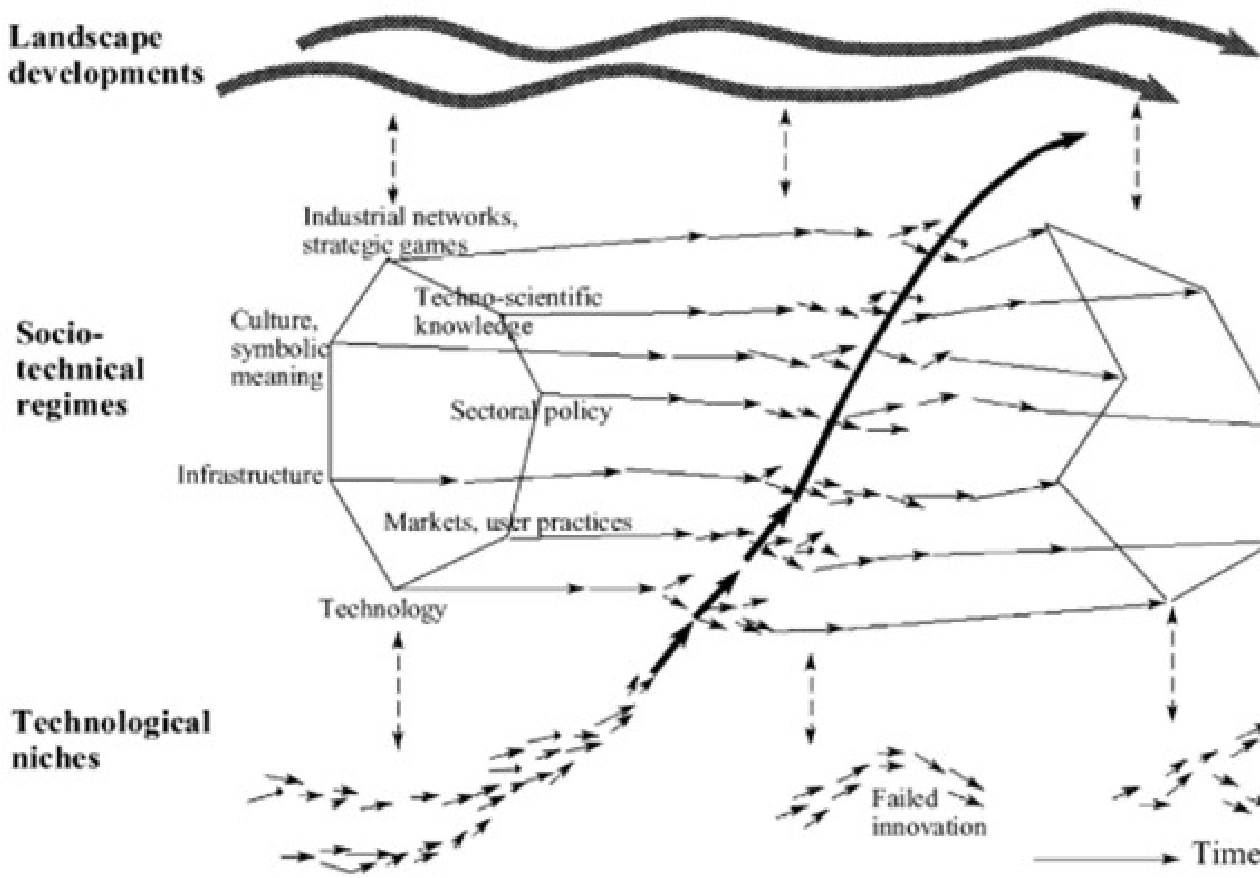


Figure. The Three Analytical Levels of MLP (Geel, 2002)

MLP framed the development of a dominant design at three analytical levels resulting in transitions. Once the material aspects of a technology were stabilized, managers and users of the socio-technical regime level often institutionalized interpretations and routinized uses of the technology [17]. The regime, composed of practices, technology rules, and institutions that guide and justify the way technology is produced [18], constituted groups of infrastructures that enabled innovation [19]. It is inside the regime that innovation can be exerted and stabilized [20].

