National Aeronautics and
Space Administration

HIGH-END COMPUTING CAPABILITY PORTFOLIO

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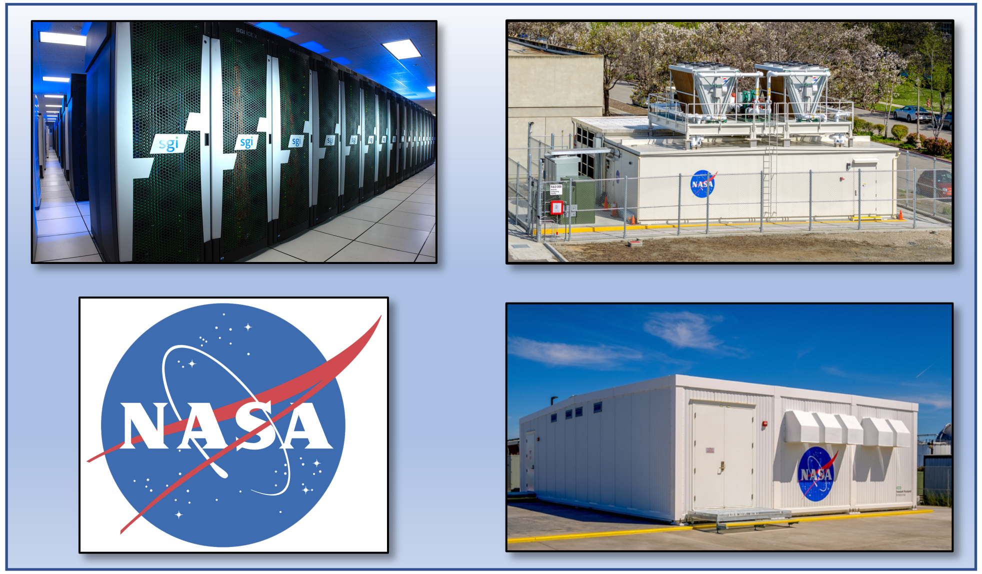
March 10, 2020

Impact of COVID-19 on HECC

- On March 8th, all members of the ARC HECC staff were notified that ARC was moving into a mandatory telework posture. This resulted in all staff except for the control room working from home.
- To the user community, this was a seamless event. No systems were affected, and all support activities continue. Specifically:
  - The control room continues to operate 24x7 with the help line operative and all system floors monitored with regularly scheduled walkthroughs.
  - 2nd level user support is handled via normal staff working remotely.
  - System support is being handled remotely by system administrators. A process is in place to allow support staff on the center in cases where physical access to the computers is required.
  - Computer security and network monitoring has been unaffected with staff able to perform these tasks remotely.
- Ongoing development work is continuing with no interruptions.
  - Work on tools, data portals and data sciences is continuing with staff able to access essential capabilities from their remote locations.
  - Visualization activities are being impacted by remoting issues on latency-sensitive applications.
- Utilizing Microsoft Teams and call-in numbers to conduct regular meetings and coordinating with other team members

Impact: HECC's ability to move from working at the ARC to mainly teleworking enables the user community to continue their important work even when staff is unable to get to the center.



All NASA HECC assets continue to be available to NASA scientists and engineers even when staff are unable to come to the center.

HECC Advances Use of Cutting-Edge InfiniBand Routing

- HECC systems experts demonstrated the use of Mellanox's InfiniBand adaptive routing technology with NAS benchmark applications using HPE's Message Passing Interface (MPI).
- Adaptive routing, an InfiniBand feature available on the Aitken supercomputer, utilizes additional communication paths between compute nodes. These additional paths increase bandwidth and better handle communication congestion.
- Systems staff worked closely with Mellanox and HPE to coordinate the introduction of adaptive routing to HPE's MPI and incorporate recent adaptive routing improvements from Mellanox.
- This collaborative work continues, with additional HECC-driven changes to adaptive routing to make it pertinent to the broad range of user applications run on Aitken.

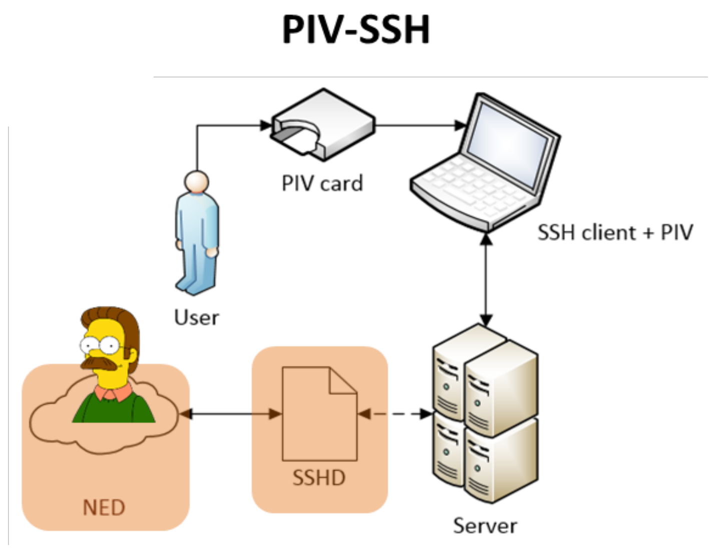
IMPACT: HECC continues to push high-performance computing technology boundaries to improve performance and reliability for NASA's scientific and engineering users.

HECC's collaboration with vendors Mellanox and HPE builds on the HPC advancements achieved with the supercomputers Columbia, Pleiades, Electra, and Aitken.

Security Team Implements PIV-SSH on Secure Front Ends

- HECC security experts implemented Personal Identify Verification-Secure Shell (PIV-SSH) on the secure front-end (SFE) systems. This has two advantages:
  - Improves HECC's security posture through compliance.
  - Simplifies the user login experience.
- Improved security posture:
  - SFEs are compliant with the agency-mandated PIV requirement for remote users.
  - HECC canceled the risk-based decision (RBD) for PIV-SSH on SFEs in the NAS security plan.
  - PIV-SSH allows the SFEs to offer the highest level of assurance (LOA 4) for authentication.
- Simplified user login experience:
  - Users with agency PIV badges or smartcards can use PIV authentication to log into the SFEs.
  - Users no longer need to set up public key authentication.

IMPACT: Implementing PIV-SSH on secure front ends brings systems into compliance with Agency PIV requirements and improves HECC's security posture.

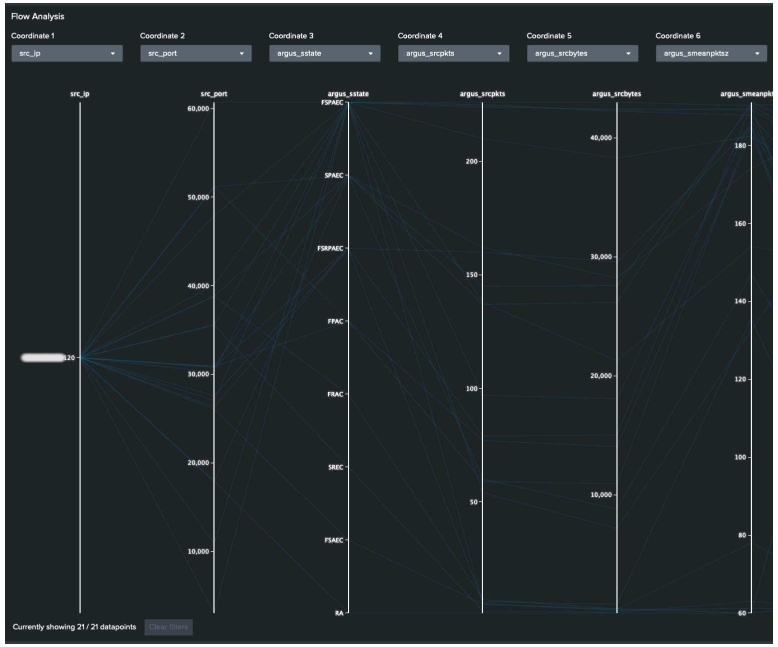


The PIV-SSH Login Process: From "Personal Identity Verification Mandatory (PIV-M) Project - Operational Readiness Review (ORR)," presented by Dan Pierson, NASA Enterprise IT Integration Manager, December 12, 2017.

Security Team Adds New Capabilities to HECC Security Monitoring System

- HECC security experts added three new capabilities to the HECC security monitoring systems:
  - Interactive visualization of network flows associated with suspicious activity allows analysts to drill down into a network flow and visualize the various attributes of a network flow.
  - Detailed insights into various suspicious and malicious activity, including SQL injection (a technique used to compromise a system, mainly used against web servers), shell code attacks, and hostile scans. This capability provides analyst with geographic, WHOIS, and other statistics about the activity and the ability to see the network flow related to the activity.
  - Improved reporting of patch and vulnerability status provides analysts with a better understanding of risks associated with unmitigated flaws and the ability to identify trouble areas that need attention.
- These increased capabilities provide the Security team with greater awareness of various threats and risks to the HECC network and computer systems.

IMPACT: New capabilities improve HECC's security posture by providing better awareness of the threats and risks to agency resources.



Part of an interactive parallel coordinate graph from the HECC monitoring system.

Tools Team Initiates Improvements to the HECC Monthly Reporting Process

- The Tools team completed Phase I of a three-phase project to improve the HECC monthly reporting process.
- The team completed Reports Automation Phase ahead of schedule, including the following activities:
  - Replicated the data currently being used for the monthly reports.
  - In completing the above task, the team found and corrected errors in the the data, as well errors in the old software.
  - Decreased the time it took to run these reports from over 10 hours to just 10 minutes.
  - Created a new Oracle materialized view with normalized data that has simplified SQL query and improved the query performance time (See slide 7).
- The Tools team continues to move to a more streamlined approach and technology stack to produce reports. This project will reduce the complexity and substantial costs (labor and maintenance) associated with report production, as well as the project's reliance on 3rd-party software, and lays the foundation for future reporting improvements.

IMPACT: As the complexity of the HECC computing environment continues to increase, automation of usage reporting helps to ensure accuracy and meet aggressive reporting schedules.

February 2020	Runtime (HH:MM:SS)				Saving
	Old Software				Diff
Reports run with old software	Start Time (AM)	End Time (AM)	Old Software	Script	Old Software - Script
Poster Data	10:20:00	10:23:00	0:03:00	0:00:11	0:02:49
Devel Queue	10:31:00	10:42:00	0:11:00	0:00:18	0:10:42
Normalized SBU	10:48:00	11:19:00	0:31:00	0:00:13	0:29:47
Queue Wait Time Pleiades	12:13:00	12:24:00	0:11:00	0:01:30	0:09:30
Queue Wait Time Electra	12:27:00	12:30:00	0:03:00	0:00:30	0:02:30
Queue Wait Time Merope	12:31:00	12:33:00	0:02:00	0:00:24	0:01:36
Queue Wait Time Endeavour	12:35:00	12:36:00	0:01:00	0:00:20	0:00:40
Queue Wait Time Aitken	12:38:00	12:39:00	0:01:00	0:00:19	0:00:41
Free Usage	12:49:00	12:51:00	0:02:00	0:00:10	0:00:50
Job Statistics Mission	10:00:00	11:52:00	1:52:00	0:00:50	1:52:02
Job Statistics Walltime	10:30:00	11:45:00	1:15:00	0:01:00	1:14:00
Job Statistics Wall Summary	9:42:00	10:32:00	0:50:00	0:00:40	0:49:20
Reports from other sources					
Time to Clear Aitken	2:15:00	2:16:35	0:01:35	0:00:03	0:01:32
Time to Clear Electra	2:15:00	2:21:04	0:06:04	0:00:03	0:06:01
Time to Clear Endeavour	2:15:00	2:15:32	0:00:32	0:00:02	0:00:30
Time to Clear Merope	2:15:00	2:21:05	0:06:05	0:00:02	0:06:03
Time to Clear Pleiades	2:15:00	2:52:09	0:37:09	0:00:02	0:35:07
Endeavour SBU MAU	2:15:00	2:15:43	0:00:43	0:00:02	0:00:41
Sponsor Program Usage	3:51:00	3:51:12	0:00:12	0:00:14	(0:00:02)
Additional Reports					
Expansion Factor			0:04:00	0:00:09	0:03:51
Sector			0:24:00	0:00:09	0:23:51
Detailed GID			1:31:00	0:02:18	1:28:42
All SBU by MD			1:00:00	0:00:14	0:59:46
Total Runtime (HH:MM:SS):			8:53:20	0:09:43	8:40:31

A list of all reports that are used to create information for the HECC monthly report. Runtimes listed for each report using MicroStrategy and the new monthly reporting process. The last column shows the time saved using the improved process.

Improved Materialized View Speeds Data Retrieval

- The HECC Tools team implemented the Materialized View (V2) database object, which is used within the Report Automation project (see slide 6) for extremely fast retrieval of aggregate data. The data is precomputed and stored at the expense of insert/update/delete of all the tables involved in the View. The Oracle process will keep the Materialized View in sync with the real data.
- Creating this new version of Materialized view with normalized data has simplified SQL queries in the reporting scripts and vastly improves the query time—less than 25% of the original query time.
- Key activities completed in order to achieve this task includes:
  - Investigated and tested all options with Materialized View and selected the best option for the HECC data and environment.
  - Cleaned up all the master tables used to get the normalized form.
  - Created a primary key for the all the tables involved.
  - Created the Materialized View Refresh on Demand, so it doesn't interfere with other processes.
  - Created Materialized log tables in the database with primary key including all the columns in the select statement to expedite refresh.
  - Created the refresh script and verified that the data is in sync at all times.

IMPACT: With normalized form, data is more accurate now with all tables involved and HECC Report generation performance has improved drastically.

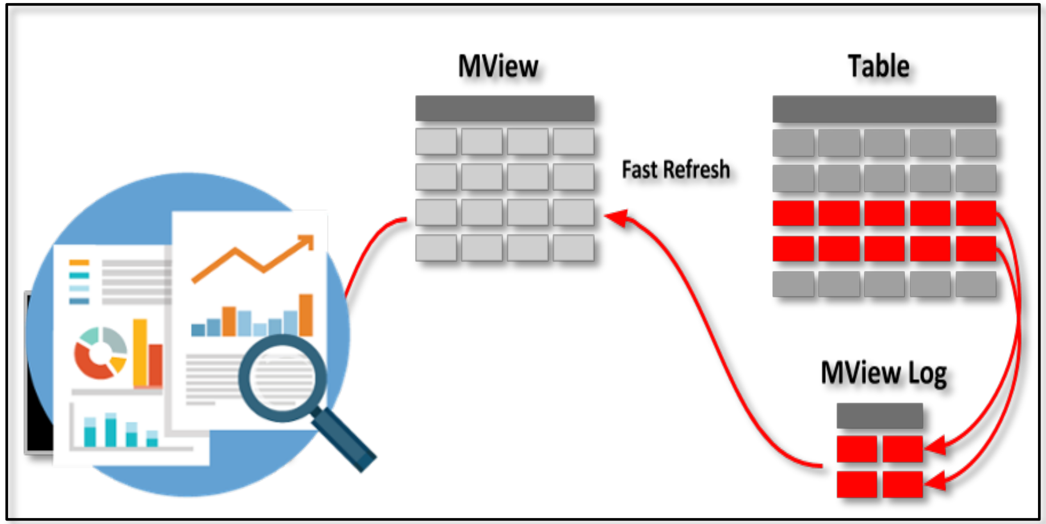


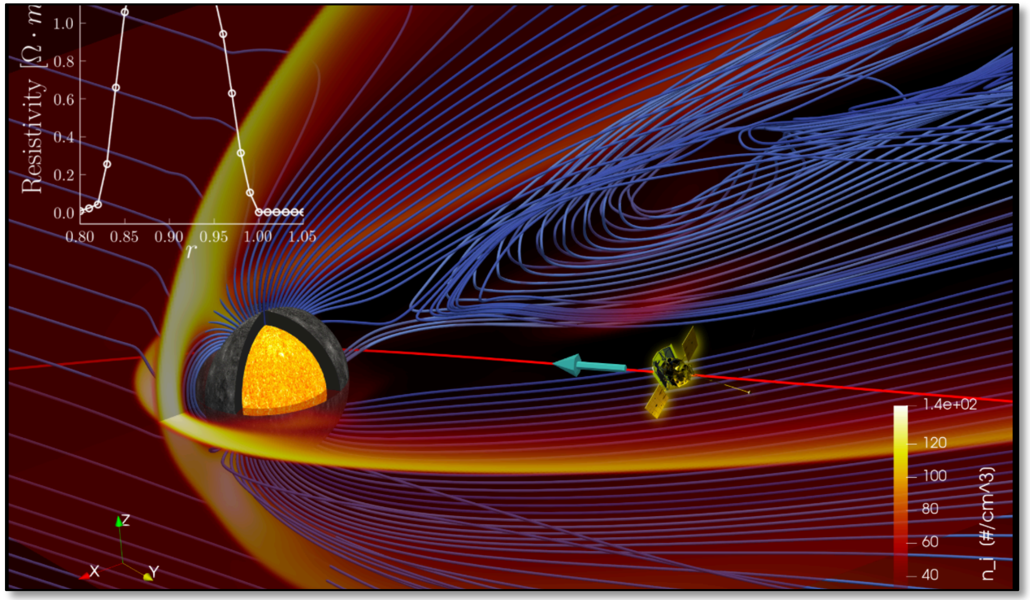
Chart showing the working flow of Materialized View. Because the data is precomputed, querying a materialized view is faster than executing the complex original query.

HECC Supercomputer Usage Sets New Normalized Record in February 2020

- In February, the combined usage of HECC supercomputers set a new normalized record of 9,514,841 Standard Billing Units (SBUs).*
- The usage by 322 of NASA's science and engineering groups exceeded the previous record of 9,037,397 SBUs set in December 2019 by 477,444 SBUs (5%).
- The record was achieved in great part by the Science Mission Directorate's Heliophysics/Planetary Science group for their Integration of Extended MHD and Kinetic Effects in Global Magnetosphere Models project.
- Usage of Pleaides, Electra, Aitken, Merope, and Endeavour contributed to this record.
- The top 10 project's usage ranged between 183,355 and 696,095 SBUs, and together accounted for over 31% of the total usage.
- The HECC Project continues to evaluate and plan resources to address the future requirements of NASA's users.

** 1 SBU represents the work that can be done in 1 hour on a Pleiades Broadwell 28-core node.*

IMPACT: The increased capacity of HECC systems and working with users to optimize their run capacities provides mission directorates with more resources to accomplish their goals and objectives.



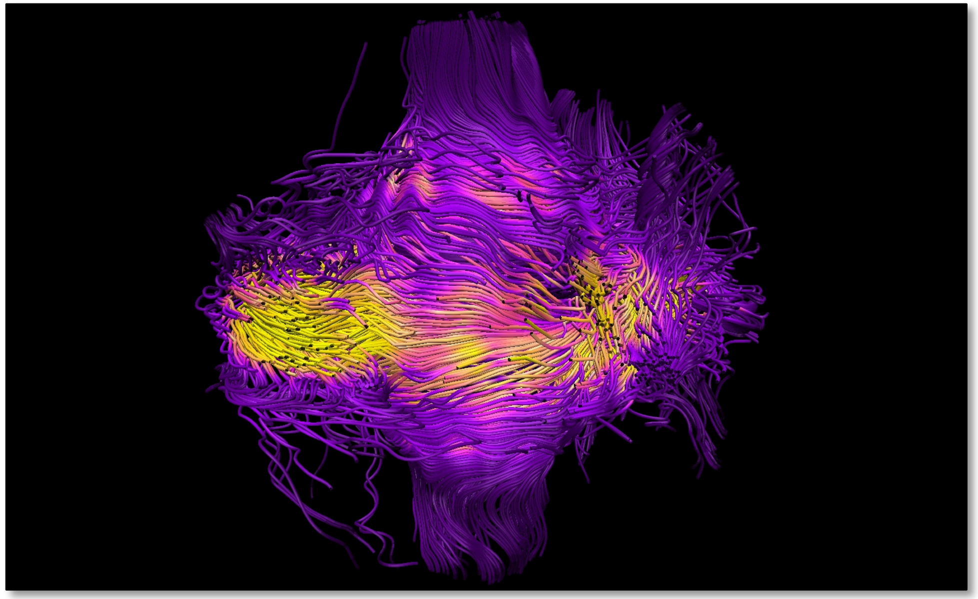
The largest usage project in February 2020 was for Mercury's 3D magnetosphere from a novel ten-moment multifluid simulation. The red line together with a cyan arrow represents the trajectory of the MESSENGER spacecraft. *Chuanfei Dong, Liang Wang, Princeton University*

Exploring the Origins of Extreme Magnetism in Red Dwarf Stars

- Researchers at the University of Colorado Boulder ran high-resolution magnetohydrodynamic simulations on Pleiades to help understand how red dwarf (or M-dwarf) stars generate intense magnetism, despite their relatively small size, cold atmosphere, and dim light.
- Their extensive studies of the types of flows and dynamos in such stars fill a knowledge gap—there are no other thorough computational studies of magnetic convection within M-dwarf stars. Some early results show:
  - The tachocline can act as a reservoir for magnetic fields in these stars, stabilizing and prolonging their global cycles, even when the tachocline is not the primary generation site.
  - Transitions between dynamo states in these stars can release enough magnetic energy in the form of buoyantly rising flux ropes to power observed superflares, whose deep origins are yet to be well explained.
  - The presence of a tachocline in these stars leads to their surface fields being stronger and organized on larger spatial scales, allowing them to shed angular momentum through their magnetized winds more quickly than stars without tachoclines.

** HECC provided supercomputing resources and services in support of this work.*

IMPACT: HECC's extensive supercomputing and storage resources make it possible for researchers to conduct comprehensive studies of the role of the tachocline over the lifetime of red dwarf stars.



