Project Status Report

High End Computing Capability
Strategic Capabilities Assets Program

September 10, 2017

Dr. Rupak Biswas – Project Manager
NASA Ames Research Center, Moffett Field, CA
Rupak.Biswas@nasa.gov
(650) 604-4411

Modular Supercomputing Facility Module 2 Nears Completion

- The Modular Supercomputing Facility (MSF) Module 2 now houses an expansion that will bring the Electra computer system from 1.24 petaflops (PF) to 4.78 PF.
- HECC facilities engineers coordinated with Ames Code J engineers and Hewlett Packard Enterprise (formerly SGI) during the installation of the module.
- Module 2 is a prefabricated steel building built in two sections that were lifted into the MSF site via crane and bolted together.
- The electrical infrastructure of the MSF site was upgraded to accommodate the 1.2 MW power draw of the new module.
- Module 2 cools the new Electra systems by circulating water from the adiabatic coolers on its the roof to the computer racks.
- The racks will be connected to the Module 2 power and water supplies during the first week of September, and will be completely operational by the end of September.

Mission Impact: The installation of Module 2 increases the infrastructure capacity of HECC to allow for an additional 1.2 megawatts of power for computing resources.

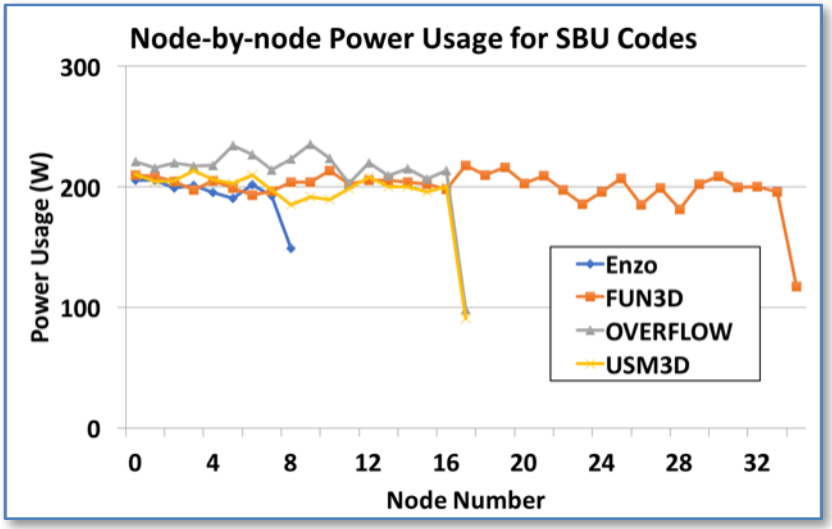
Photo of Module 2 installed at the MSF site. The adiabatic coolers are installed on a platform above the roof of the module. Fans in the coolers draw over air-cooling coils through which water circulates, rejecting heat into the outside air and delivering cool water down to the computers in the module.

POC: Chris Tanner, christopher.tanner@nasa.gov, (650) 604-6754, NASA Advanced Supercomputing Division, CSRA LLC

HECC Team Enables Measurements of Power Usage by Applications

- The HECC Application Performance and Productivity (APP) team recently implemented a framework for measuring electrical power used by applications.
- The framework builds on the availability of real-time power readings on recent generations of Intel processors (such as Haswell, Broadwell, and Knights Landing) running SLES12.
- The framework consists of:
  - A new version of MPIProf, which can be configured to report power usage for an MPI code.
  - A dynamic library and runtime daemon that can be invoked from the prologue and epilogue of a PBS job to record a job's power usage in system logs.
- In the coming months, the APP team will investigate the power requirements of a variety of codes to see how those statistics correlate to application performance, and to understand the power efficiency of different architectures. They will also work with the Systems team to turn on the recording of power usage data in system logs, thereby facilitating the discovery of codes that are not using resources effectively.

Mission Impact: Measuring the power used by specific nodes running an application helps with understanding its performance characteristics and whether it has been mapped appropriately to the hardware, enabling optimal use of system resources.



This chart shows the power required by each node for runs of four benchmarks in the standard billing unit (SBU) suite. Note that each of the four runs shows a large drop in power used by the last node. This is due to unused cores on that node.

POCs: Henry Jin, haoqiang.jin@nasa.gov, (650) 604-0165, NASA Advanced Supercomputing (NAS) Division;
David Barker david.p.barker@nasa.gov, (650) 604-4292, NAS Division, Supersmith

APP Team Contributes to Successful Cross-Center Collaboration at GPU Code-a-thon

- Teams from Langley, Ames, and Glenn participated in an intensive five-day code modernization effort targeted toward graphics processing units (GPUs).
- HECC provided compute resources with Pleiades GPUs and two mentors from the Application Performance and Productivity (APP) team.
- The success of the code-a-thon was predicated on five key ingredients:
  - Down-selecting to seven highly motivated teams.
  - Pairing teams with expert mentors from NVIDIA/PGI and Oak Ridge National Laboratory.
  - APP experts to assist with overcoming hurdles in the utilization of Pleiades GPU resources.
  - Providing at least one expert per team, so that no team would be waiting for assistance during the event.
  - An event leader who kept everyone "moving" with daily progress reports and avoiding getting stuck in a rut.
- A team studying aero thermodynamic radiation achieved a factor of 7-10 speedup on a node-to-node comparison when using GPUs; the EDL Trajectory Reconstruction team learned that their code, as currently written, is not amenable to GPU optimization.
- Lessons learned from this very successful event will enable HECC/NAS to host future code-a-thons to further the goal of code modernization across more application teams.

Mission Impact: The GPU code-a-thon was a very successful cross-center collaboration, and served as a major impetus for application developers to modernize their codes. A key to the success was in pairing teams with industry and other agency experts.

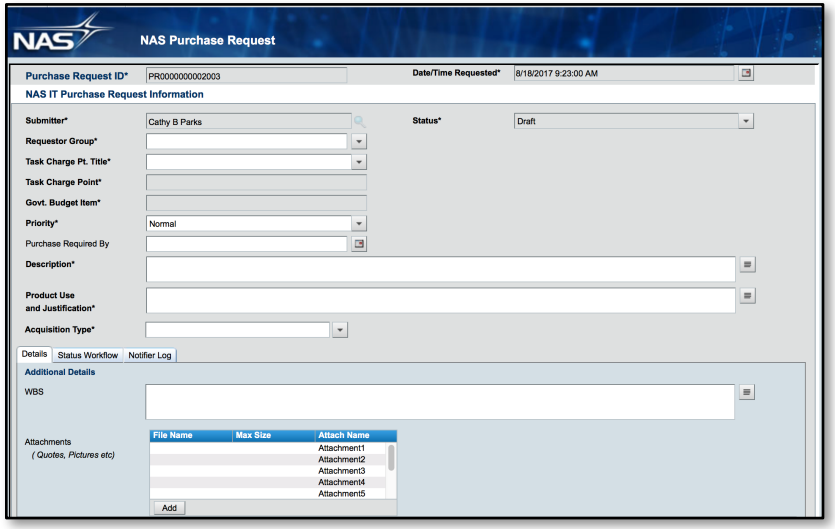
Application teams huddle around large computer screens to work through code modifications for GPU acceleration held at NASA Langley.

POCs: Gabriele Jost, gabriele.jost@nasa.gov, (650) 604-0468, NASA Advanced Supercomputing (NAS) Division, Supersmith; Johnny Chang, johnny.chang@nasa.gov, (650) 604-4356, NAS Division, CSRA LLC

Tools Team Releases and Enhances Remedy Purchase Request Workflow for HECC

- The HECC Tools team developed the Remedy Purchase Request module to facilitate a common input vehicle for requesting HECC purchases. This module will eventually allow tracking of purchases through a variety of NASA purchase processes (such as ACES, ELMT, P-card).
- A Remedy workflow was developed that provides input for description and justification for purchase, budget category, acquisition type, WBS, and vendor quotes; and automatically identifies the government approver.
- Automatic emails are routed to government leads for online or email purchase approval.
- Charts are available to show group purchase totals during identified timeframes.
- Future development will continue to more closely track the status of purchases as they progress through the NASA processes.

Mission Impact: Online entry of purchase requests allows for easier tracking and ensures progress of HECC purchases.



NAS Purchase Request Remedy workflow requires entry of all information necessary to process HECC purchases through NASA processes.

POC: Vidya Bobbiligama, vidyareddy.bobbiligama@nasa.gov, (650) 604-4460, NASA Advanced Supercomputing Division, Intrinsyx

ESS Team Completes Deployment of macOS 10.12 Sierra to Staff Workstations

- The HECC Engineering Servers and Services (ESS) team completed the deployment of macOS 10.12 (Sierra) to 190 Macs used by staff at the NAS facility.
- The ESS team began the rollout in April, after ARC IT Security approved the ESS Sierra OS image, and less than a month after the OS version was approved by NASA.
- Deployment of Sierra included:
  - Utilizing Jamf Pro, a software tool to install Sierra and enforce configuration controls.
  - Automating implementation of NASA IT security benchmarks.
  - Integrating native smartcard support into Centrify.
  - Creating SSH configurations to work with Apple's "local items keychain."
  - Testing new versions of software applications.
- Leveraging lessons learned from Sierra, ESS staff are beginning to evaluate the next version of macOS 10.13 High Sierra.

Mission Impact: Deployment of macOS 10.12 (Sierra) with Centrify smart card authentication enhances system security and enables HECC users to take advantage of the latest Apple software and hardware features.

With HECC's completion of the Sierra upgrade, work is beginning on development of its successor, macOS 10.13 High Sierra.

POCs: Ted Bohrer, theodore.w.bohrer@nasa.gov, (650) 604-4335, Ed Garcia, edmund.a.garcia@nasa.gov, (650) 604-1338, NASA Supercomputing Division, ADNET Systems

Code42 CrashPlan Selected to Replace ASG Time Navigator for Mac Backups

- The HECC Engineering Servers and Services (ESS) team evaluated Code42 CrashPlan to handle staff Mac backups after detecting numerous occasions of corrupted catalogs with ASG Time Navigator.
- The benefits of CrashPlan include: its web-based administration, capability to independently write to multiple backup locations, the association of a backup to a user rather than a system, and a reduced amount of daily maintenance.
- For the evaluation, ESS successfully created 3 virtual machines to simulate a master server with redundant storage locations, backed up and restored several systems, and evaluated IPv4 and IPv6 operability. They replaced the embedded Java with a patchable global Java and fixed incompatibilities with Red Hat 7.
- CrashPlan will be put into production on receipt of the new hardware and software that is currently in the procurement process.

Mission Impact: CrashPlan will provide HECC staff with a more stable Mac backup solution for their systems and require less ESS administrative support to ensure stable backups.

The new Code42 CrashPlan application will provide an easy-to-use administrator interface that clearly shows usage, licensing, and user information.

POC: Ted Bohrer, theodore.w.bohrer@nasa.gov, (650) 604-4335, NASA Supercomputing Division, ADNET Systems

ESS Team Adopts Ansible for Patching and Configuration Management

- The HECC Engineering Servers and Services (ESS) team recently switched to the open source Ansible platform to manage patching and system configuration management of ~350 Red Hat systems at the NAS facility. Easy-to-use Ansible playbooks (scripts) replace more complicated and less effective manual updates and shell scripts.
- Ansible offers the following improvements over our previous processes:
  - Simple or complex playbooks that are customizable per system, group, requests, etc.
  - Version controlled playbooks.
  - Can be used in conjunction with current scripts to allow for gradual migration.
  - An "Ensure" option allows rerunning playbooks to perform functions and test for compliance.
  - Uses SSH and doesn't require an agent on system.
  - Can run multiple forks instead of looping through a list of systems.
- As our staff become more familiar with Ansible, additional scripts and processes are being moved to playbooks.

Mission Impact: Ansible playbooks for system patching and management help ESS to continue to take on the administration of additional systems without additional staff.

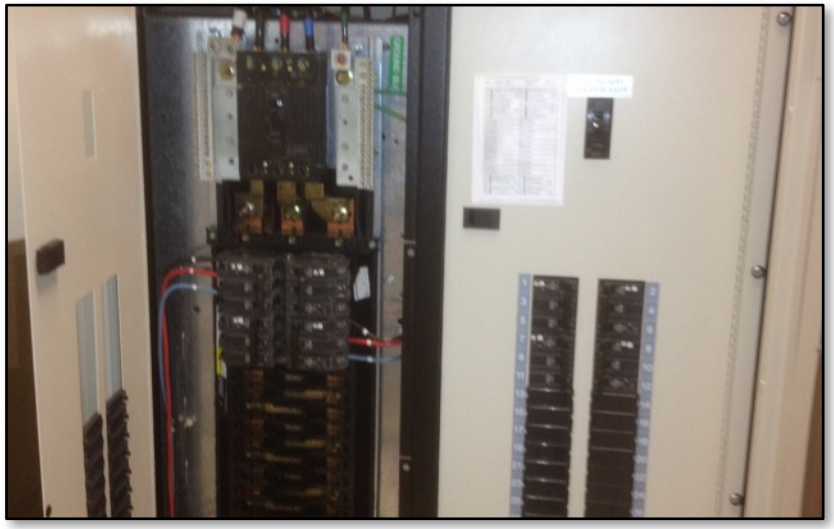
Open source Ansible playbooks have reduced the amount of time needed to apply Linux patches to NAS facility user workstations.

POC: Nicholas Hunt, nicholas.hunt@nasa.gov, (650) 604-4935, NASA Supercomputing Division, ADNET Systems

HECC Facilities Achievements for the First Half of 2017

- HECC Facilities team activities for the first half of 2017 included several important achievements beyond new projects:
  - Adjusted the cooling in Room 190 of building N233A to allow Merope to increase power consumption by 55%.
  - Torqued thousands of circuit breaker screws in PDUs delivering power to Pleiades to preserve continuous compute availability for users.
  - Continued to modify (in tandem with Ames Code J engineers) temperature set points and tune the performance of the new N258 cooling tower.
  - Generated the design and drawing package for the installation of Module 2 at the MSF site.
  - Installed the power delivery infrastructure for the nobackupp1/p2 filesystem upgrades.
  - Redesigned the power delivery system to the N258 communications room to provide network connectivity during annual power shutdowns.
- Such efforts by the HECC Facilities team help increase computing capacity and ensure uptime availability for users.

Mission Impact: Maintaining and fine-tuning facility-related resources to meet new and changing demands allows for increased HECC computational capacity and reliability.



Fasteners on the circuit breakers in the power distribution units for Pleiades require periodic torqueing to maintain solid electrical connections for continuous availability—one of many regular maintenance tasks handled by the HECC Facilities team.

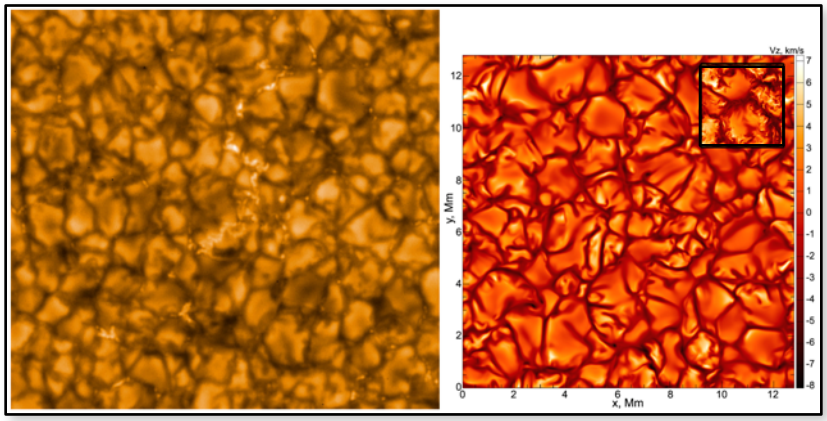
POC: Chris Tanner, christopher.tanner@nasa.gov, (650) 604-6754, NASA Advanced Supercomputing Division, CSRA LLC

Detailed MHD Simulations Give New Insight into Stellar Dynamics

- Numerical simulations are crucial to studying the structure and dynamics of stars, since observations from satellites such as Hinode are restricted to the stars' exteriors.
- Researchers at NASA Ames used two of their in-house developed codes, StellarBox and StellarSegment, to run important and highly accurate radiative magnetohydrodynamics (MHD) simulations on the Pleiades supercomputer.
  - Stellarbox simulates a small rectangular block of stellar matter that extends a few tens of megameters (Mm) down into the interior and a few Mm up into the stellar atmosphere.
  - StellarSegment simulates an orange-segment-shaped piece of a star down to some radius below the surface.
  - Both codes use a form of highly accurate radiation transfer calculation that uses light rays that extend in many directions from each point.
- The researchers' highly parallel programming algorithms enable a new level of accuracy in stellar simulation, while reducing computational costs, which can be extremely high.
- Future work will incorporate these methods into new codes with more accurate stellar geometries, including much larger portions of the stars—ultimately leading to full compressible radiative MHD over an entire star.