The first experimental Block-I GPS satellite was launched in February 1978. In 1983, after Soviet interceptor aircraft shot down the civilian airliner KAL 007 in restricted Soviet airspace, killing all 269 people on board, U.S. President Ronald Reagan announced that the GPS system would be made available for civilian uses once it was completed. By 1985, ten more experimental Block-I satellites were launched to validate the concept. On February 14, 1989, the first modern Block-II satellite was launched. The oldest GPS satellite still in operation was launched in

August 1991. By December 1993 the GPS system achieved initial operational capability, and a complete constellation of 24 satellites was in orbit by January 17, 1994.

1984	1993	1996	2001
World Geodetic System Allows position fix to be placed on a world grid. Maps can be referenced to the same grid.	GPS Block II system achieved initial operational capability and a complete constellation of 24 satellites was in orbit	In 1996, recognizing the importance of GPS to civilian users as well as military users, U.S. President Bill Clinton issued a policy directive declaring GPS to be a dual-use system and establishing an Interagency GPS Executive Board to manage it as a national asset. Additionally. he directed DoD to turn off GPS Selective Availability feature.	"Selective availability" discontinued allowing users outside the US military to receive a full quality signal on May 2, 2000.
NASA Black Workforce --Not Available	NASA Black Workforce --Not Available	10.5% (vs All NASA Workforce, n=21,700)	10.7 (n=19,283)
NASA B/H/A Workforce --Not Available	NASA B/H/A Workforce NASA AST Engineers B/H/A --Not Available	10.5%/ 5.4%/ 4.3% 5.4%/ 4.4%/ 5.9%	10.7%/ 4.7%/ 5.4% 6.0%/ 4.7%/ 7.1%

During the 1990s, civil GPS readings could be incorrect by as much as a football field (100 meters). However, with rapid development of receiver technology, error reading decreased to about 20 meters, enough to pose a national threat. On the day selective availability (SA) features were deactivated, civil GPS accuracy improved tenfold, unleashing a worldwide revolution in civil and commercial applications. In 2007, the government announced that GPS III would be built without the SA feature. Like the Internet, GPS became an essential element of the global information infrastructure. The GPS.gov website was established in 2006, describing a tiny sample of existing GPS applications. New uses of GPS were invented every day, thus affording an ongoing functioning MLP's niche level. GPS modernization involved a series of consecutive satellite acquisitions, including GPS Block IIR-M, GPS Block IIF, GPS III, and GPS III Follow-On. Currently, GPS is operated and maintained by the US Space Force. GPS.gov is maintained by the National Coordination Office for Space-based Positioning, Navigation, and Timing.

"GPS almanacs". Navcen.uscg.gov. Archived from the original on September 23, 2010.

Block	Launch period	Satellite launches				Currently in orbit and healthy
		Suc-cess	Fail-ure	In prep-aration	Plan-ned	
I	1978–1985	10	1	0	0	0
II	1989–1990	9	0	0	0	0
IIA	1990–1997	19	0	0	0	0
IIR	1997–2004	12	1	0	0	7
IIR-M	2005–2009	8	0	0	0	7
IIF	2010–2016	12	0	0	0	12
IIIA	2018–	5	0	5	0	5
IIIF	—	0	0	0	22	0
Total		75	2	5	22	31

(Last update: 08 July 2021)

USA-203 from Block IIR-M is unhealthy

[51] For a more complete list, see List of GPS satellites

All NASA Employees by Race, Ethnicity, and Gender: FY 96 to FY 16 (including comparison data)

	AAPI	Black	Hispanic	More than One Race	AIAN	White	Male	Female
FY 96 (n=21,700)	4.5%	10.5%	4.3%	0.0%	0.8%	79.9%	67.1%	32.9%
FY 01 (n=19,283)	5.4%	10.7%	4.7%	0.0%	0.9%	78.3%	65.9%	34.1%
FY 06 (n=18,732)	6.2%	11.5%	5.8%	0.2%	1.1%	75.2%	64.8%	35.2%
FY 11 (n=18,916)	6.8%	11.6%	6.5%	0.2%	1.1%	73.8%	64.8%	35.2%
FY 16 (n=17,504)	7.4%	11.7%	7.5%	0.3%	1.1%	72.0%	65.5%	34.5%
Federal STEM Workforce	10.0%	9.4%	5.5%	1.4%	0.9%	72.8%	74.1%	25.9%
U.S. Population, 18+	4.9%	11.7%	14.2%	1.2%	0.7%	67.1%	48.5%	51.5%
U.S. Population	4.7%	12.3%	16.3%	1.8%	0.7%	63.9%	49.2%	50.8%