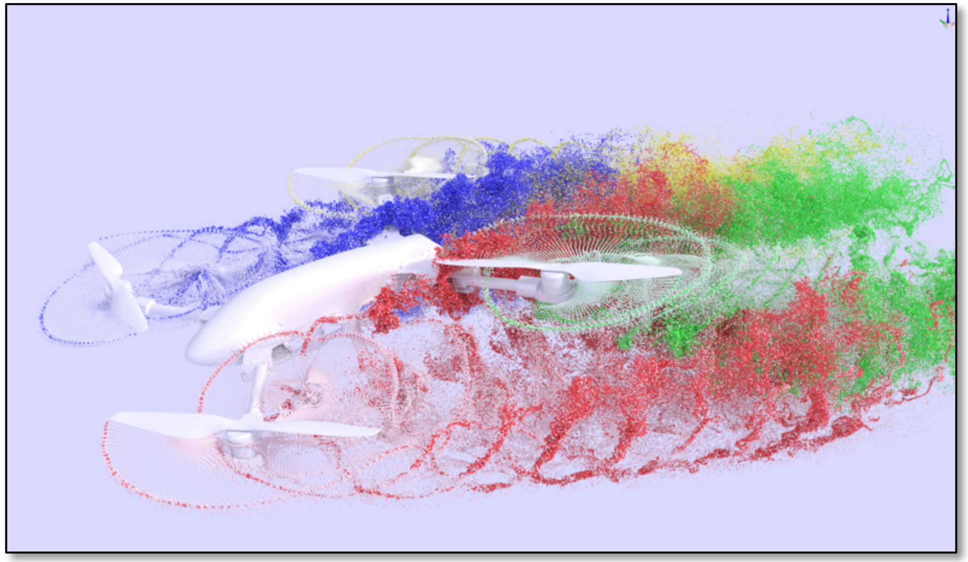
Magnetic fields achieved in one model of an M-type star, with a rectangular section removed to reveal the internal structure. Brighter colors denote stronger fields. A wreath of intense magnetism wraps 360 degrees around the star's equator. Fields turn radially near the poles, where they collectively extend beyond the stellar surface.
Connor Bice, Juri Toomre, University of Colorado and JILA

New CFD Methods for Predicting Quadcopter Drone Noise

- NASA Ames aerospace engineers ran computational fluid dynamics (CFD) simulations on Electra to predict the aeroacoustic noise generated by a Straight Up Imaging (SUI) quadcopter drone in forward flight, derived from first principles, using the Lattice Boltzmann Method (LBM).
  - To produce the simulations, the team used a Lattice Boltzmann solver within NASA's Launch Ascent and Vehicle Aerodynamics (LAVA) solver framework.
  - The blades were represented on the automatically generated Cartesian grid through an in-house algorithm to complete the streaming step for lattice links broken by the geometry.
- Coupled with far-field acoustic propagation in the LAVA framework, LBM successfully predicted tonal noise levels and captured broadband noise trends accurately for the first time.
  - In detailed comparisons with test data, the predicted mean thrust was within 5% of the value measured experimentally.
  - No manual mesh generation was required; the model used adaptive mesh refinement based on running statistics of pressure fluctuations and turbulent kinetic energy.
  - 30-rotor rotations were simulated with 568 million cells in under 125 hours.
- The solver's computational efficiency—and the absence of labor-intensive manual mesh generation—are key to making routine aeroacoustic analysis of urban air taxis and drones from first principles possible.

** HECC provided supercomputing resources and services in support of this work.*

IMPACT: Up to ten times faster than traditional approaches to analyzing quadcopter aeroacoustics, new CFD methods—enabled by the Electra supercomputer—help design engineers address noise, which is a major roadblock to community acceptance of autonomous air taxis and drones.



Passive particles tracing the complex flow structures generated by four sets of blades spinning at up to 4,937 RPM, in this simulation of a Straight Up Imaging quadcopter in forward flight. *Francois Cadieux, Timothy Sandstrom, NASA/Ames*

HECC Facility Tours in February 2020

- HECC hosted 6 tour groups in February; guests learned about the agency-wide missions being supported by HECC assets, and also viewed the D-Wave 2000Q quantum system. Visitors this month included:
  - Jean-Eric Paquet, the European Union Director General for Research & Innovation. Paquet leads the EU's Horizon 2020 funding program and he is seeking to learn more about how Ames manages innovation.
  - A group from Ames Thermal Protection Materials Branch, who are working to develop new technologies to design thermal protection systems for future spacecraft.
  - A group visit hosted by Brainpool, a Swedish non-profit that promotes STEM for rising high school and university students. The students are winners of a national STEM competition in Sweden.
  - Ames employees, as part of the Ames 80th Anniversary Tour Series.
  - Ames spring interns.

Darrel Robertson (center, facing left), a research engineer in the NASA Advanced Supercomputing (NAS) Division, briefs students in the NAS facility's primary computing room, which houses the Pleiades supercomputer and mass storage system.
Gina Morello, NASA/Ames

Papers

- "**A Systematic, Regional Assessment of High Mountain Asia Glacier Mass Balance**," D. Shean, et al., Frontiers in Earth Science: Cryosphere Sciences, January 30, 2020. *
https://www.researchgate.net/profile/Shashank_Bhushan2/publication/339115231_A_Systematic_Regional_Assessment_of_High_Mountain_Asia_Glacier_Mass_Balance
- "**Ergostar Models: Where do they reside?**" A. Tsokaros, M. Ruiz, S. Shapiro, arXiv:2002.01473 [gr-qc], February 4, 2020. *
https://arxiv.org/abs/2002.01473
- "**Evaluating Impacts of Snow, Surface Water, Soil and Vegetation on Empirical Vegetation and Snow Indices for the Utqiaġvik Tundra Ecosystem in Alaska with the LVS3 Model**," Q. Zhang, et al., Remote Sensing of Environment, vol. 240, published online February 4, 2020. *
https://www.sciencedirect.com/science/article/pii/S0034425720300468
- "**Polarimetric Radar Characteristics of Simulated and Observed Intense Convective Cores for a Midlatitude Continental and Tropical Maritime Environment**," T. Matsui, et al., Journal of Hydrometeorology, vol. 21, no. 2, published online February 7, 2020. *
https://journals.ametsoc.org/doi/abs/10.1175/JHM-D-19-0185.1
- "**GJ 1252 b: A 1.2 $R_\oplus$ Planet Transiting an M3 Dwarf at 20.4 pc**," A. Shporer, et al., The Astrophysical Journal Letters, vol. 890, no. 1, February 10, 2020. *
https://iopscience.iop.org/article/10.3847/2041-8213/ab7020/meta

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

- “**Thermal Conductivity of Two-Dimensional Disordered Fibrous Materials Defined by Interfiber Thermal Contact Conductance and Intrinsic Conductivity of Fibers**,” A. Volkov, L. Zhigilei, Journal of Applied Physics, vol. 127, issue 6, February 10, 2020. *
  https://aip.scitation.org/doi/full/10.1063/1.5136238
- “**Moving and Reactive Boundary Conditions in Moving-Mesh Hydrodynamics**,” L. Prust, arXiv:2002.04287 [physics.comp-ph], February 11, 2020. *
  https://arxiv.org/abs/2002.04287
- “**Patterns and Dynamics of SST Fronts in the California Current System**,” Y. Mauzole, H. Torres, L.-L. Fu, Journal of Geographical Research: Oceans, vol. 125, issue 2, February 15, 2020. *
  https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019JC015499
- “**Takeoff Simulation of Lift+Cruise Air Taxi by Using Navier-Stokes Equations**,” G. Guruswamy, AIAA Journal, published online February 17, 2020. *
  https://arc.aiaa.org/doi/full/10.2514/1.J059212
- “**Flamelet Modeling for Supersonic Combustion**,” T. Drozda, J. Quinlan, J. P. Drummond, Modeling and Simulation of Turbulent Mixing and Reaction, pp.127-168, published online February 20, 2020. *
  https://link.springer.com/chapter/10.1007/978-981-15-2643-5_6

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

- "**Electron Heating in Perpendicular Low-Beta Shocks**," A. Tran, L. Sironi, arXiv:2002.11132 [physics.space-ph], February 25, 2020. *
  https://arxiv.org/abs/2002.11132
- "**Physics of Tidal Dissipation in Early-Type Stars and White Dwarfs: Hydrodynamical Simulations of Internal Gravity Wave Breaking in Stellar Envelopes**," Y. Su, D. Lecoanet, D. Lai, arXiv:2002.11118 [astro-ph.SR], February 25, 2020. *
  https://arxiv.org/abs/2002.11118
- "**Simulating Compound Flooding Events in a Hurricane**," Y. Zhang, et al., Ocean Dynamics, February 27, 2020. *
  https://link.springer.com/article/10.1007%2Fs10236-020-01351-x

** HECC provided supercomputing resources and services in support of this work*

Presentations

- "**GLM Observations of Bolides LI MAG Meeting #9**," R. Longenbaugh, L. Dolmo, J. Dotson, C. Henze, R. Morris, P. Register, C. Rumpf, J. Smith, presented at the LI Mission Advisory Group Meeting, January 29, 2020. *
https://ntrs.nasa.gov/search.jsp?R=20200001096
- "**Free-Space Optical Communication for CubeSats in Low Lunar Orbit (LLO)**," P. Goorjian, presented at SPIE Photonics West, San Francisco, CA, February 1-6, 2020.
https://ntrs.nasa.gov/search.jsp?R=20200000650

** HECC provided supercomputing resources and services in support of this work*

News and Events

- **Pluto’s Icy Nitrogen Heart Makes its Atmosphere Spin Backwards**, *New Scientist,* February 5, 2020–A weather forecast simulation run at the NASA Advanced Supercomputing (NAS) facility shows that cyclical changes in nitrogen ice on Pluto’s surface drive winds that blow in the opposite direction to the frigid world’s spin. https://www.newscientist.com/article/2232638-plutos-icy-nitrogen-heart-makes-its-atmosphere-spin-backwards/
- **Podcast: Simulating Galaxy Clusters with XSEDE Supercomputers**, *insideHPC*, February 8, 2020–Inspired by the science fiction of the spacefaring Romulans of Star Trek, astrophysicists have developed cosmological computer simulations called RomulusC and run it on some of the most powerful supercomputers in the US, including NASA’s Pleiades supercomputer. With a focus on black hole physics, RomulusC has produced some of the highest resolution simulations ever of galaxy clusters, which can contain hundreds or even thousands of galaxies. https://insidehpc.com/2020/02/podcast-simulating-galaxy-clusters-with-xsede-supercomputers/
- **How Quiet Can You Go?** *Science Node*, February 10, 2020–Full-scale simulations of a Boeing 777 run on the NAS facility’s Pleiades supercomputer by scientist Mehdi Khorrami, NASA Langley Research Center, aim to reduce aircraft landing noise and improve the quality of life for communities near major airports. https://sciencenode.org/feature/How%20quiet%20can%20you%20go.php

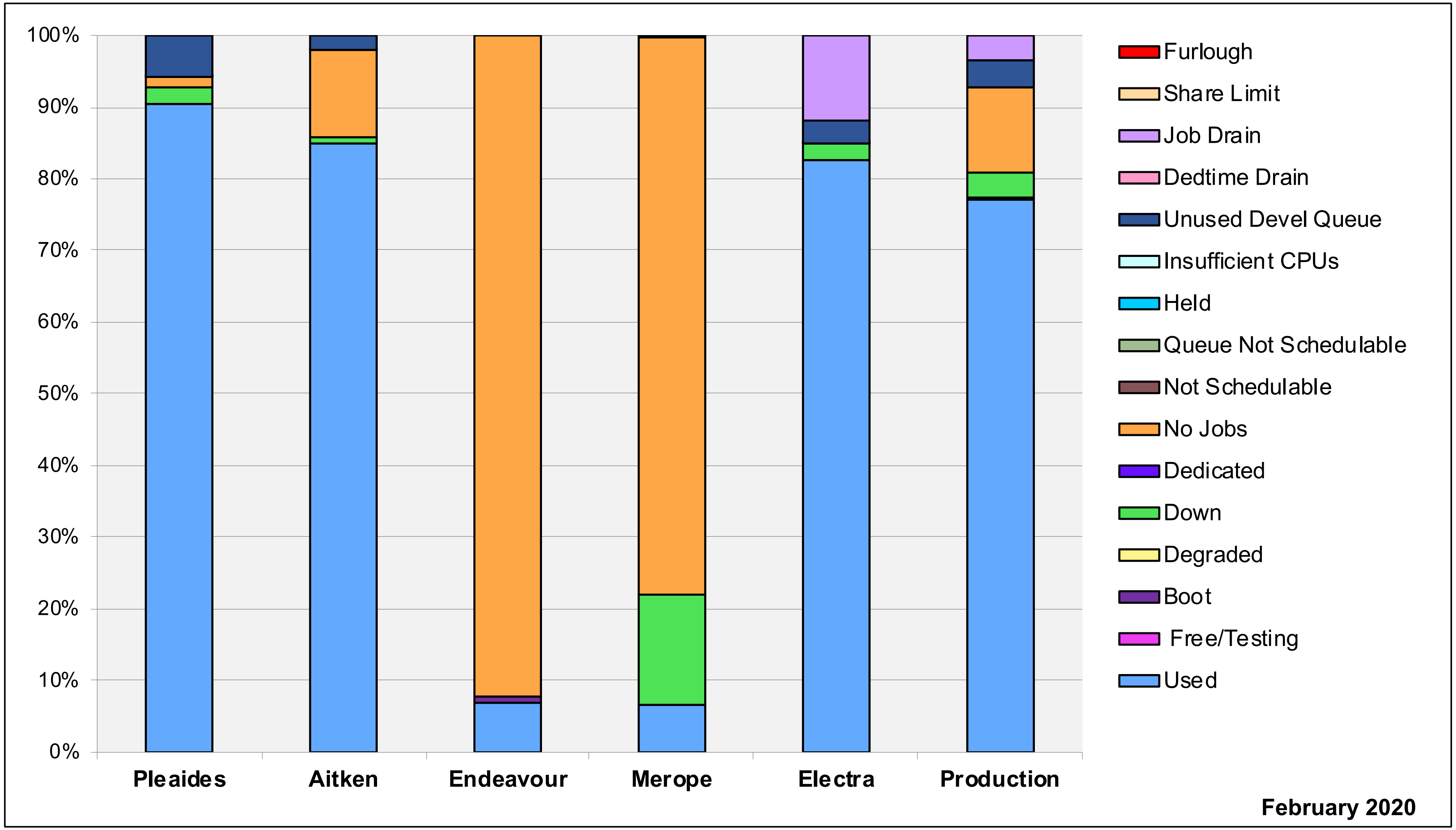
News and Events (cont.)

- **NASA Plans to Send a Woman to the Moon…and Really Soon**, *KQED.org*, February 20, 2020–Local media visited NASA's Ames Research Center, including the wind tunnel facilities being used to test a model of the Space Launch System, the data from which is getting funneled directly to the Pleiades supercomputer to allow aerospace engineers to get near-instantaneous feedback from the experiment.
  https://www.kqed.org/science/1956918/nasa-aiming-to-send-woman-to-moon-and-really-soon
- **Galactic Center Visualization Delivers Star Power**, *Chandra X-Ray Observatory Blog*, February 28, 2020–By combining the power of the systems at the NASA Advanced Supercomputing Facility with data from NASA's Chandra X-ray Observatory, researchers have created a new immersive, ultra-high-definition 360-degree visualization of the center of the Milky Way Galaxy.
  https://chandra.si.edu/photo/2019/gcenter/

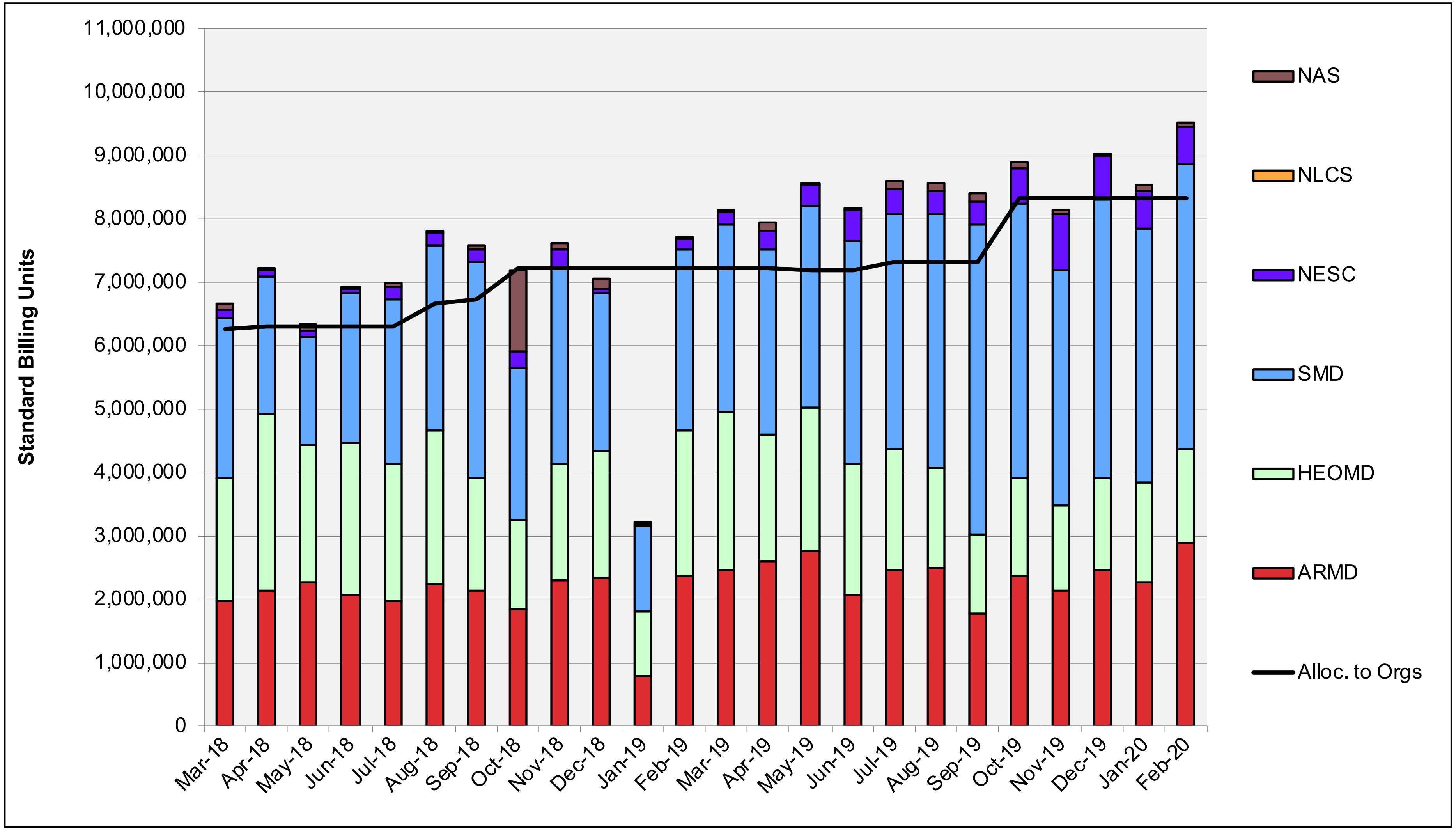
News and Events: Social Media

- **Coverage of NAS Stories**
  - Aeroacoustic Simulations run on NAS systems:
    - NAS: Twitter 2 retweets, 15 favorites
    - @SciNode campaign: 13 tweets over two weeks
  - Sagittarius A*/Milky Way Chandra visualization:
    - NAS: Twitter 4 retweets, 4 likes; Facebook 142 users reached, 9 engagements, 5 likes, 1 share.
    - Chandra Observatory: Twitter 125 retweets 289 favorites; YouTube 408k views, 2.9 likes; Facebook 379 reactions, 150 shares.