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

Mission Impact: These high-resolution simulations, made possible with HECC resources, support NASA programs that seek to understand stars in terms of their dynamics and evolution, along with their interaction with planetary systems and role in the large-scale structure of the universe.



Left: Hinode satellite image of solar granulation. Right: StellarBox image of granulation at a resolution of 25 km/cell. Inset on right: StellarBox image at a resolution of 6.25 km/cell. The Hinode image is near the limit of observational resolution obtainable today. The inset image shows how much more detail is present in the flowfield that cannot be observed but that the NAS research team can simulate. *Irina Kitiashvili, NASA/Ames*

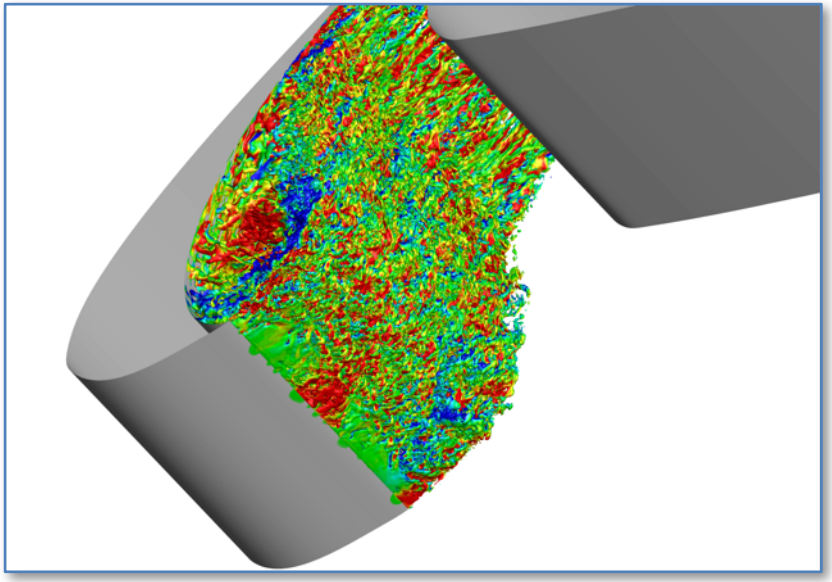
POC: Alan Wray, alan.a.wray@nasa.gov, (650) 604-6066, NASA Advanced Supercomputing Division

Numerical Simulation of Jet and Slat Noise for Next-Generation Aircraft Design

- Reduction of overall aircraft noise levels is a strong component of the design of next-generation subsonic and supersonic aircraft.
- Researchers at NASA Ames used their Launch Ascent and Vehicle Aerodynamics (LAVA) solver framework to run high-fidelity, time-accurate near-field CFD simulations on Pleiades, focused on jet and airframe slat noise. Results include:
  - Performed validation studies of the LAVA solver on jet noise and slat noise for predicting noise generation and sound propagation from both jets and high-lift devices.
  - Produced high-fidelity datasets to explore the noise-generating mechanisms using advanced post-processing tools also available in LAVA.
  - Demonstrated the weakness of several popular hybrid Reynolds-Averaged Navier-Stokes/Large Eddy Simulation (RANS/LES) models implemented within LAVA, as the mesh is refined to very fine levels.
- Noise generated by either the jet or the slat was propagated to the far field using the LAVA Ffowcs Williams-Hawkings (FWH) acoustic module. Large-memory nodes on Pleiades, containing up to 256 gigabytes of memory, were used to efficiently perform this part of the FWH procedure.

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

Mission Impact: These numerical simulations, enabled by HECC resources, play a key role in understanding the dominant noise-generation mechanisms and assessing noise reduction concepts for the design of next-generation subsonic and supersonic aircraft.



An iso-contour of streamwise vorticity (colored by span-wise velocity) highlights the wake generated from the leading edge of an aircraft slat as it impinges on the slat cove region of an aircraft. *Jeff Housman, NASA/Ames*

POCs: Cetin Kiris, cetin.c.kiris@nasa.gov, (650) 604-4485,
Jeffrey Housman, jeffrey.a.housman@nasa.gov,
(650) 604-5455, NASA Advanced Supercomputing Division

HECC Facility Hosts Several Visitors and Tours in August 2017

- HECC hosted 16 tour groups in August; guests learned about the agency-wide missions being supported by HECC assets, and some groups also viewed the D-Wave 2X quantum computer system. Visitors this month included:
  - Lisa August, White House Office of Management and Budget.
  - Robert Gibbs, HQ Associate Administrator (AA), Office of Human Capital Management, and Jessica Lee, Office of Legislative and Intergovernmental Affairs, and staff.
  - Terry Jackson, HQ Associate Chief Information Officer, Technology and Innovation; and Yulan Lin, data scientist/software engineer in the Technology and Innovation Division, NASA OCIO.
  - A delegation from Poland, including Piotr Dardzinski, Undersecretary of State for the Ministry of Science and Higher Education.
  - Smithsonian Magazine filmed a video of scientist Natalie Batalha at the NAS hyperwall to showcase her Kepler work; Batalha was awarded the magazine's 2017 American Ingenuity Award.
  - Two groups of students from the Ames Fall Intern program and the Monterey Bay Aquarium Research Institute; the latter as part of the Ames Space Life Sciences Training program.

NAS Division Chief Piyush Mehrotra presents science results at the hyperwall to Robert Gibbs, Associated Administrator, Office of Human Capital Management; Jessica Lee, Office of Legislative and Intergovernmental Affairs, and staff.

POC: Gina Morello, gina.f.morello@nasa.gov, (650) 604-4462, NASA Advanced Supercomputing Division

Papers

- ”**The VIMOS Public Extragalactic Redshift Survey (VIPERS): An Unbiased Estimate of Growth Rate of Structure at ⟨z⟩ = 0.85 Using the Clustering of Luminous Blue Galaxies**,” F. Mohammad, et al., arXiv:1708.00026 [astro-ph.CO], July 31, 2017. * *https://arxiv.org/abs/1708.00026*
- “**Coherent Backscattering Effect in Spectra of Icy Satellites and its Modeling Using Multi-Sphere T-Matrix (MSTM) Code for Layers of Particles**,” K. Pitman, et al., Planetary and Space Science, available online August 9, 2017. * *http://www.sciencedirect.com/science/article/pii/S0032063316304457*
- “**Assessment of USM3D Hierarchical Adaptive Nonlinear Method Preconditioners for Three-Dimensional Cases**,” M. Pandya, et al, AIAA Journal, vol. 55, no. 8, August 9, 2017.* *https://arc.aiaa.org/doi/full/10.2514/1.J055823*
- “**On the Vertical Structure and Stability of the Lofoten Vortex in the Norwegian Sea**,” L. Bashmachnikov, et al., Deep Sea Research Part I: Oceanographic Research Papers, available online August 10, 2017. * *http://www.sciencedirect.com/science/article/pii/S0967063716300243*
- “**Ionosphere-Thermosphere Energy Budgets for the ICME Storms of March 2013 and 2015 Estimated with GITM and Observational Proxies**,” O. Verkhoglyadova, et al., Space Weather (AGU), August 10, 2017. * *http://onlinelibrary.wiley.com/doi/10.1002/2017SW001650/full*

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

Papers (cont.)

- "**Alfvén Wave Turbulence as a Coronal Heating Mechanism: Simultaneously Predicting the Heating Rate and the Wave-Induced Emission Line Broadening**," R. Oran, et al., The Astrophysical Journal, vol. 845, no. 2, August 16, 2017. * *http://iopscience.iop.org/article/10.3847/1538-4357/aa7fec/meta*
- "**Seasonal and Interannual Variability in Terminus Position, Glacier Velocity, and Surface Elevation at Helheim and Kangerlussuaq Glaciers from 2008 to 2016**," L. Kehrl, et al., Journal of Geophysical Research: Earth Surface, August 17, 2017. * *http://onlinelibrary.wiley.com/doi/10.1002/2016JF004133/full*
- "**The Formation of Stellar Clusters in Magnetized, Filamentary Infrared Dark Clouds**," P. S. Li, R. Klein, C. McKee, arXiv:1708.06770 [astro-ph.GA], August 22, 2017. * *https://arxiv.org/abs/1708.06770*
- "**On Transient Climate Change at the Cretaceous-Paleogene Boundary Due to Atmospheric Soot Injections**," C. Bardeen, et al., PNAS, vol. 114, no. 35, August 29, 2017. * *http://www.pnas.org/content/early/2017/08/15/1708980114.short*

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

News and Events

- **Exploring the Ocean's Depths with a New Hyperwall Visualization Tool**, *NAS Image Feature*, August 2, 2017—Earth scientists are using a new visualization toolbox on the NAS facility's hyperwall to take a deeper dive into their high-resolution global ocean simulation. *https://www.nas.nasa.gov/publications/articles/feature_ocean_vis.html*
  - **Scientists Explore Ocean Currents Through Supercomputer Simulations**, NASA Ames, August 3, 2017. *https://www.nasa.gov/feature/ames/scientists-explore-ocean-currents-through-supercomputer-simulations*
  - **Supercomputing Ocean Currents at NASA**, InsideHPC, August 5, 2017. *https://insidehpc.com/2017/08/supercomputing-ocean-currents-nasa/*
  - **Hypnotic Supercomputer Simulations Reveal how Ocean Currents Move Around the World** *http://www.dailymail.co.uk/sciencetech/article-4775872/NASA-supercomputer-simulation-reveals-ocean-current-motion.html#ixzz4rScms700*
- **Realistic Simulations Reveal Something New Under the Sun**, *NAS Image Feature*, August 17, 2017—A combination of supercomputers and visualization helped scientists make an important discovery about magnetic field activity taking place deep below the solar surface. *https://www.nas.nasa.gov/publications/articles/feature_solar_simulations_Stejko.html*
  - **Simulations Reveal Mysteries of the Solar Cycle**, NASA Ames, August 25, 2017. *https://www.nasa.gov/image-feature/ames/simulations-reveal-mysteries-of-the-solar-cycle*
- **Zooming in on Climate Predictions**, *Phys.org*, August 17, 2017—Engineers at Northeastern University, in collaboration with researchers in the NASA Earth Exchange (NEX) project, used the Pleiades supercomputer to analyze a "colossal amount" of historic climate data, as part of their work to develop a system that zooms in on climate data to produce higher-resolution projections. *https://phys.org/news/2017-08-climate.html*

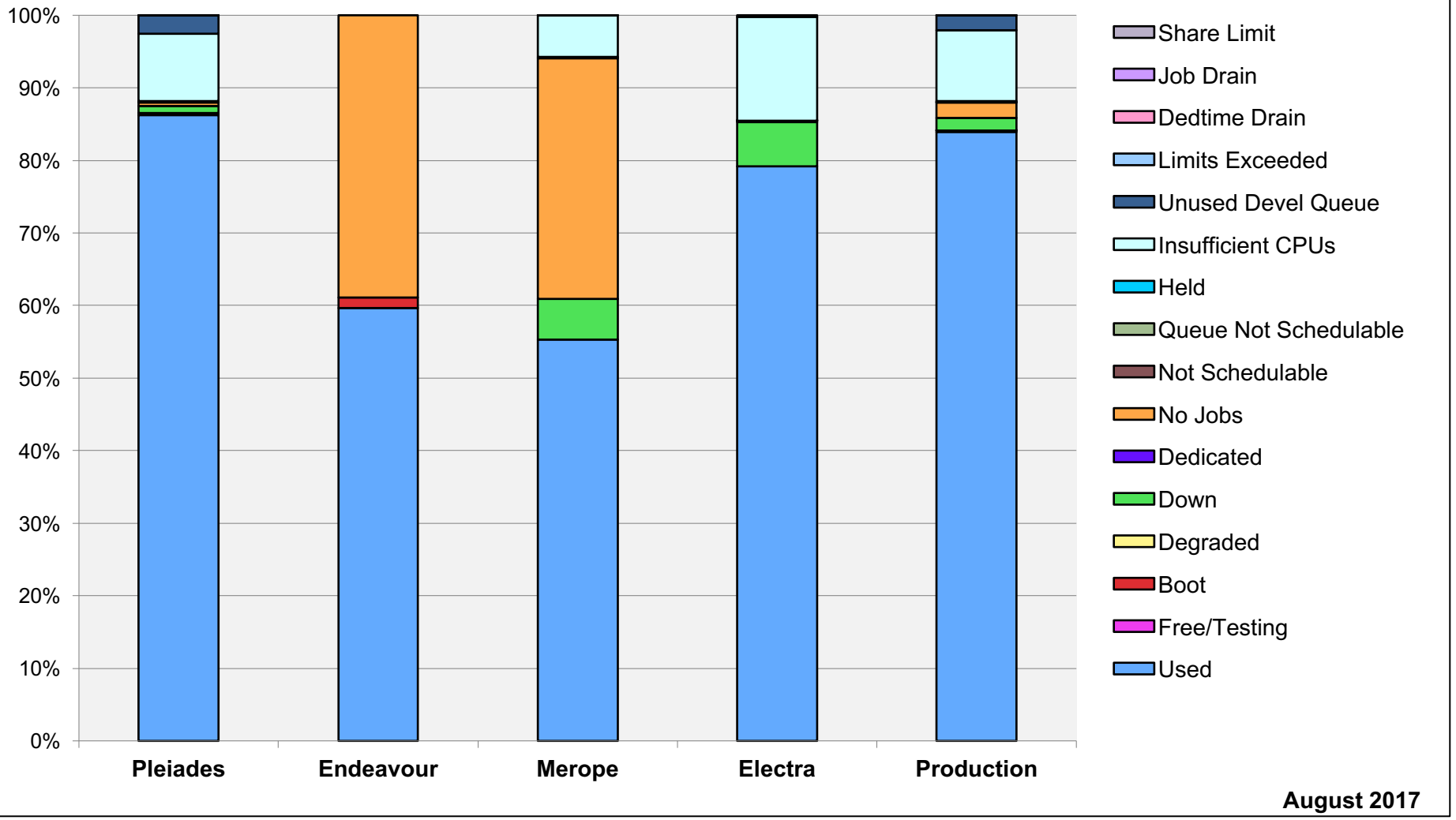
News and Events (cont.)