Sources: WICN (data as of 10/1/2016); U.S. Office of Personnel Management, FedScope, Federal Human Resources Data, Diversity Cube, data as of March 2016 <https://www.fedscope.opm.gov>; U.S. Census Bureau, Population Division, Annual Estimates of the Resident Population by Sex, Age, Race, and Hispanic Origin, June 2016, <http://www.census.gov/popest/data/national/asrh/2015/index.html>.

The United States' Global Positioning System reached full operational capability on 17 July 1995, completing its original design goals. Group III GPS satellites were not launched until 2018. A new military signal called M-code was designed for Group III GPS satellites to further improve the anti-jamming and secure access of the military GPS signals. The M-code is intended to be broadcast from a high-gain directional antenna, in addition to a wide angle (full Earth) antenna [21].

AST Promotions		White	Black	Hispanic	AAPI
GS 13	Pool (n=319)	69%	9%	10%	12%
	Promoted (n=167)	68%	8%	11%	13%
GS 14	Pool (n=2,927)	73%	8%	8%	10%
	Promoted (n=308)	80%	3%	10%	6%
GS 15	Pool (n=3,167)	79%	6%	6%	8%
	Promoted (n=209)	80%	9%	6%	4%

FY2016 Internal Promotions

In contrast to the total NASA workforce decreasing, NASA's minority workforce rates remained the same with one exception. The Asian minority saw a significant 1.1 percent increase in NASA workforce statistics between 1996 and 2001; growth in Asian workforce demographic continued unabated. Although successful from STS networks of artifacts, scientists, engineers, and institutions, MLP's regime level gained stability and path-dependence from standard operating procedures. Other important factors for the innovation included search routines, knowledge capabilities [22]. STS sustainability required not so much a substitution of old technologies by new ones, but shifts in work patterns, user preferences, regulations, and artifacts [23]. Any change affecting workforce composition causes pressure on socio-technical niches and regimes. And, this is how room and opportunity for niches feed on each other [24]. For FY 2016, the promotional pools for all workforce demographics showed increases. Yet, the higher the grade level promotion pools, the more DEI modifications in actual promotions seemed disproportionate. Whereas coupling of niche and regime levels provided the platform for developing standard operating procedures for the innovations they matured, the landscape level elevated the platform into a property space for developing institutions, socio-economic and legal structures and (incumbent) stakeholder constellations. It was the level, where economic, political and social factors, routines, and institutions played a core role and where the dominant economic and governmental actors located. In other words, niche innovations and those linked to the regime applied pressure and dislocated the landscape level over time which may explain for pool vs actual promotional disparities [25].

Social knowledge and social network density are independent predictors of innovation involvement within an organization. Microprocesses in the social networks of those involved in organizational innovation and their strategic connecting people in their social networks, either introduce disconnected individuals or facilitate new coordination between connected individuals [26]. Such approaches explain pool vs. actual promotion disparities. Social knowledge interweaves in dense networks as innovation efforts unfold. Social organization built around competition resulting in promotions gains from a disconnected workforce or a promotion pool to generate a social momentum that creates new ties or solidify old ones [27].

Promotion to Grade	AAPI		Black		Hispanic	
	Pool	*Promoted*	*Pool*	*Promoted*	*Pool*	*Promoted*
FY 2017						
GS-14 (n=157)	10%	9%	8%	9%	9%	11%
GS-15 (n=110)	8%	12%	5%	12%	7%	5%
SES (n=18)	8%	11%	5%	11%	5%	11%
FY 2016						
GS-14 (n=226)	10%	8%	8%	4%	8%	10%
GS-15 (n=141)	8%	3%	6%	10%	7%	6%
SES (n=28)	8%	7%	5%	4%	5%	4%

Internal Competitive Promotions in S&E Positions,

NASA Role in GNSS Technology.