HECC Utilization



HECC Utilization Normalized to 30-Day Month



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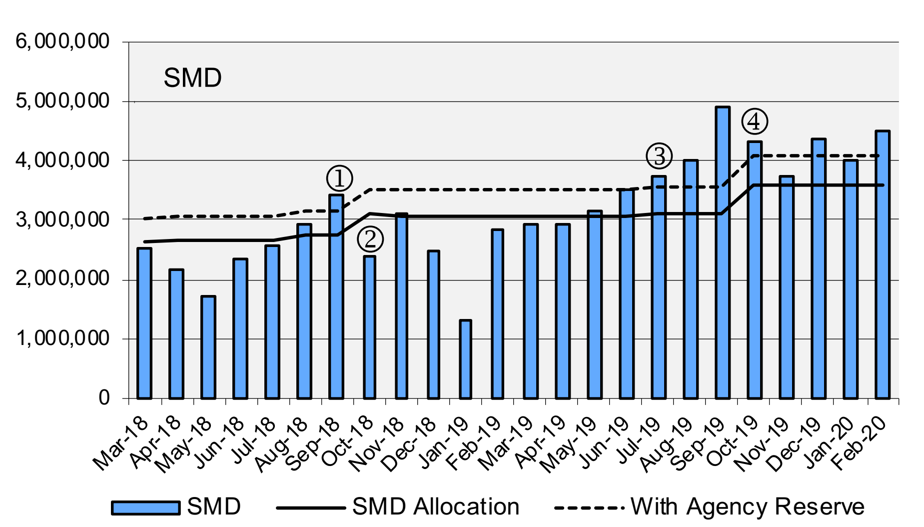
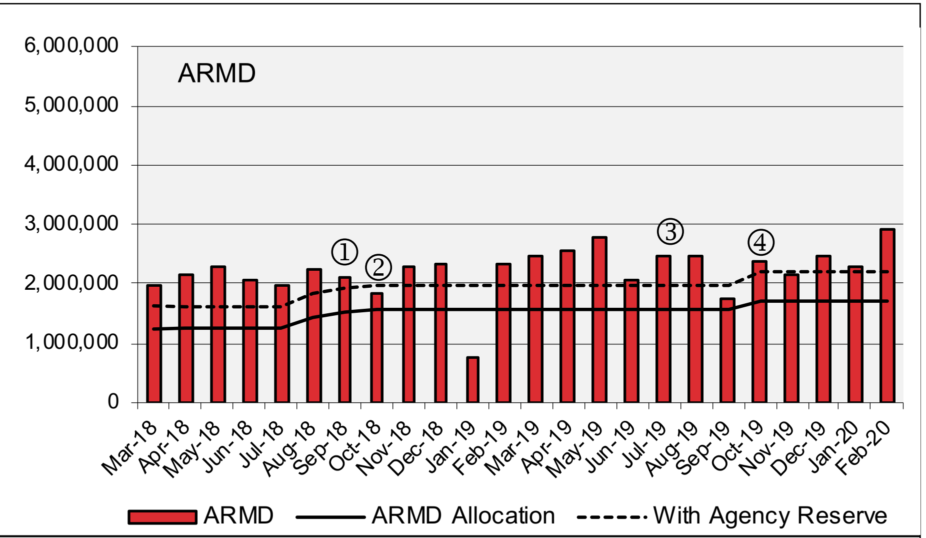
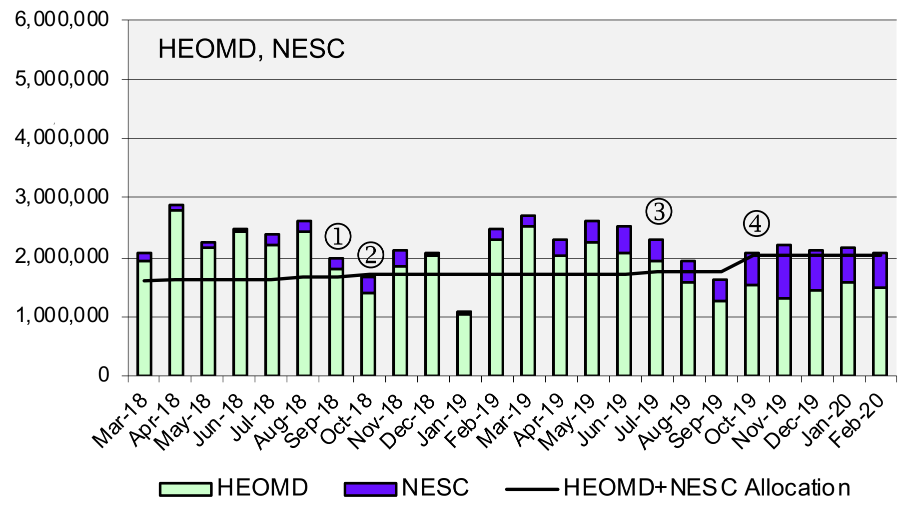






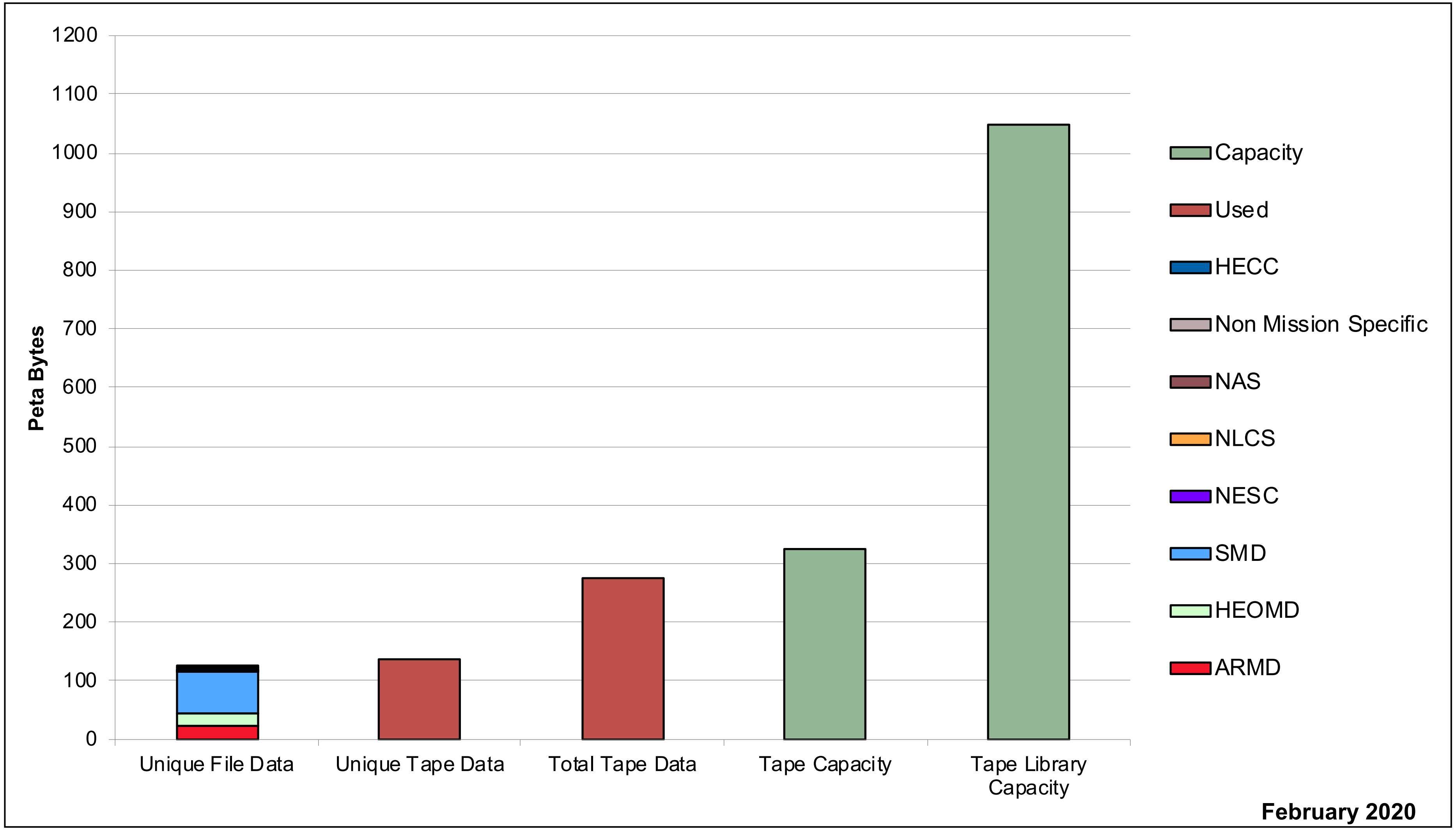
① 4 Skylake E cells (16 D Rack Equivalence) added to Electra

② 2 Skylake E cells (8 D Rack Equivalence) added to Electra; 1 rack is dedicated to ARMD

③ 2 Skylake E cells (8 D Rack Equivalence) added to Electra; 1 rack is dedicated to SMD

④ Skylake Tesla GPU V100 Nodes installed

Tape Archive Status



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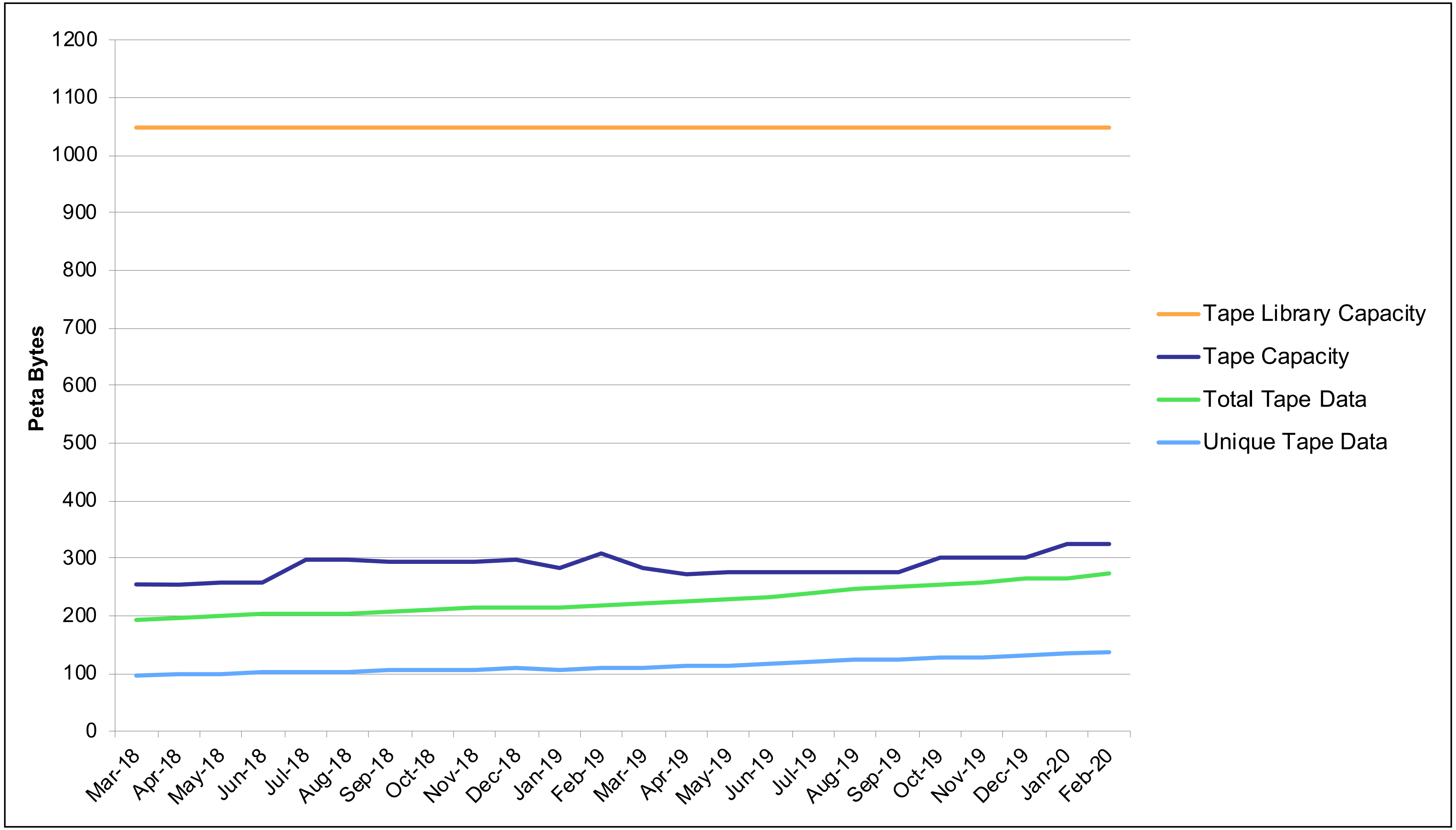
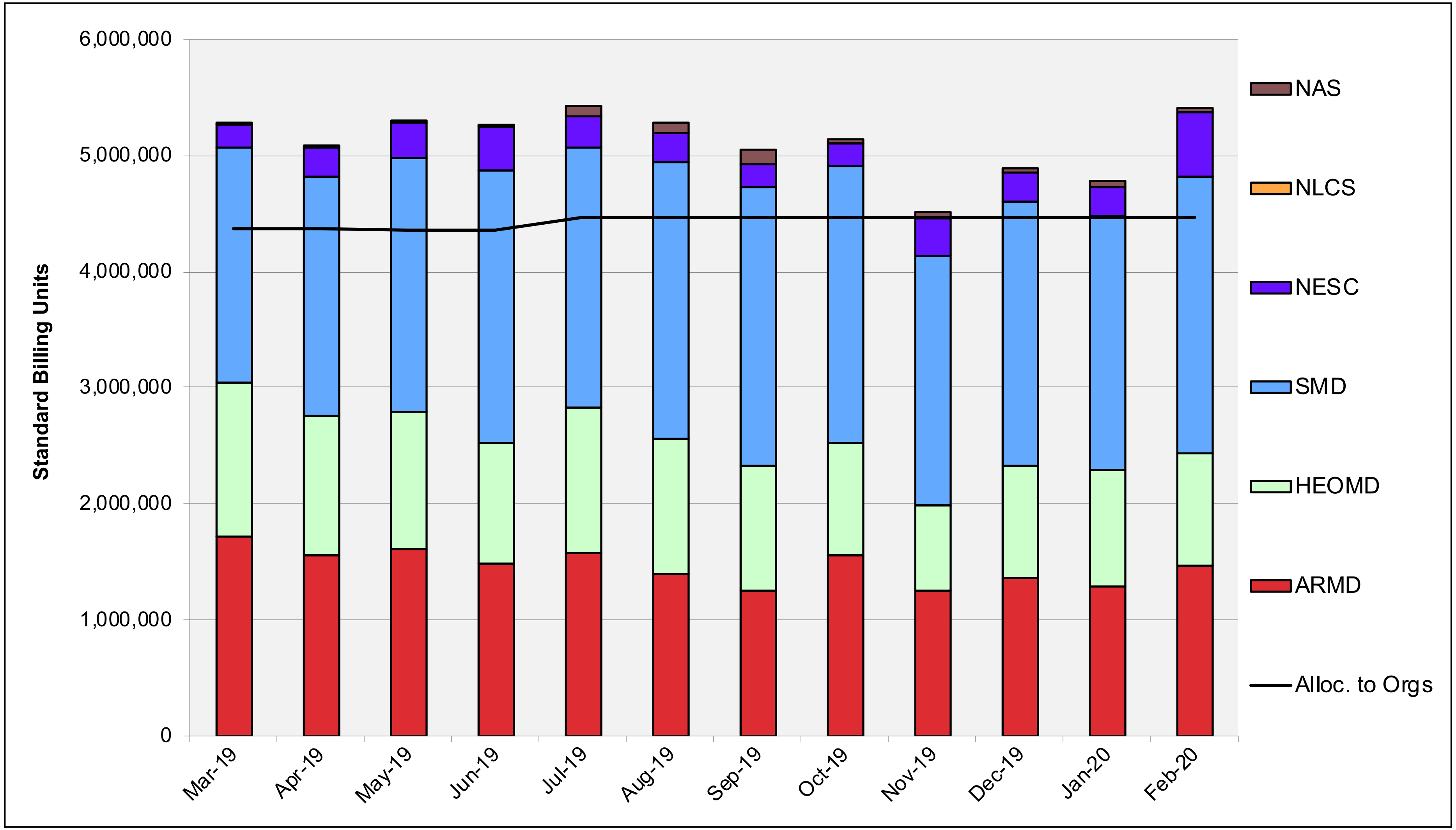
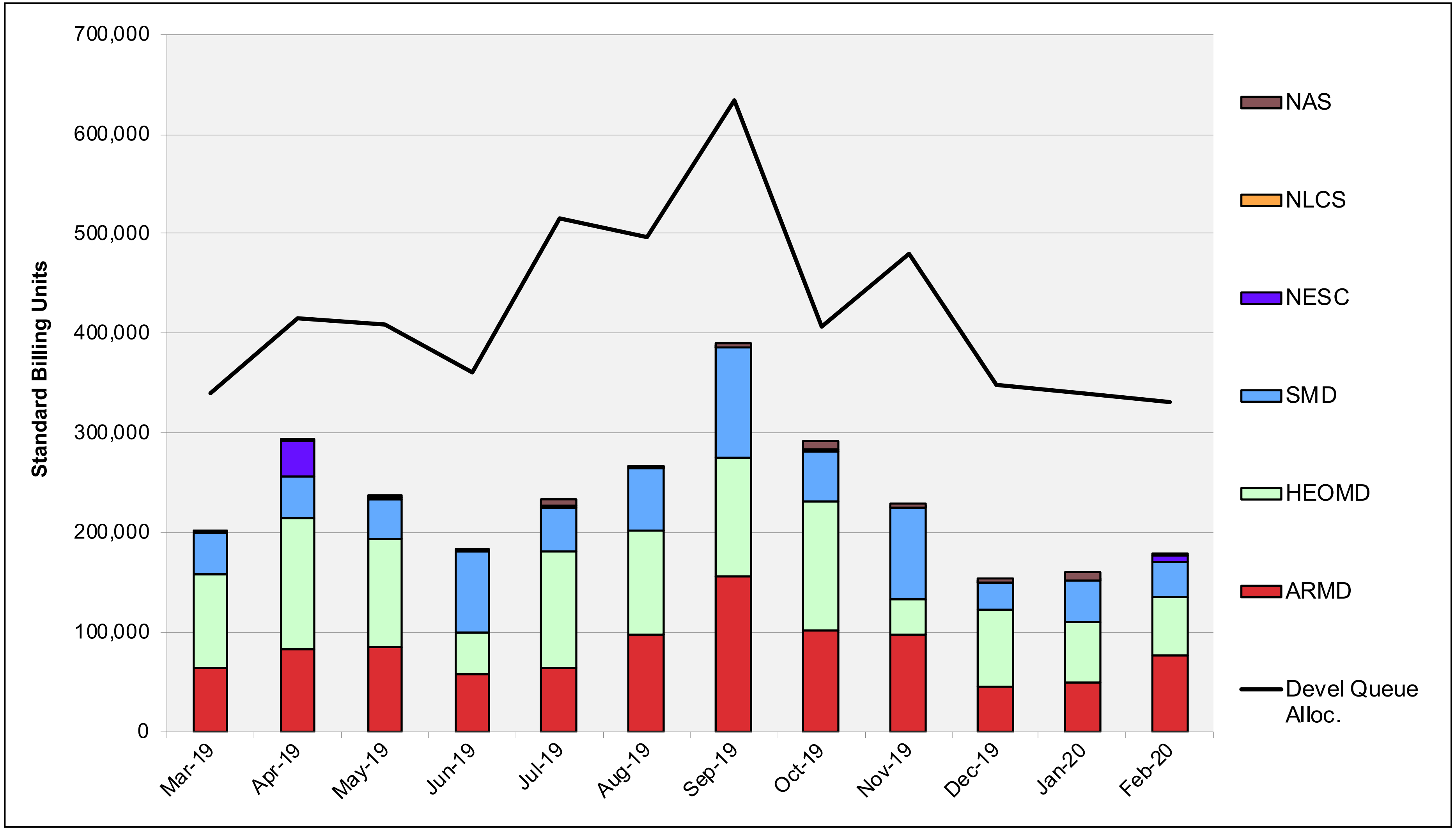


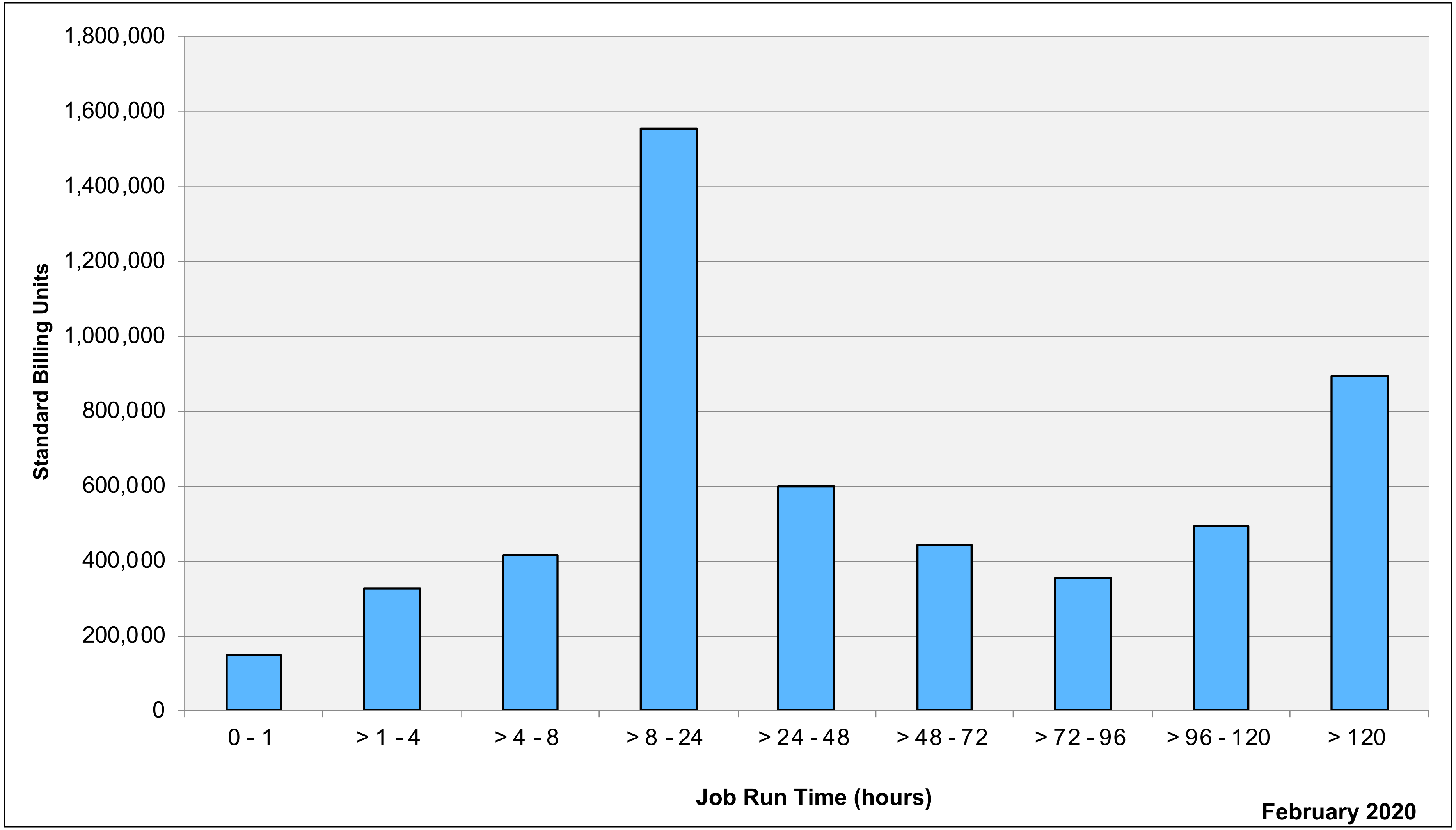
Pleiades: SBUs Reported, Normalized to 30-Day Month