- **Spoiler Alert: Computer Simulations Provide Preview of Solar Eclipse**, *Texas Advanced Computing Center*, August 17, 2017—A team from Predictive Science, Inc., with support from NASA, the Air Force Office of Scientific Research, and the National Science foundation, created large-scale simulations of the Sun's surface in order to predict what the solar corona will look like during the total solar eclipse on August 21, 2017. The series of highly-detailed solar simulations were run on several supercomputers, including Pleiades at the NASA Advanced Supercomputing (NAS) Division.
  https://www.tacc.utexas.edu/-/spoiler-alert-computer-simulations-provide-preview-of-solar-eclipse
  - **Spoiler Alert: Glimpse Next Week's Solar Eclipse via Simulation from TACC, SDSC and NASA**, *HPCwire*, August 17, 2017.
    https://www.hpcwire.com/2017/08/17/spoiler-alert-glimpse-next-weeks-solar-eclipse-via-simulation-tacc-sdsc-nasa/
  - **Researchers Use TACC, SDSC and NASA Supercomputers to Forecast Corona of the Sun**, *InsideHPC*, August 18, 2017.
    https://insidehpc.com/2017/08/researchers-use-tacc-sdsc-nasa-supercomputers-forecast-corona-sun/
- **Oregon Solarfest**, Madras, OR, August 17-22, 2017—Staff from the NASA Advanced Supercomputing Division were part of an agency presence at the Oregon Solarfest for the total solar eclipse on August 21. They spoke with the public about heliophysics work done on NASA supercomputers.
  https://www.oregonsolarfest.com/

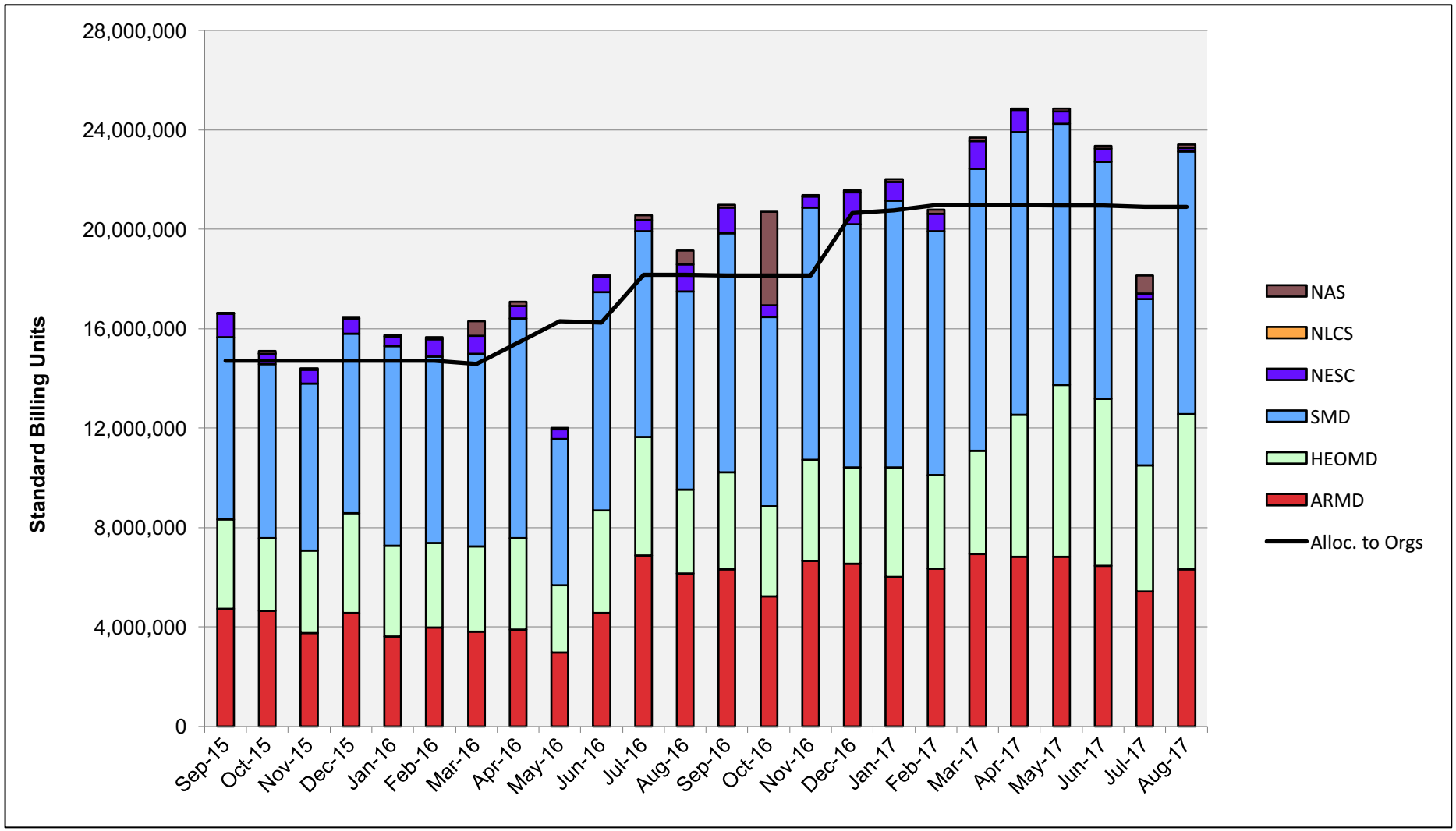
News and Events (cont.)

- **Dino-Killing Asteroid Could Have Thrust Earth into Two Years of Darkness**, *NCAR/UCAR Atmos News*, August 21, 2017—A new study by National Center for Atmospheric Research (NCAR) scientists looks at the short-term effects of a massive asteroid strike 66 millions years ago, which could have dramatically changed Earth's climate. Simulations were run on supercomputers at the NASA Advanced Supercomputing facility and NCAR. *https://www2.ucar.edu/atmosnews/news/128593/dino-killing-asteroid-could-have-thrust-earth-two-years-darkness*
- **First Quantum Annealing Computer in the U.S. to Have More than 2000 Qubits Installed and Operational**, *USRA Press Release*, August 31, 2017—The Universities Space Research Association, in partnership with NASA and Google, have upgraded the quantum annealing computer at the NASA Advanced Supercomputing Division to a D-Wave 2000Q system. *http://newsroom.usra.edu/first-quantum-annealing-computer-in-the-us-to-have-more-than-2000-qubits-installed-and-operational/*
  - **USRA Upgrades D-Wave Quantum Computer to 2000 Qubits**, *InsideHPC*, September 1, 2017. *https://insidehpc.com/2017/09/usra-upgrade-d-wave-quantum-computer-2000-qubits/*
- **NASA Supercomputing Strategy Takes the Road Less Traveled**, *The Next Platform,* August 31, 2017—"For a large institution playing at the leadership-class supercomputing level, NASA tends to do things a little differently than its national lab and academic peers." Based on an interview with Bill Thigpen, long-time HPC publisher and editor Nicole Hemsoth describes the MSF and HECC's approach to expanding the agency's computational capability and capacity down the road.

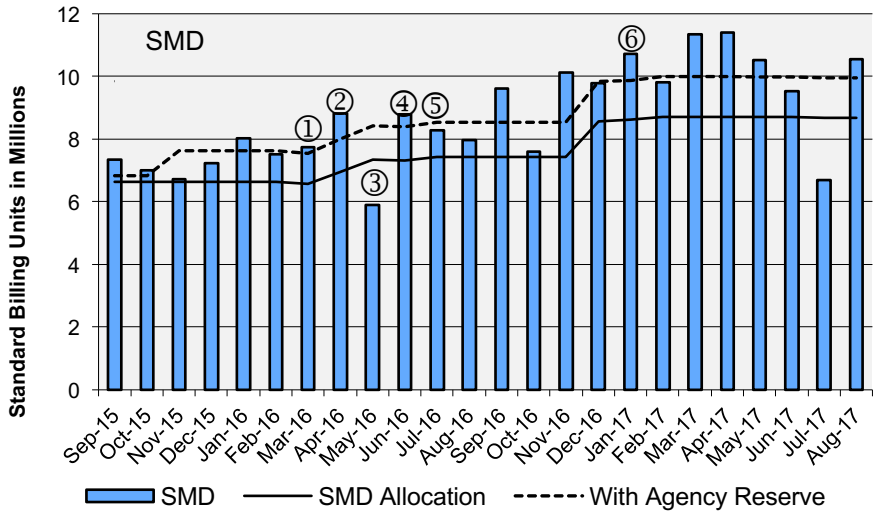
HECC Utilization

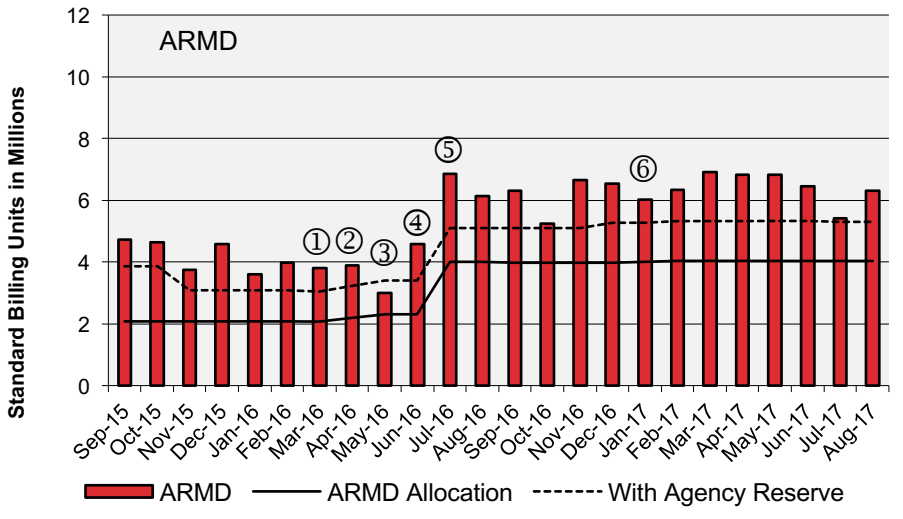


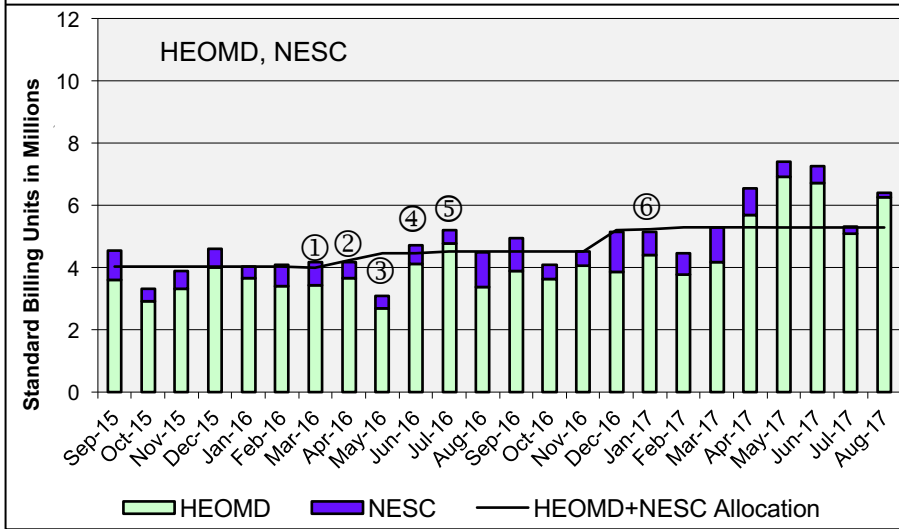
HECC Utilization Normalized to 30-Day Month



HECC Utilization Normalized to 30-Day Month

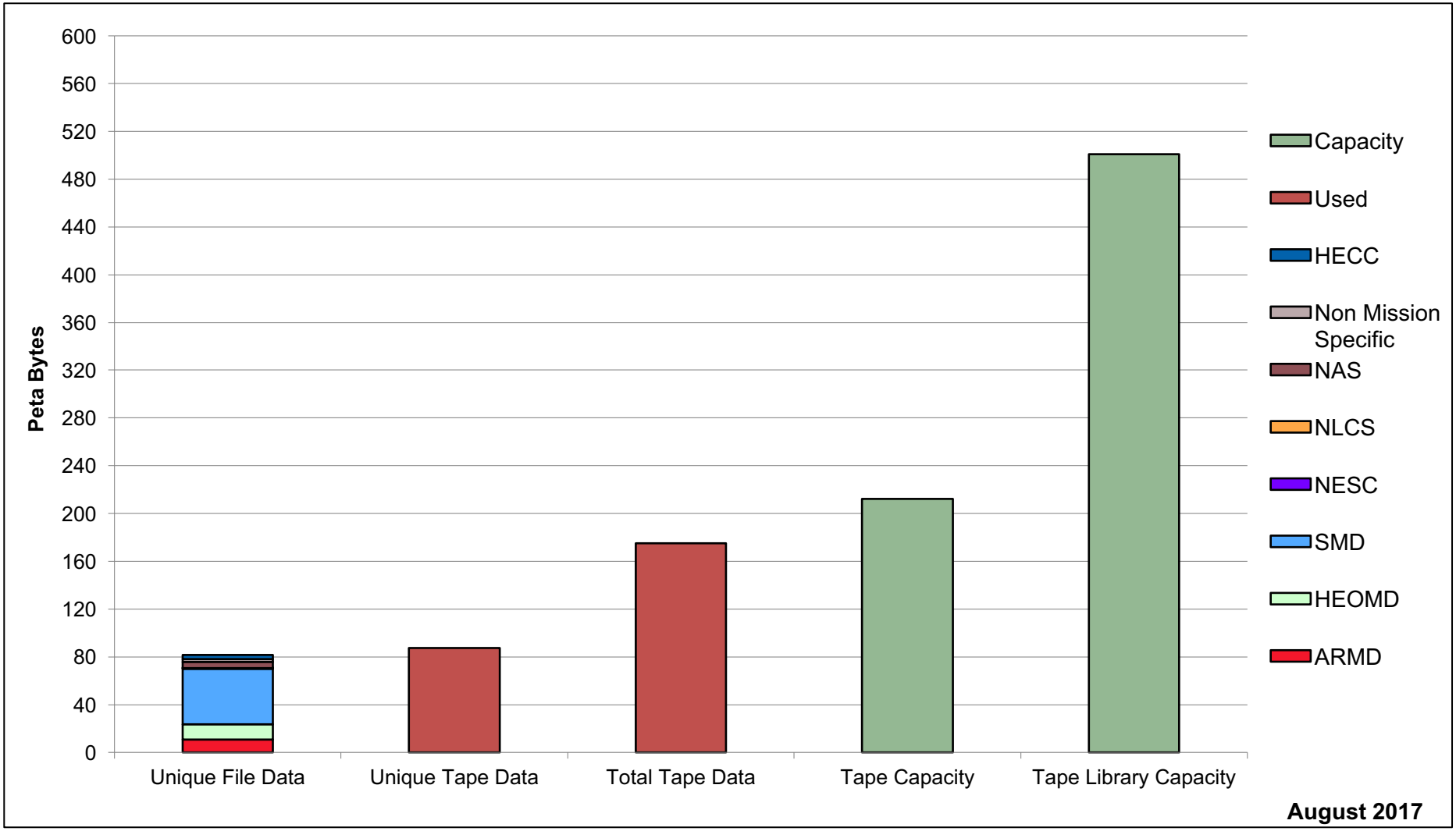






① 16 Westmere racks retired from Pleiades
② 10 Broadwell racks added to Pleiades
③ 4 Broadwell racks added to Pleiades
④ 14 (All) Westmere racks retired from Pleiades
⑤ 14 Broadwell Racks added to Pleiades
⑥ 16 Electra Broadwell Racks in Production, 20 Westmere 1/2 racks added to Merope