NASA minority workforce statistics between 2016 and 2020 appear stabilized. However, NASA's GPS equities are managed and protected through policy development and advocacy by Space Communications and Navigation (SCaN) Program Office at NASA. Traditionally, space missions have determined their orbit by using communications channel tracking, in which a Flight Dynamics Facility uses positioning information from two-way communication signals between the spacecraft and a ground station or relay satellite to calculate the spacecraft's orbit. Alternatively, missions that choose to use GPS to determine their position, track radio-navigation signals from GPS satellites, which are then processed on-board to determine position and time. This increases spacecraft autonomy and reduces the burden on NASA's tracking stations. The 2004 U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy tasked the NASA Administrator to develop and provide requirements for the use of GPS and its augmentation to support civil space systems. The first African-American NASA Administrator, Bolden, former astronaut, worked with U.S. Air Force leadership to approve Laser Reflector Arrays (LRAs) onboard GPS III [28]. To formally stabilize GPS signals for high altitude space users, NASA worked with U.S. Air Force to create a new Space Service Volume (SSV) definition and specifications. While GPS signals are beamed directly at the earth, some radio signals escape into space and spill over the main beam and any side lobes, a frontier technology in development. Were a Magnetospheric Multi-Scale receiver used on a lunar mission with 14dBi high-gain antenna, visibility may average greater than 30 dB-Hz from side lobes [29].

2016	2018	2019	2020
Two Prometheus Block 2 nanosatellites included a GPS receiver module to enable improved instantaneous orbit knowledge and independent calculation of orbit ephemeris.	One GPS Block III satellite launched	Two GPS Block III satellites launched	The estimate exploiting in-space measurements from a CubeSat is an innovative technology to be explored. Bobcat-1 CubeSat is a "stepping-stone" to a Master clock in space.
NASA Black Workforce- 11.7	11.6%	11.5%	11.1%
NASA B/H/A 11.7/ 7.5/7.4	NASA-B/H/A Workforce— 11.6%/ 7.5%/ 7.6% Science & Engineering 6.2%/ 7.2%/ 9.0%	11.5%/ 7.9%/ 7.9% Science & Engineering 6.2%/ 7.6%/ 9.2%	Not Available Science & Engineering 6.2%/ 8.0%/ 9.7%

NASA in partnership with the Italian Space Agency, starting in 2023, intend to land the Lunar GNSS Receiver Experiment (LuGRE) on the Moon's Mare Crisium basin. There, LuGRE is expected to obtain the first GNSS fix on the lunar surface. Additionally,NASA awarded a contract to Firefly Aerospace to deliver a suite of 10 science investigations and technology demonstrations aboard a Blue Ghost lander to the Moon in 2023. The mission, destined for Mare Crisium, a low-lying basin on the Moon's near side, will investigate a variety of lunar surface conditions and resources. LuGRE will receive signals from both GPS and Galileo. The data gathered will be used to develop operational lunar GNSS systems in preparation for human missions to the lunar surface.

2022 LunaNet Artemis Program includes lunar communications and navigation architecture that to bring PNT and science services to the Moon.	2022 Luna-Polar Hydrogen Mapper To launch with Artemis I.	2022? CAPSTONE (Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment)	2023 LuGRE (Lunar GNSS Receiver Experiment)
	12-unit cubesat	12-unit cubesat	
A constellation of CubeSats in Low Lunar Orbit (LLO), 100 km, could form an optical communications and navigation network and data transmission between nodes in a single link or over a multi-node, and end-to-end paths, with terminals on the lunar surface, including mobile ones such as with astronauts and rovers.	To reveal hydrogen abundances at spatial scales below 10 km in order to understand the relationship between hydrogen and permanently shadowed regions, particularly craters, at the Moon's South Pole.	CAPSTONE will (1) test a unique lunar orbit intended for Gateway, the Moon-orbiting outpost for NASA's Artemis program. AND (2) demonstrate the ability of its entry into orbit and maintain special lunar orbit for approximately six months	The payload will receive signals from both GPS and Galileo and is expected to obtain the first-ever GNSS data to develop operational lunar GNSS systems in preparation for human missions to the lunar surface.