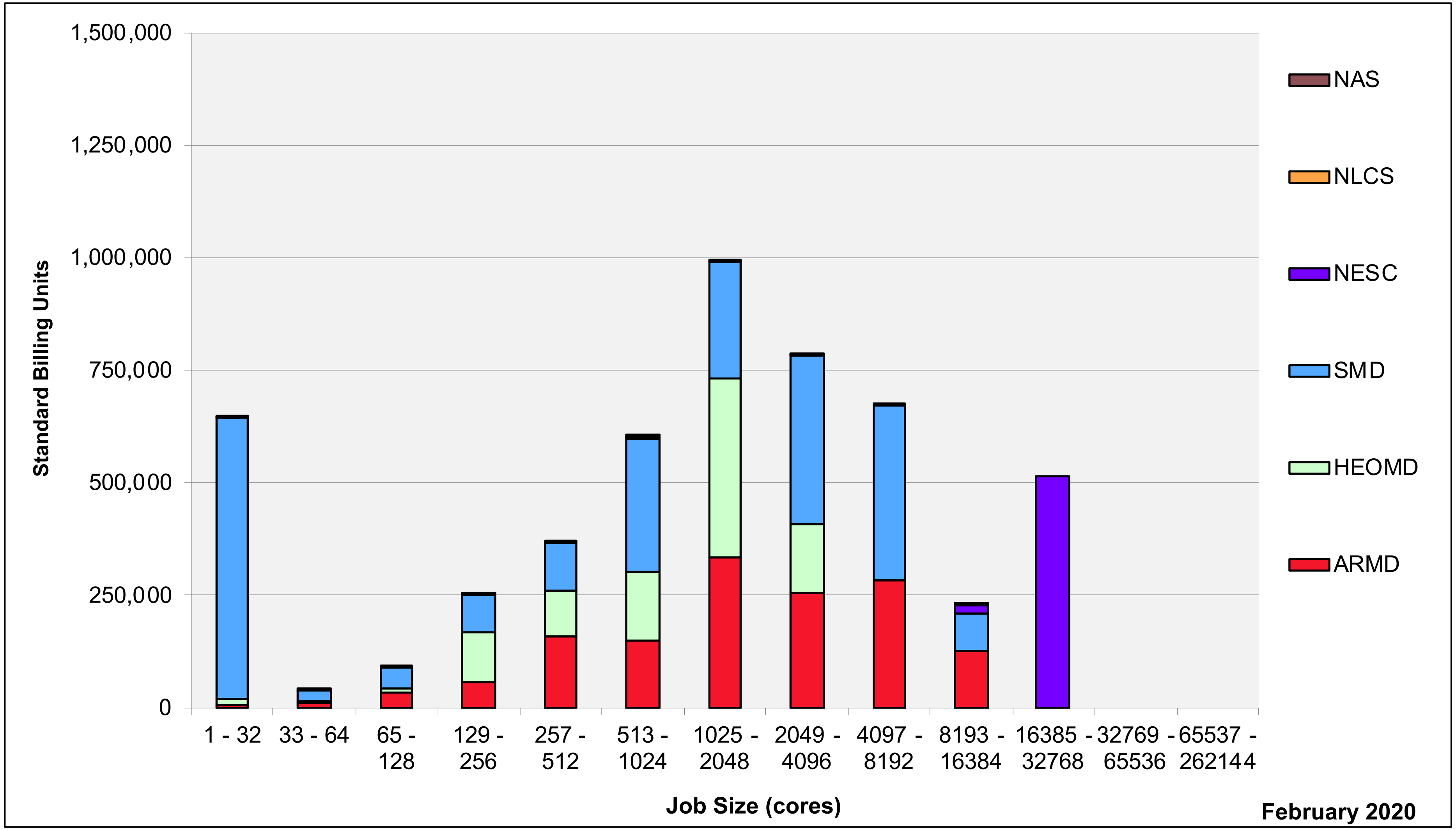
Pleiades: Devel Queue Utilization



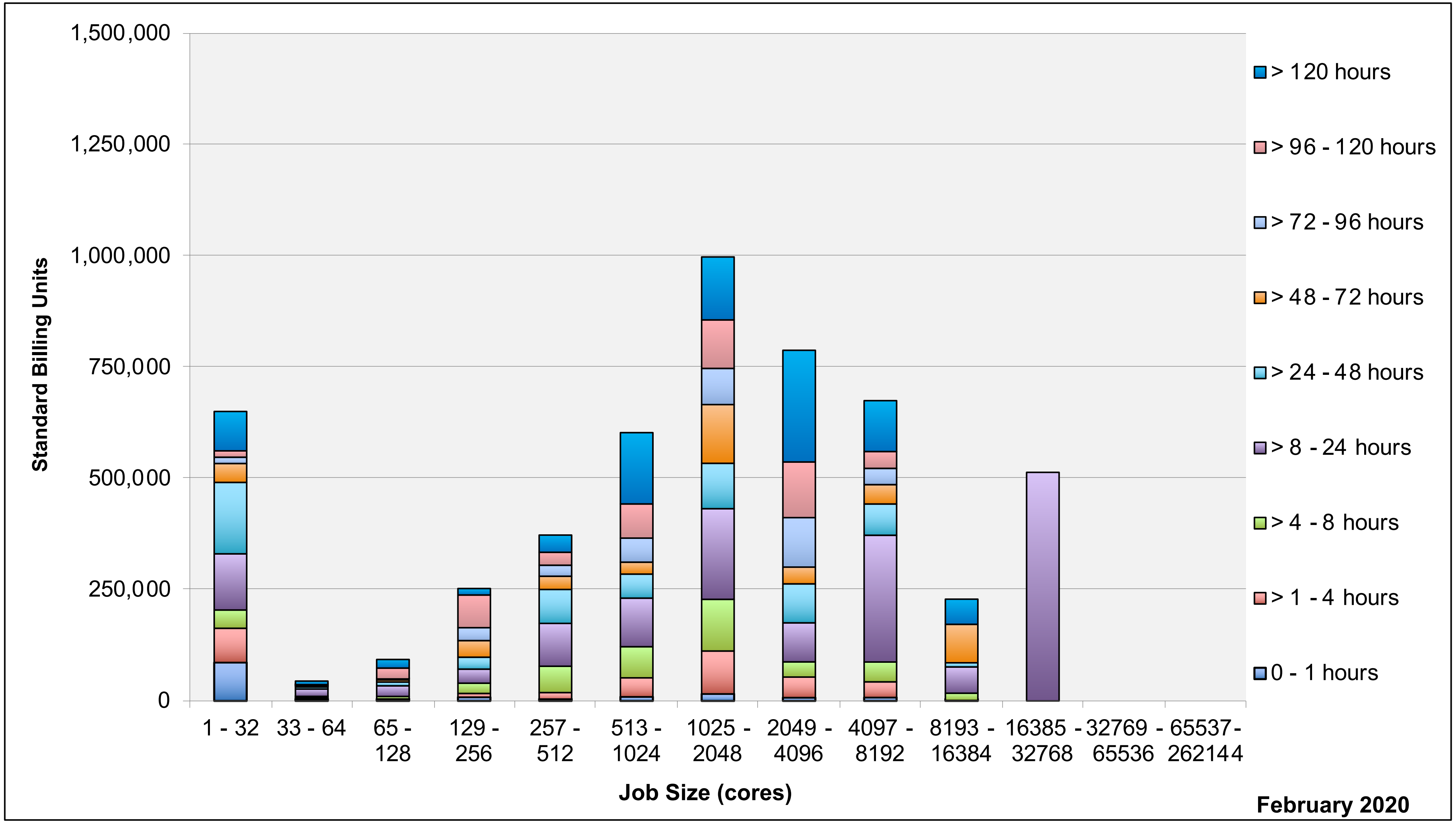
Pleiades: Monthly Utilization by Job Length



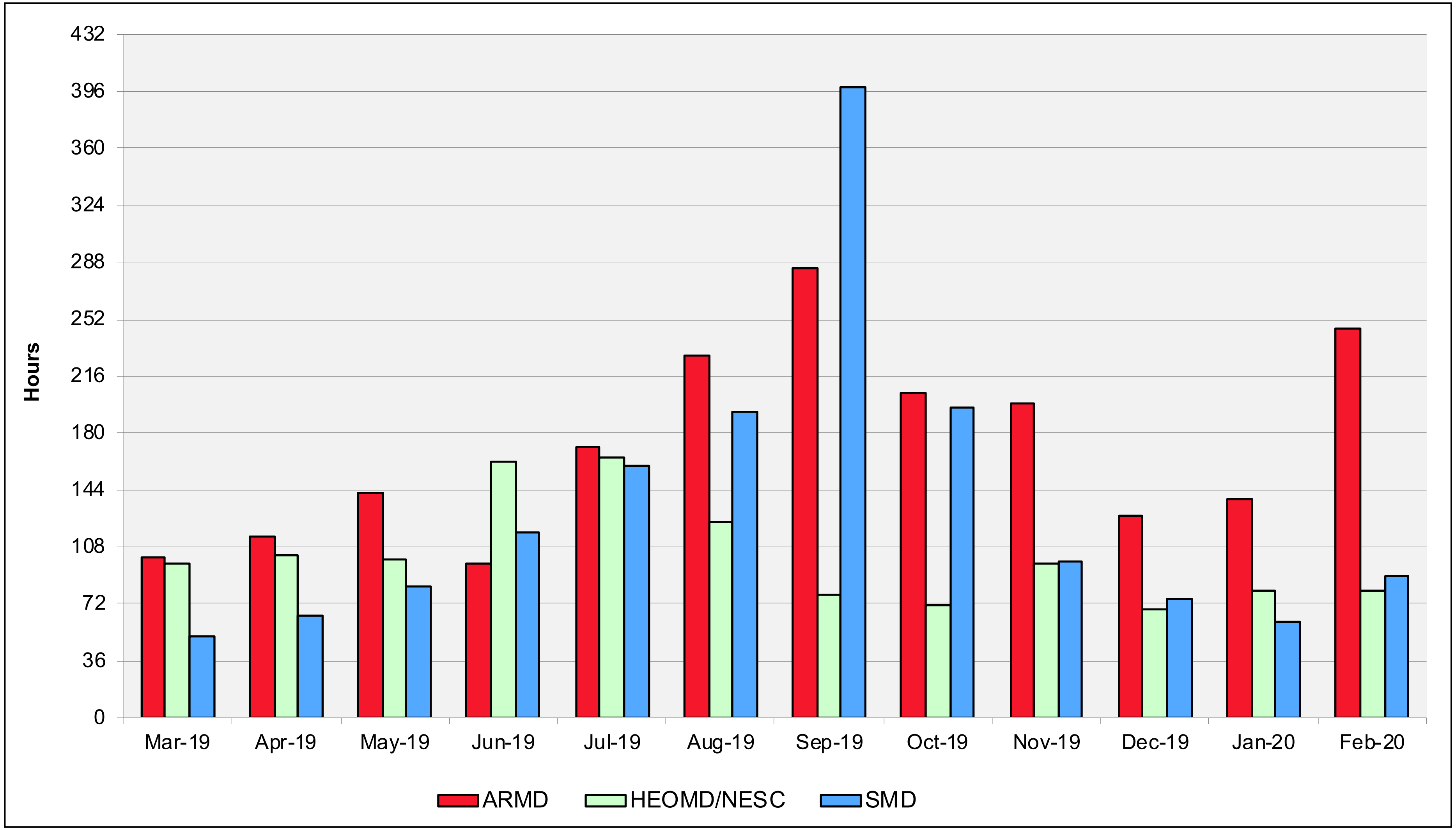
Pleiades: Monthly Utilization by Job Length



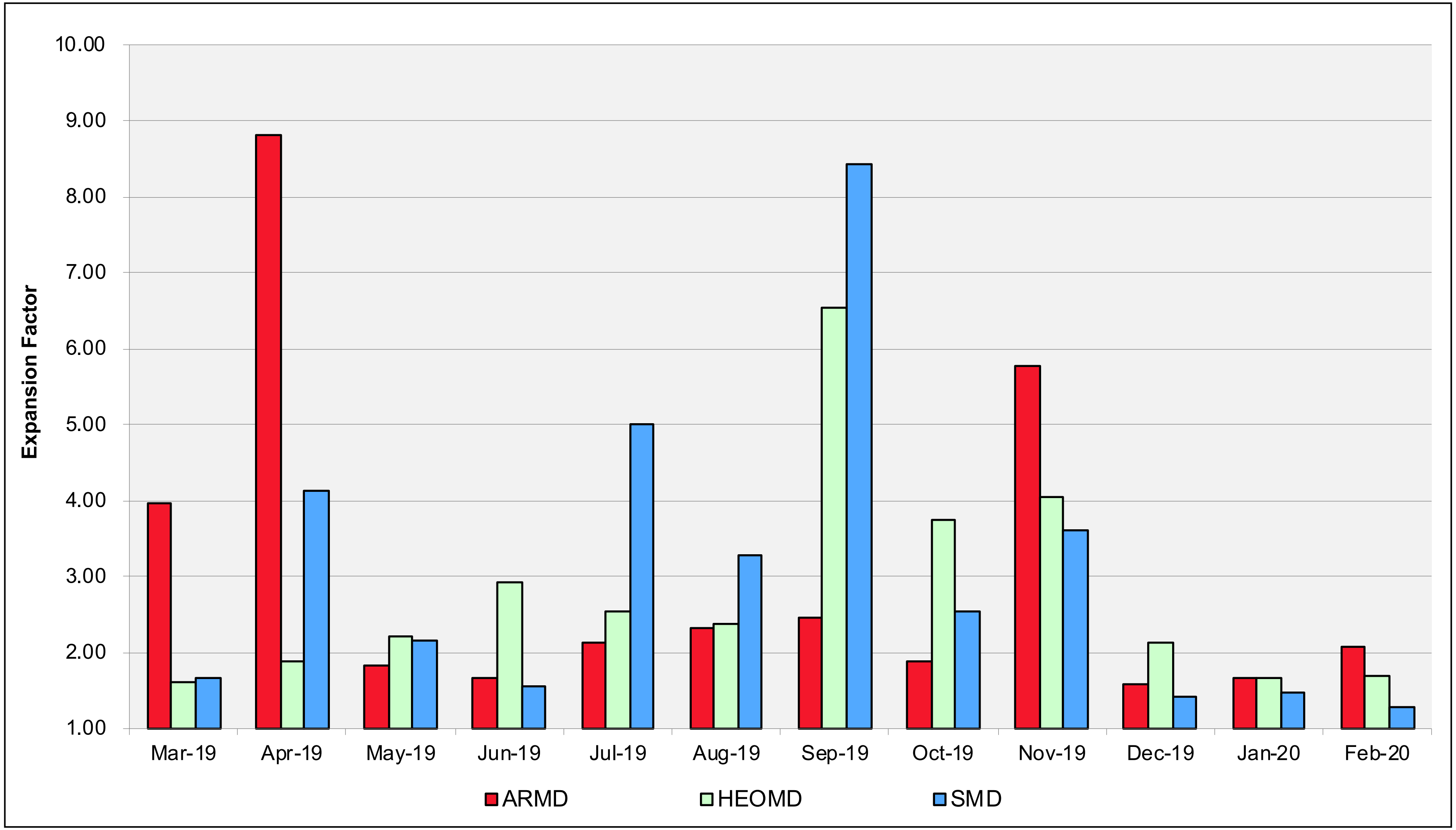
Pleiades: Monthly Utilization by Size and Length



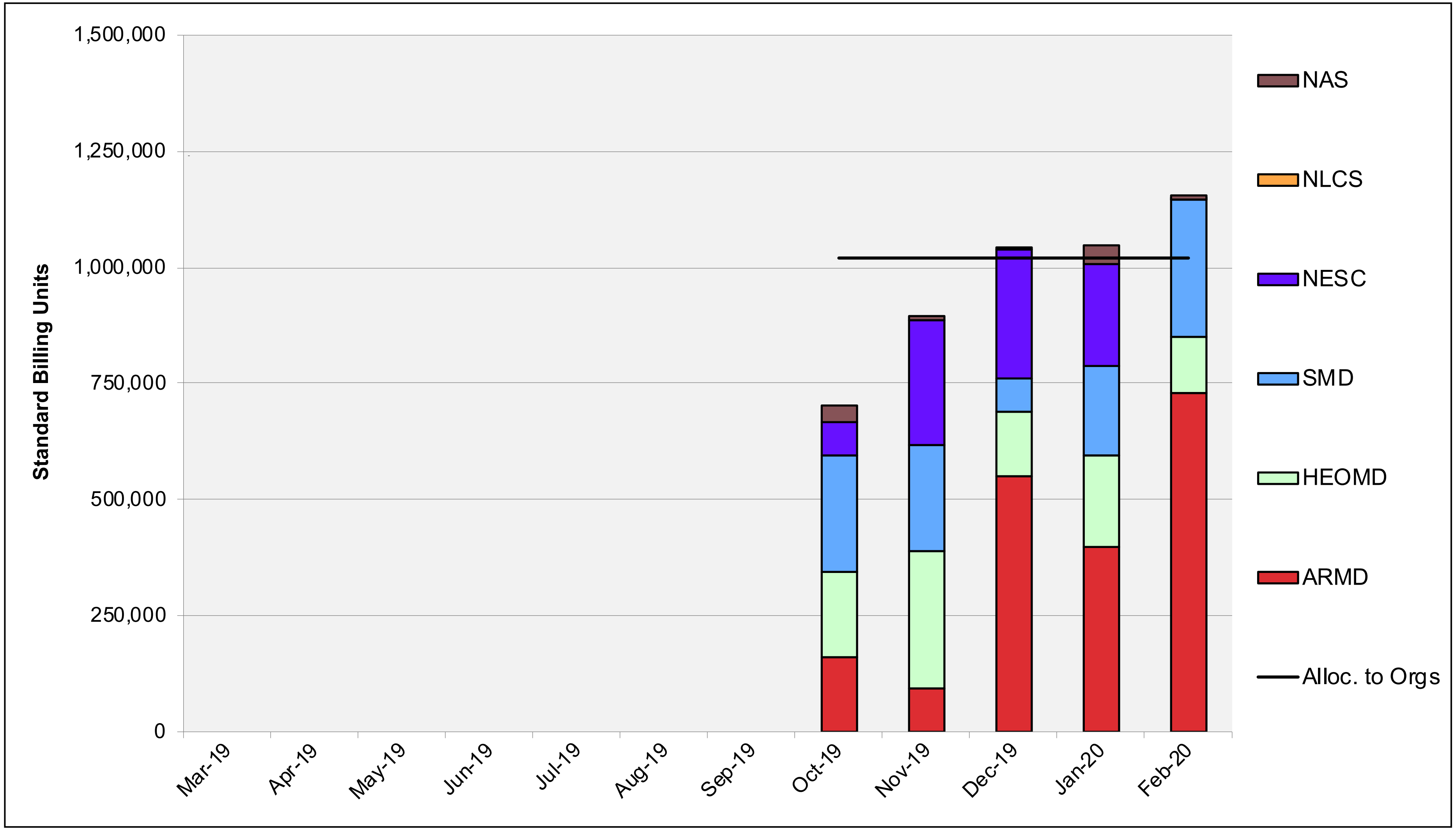
Pleiades: Average Time to Clear All Jobs