Tape Archive Status



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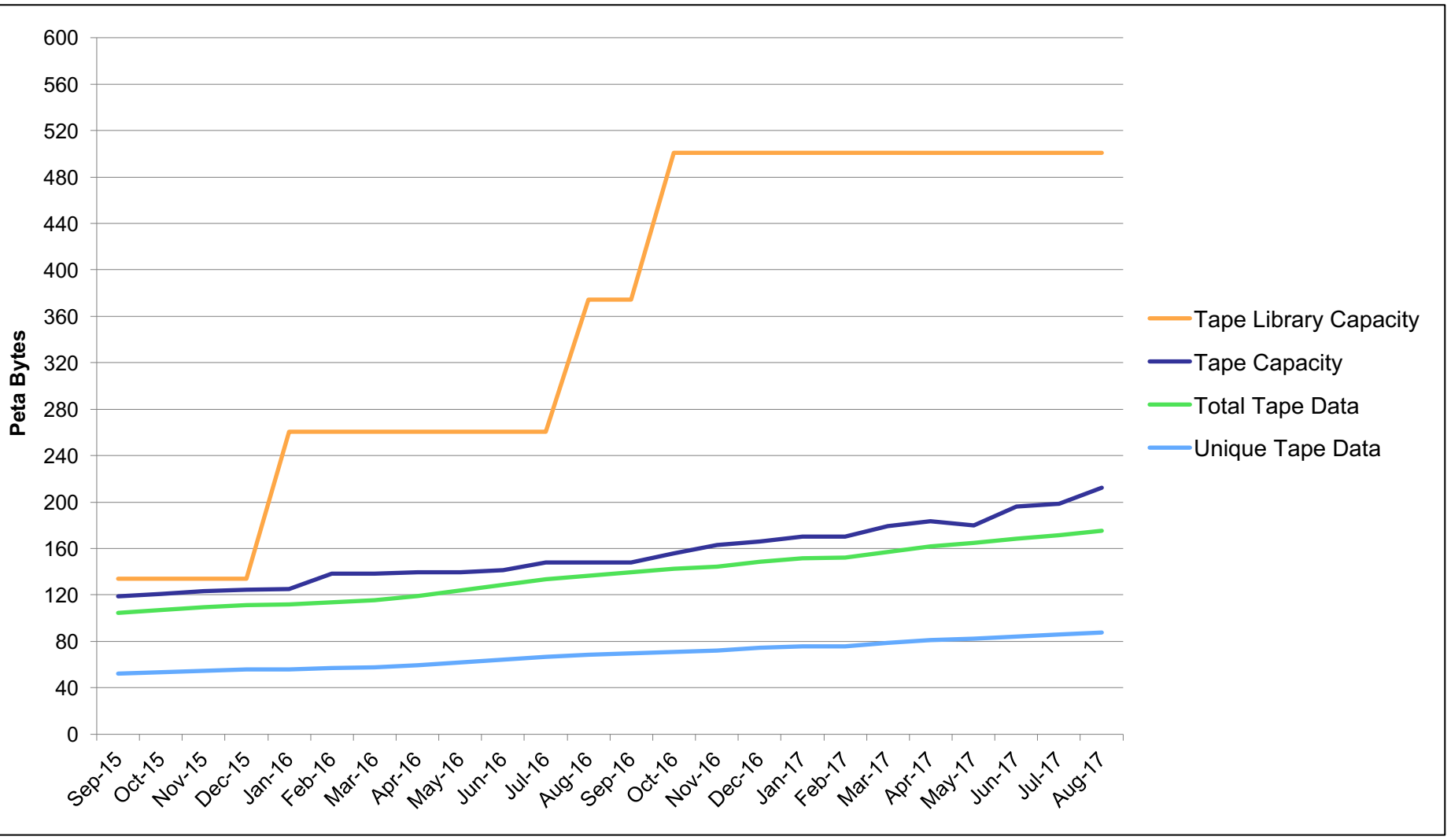
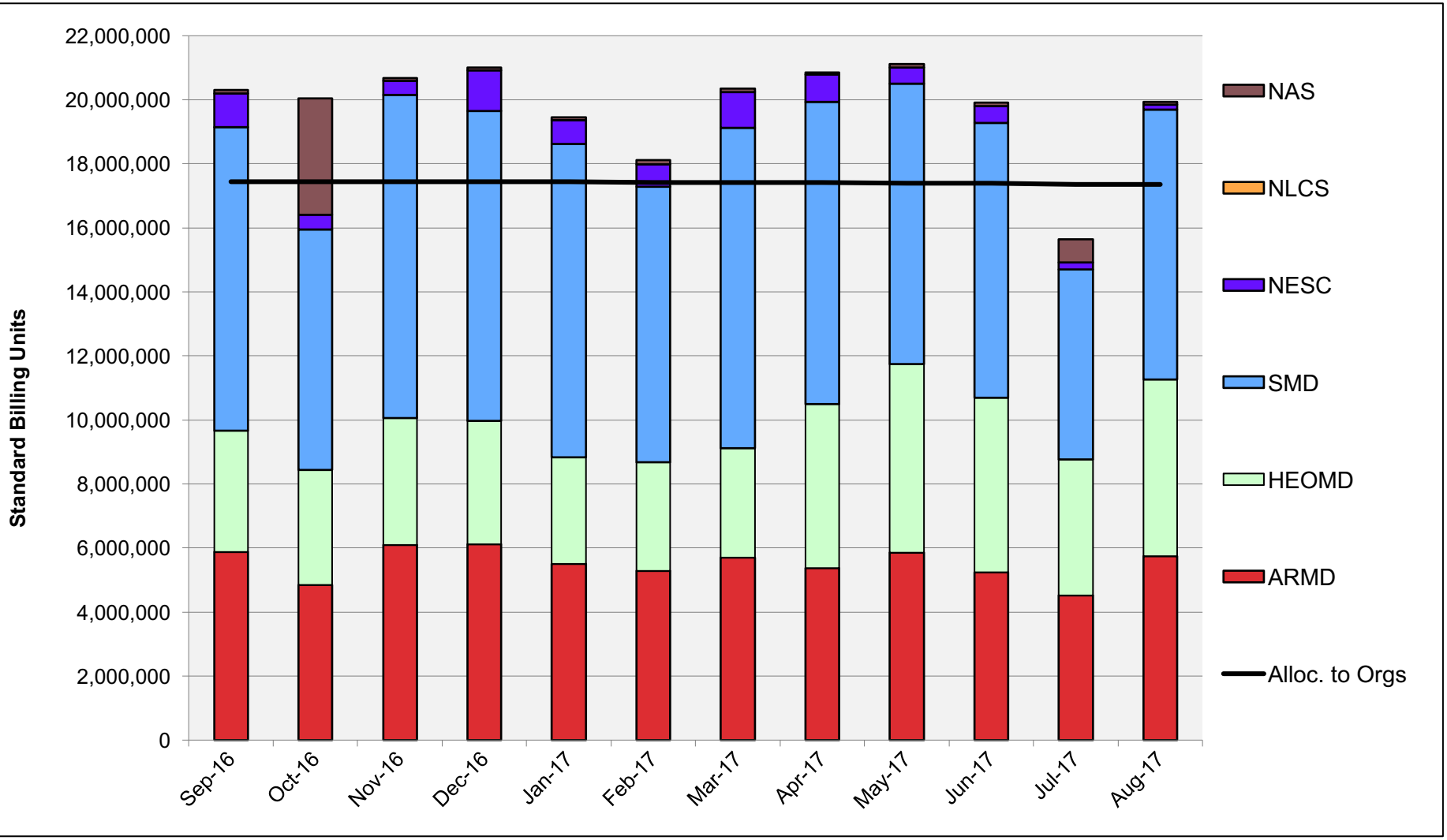
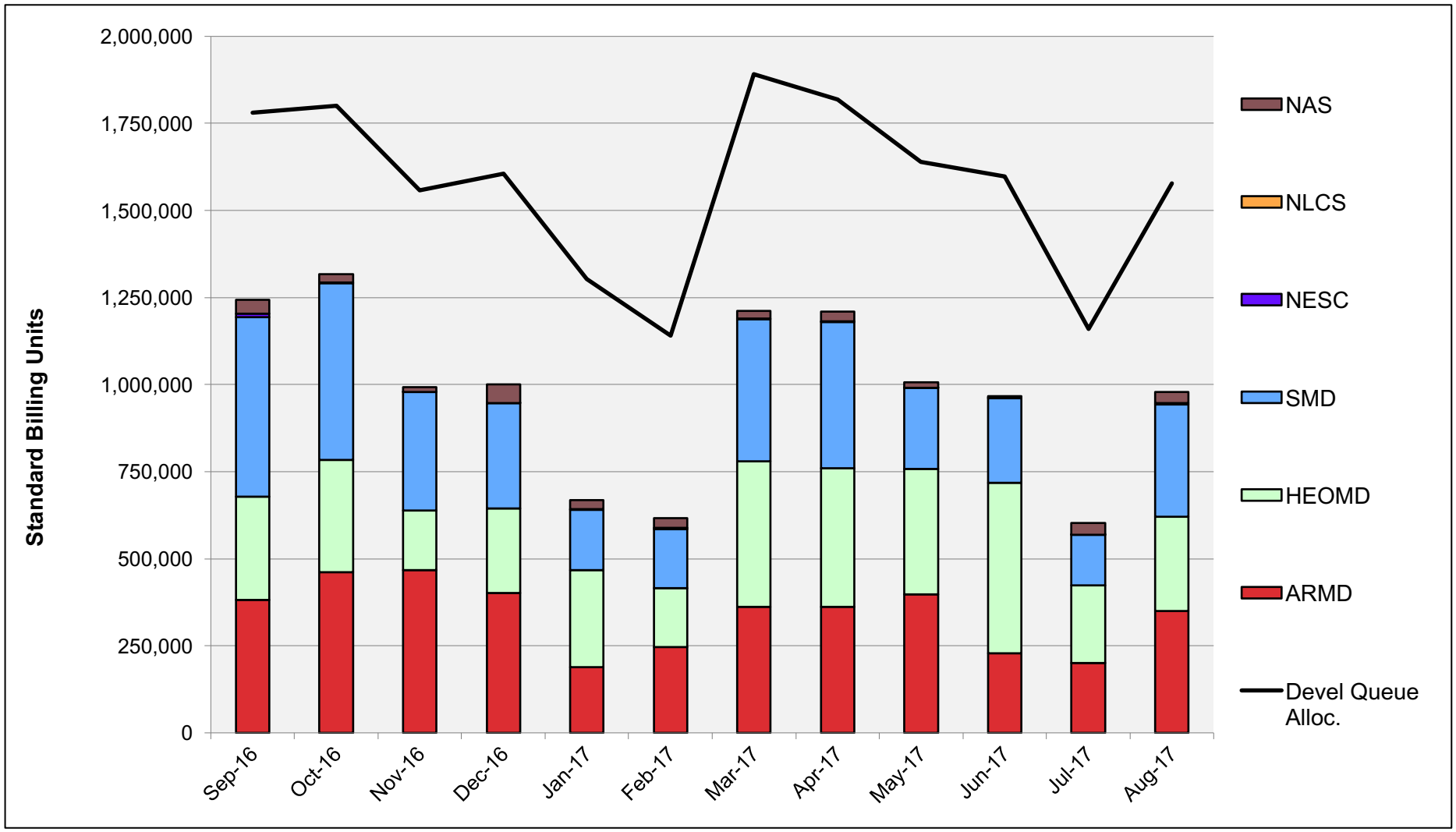


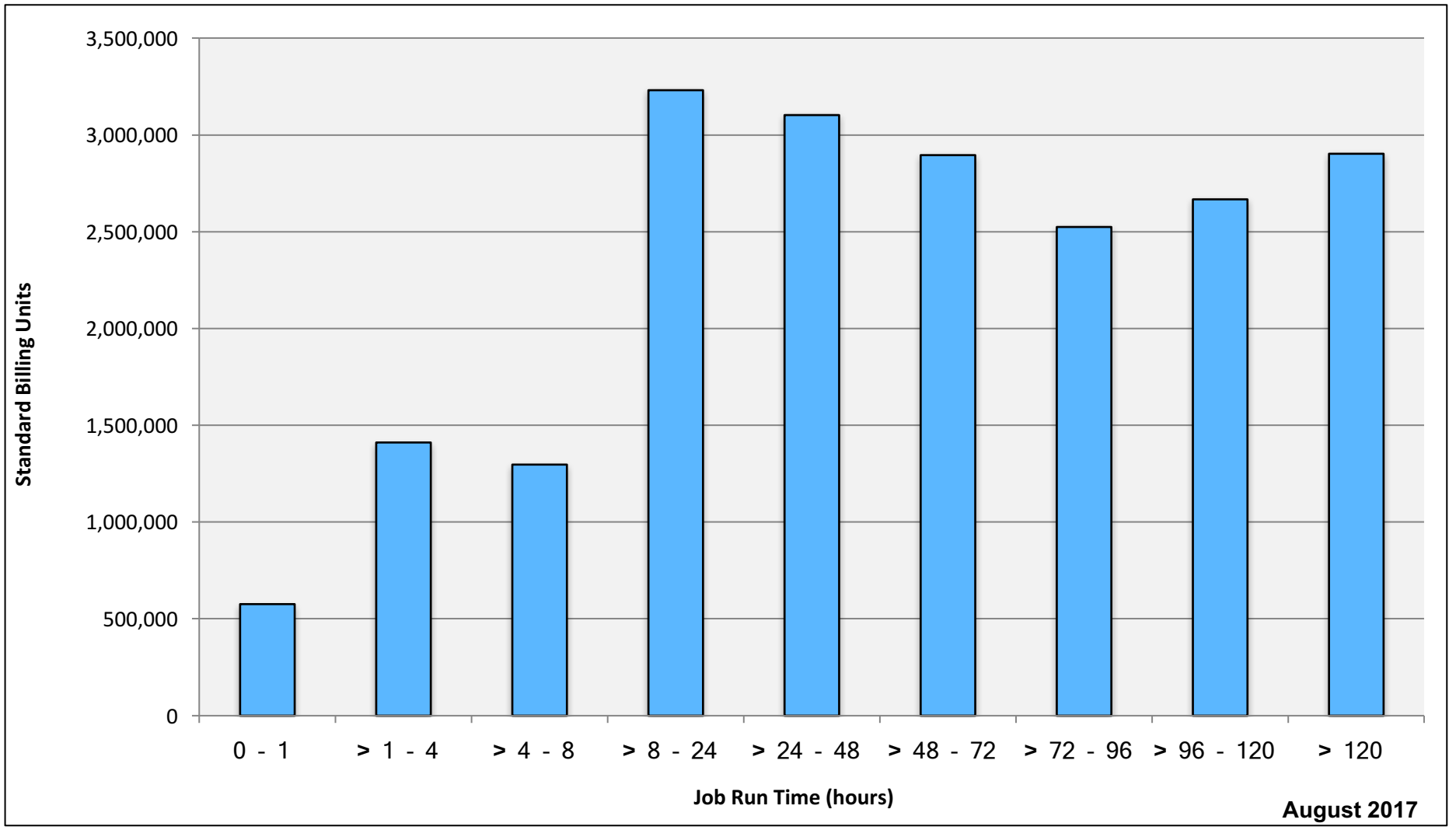
Pleiades:
SBUs Reported, Normalized to 30-Day Month