Space systems should be prepared to tolerate loss or interference with GNSS signals [30]. Sub-system manufacturers have developed GNSS receiver systems for satellites that enable navigation information and positioning activities on a cubesat. There are various structural differences between terrestrial and space-based GNSS equipment to operate effectively in space. Components may need to be adapted to meet the huge thermal and mechanical stresses of launch, radiation-hardened, and made suitable for operating in a vacuum. CubeSat GPS antennas and GNSS antennas play an important role in the acquisition and translation of the GNSS signal originating at one or more of the existing networks.

NASA organizes multiple cubesat missions as part of the Artemis Program to prepare a human presence on the moon. The multiple cubesat studies and designs relating to Artemis Program suggest a socio-technological paradigm shift to lunar-based GNSS architectural technology. Therefore, the resultant MLP-2 suggests a current niche level for lunar cubesat designs yet to progress to a regime level analogous to Group I and II GPS satellites. The discernment of the DEI prospectus will have to wait for future NASA minority workforce statistics.

Conclusion

Since 2004, NASA role in GNSS technology appears collaborative with US Air Force and other federal agencies. The institutionalization and regulatory activities imposed on GNSS progressive lifecycle of innovation additionally suggest MLP's landscape level. The background of socio-technical transitions is in the sociology of technology, institutional theory, evolutionary economics, niche management, and technological transitions. This study reviewed minority representation of GNSS technology progressing through multi-level hierarchy of niche-, regime-, and landscape- levels of its innovation maturation process. NASA minority workforce statistics was used as a barometer of the GNSS industry sentiment toward diversity actualized through interagency regimes and multiple agency-operations. Although the pinnacle of minority representation at the landscape level included the well-recognized NASA Administrator Bolden, identification of early niche-level minority representation was delayed by 50 years. Intervening between those two, the regime level was organized into routines and policies for an increased minority workforce effort. As the niche level progressed to the routinization of GNSS technology, the MLP's regime level showed grade-level promotions characterized in strategic coordination of social ties. The science of broadening participation (SoBP) is necessary to inform a comprehensive understanding of what the pertinent issues are, why they occur, and how various organizations create pathways toward more DEI entities. The interactive and affective roles enacted in DEI impact the socio-technical processes of strategic leadership [31].When organizational leadership senses a technology transition, vulnerabilities surface. And, leadership at the landscape level defensively jockey to acquire allies for increased support. Selective promotions may serve that purpose.

Global Navigation Satellite System (GNSS) and the USA-specific GPS work together, but the main difference is that GNSS-compatible equipment uses navigational satellites from other networks beyond the GPS system. The more satellites mean, increased receiver accuracy and reliability. Similar to the Earth-directed GPS infrastructure, Artemis base camp will require Moon-directed GPSS infrastructure. Developing receiver technology for a miniaturized satellite to communicate with lunar-surface rovers and facilities constitute an additional MLP-specific innovation cycle. The real prospectus asks how DEI will be characterized post-GNSS technology transition.

References

[1] Schönfeldt, M., Grenier, A., Delépaut, A., Giordano, P., Swinden, R., & Ventura-Traveset, J. (2020). Across the Lunar Landscape: Towards a Dedicated Lunar PNT System. *Inside GNSS).*

[2] Schönfeldt, M., Grenier, A., Delépaut,A., Swinden, R., Giordano, P., & Ventura-Traveset, J. (October 2, 2020). Across the lunar landscape – Exploration with GNSS technology. *Inside GNSS.*

[3] Silva, P., Lopes, H., Peres, T., Silva, J., Ospina, J., Cichocki, F., ... & Perello, J. (2013, September). Weak GNSS signal navigation to the moon. In *Proceedings of the 26th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2013)* (pp. 3357-3367).

[4]. Calmettes, T., Lopes, H. D., Silva, J. S., Silva, P. F., Musumeci, L., Dovis, F., Serant, D., ... & Perello, J. V. (2014, September). GNSS-based navigation for lunar missions. In *Proceedings of the 27th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2014)* (pp. 1536-1553).

[5] Chen, H., Liu, J., Long, L., Xu, Z., Meng, Y., & Zhang, H. (2019). Lunar far side positioning enabled by a CubeSat system deployed in an Earth-Moon halo orbit. *Advances in Space Research*, *64*(1), 28-41.