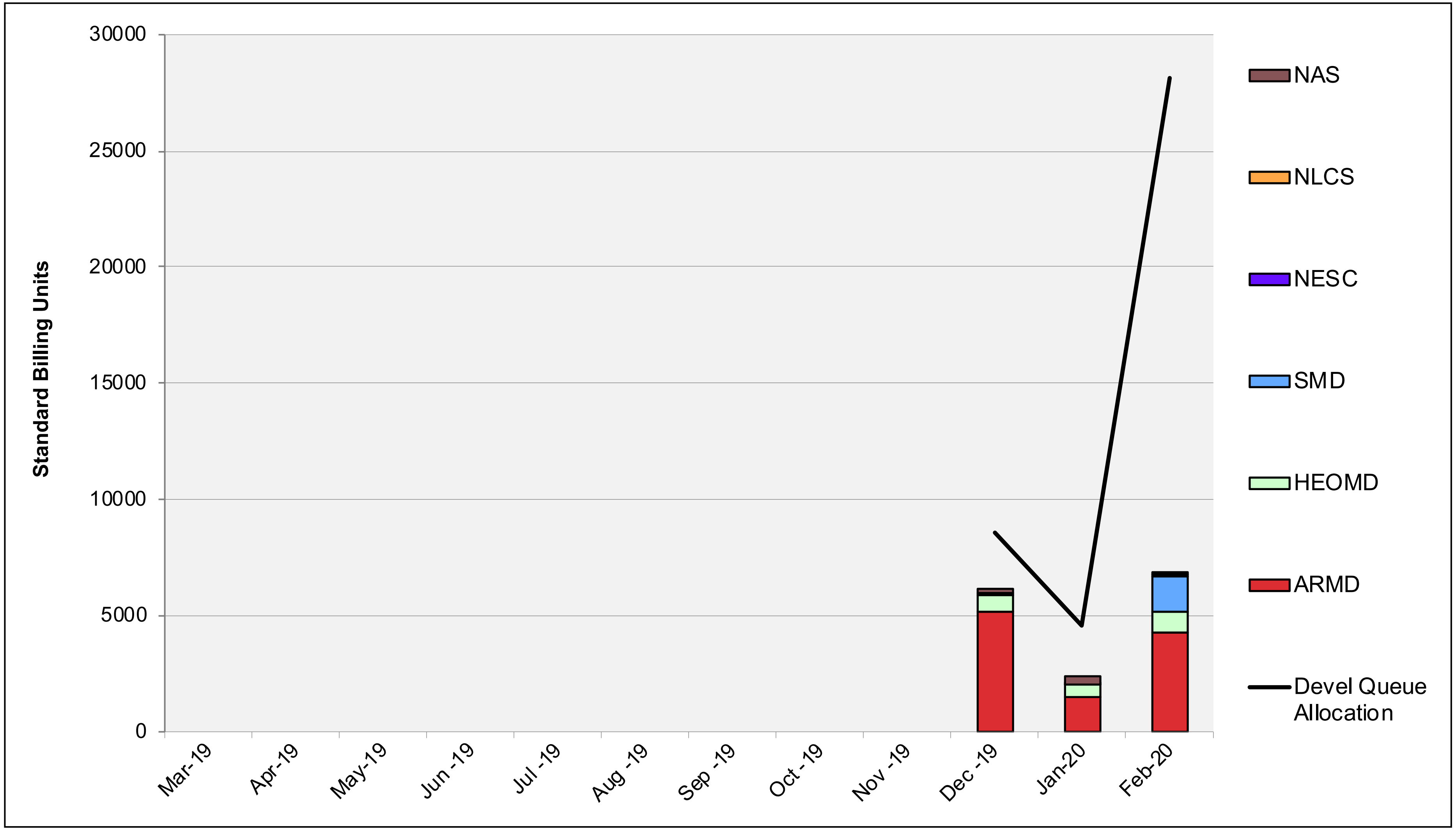
Pleiades: Average Expansion Factor



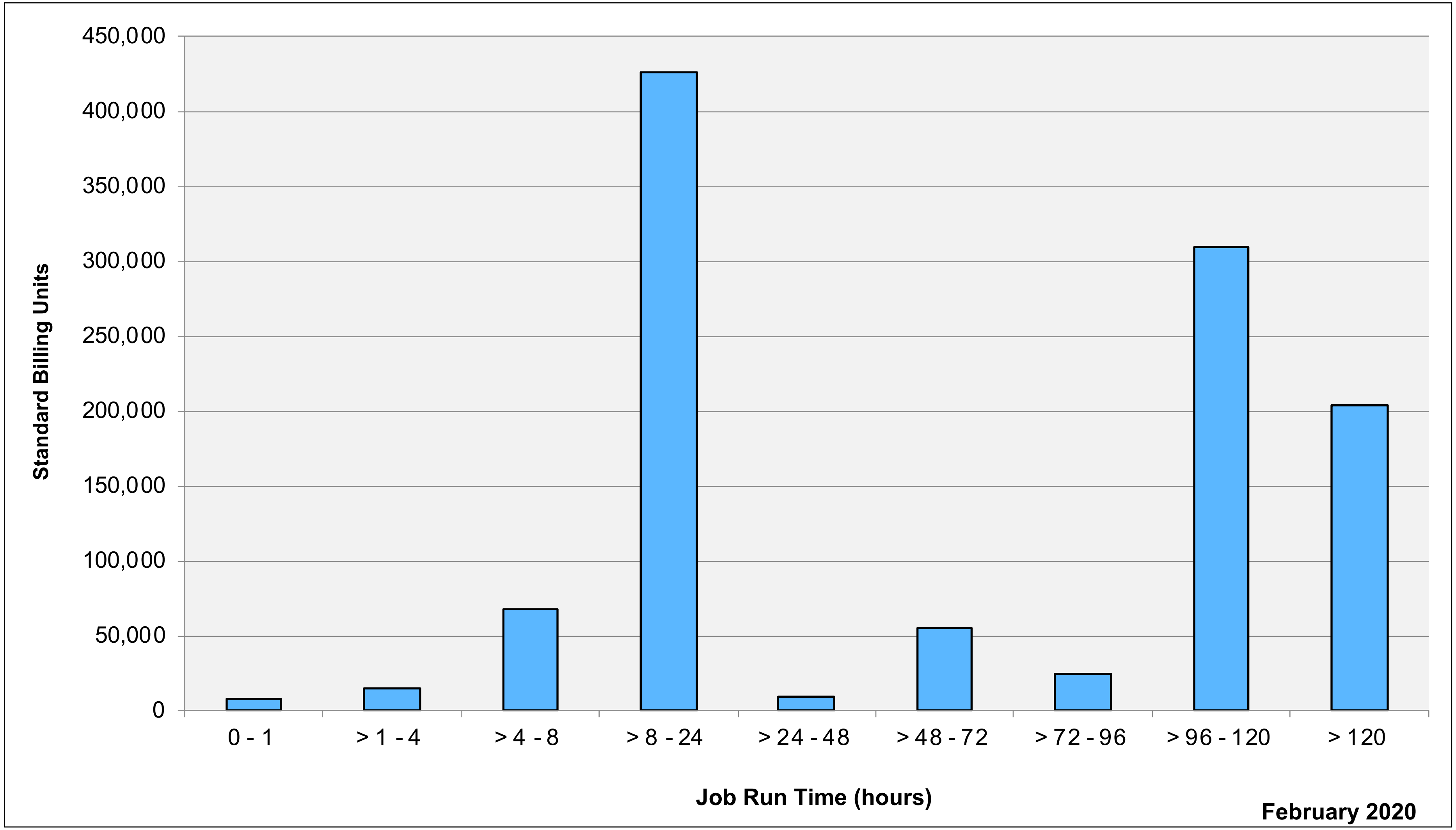
Aitken: SBUs Reported, Normalized to 30-Day Month



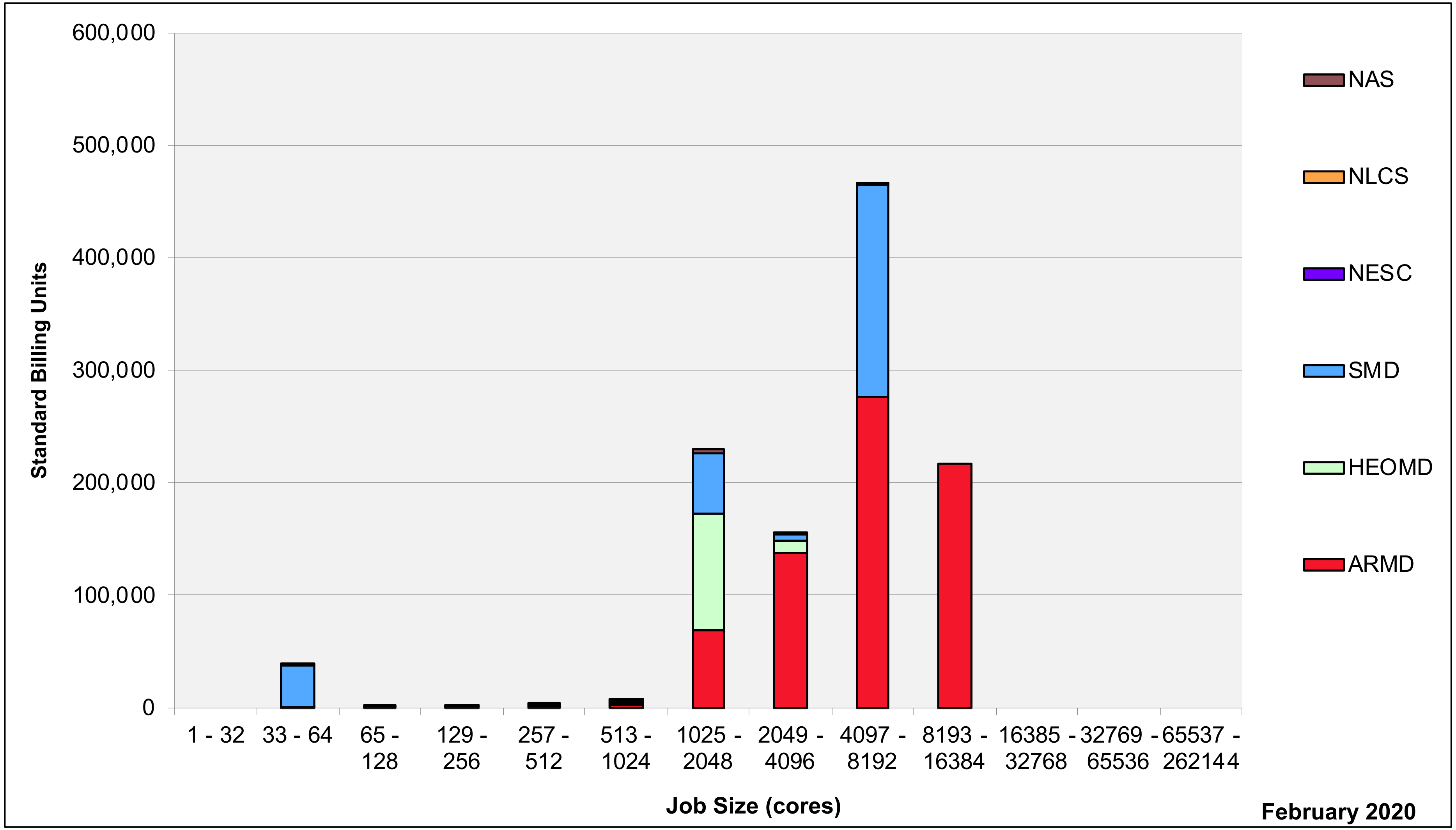
Aitken: Devel Queue Utilization



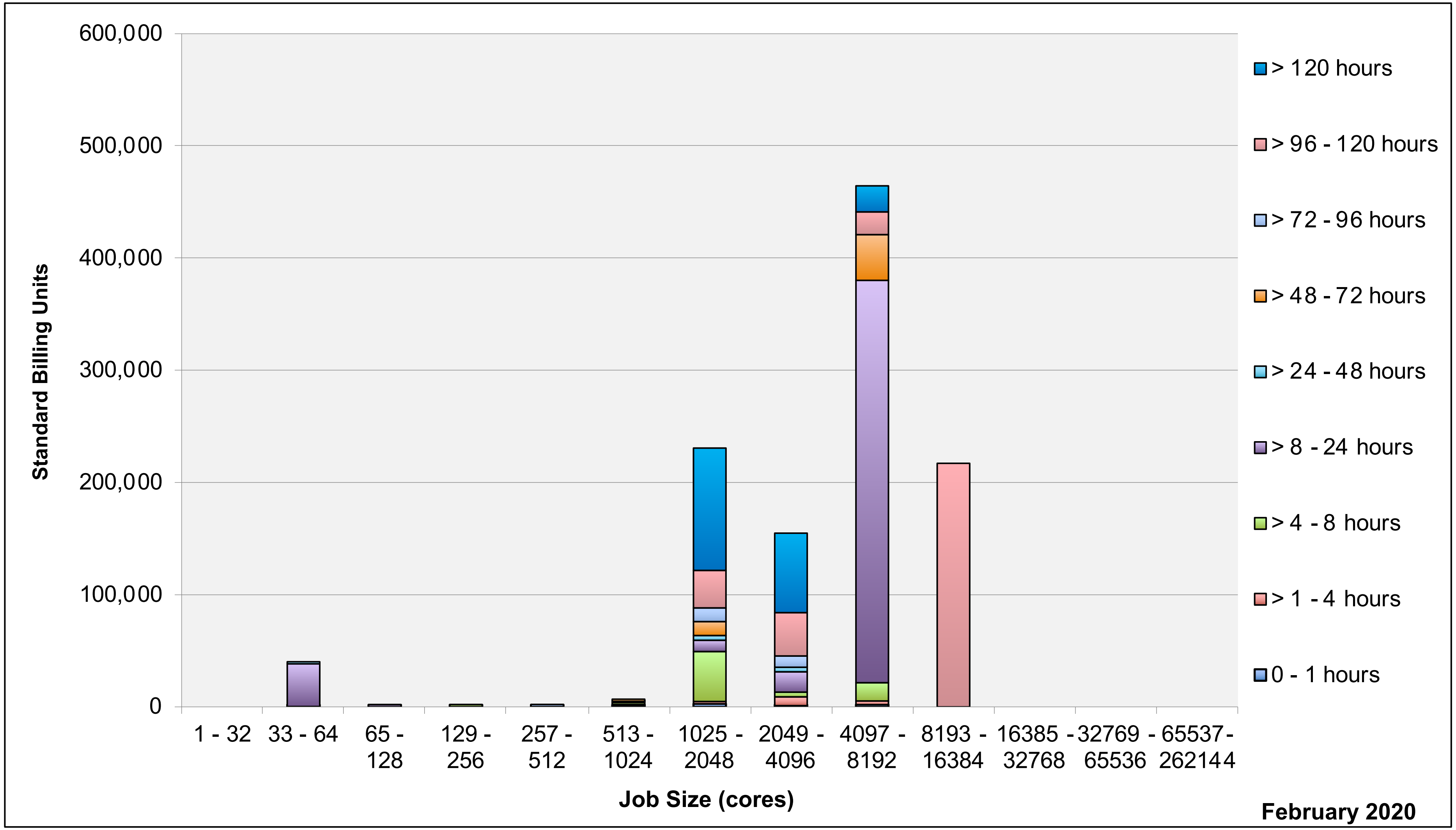
Aitken: Monthly Utilization by Job Length



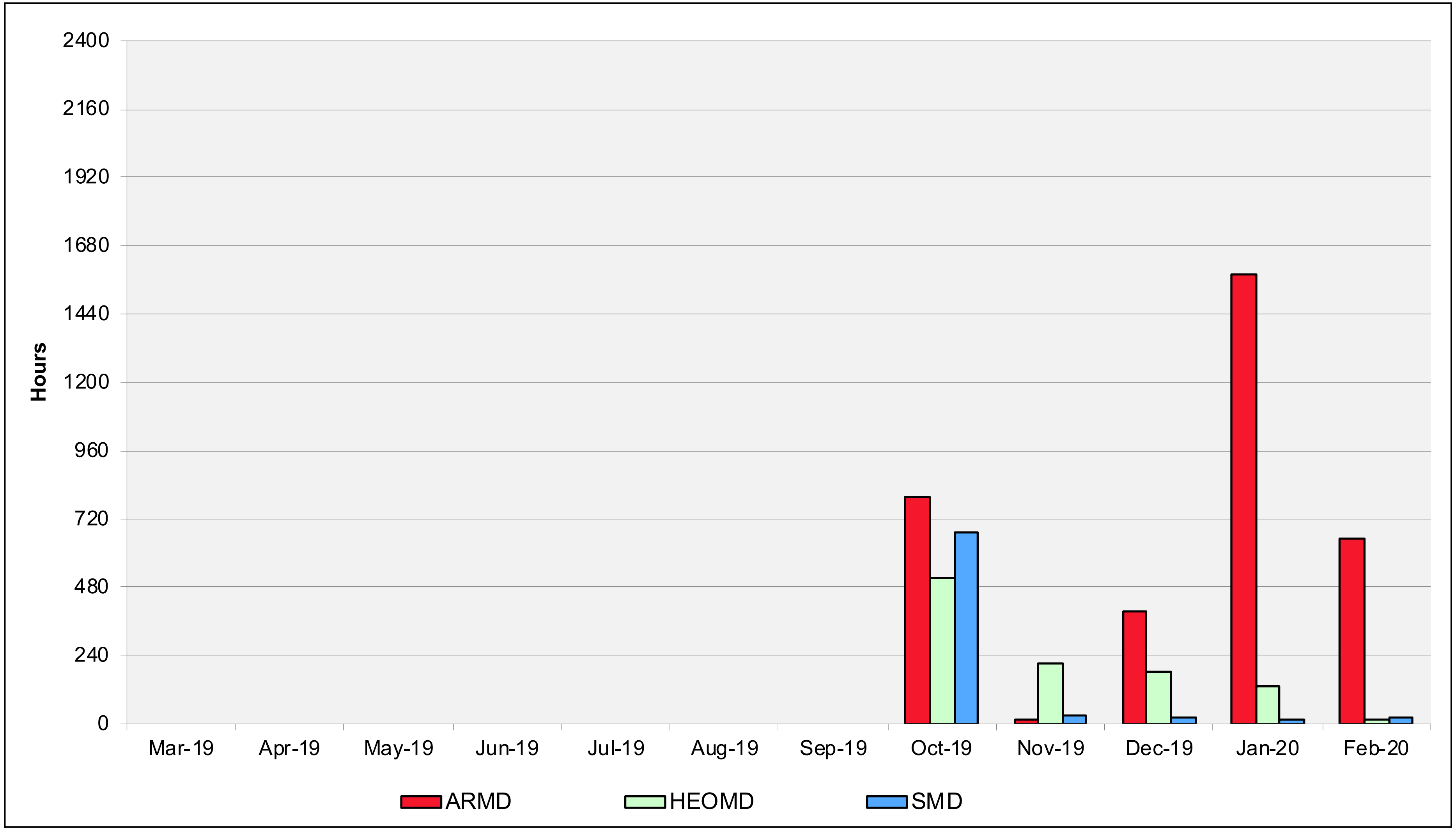
Aitken: Monthly Utilization by Job Length



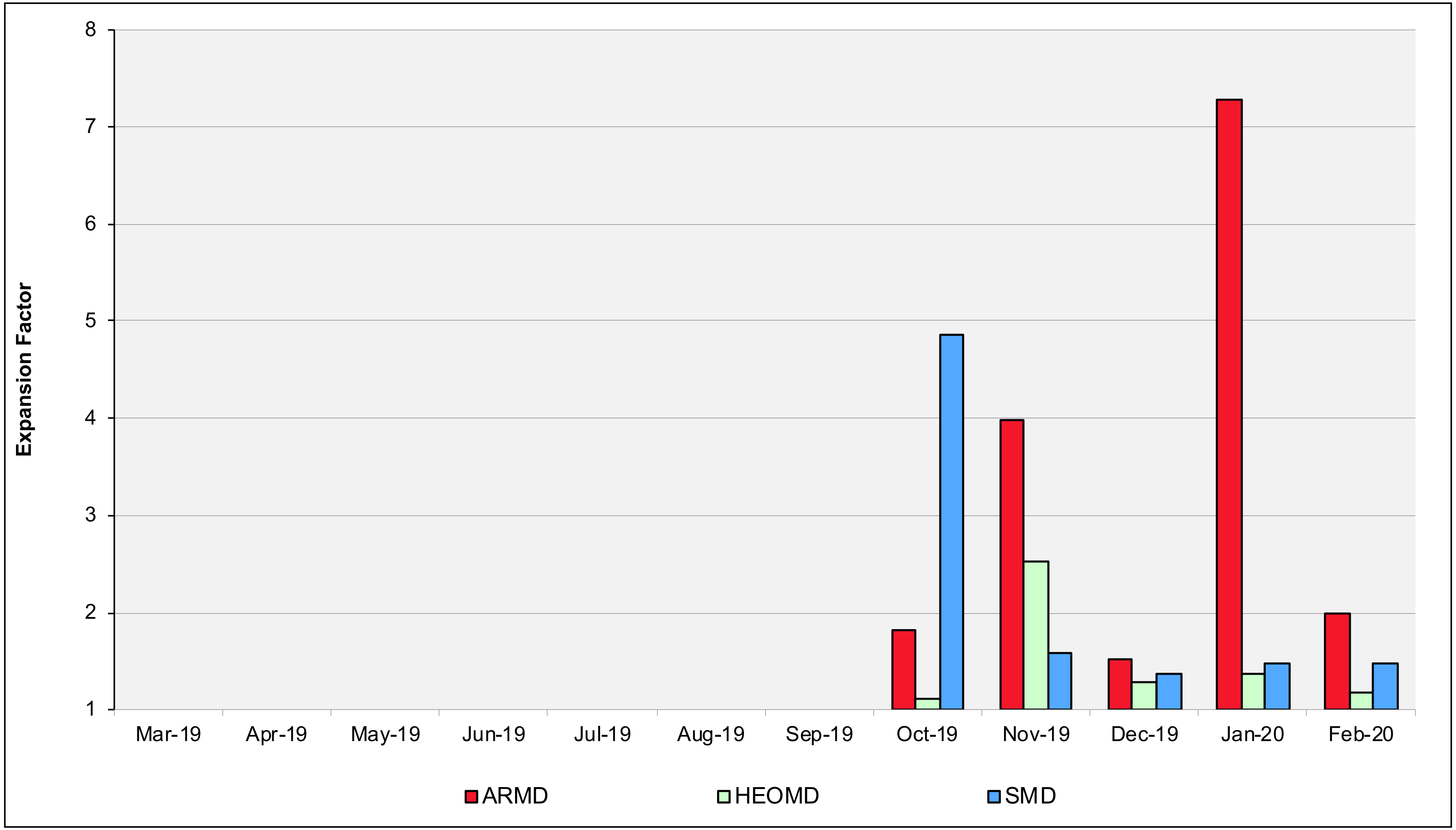
Aitken: Monthly Utilization by Size and Length