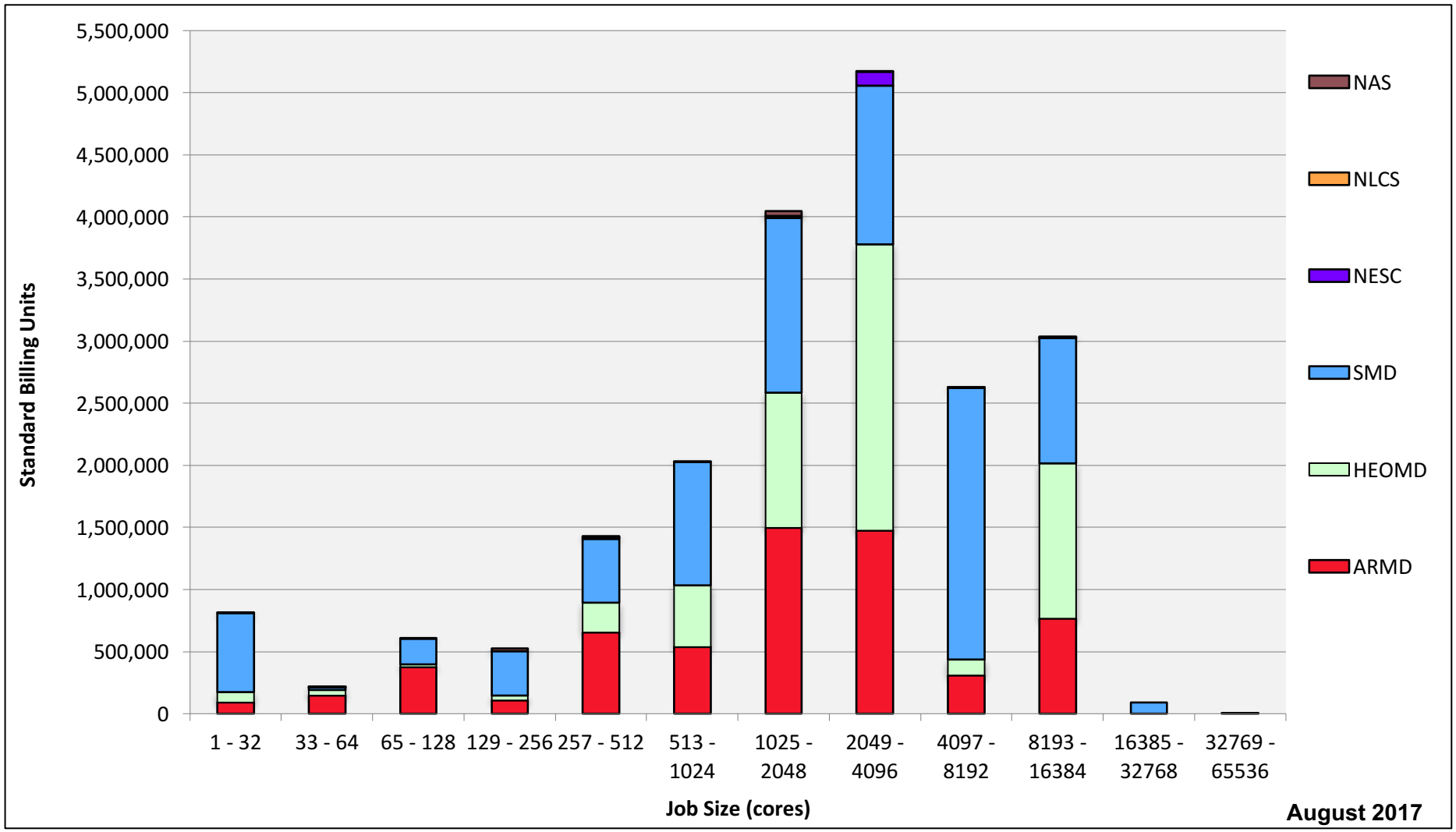
Pleiades:
Devel Queue Utilization



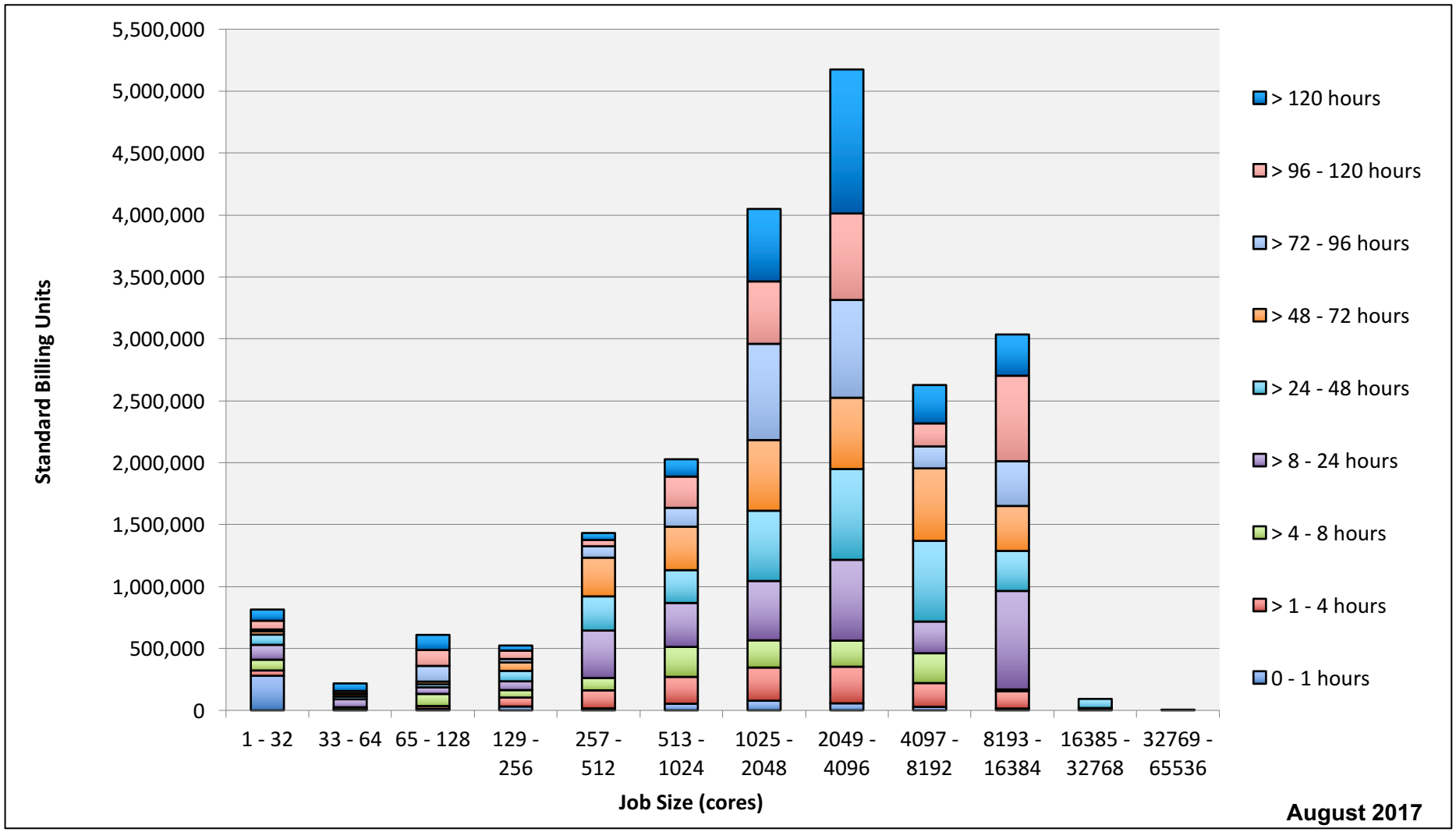
Pleiades:
Monthly Utilization by Job Length



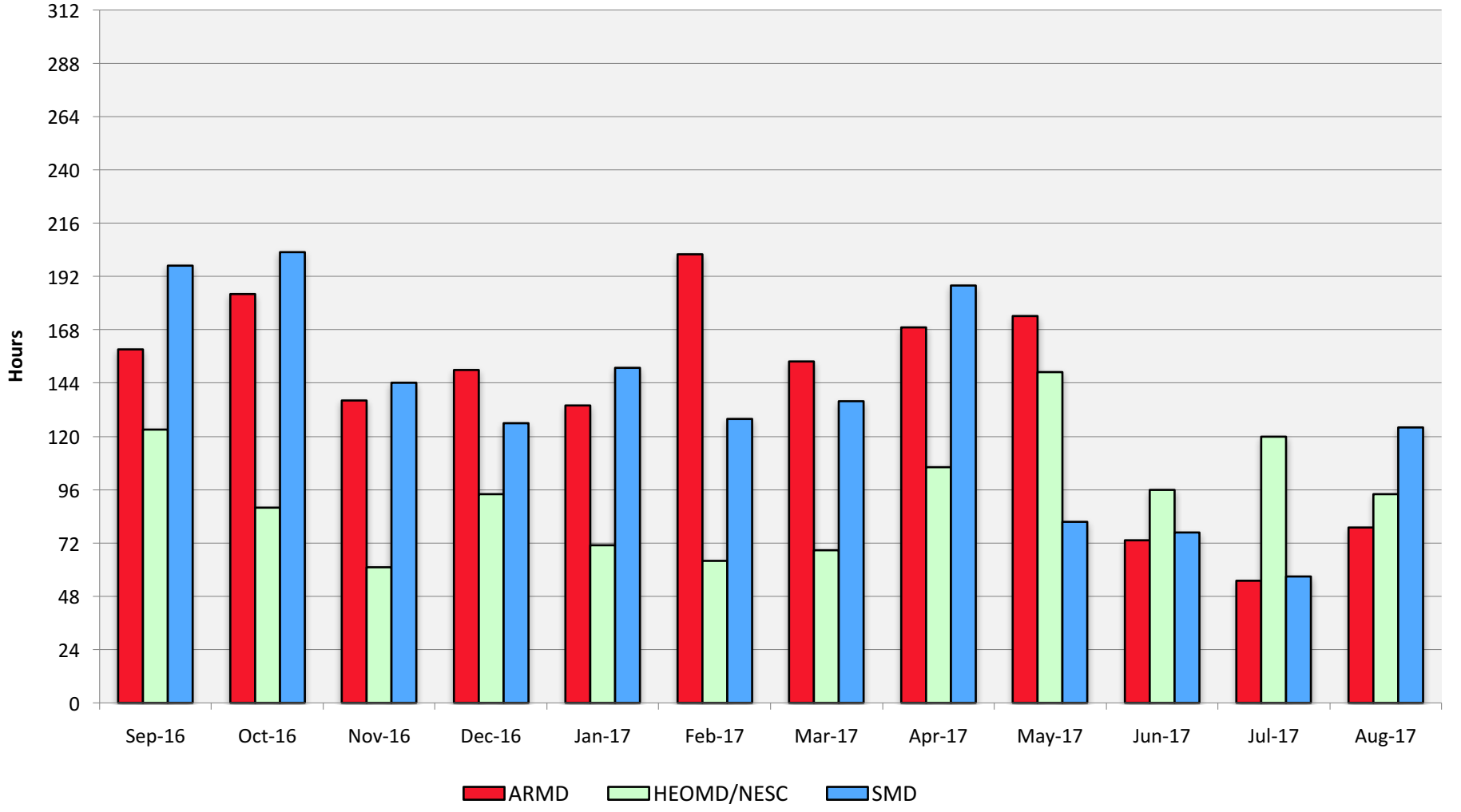
Pleiades:
Monthly Utilization by Size and Mission



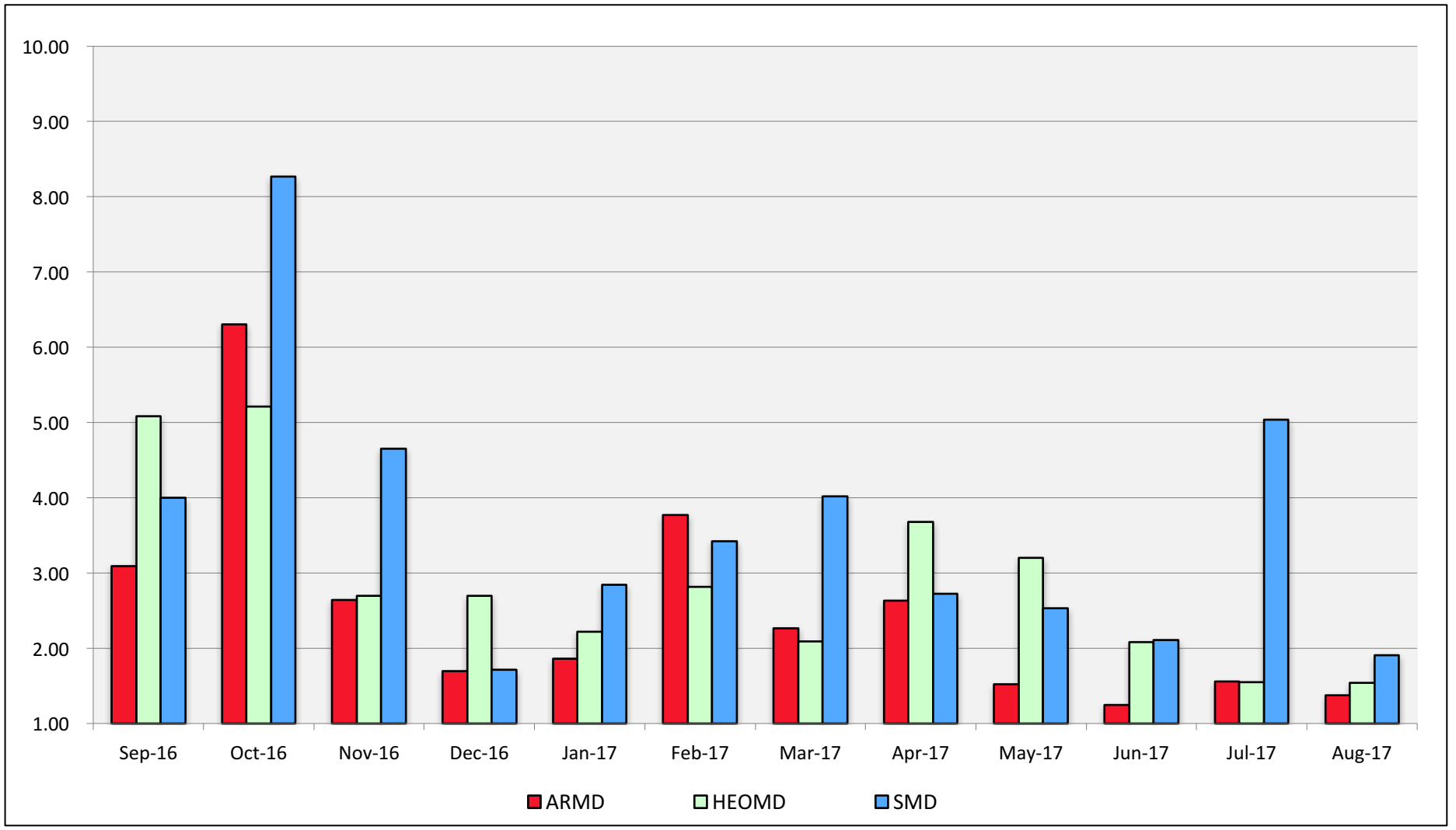
Pleiades:
Monthly Utilization by Size and Length



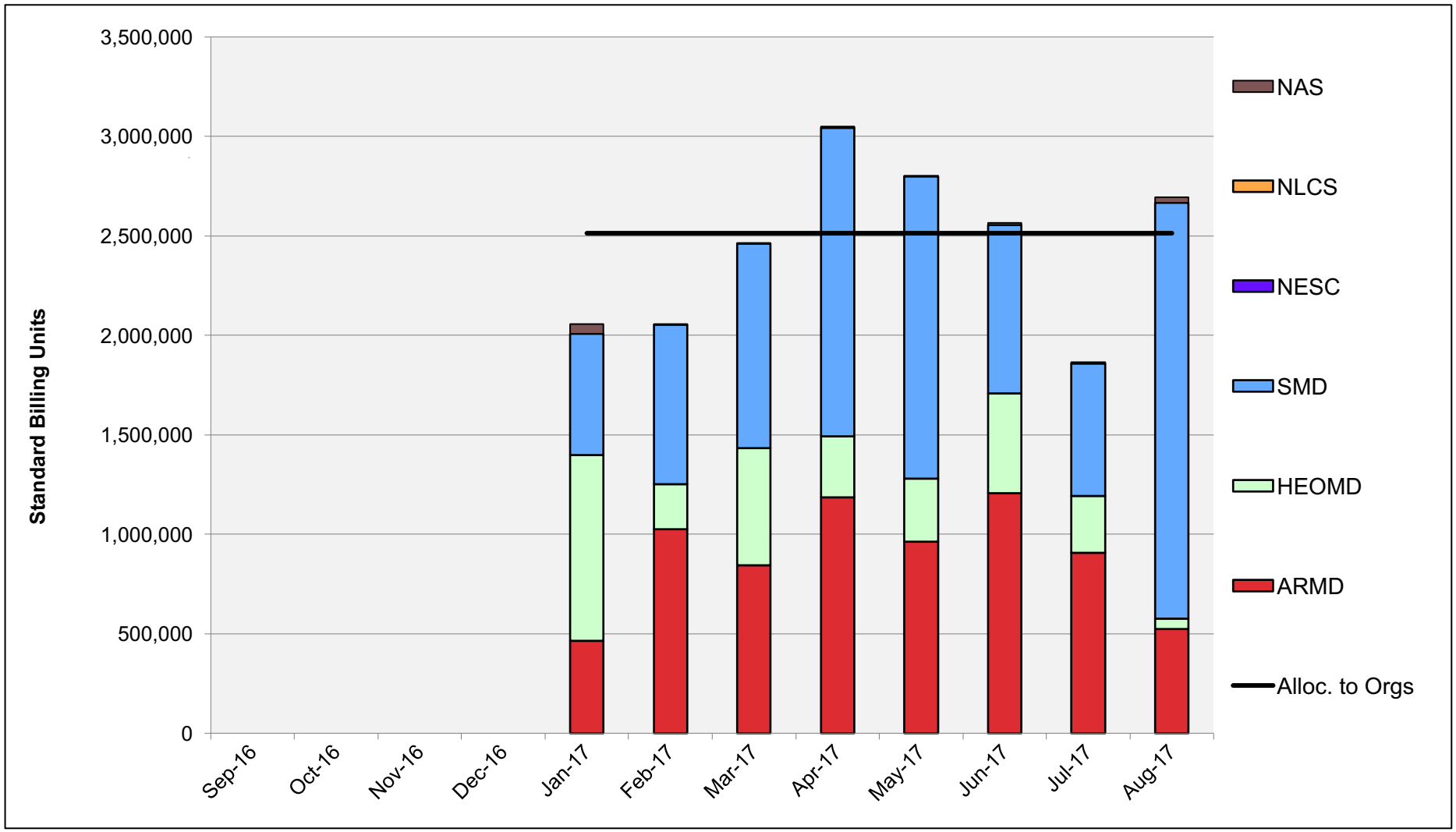
Pleiades:
Average Time to Clear All Jobs