[6] Stone, J., LeMaster, E., Powell, J., & Rock, S. (1999, January). GPS pseudolite transceivers and their applications. In *Proceedings of the 1999 National Technical Meeting of The Institute of Navigation* (pp. 415-424).].

[7] Anzalone, E., Iyer, A., & Statham, T. (2020, March). Use of Navigation Beacons to Support Lunar Vehicle Operations. In *2020 IEEE Aerospace Conference* (pp. 1-13).

[8] Black, H. (1990). Early development of transit, the navy navigation satellite system. *Journal of Guidance, Control, and Dynamics*, *13*(4), 577-585.

[9] Beard;R. Murray, J & White, J. (1986). *GPS Clock Technology and the Navy PTTI programs at the U.S. Naval Research Laboratory,.p.39-40.*

[10] Burgelman, R., Floyd, S., Laamanen, T., Mantere, S., Vaara, E., & Whittington, R. (2018). Strategy processes and practices: Dialogues and intersections. Strategic Management Journal, 39(3), 531-558.].

[11] Geels, F. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environ. Innov. Soc. Transit., 1*, 24–40.

[12] Retrieved from www.history.nasa.gov.

[13] AlShebli, B, Rahwan T, & Woon W. (2018). The preeminence of ethnic diversity in scientific collaboration. *Nat Commun*. *9*(1), 5163.

[14]Nielsen, M., et al. (2017) Opinion: Gender diversity leads to better science. *Proc Natl Acad Sci USA*., *114*(8),1740–1742.

[15] McNeely, C. & Fealing, K. (2018). *Moving the needle, raising consciousness: The science and practice of broadening participation.*

[16] Geels, F. (2006). Major system change through stepwise reconfiguration: a multi-level analysis of the transformation of American factory production (1850–1930). *Technology in Society*, *28*(4), 445-476.

[17] Geels, F. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), 1257-1274.

[18] Roep, D., Van der Ploeg, J., & Wiskerke, J. (2003). Managing technical-institutional design processes: Some strategic lessons from environmental co-operatives in the Netherlands. *NJAS—Wagening. J. Life Sci., 51*, 195–217.

[19] Bolton, R. & Hannon, M. (2016). Governing sustainability transitions through business model innovation: Towards a systems understanding. *Res. Policy 45*, 1731–1742.

[20] Hargreaves, T., Longhurst, N., & Seyfang, G. (2013). Up, down, round and round: Connecting regimes and practices in innovation for sustainability. *Environ. Plan. A, 45*, 402–420.

[21] Lazar, S. (Summer 2002). Modernization and the move to GPS III. Crosslink. 3 (2), 42–46.

[22] Kemp, R. (1994). Technology and the transition to environmental sustainability: the problem of technological regime shifts. *Futures*, *26*(10), 1023-1046.

[23] Smith, A., Voß, J., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research policy*, *39*(4), 435-448.

[24] Smith, A. & Stirling, A. (2010). The politics of social-ecological resilience and sustainable socio-technical transitions. *Ecol. Soc., 15*, 1–13.

[25] Hinrichs, C. (2014). Transitions to sustainability: A change in thinking about food systems change? *Agric. Hum. Values, 31*, 143–155.

[26] Kauppila, O., Bizzi, L., & Obstfeld, D. (2018). Connecting and creating: Tertius iungens, individual creativity, and strategic decision processes. *Strategic Management Journal*, *39*(3), 697-719.].

[27] Obstfeld, D. (Mar., 2005). Social networks, the tertius iungens, orientation, and involvement in innovation**.** *Administrative Science Quarterly, 50* (1), 100-130**.]**

[28] Miller, J. (2015).*Update on NASA GPS applications for space operations andsScience*. Retrieved from www.nasa.gov.

[29] Miller, J. & Parker, N. (2018). *NASA GNSS activities WG-B—Enhancement of GNSS performance, new services & capabilities*. Retrieved from www.nasa.gov.

[30] NASA/TP—20210021263 (October 2021). *State-of-the-Art Small Spacecraft Technology Small Spacecraft Systems*.Virtual Institute Ames Research Center, Moffett Field, California

[31] McNeely, C. & Fealing, K. (2018). *Moving the needle, raising consciousness: The science and practice of broadening participation*.