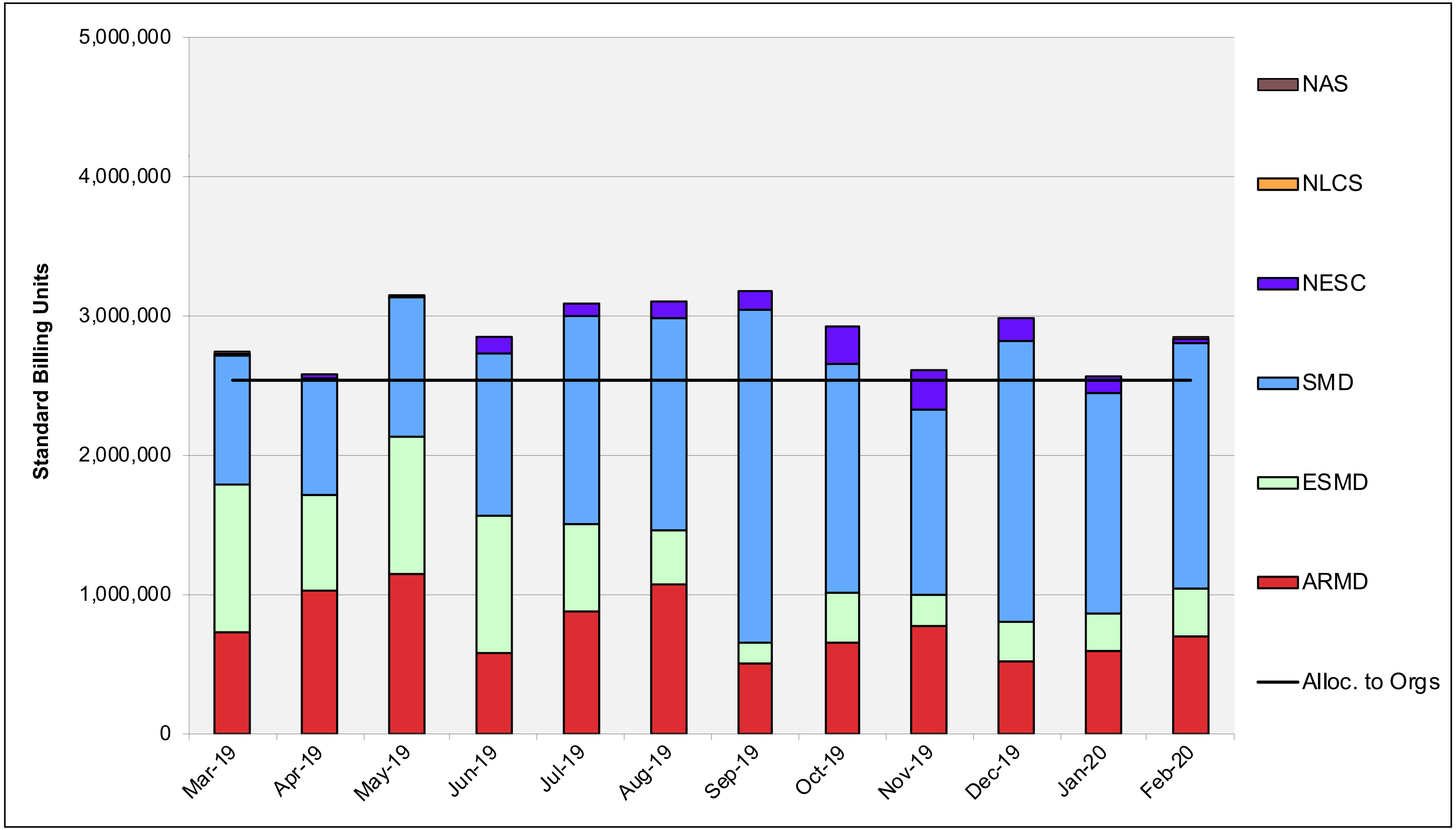
Aitken: Average Time to Clear All Jobs



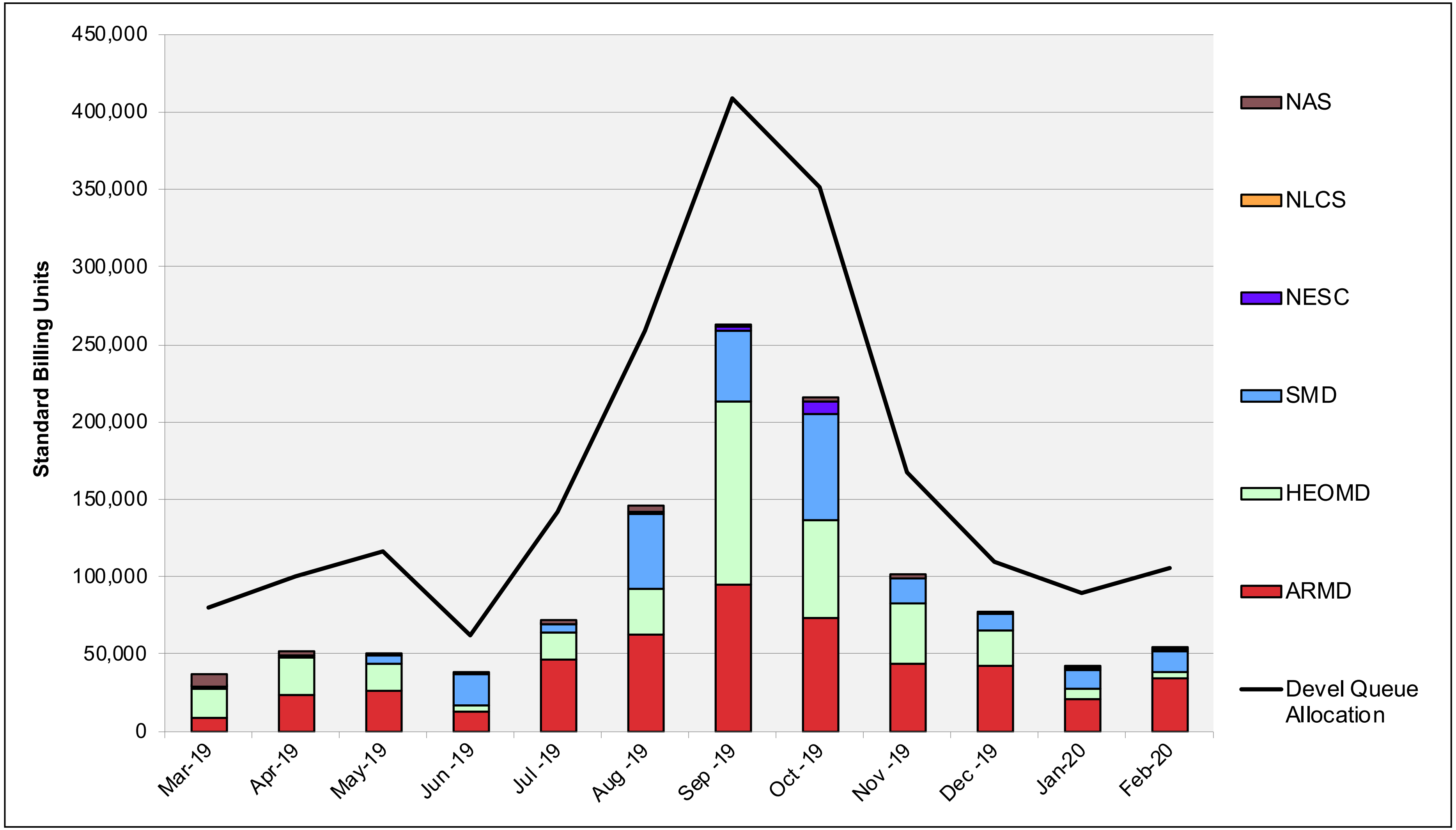
Aitken: Average Expansion Factor



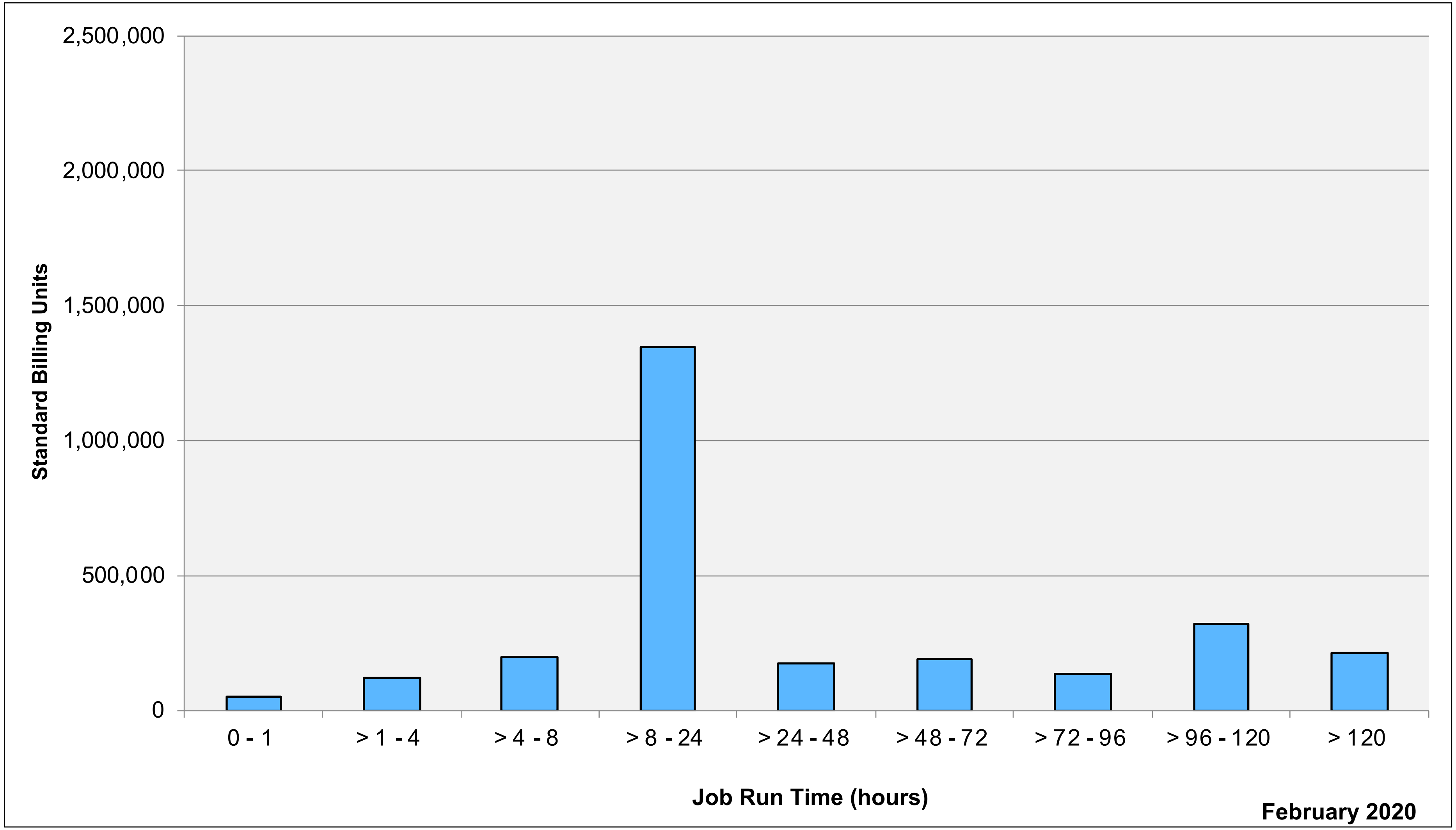
Electra: SBUs Reported, Normalized to 30-Day Month



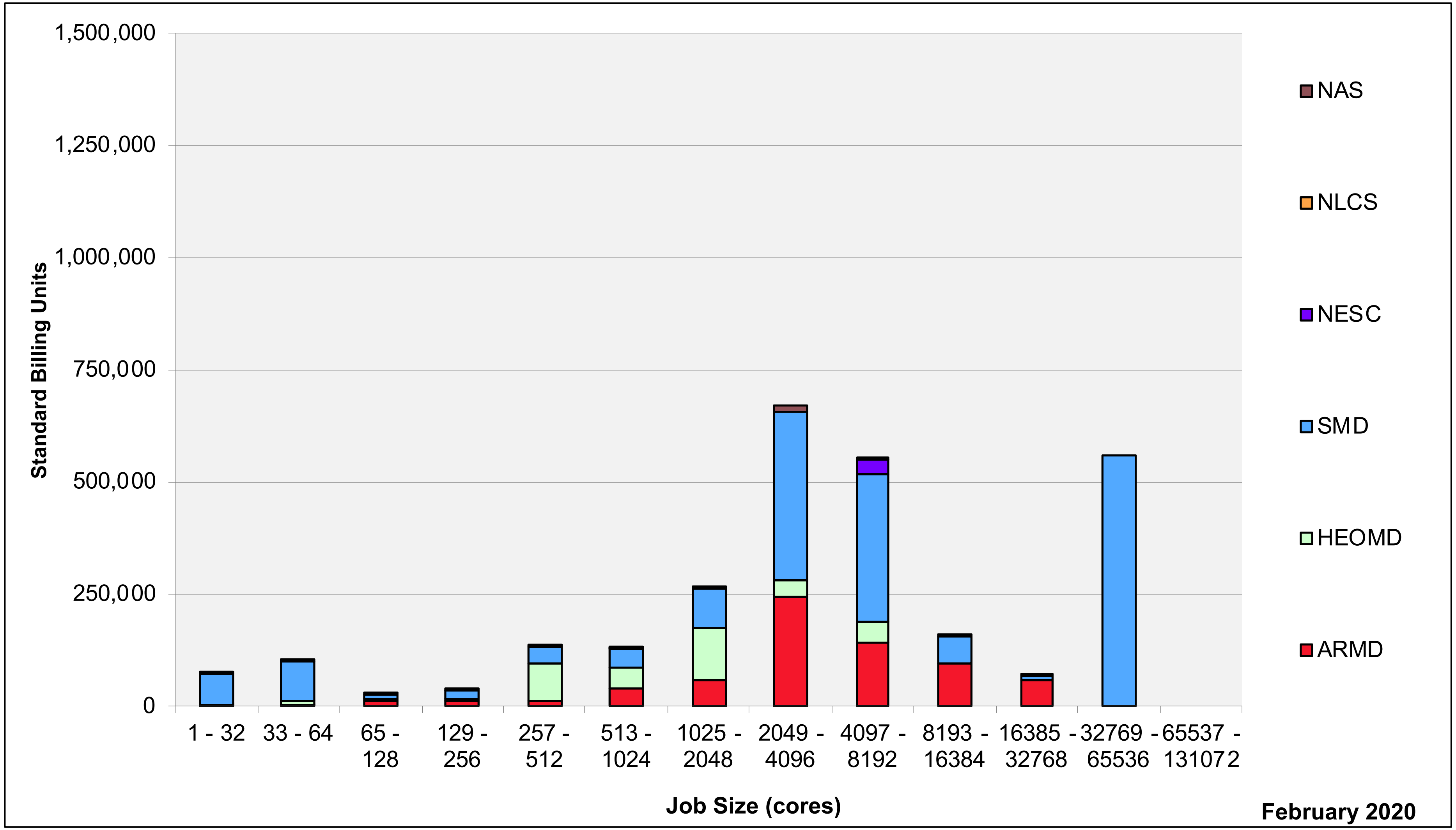
Electra: Devel Queue Utilization



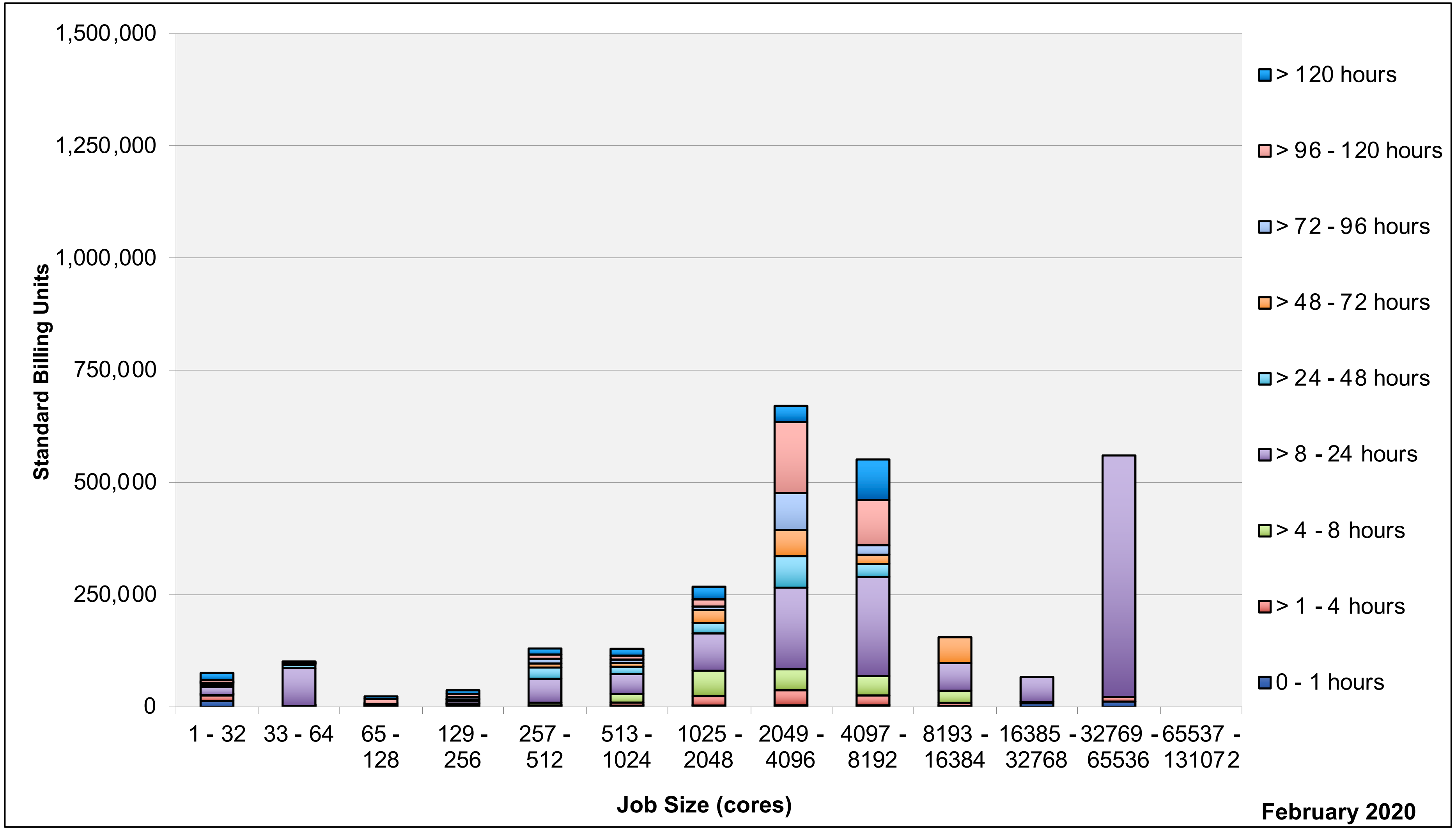
Electra: Monthly Utilization by Job Length



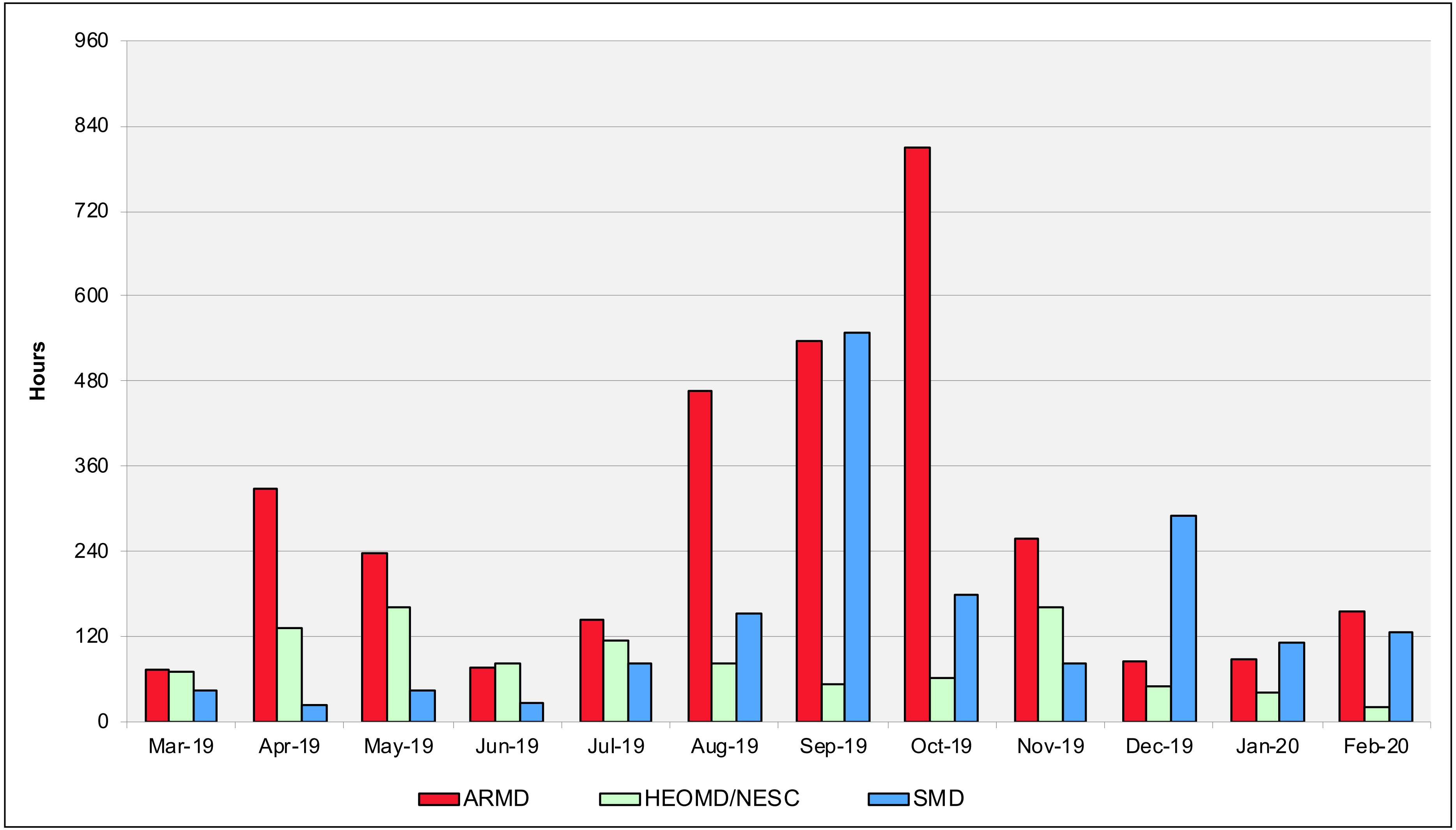
Electra: Monthly Utilization by Job Length