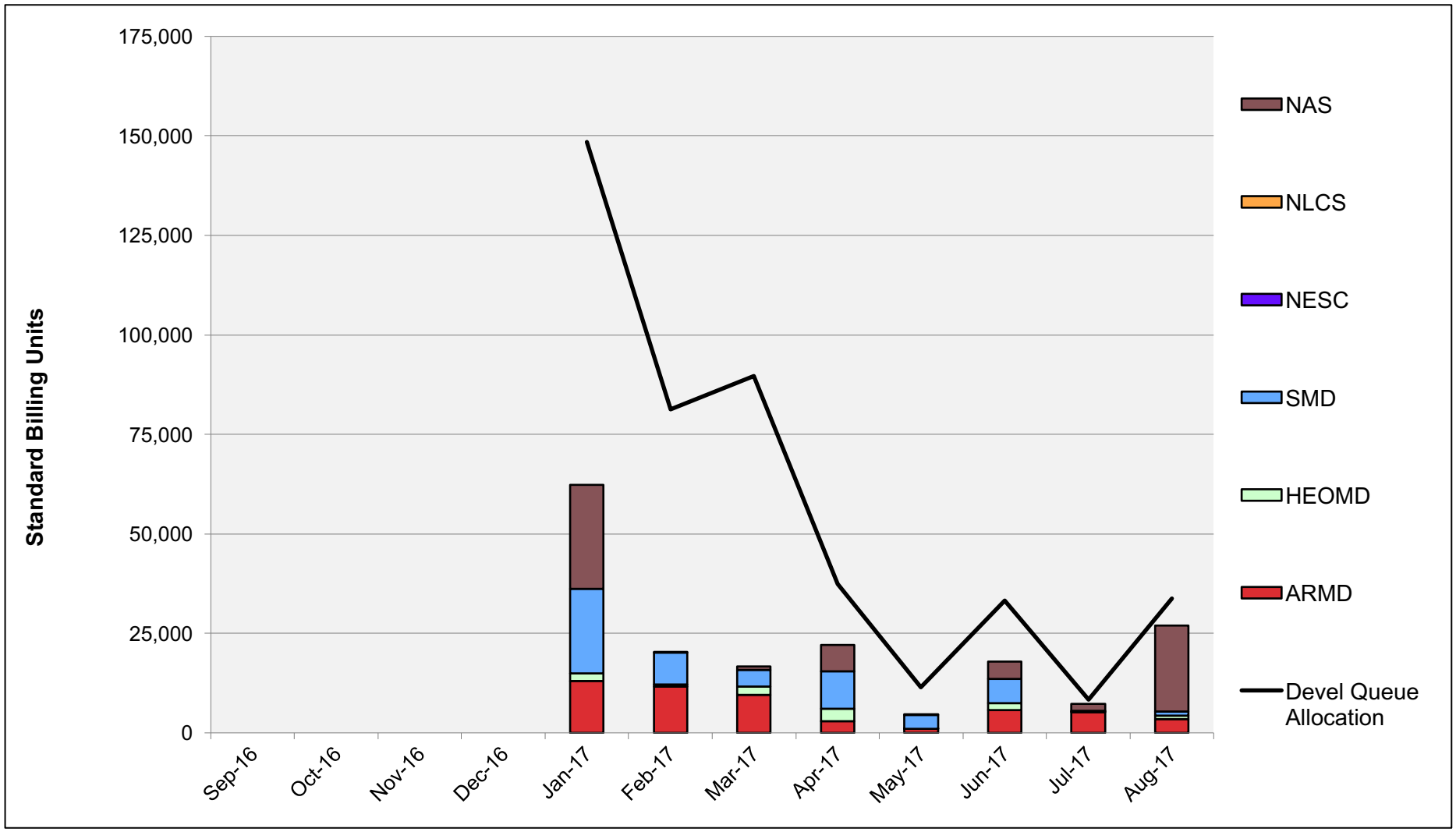
Pleiades:
Average Expansion Factor



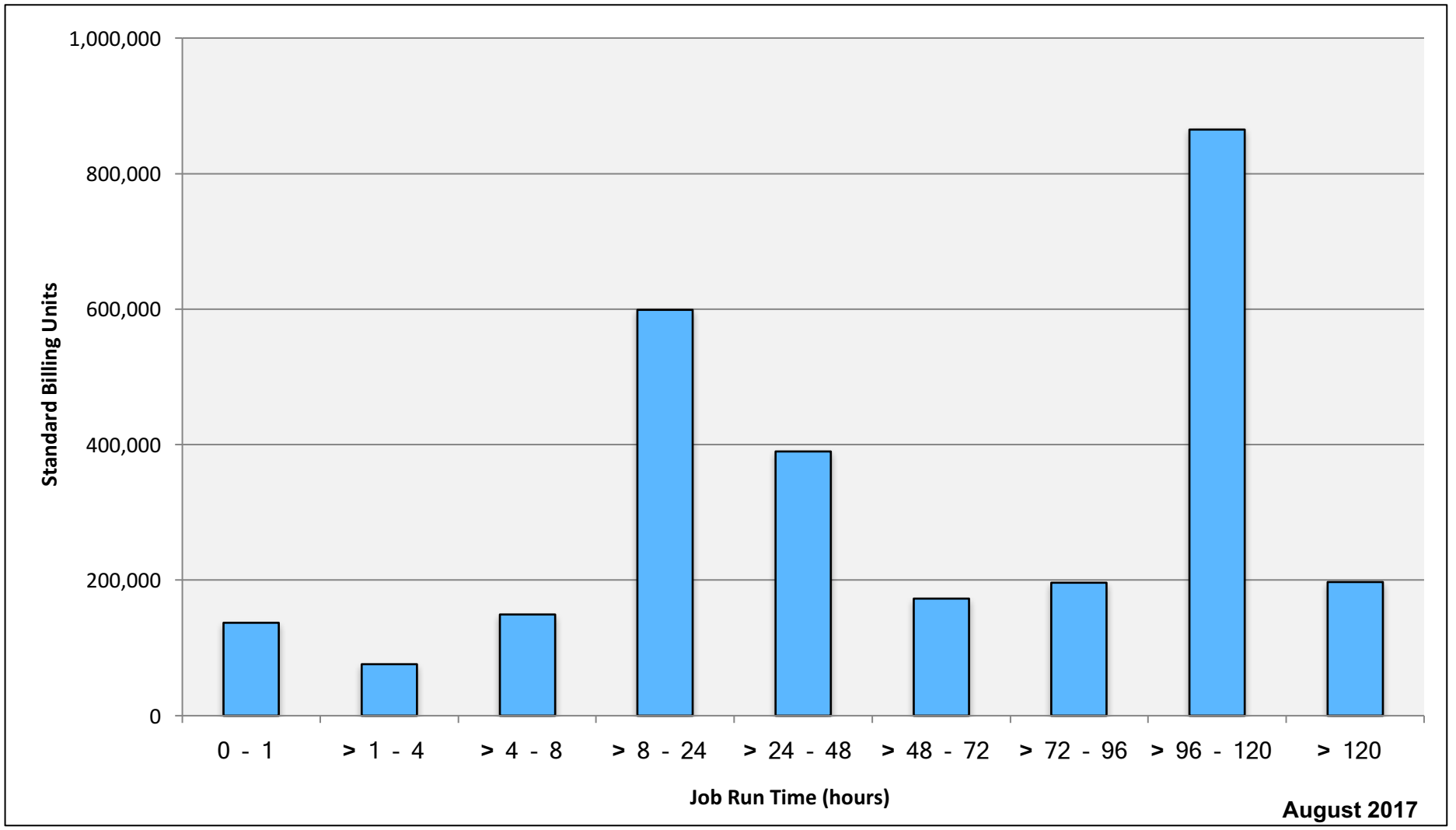
Electra:
SBUs Reported, Normalized to 30-Day Month



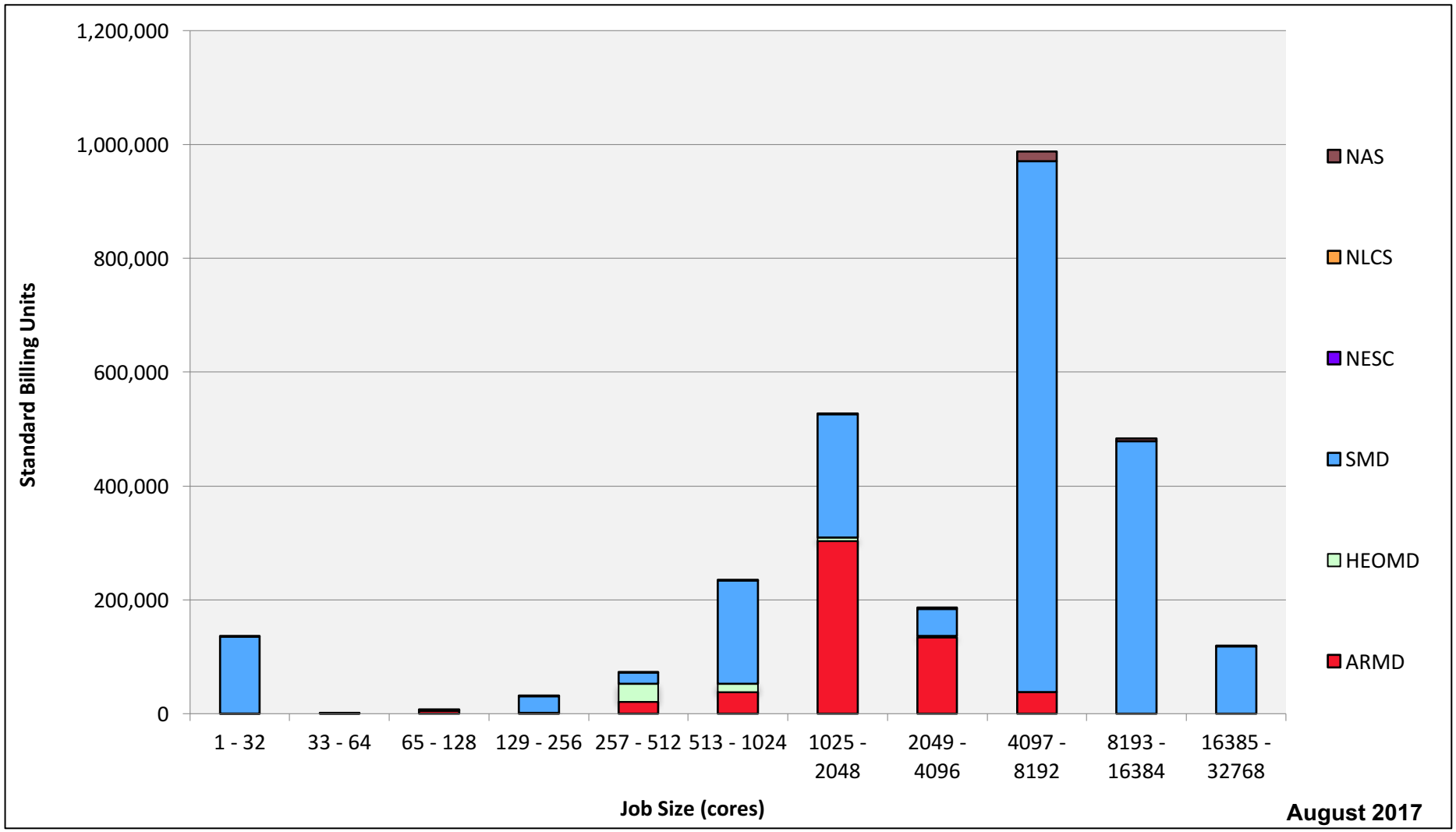
Electra:
Devel Queue Utilization



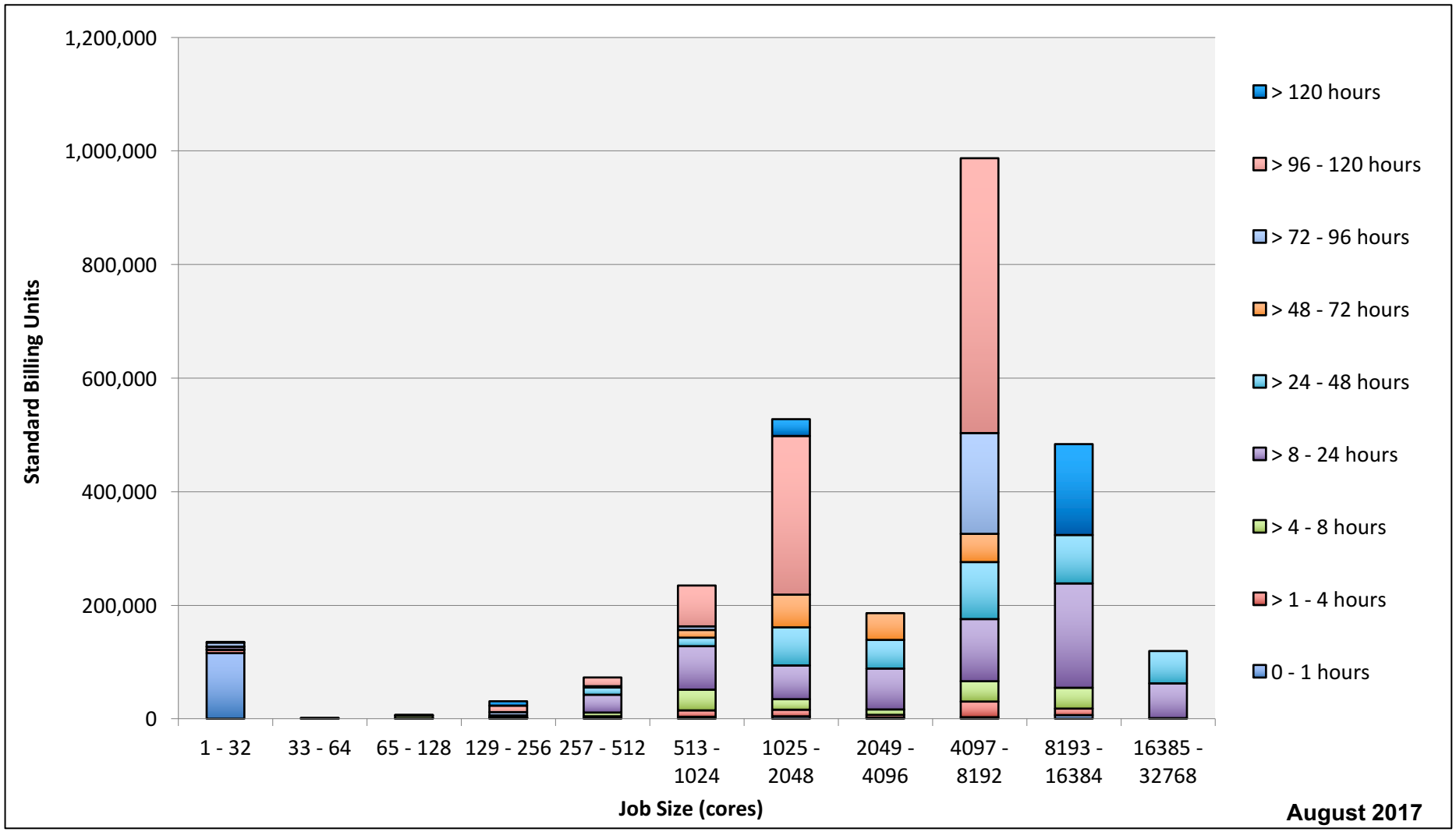
Electra:
Monthly Utilization by Job Length



