THE GROWING DIGITAL DIVIDE AND ITS NEGATIVE IMPACTS ON NASA'S FUTURE WORKFORCE.

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Introduction: The Digital Divide is often understood to be an inequity in availability of broadband internet access. Digital inequities create disparities in access to computing devices and technology as a whole, not just internet access. Computing devices and related communications technologies do not, by themselves, solve social and economic inequities, and can often exacerbate them. New technologies do not always replace the old; it is often the case that we have old technologies meeting the needs for many people, while the new technologies make improvements in the lives of a select few. The key here is that it is always better for those institutions with the power to do so to meet people where they are rather than asking people to expend their limited resources trying to catch up to the institution's inexorable movement "forward."

COVID-19 Exposed major inequalities between households in lower, middle, and upper income brackets. A recent poll by the Pew Research Center found that: A) 36% of children in lower income households were unable to complete their assigned homework because they did not have access to a computer at home; B) 40% of students had to travel out of the home to find a public Wi-Fi connection because their home does not have a reliable internet connection; and C) 43% of students in low-income households had to do their homework on a cellphone [1]. The proportions of students in urban and rural settings were similar: Unable to complete homework: A) 24% rural households compared with 33% urban; Unreliable home internet: B) 31% rural and 30% urban; Homework on a cellphone: C) 33% rural and 36% urban. The digital divide negatively impacts students in both rural and urban households. This report also found 28% of households with a high-speed broadband connection at home have worried about their ability to pay for the service over an extended pandemic; 30% of smartphone users worry about affording their data charges. The digital divide is especially problematic for Native Americans: at least 35% of Native American students have no access to broadband internet or even cell phone service [1]. **When learning is dependent on what one can afford, the divide between those who have and those who do not grows.**

Costs increase the divide. A related problem is the cost of broadband data plans and the data needs of solutions. For example, a one-on-one Zoom meeting for one hour uses ~540 to >800 MB of data; a single student using video conferencing for 5-hours/day could easily use 100 GB/month. Multi-student households see increased data usage proportional to the number of students; this does not include other household use (e.g. parents or care-givers also working from home). The average cost of the minimum broadband plan that will allow videoconferencing in the United States is about $70/month ($840/year). Data overage fees can easily increase this cost by a multiple of 2 to 5 [6]. For many lower income families, COVID-19 has suddenly and unexpectedly increased technology costs not accounted for in household budgets. A survey of K-12 schools by the RAND Corporation [2] found that 75% of teachers think students on the under-resourced side of the digital divide face serious obstacles to effective remote learning. Of parents in low-income and single-parent households, ~65% (and ~75% of parents of students with severe or moderate disabilities) think they would benefit from borrowing mobile technologies such as tablets and Wi-Fi hotspots [3,4,5], but fewer than ⅓ of school districts surveyed had the capacity or plans to provide these technologies. Even districts that had planned for this were unable to provide such technology to each student, forcing some students (and working parents) to travel long distances to access available hotspots [5].

Race impacts the divide. Several studies have shown that both access to the internet and owning a home computer vary by race [7]. A Pew Research Report from its "Internet and American Life" Project in 2017 showed that 79% of white households were online compared to 70% of Black households and 63% of Hispanic households [8]. Only 6% of White respondents needed to use the internet outside of the home as compared to 15% of Black respondents and 13% of Hispanic respondents. For these users, 50% of the reasons given for using the internet outside of the home related to cost and access. In 2017, the US Census Bureau [9] illustrated that the proportion of Black-alone households with no broadband connection and no home computer was 15% higher than White-only households. Hispanic-only households were 9% higher than White-only households with no internet access or home computer. Native American, Alaskan Native, and Pacific Islander (NA/AN/PI) households are typically excluded from these survey results because they represent less than the than the margins of error for these types of surveys (1% of the

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population), but are definitely impacted by the digital divide in similar and often greater proportions to other BIPOC communities. Indigenous and Native American communities are also bearing a disproportionate fallout from the pandemic and climate change [10]. Broadband internet has become critical to daily life, and these needs are heightened when geographical and economic isolation are compounded by sheltering in place. **Lack of access to adequate technologies, including the internet, threatens to hold American school children back a grade, and set its future workers back by years of missed learning and opportunities. This digital chasm will not be easily bridged in the near future without intentional and early mitigation at the federal and agency levels.**

Disabilities can increase the divide. Because of the pandemic, K-12, undergraduate, and graduate schools moved very swiftly to online, digital education models. The sudden change meant that many issues were left for later, including issues of Section 504 and 508 compliance [11], ADA compliance, and student safety.

Conversely, COVID-19 has also provided opportunities for some people with disabilities. In higher education spaces, there has been an increased interest in virtual/remote participation in field work (nearly ¾ of geosciences courses surveyed transitioned some or all field and lab courses to virtual instruction) [12]. Virtualized instructional methods can be barriers when deployed haphazardly, but provide increased accessibility when designed appropriately and when students have digital access [13]. However, this study notes "nearly three-quarters of students had fieldwork activities cancelled.", which may leave planetary science students lacking in key field/research experiences [14]. **The pandemic has increased problems with access, but has also provided solutions that allow more people access. These solutions will help NASA, other agencies, and our community to model those successes and build greater resiliency to future disruptions.**

The Divide impacts educators as well. Many teachers face similar challenges as their students. In some districts, schools are distributing paper packets for their students because neither the districts nor the students have the resources for online education [15]. Approximately 47% of high-poverty rate districts do not have the financial resources to provide students with computing devices and internet access. Thus a primary component of their education plans is physical distribution of learning materials [16].

Summary of the Problem: COVID-19 has exposed and exacerbated the digital divide and digital inequalities especially for Black, Indigenous and People of Color (BIPOC); low income; urban; and rural families and students; and families and students with mental health issues and disabilities that are negatively impacted by online educational models. This growing digital divide and its sudden increase caused by COVID-19 will have negative impacts on NASA's workforce in 10 years or fewer, when these students are, or are not, graduating from high school or with undergraduate degrees.

What can NASA, NSF, other agencies, and professional societies do to help with this problem? Improving access to high-speed internet is a nontrivial problem; we have seen limited progress over the past two decades despite federal and private initiatives. Options offered through ground-based infrastructure tend to serve high-density population centers better than rural populations or low density areas. This is especially true where the terrain or large expanses of land may lead to spotty connections, or where local internet company monopolies lead to low-quality bandwidth. Solutions are not just ground-based but increasingly space-based, with the rapid increase of many thousands of privately funded satellites in low-Earth orbits. Large satellite constellations have the potential to bridge the digital divide, but it is not clear whether their promise of low-cost high-speed broadband internet will be achieved to the degree claimed. These constellations also come with new ethical concerns [17]. Such private actors partner closely with NASA and NSF. As publicly funded agencies, it is imperative that NASA, NSF, and other agencies hold these companies accountable to all of humanity and its pressing needs, especially when satellite constellations have already begun to have an enormous impact on scientific astronomy and dark skies.

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