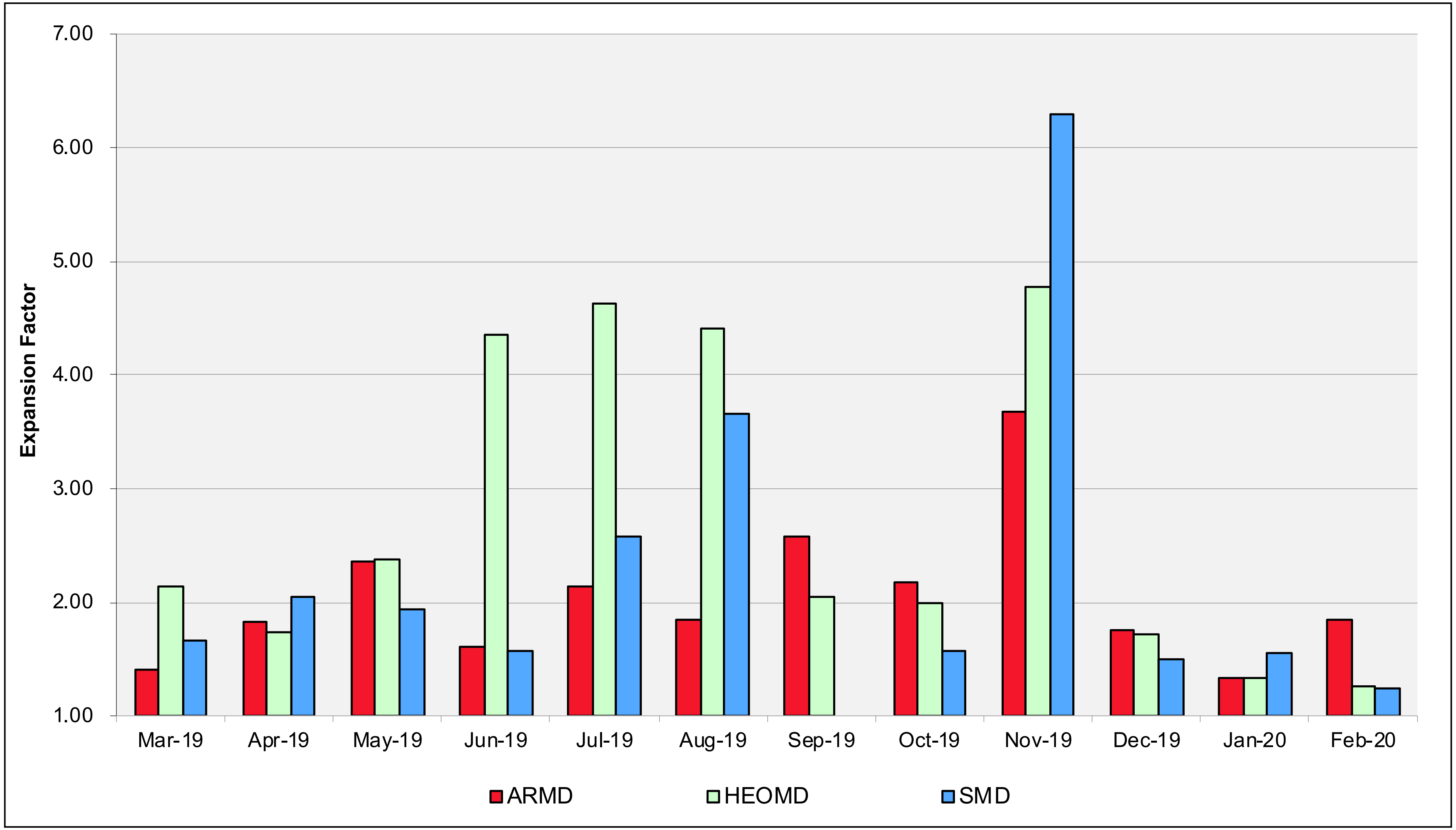
Electra: Monthly Utilization by Size and Length



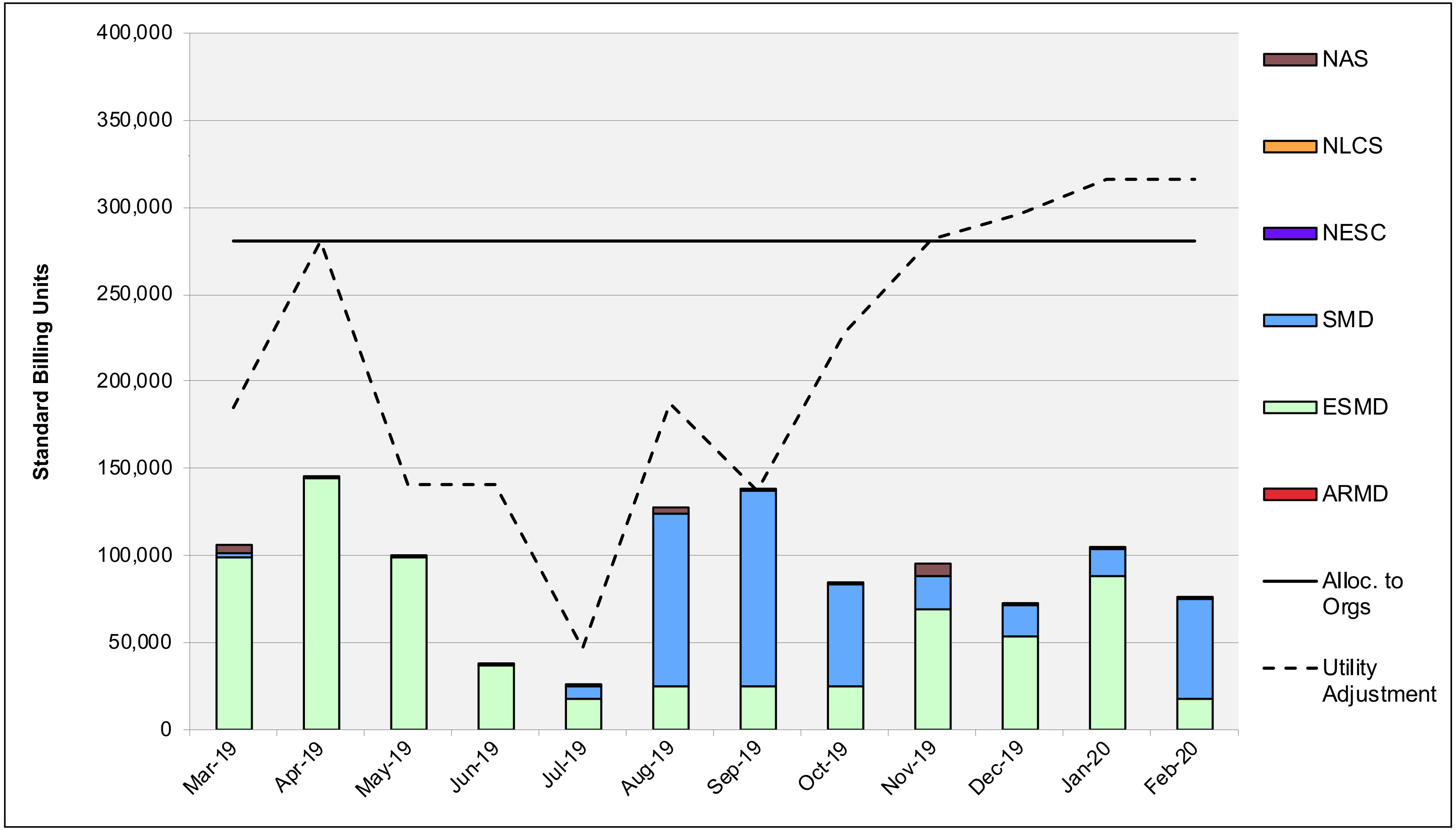
Electra: Average Time to Clear All Jobs



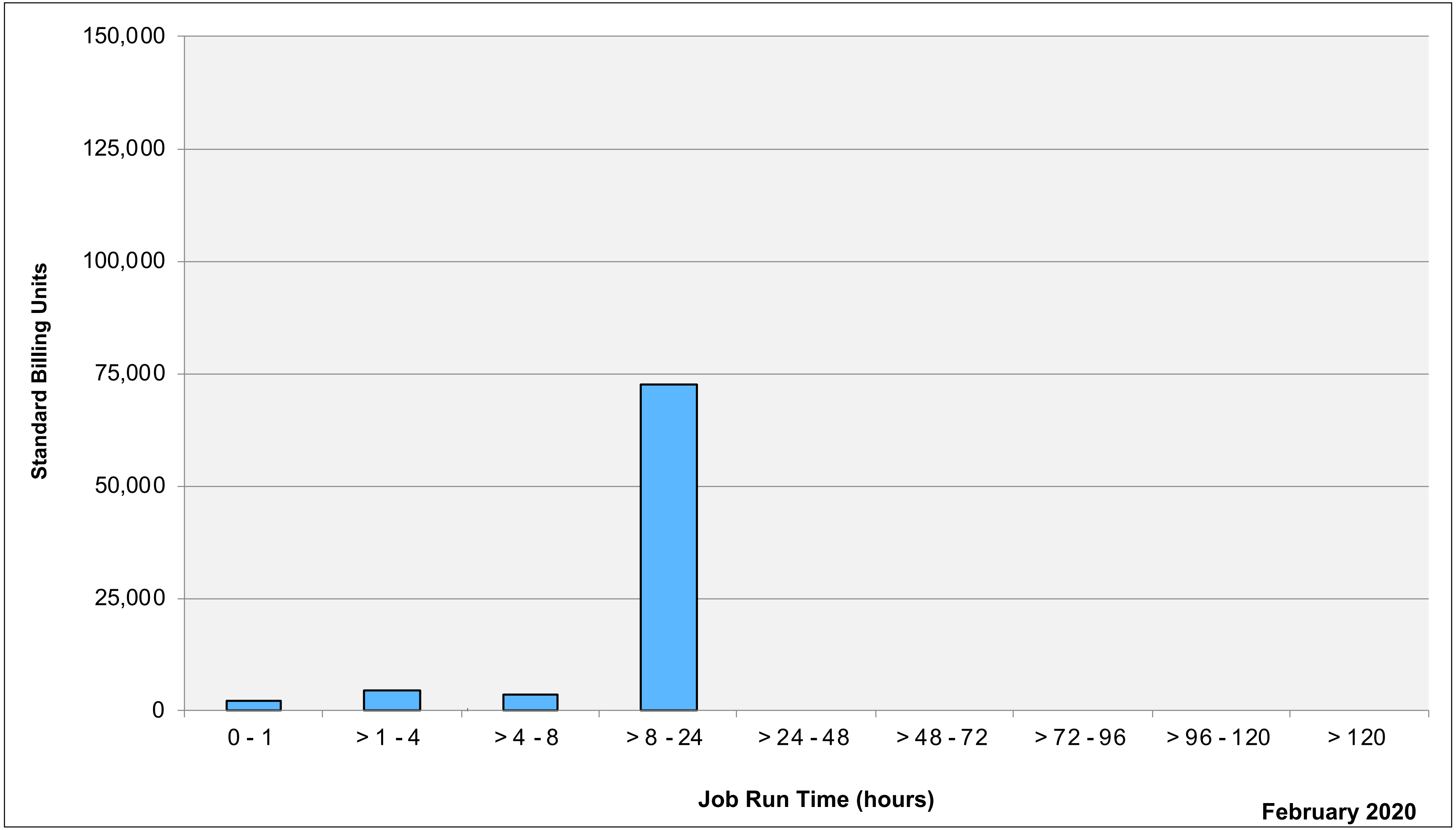
Electra: Average Expansion Factor



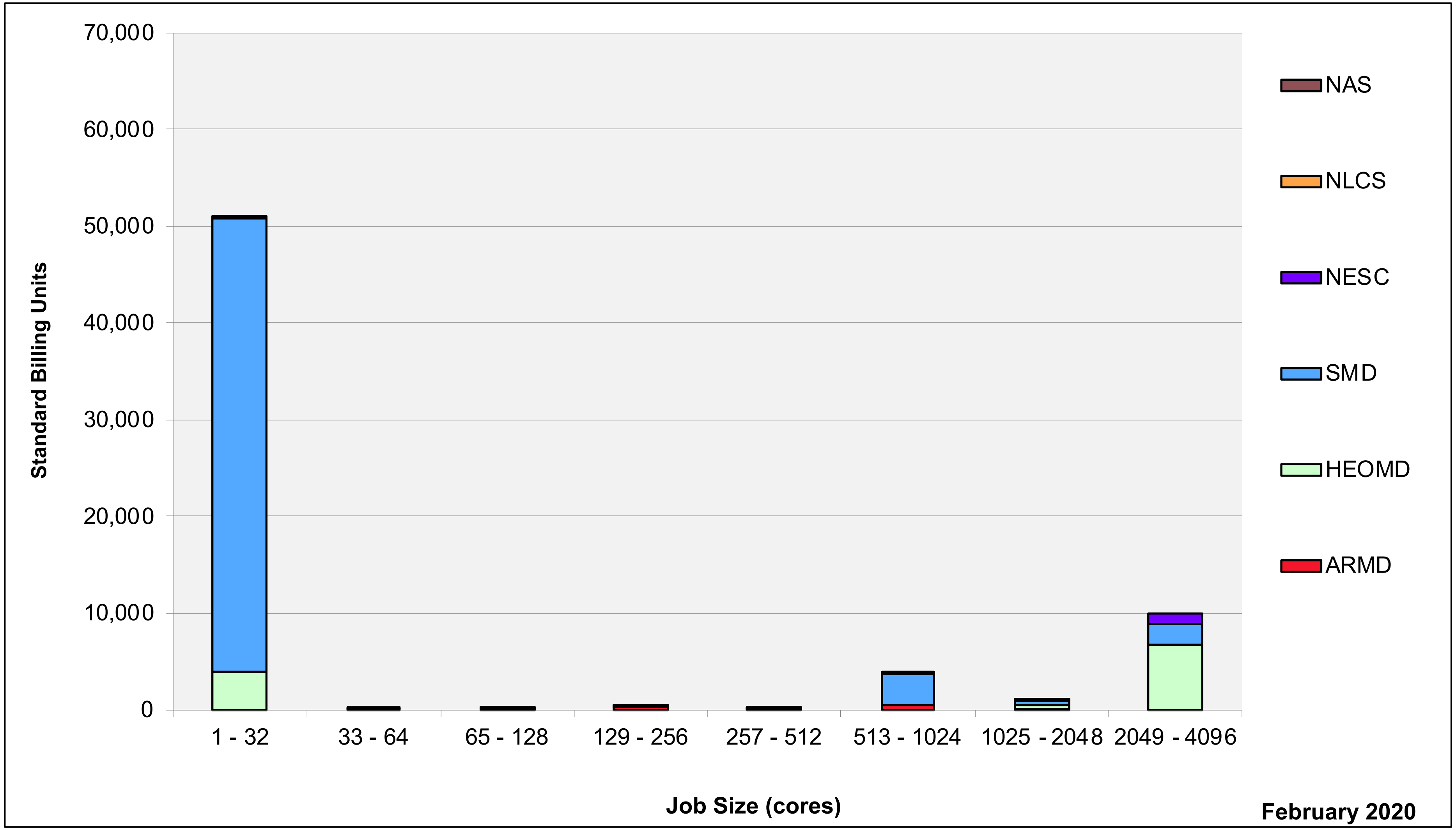
Merope: SBUs Reported, Normalized to 30-Day Month



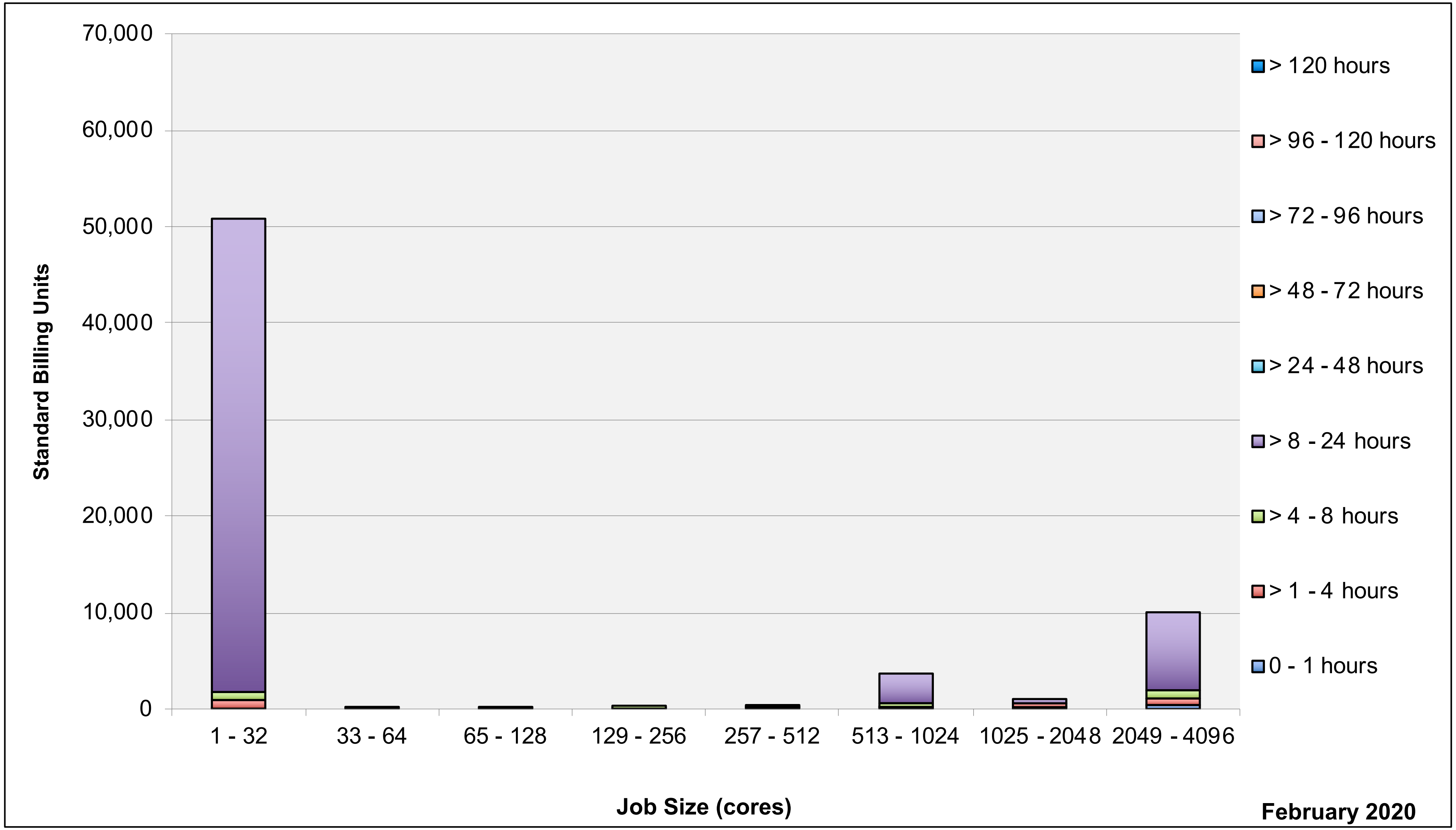
Merope: Monthly Utilization by Job Length



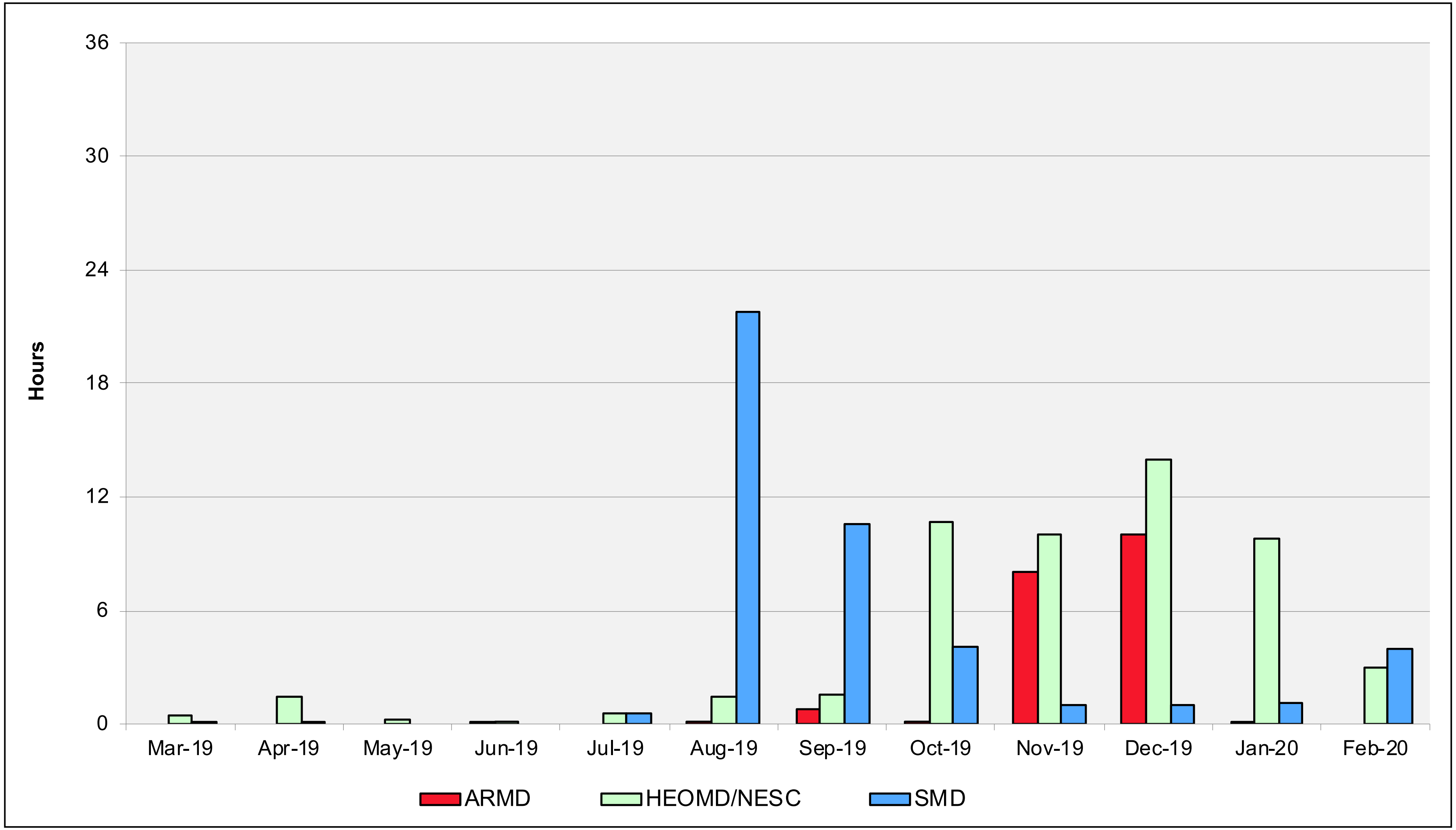
Merope: Monthly Utilization by Job Length