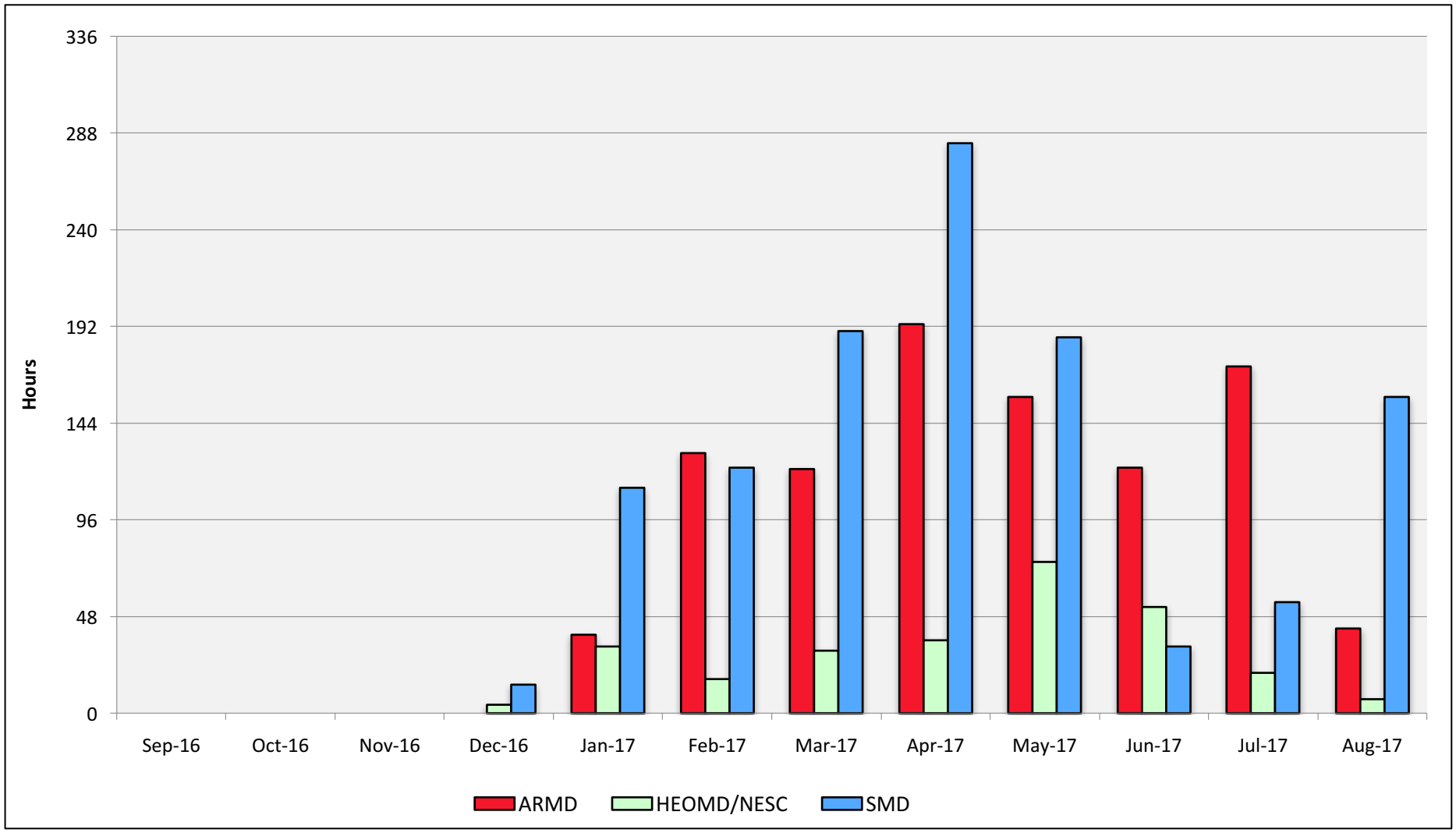
Electra:
Monthly Utilization by Size and Mission



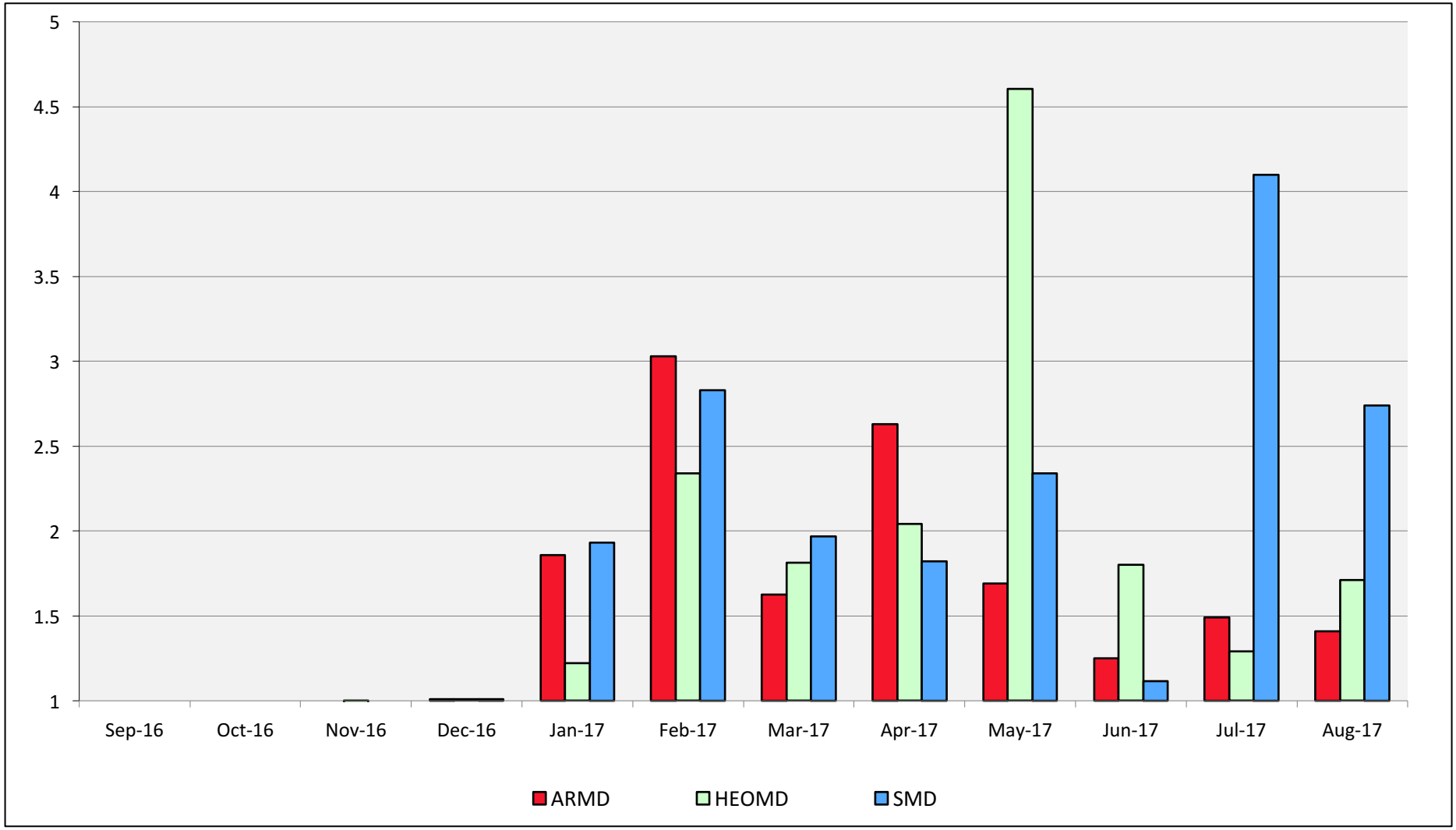
Electra:
Monthly Utilization by Size and Length