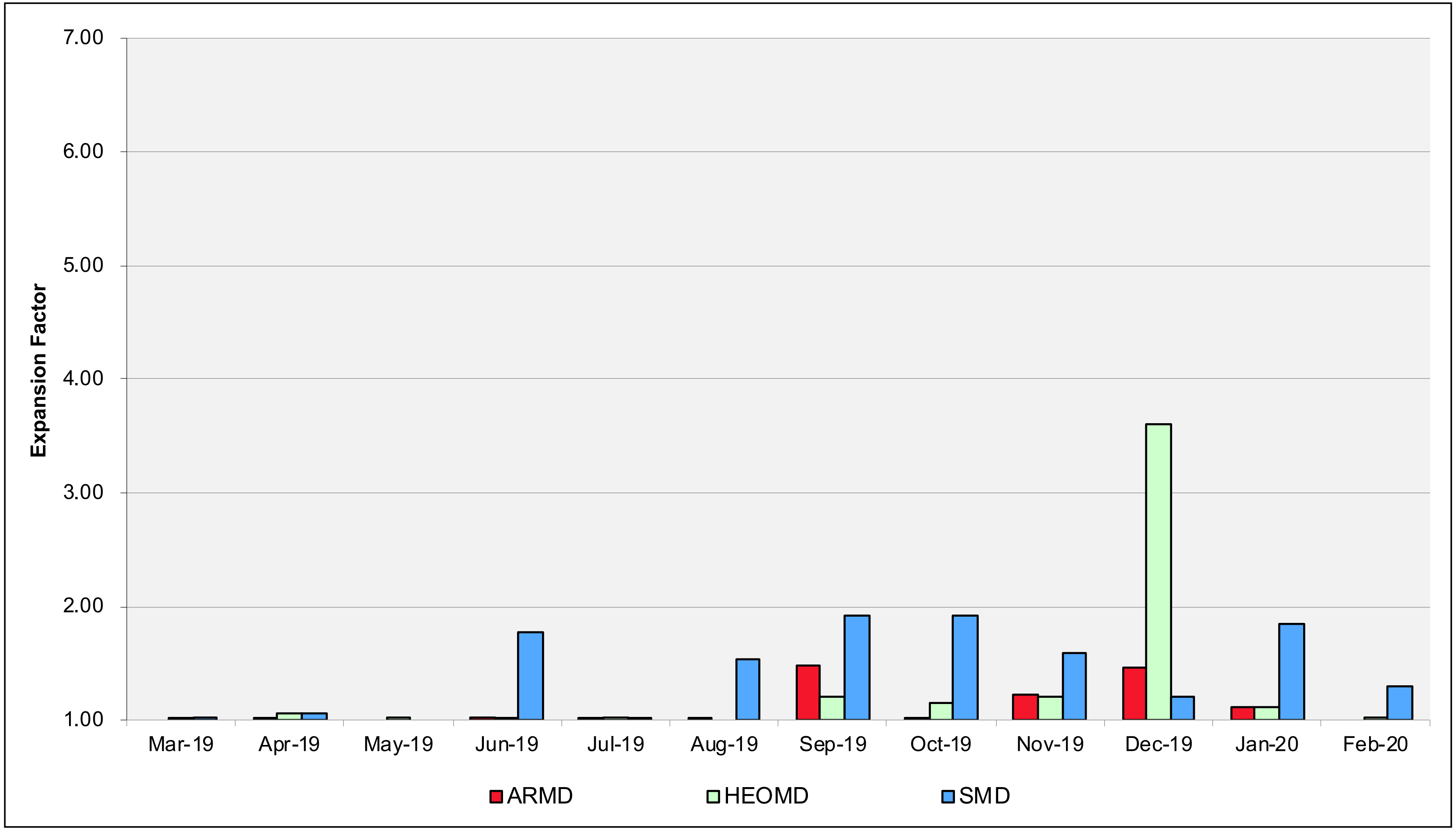
Merope: Monthly Utilization by Size and Length



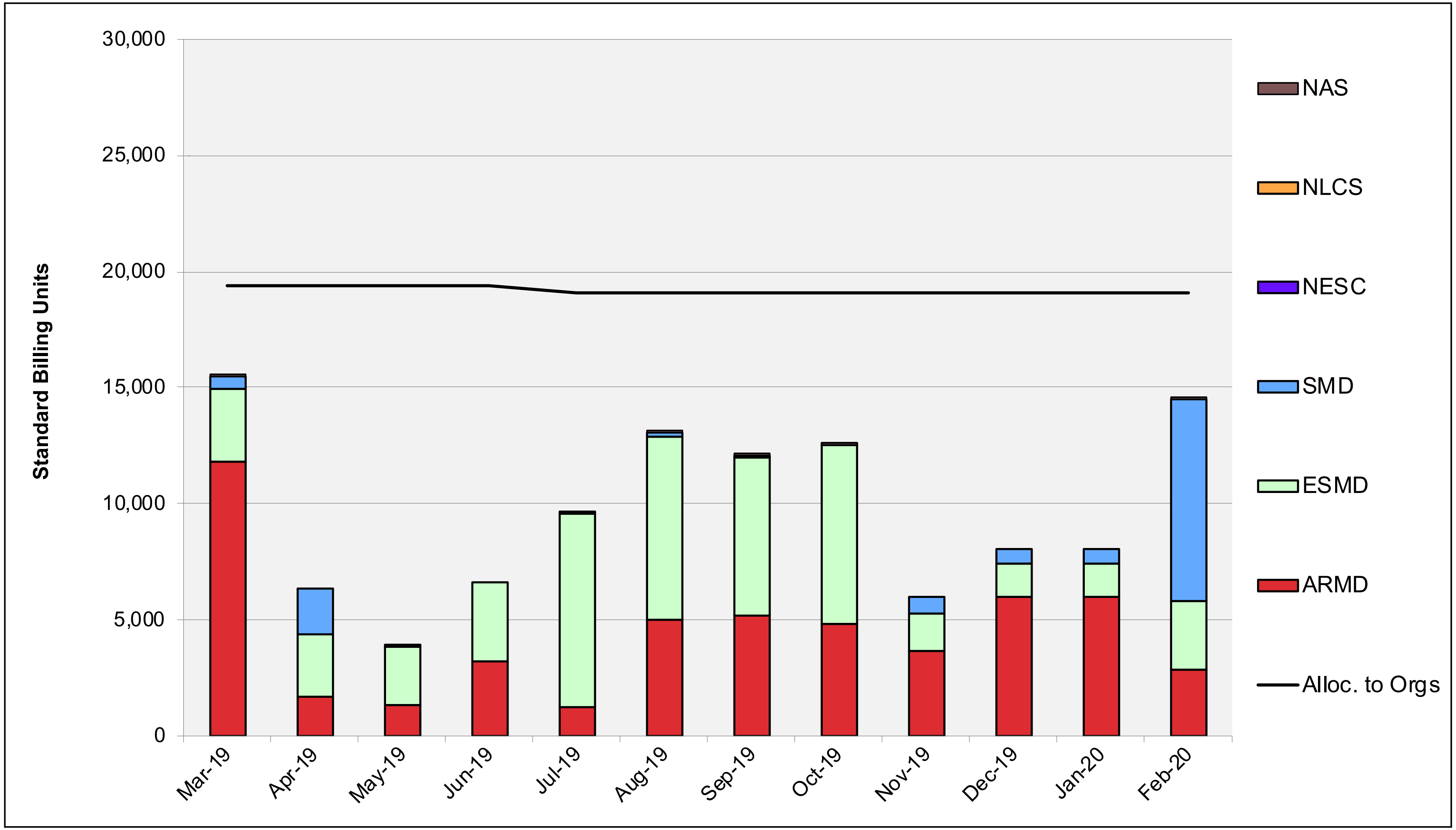
Merope: Average Time to Clear All Jobs



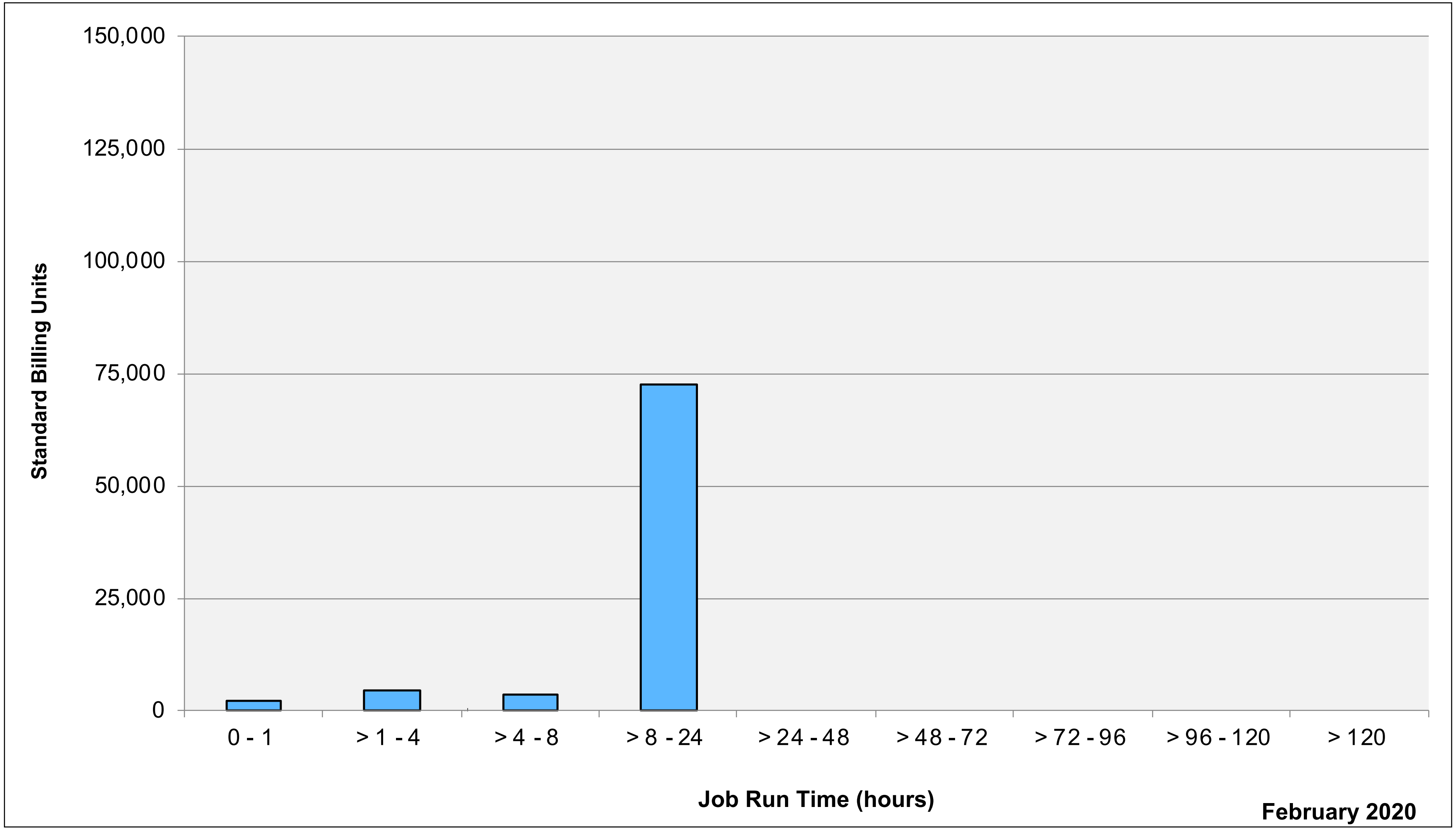
Merope: Average Expansion Factor



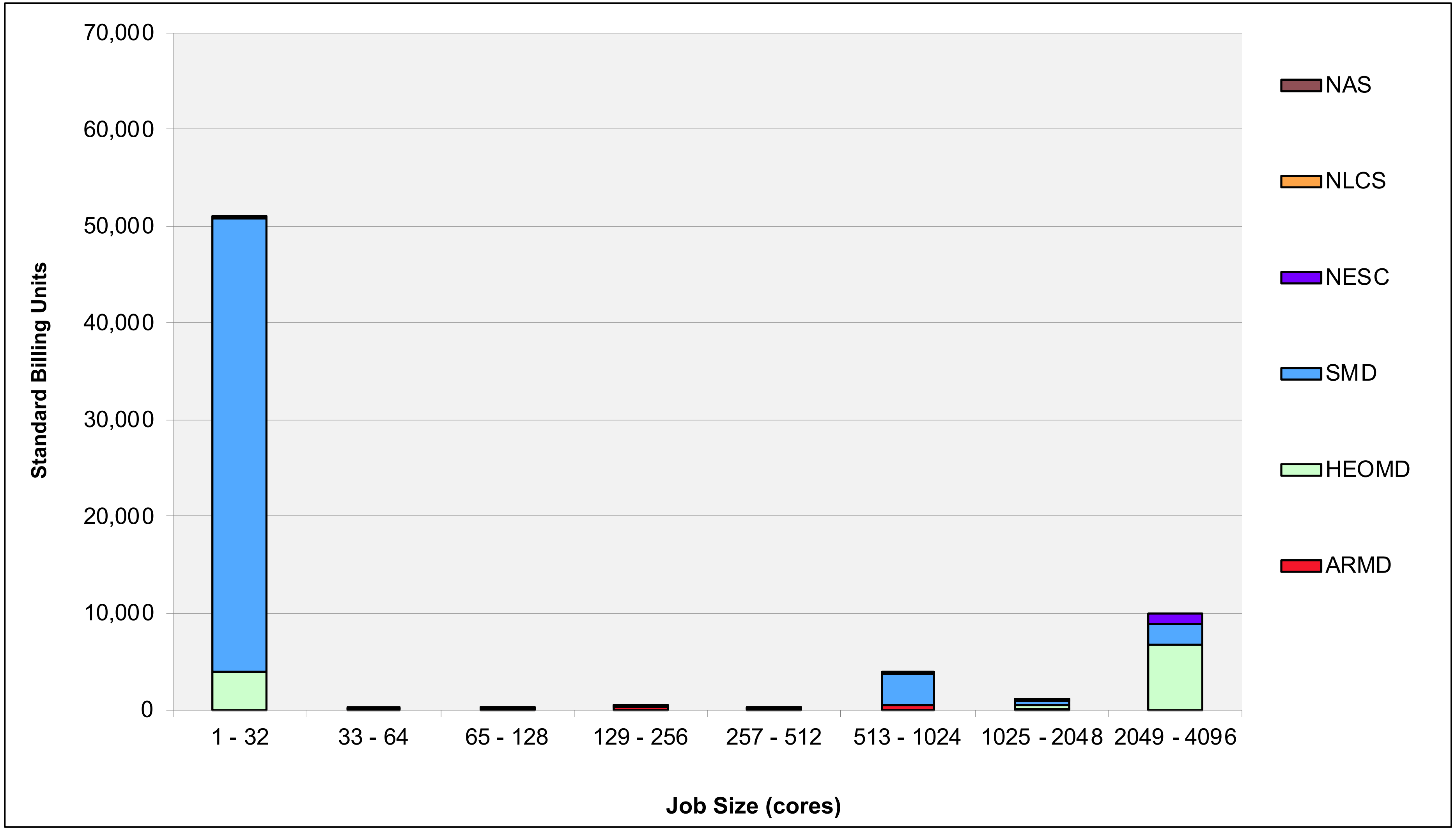
Endeavour: SBUs Reported, Normalized to 30-Day Month



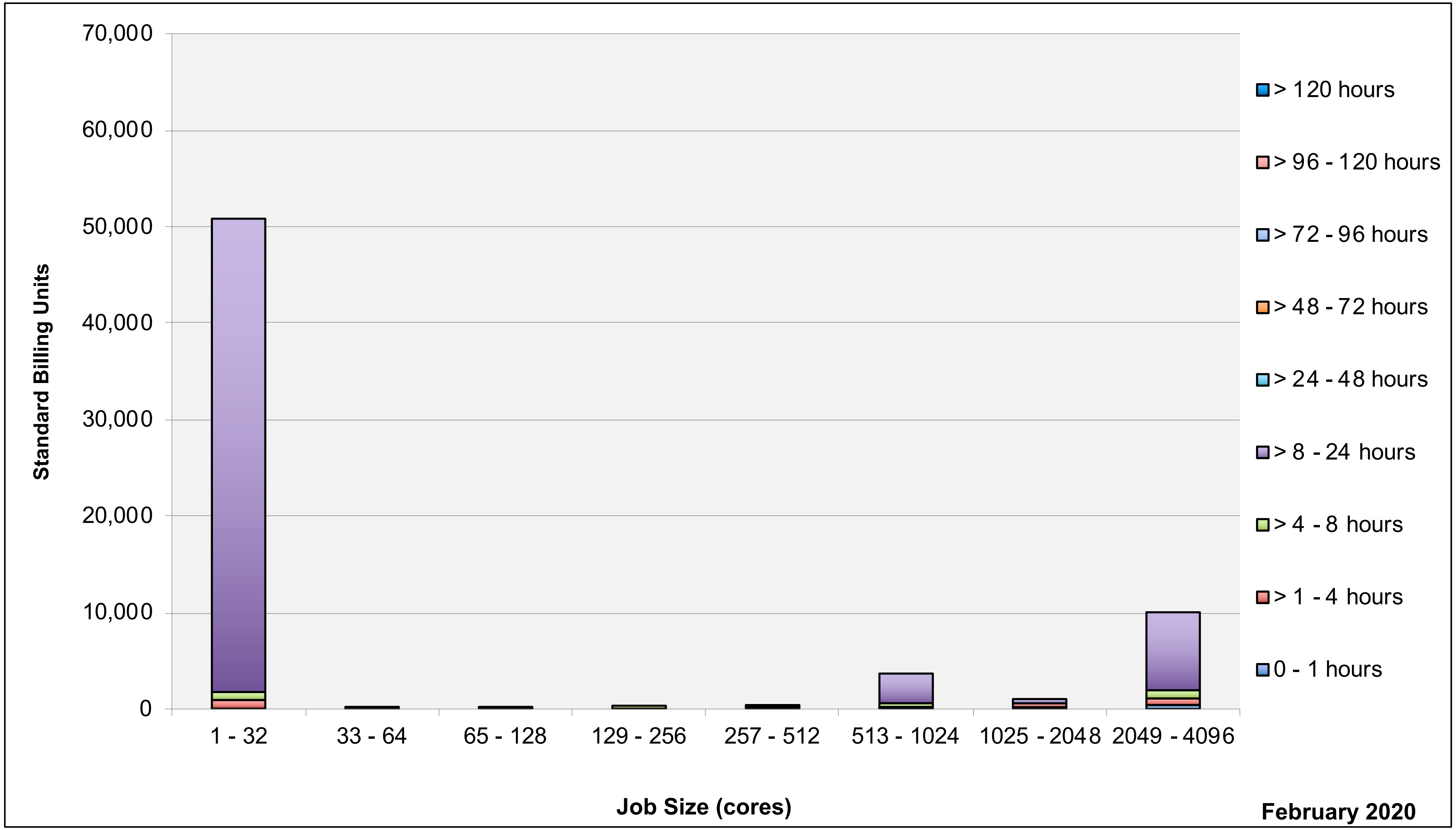
Endeavour: Monthly Utilization by Job Length



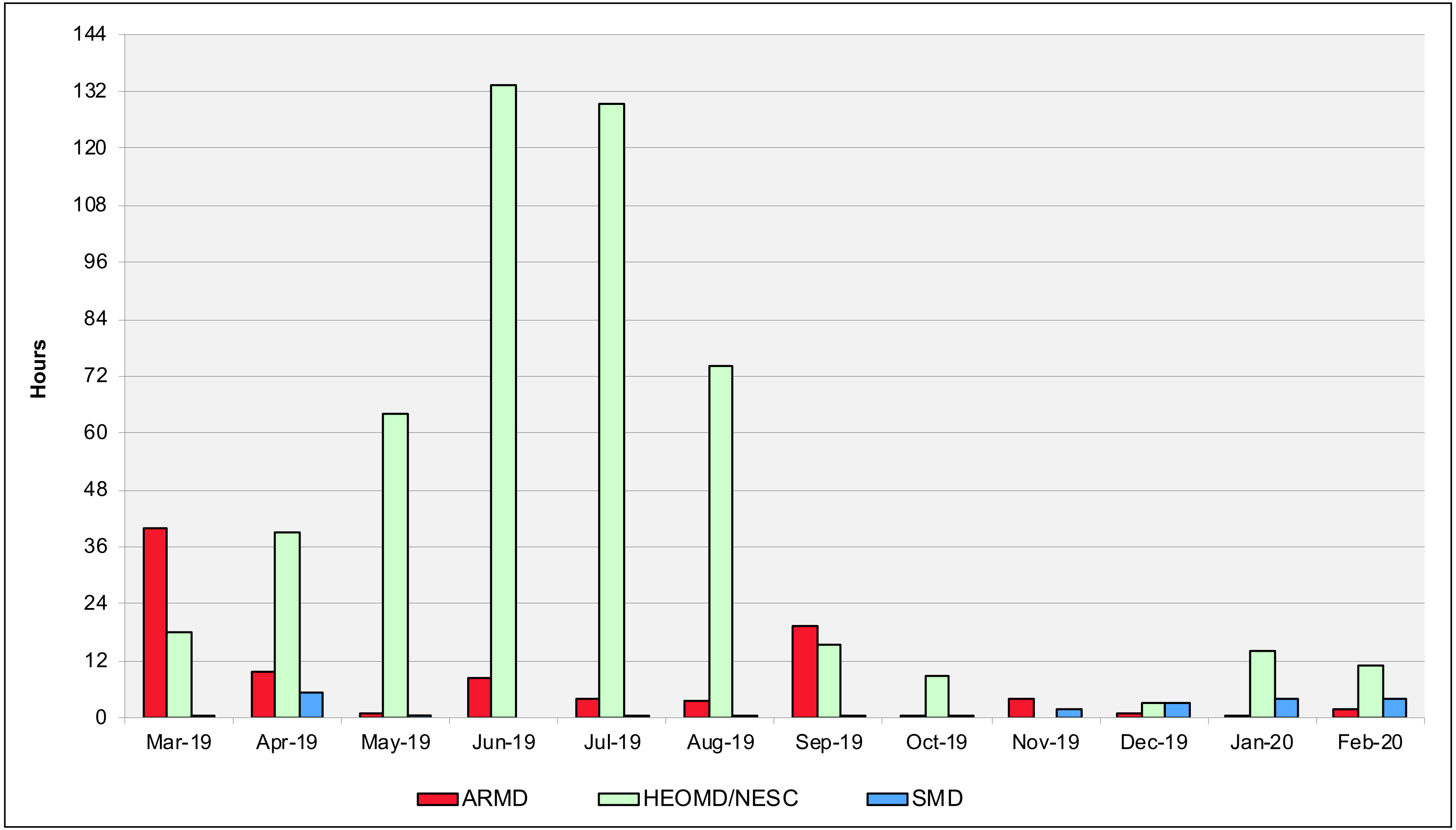
Endeavour: Monthly Utilization by Job Length



Endeavour: Monthly Utilization by Size and Length



Endeavour: Average Time to Clear All Jobs



Endeavour: Average Expansion Factor