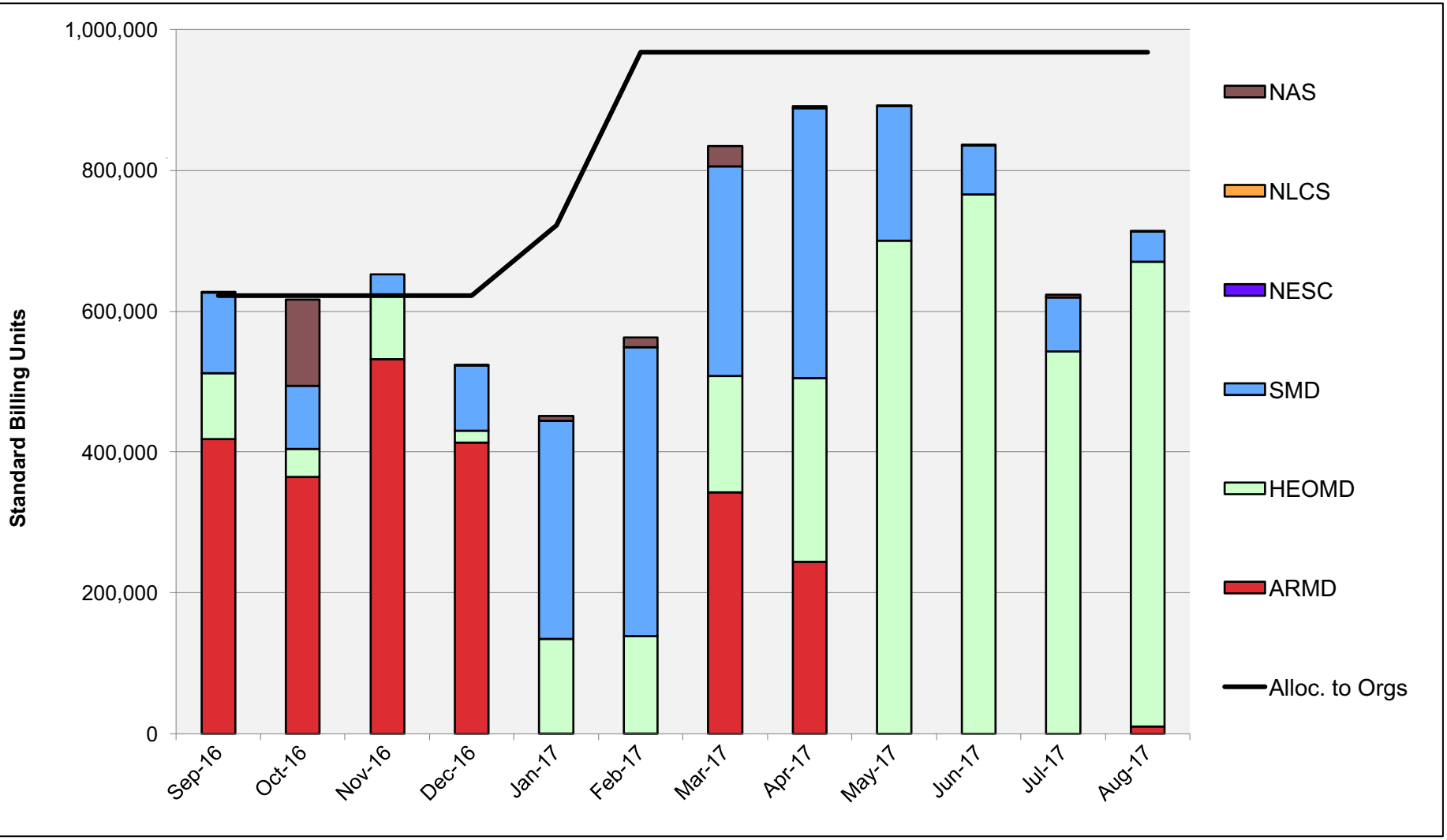
Electra:
Average Time to Clear All Jobs



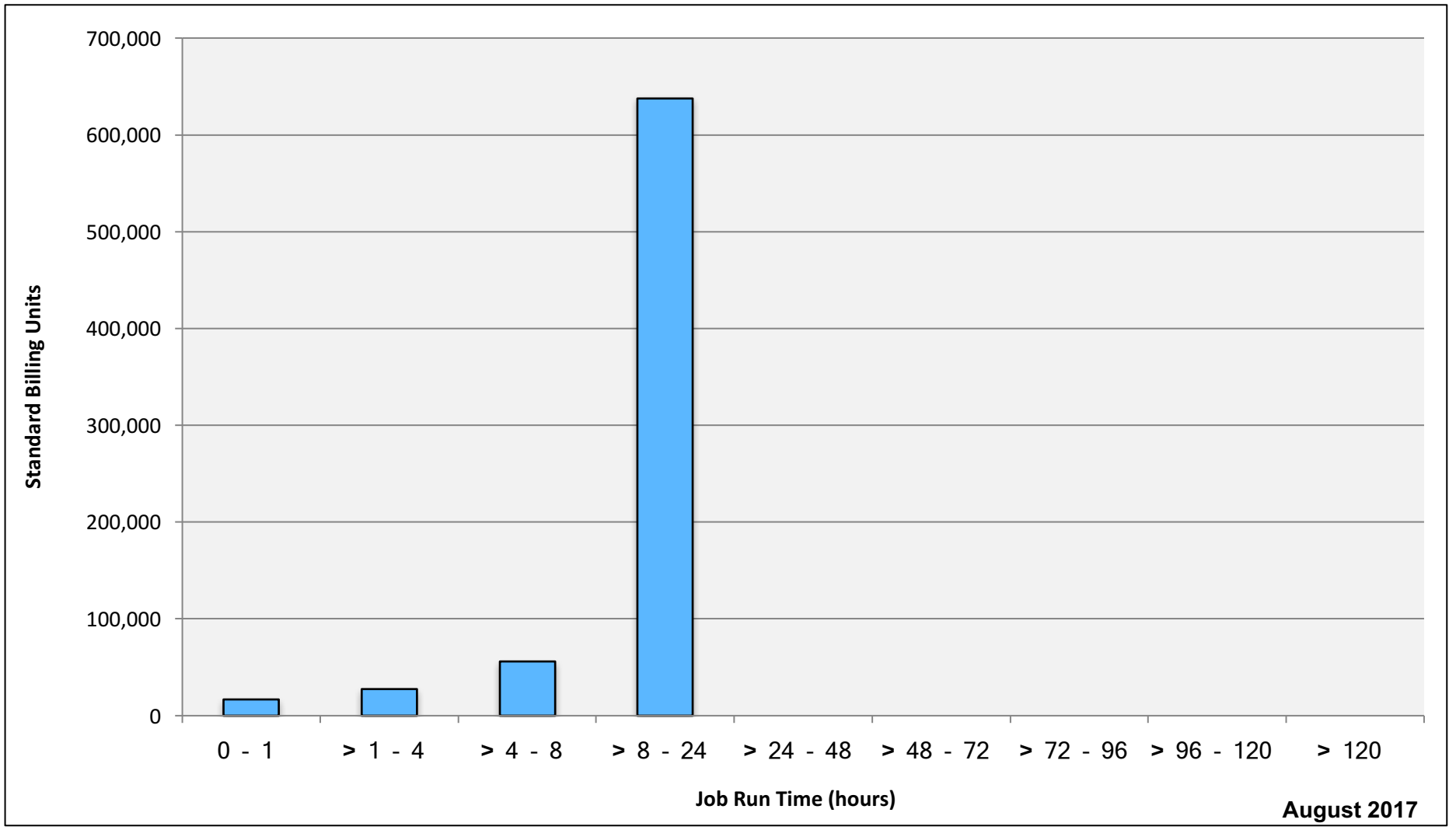
Electra:
Average Expansion Factor



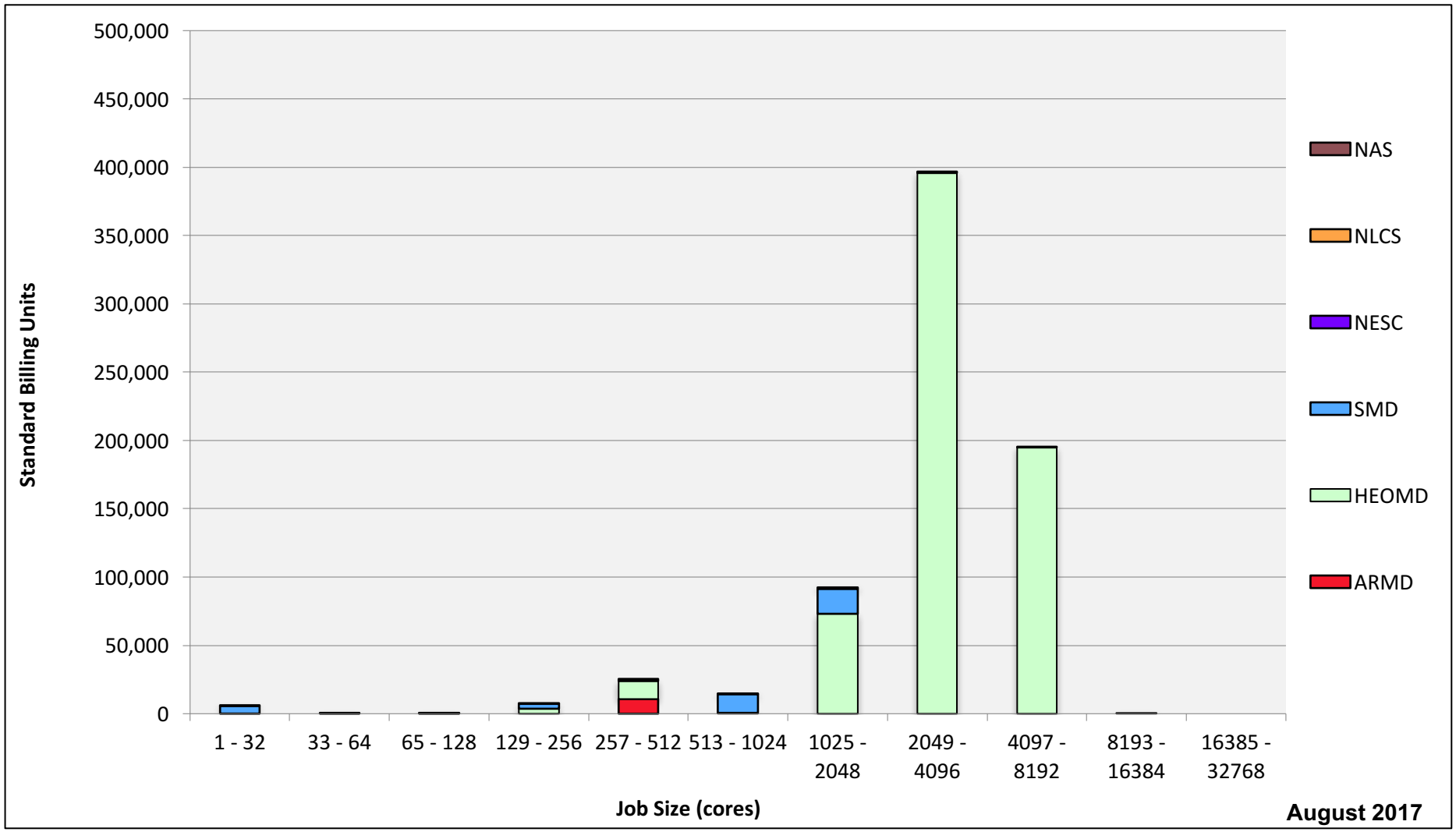
Merope:
SBUs Reported, Normalized to 30-Day Month



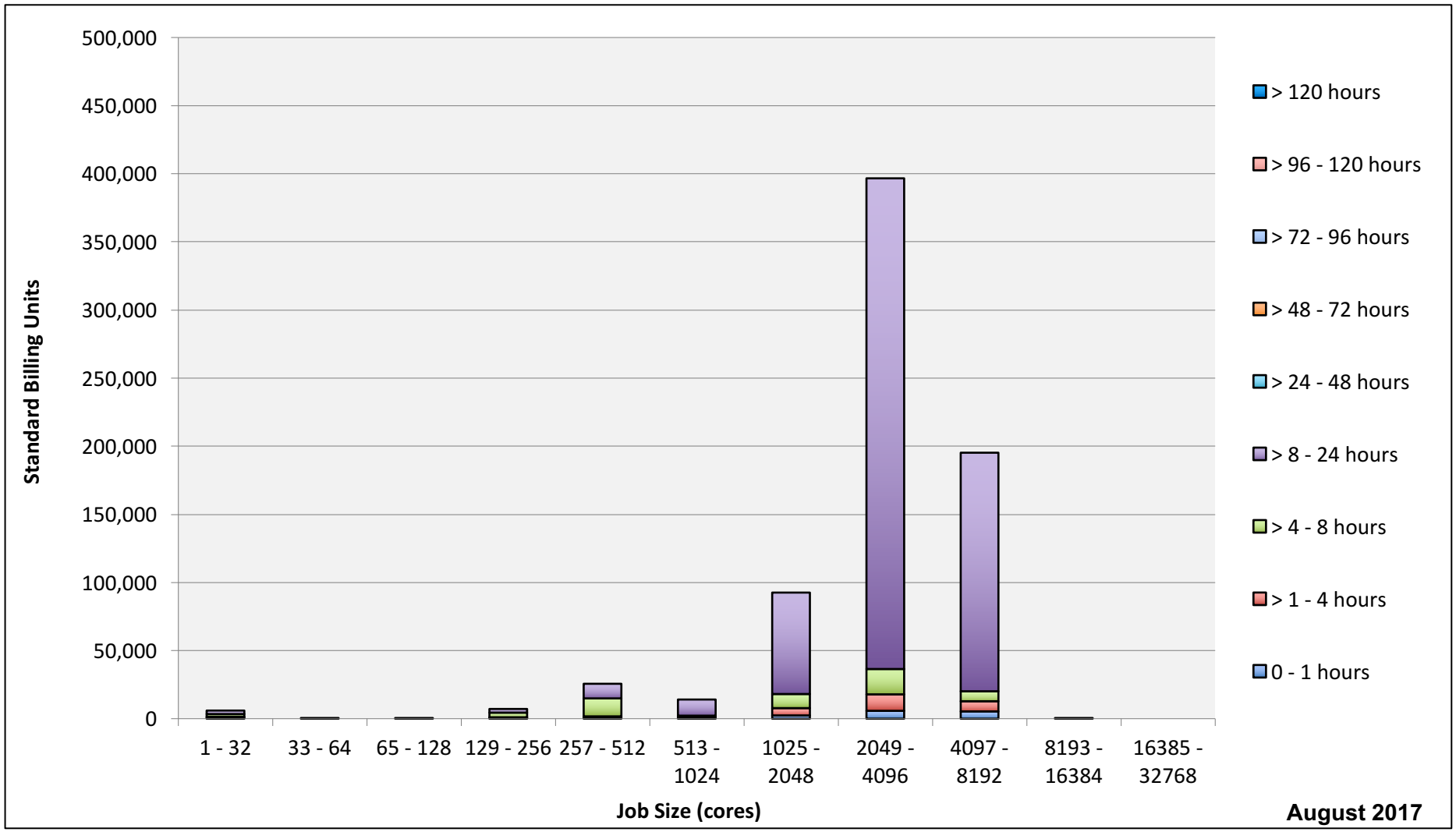
Merope:
Monthly Utilization by Job Length



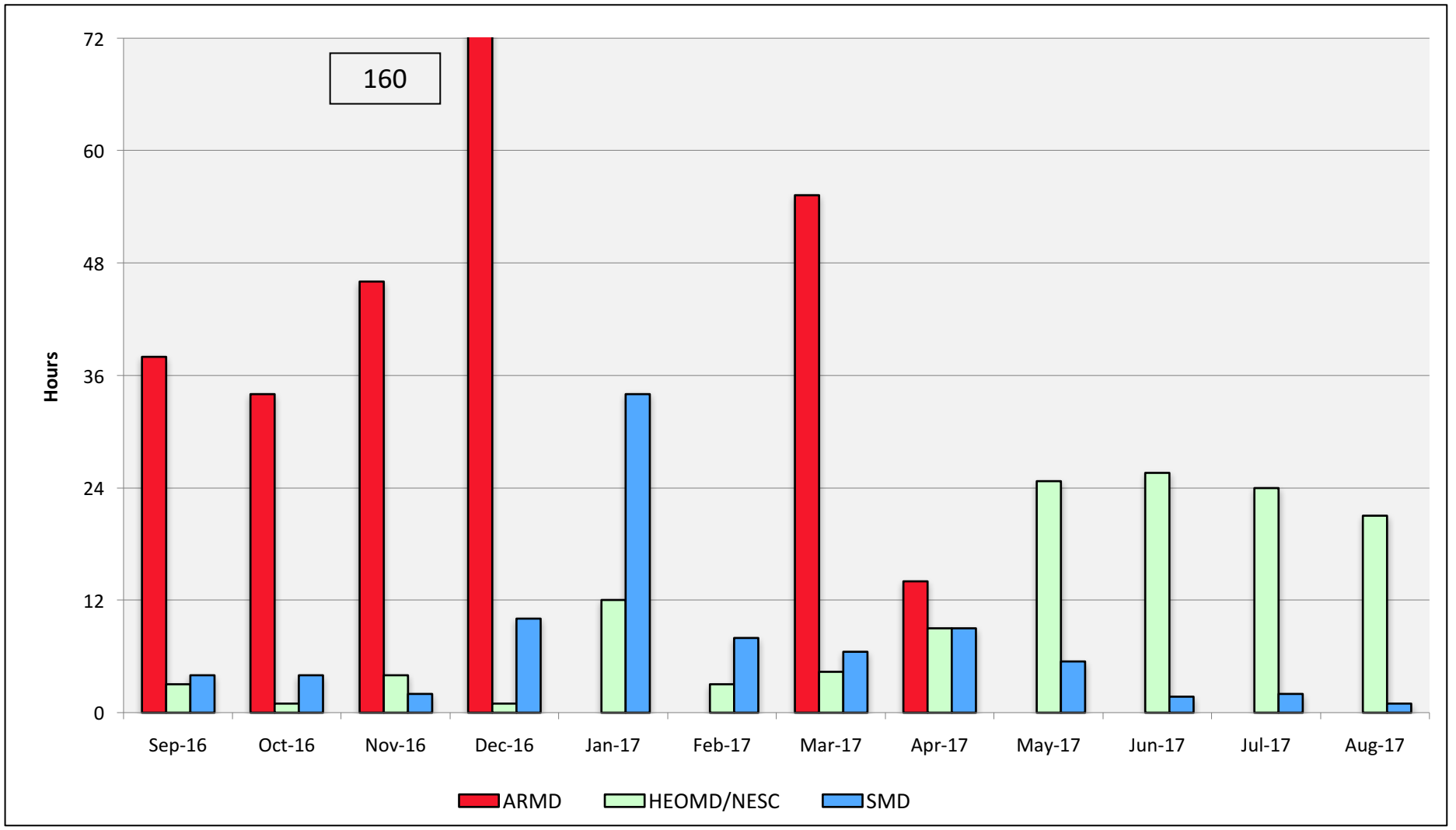
Merope:
Monthly Utilization by Size and Mission



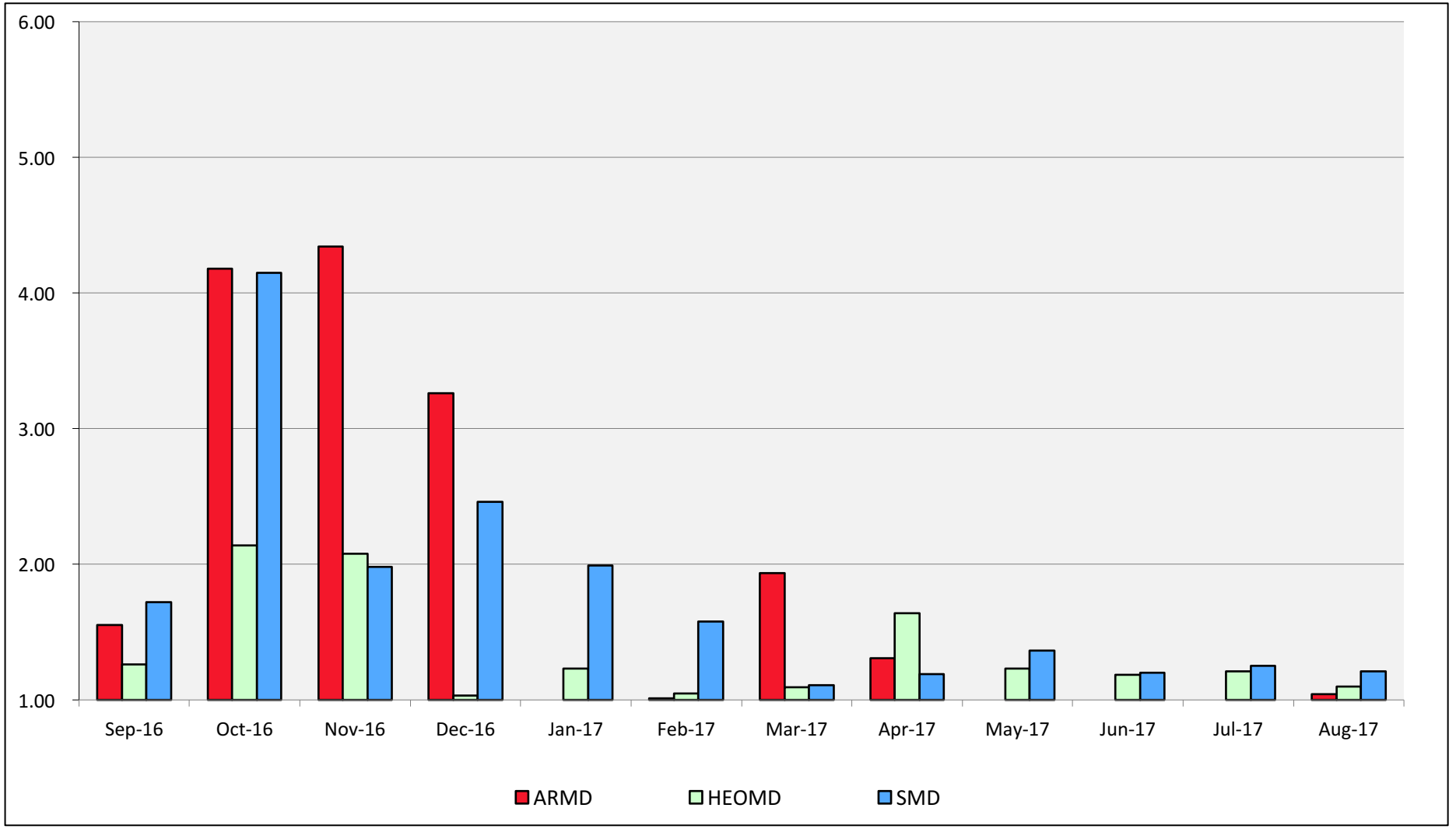
Merope:
Monthly Utilization by Size and Length



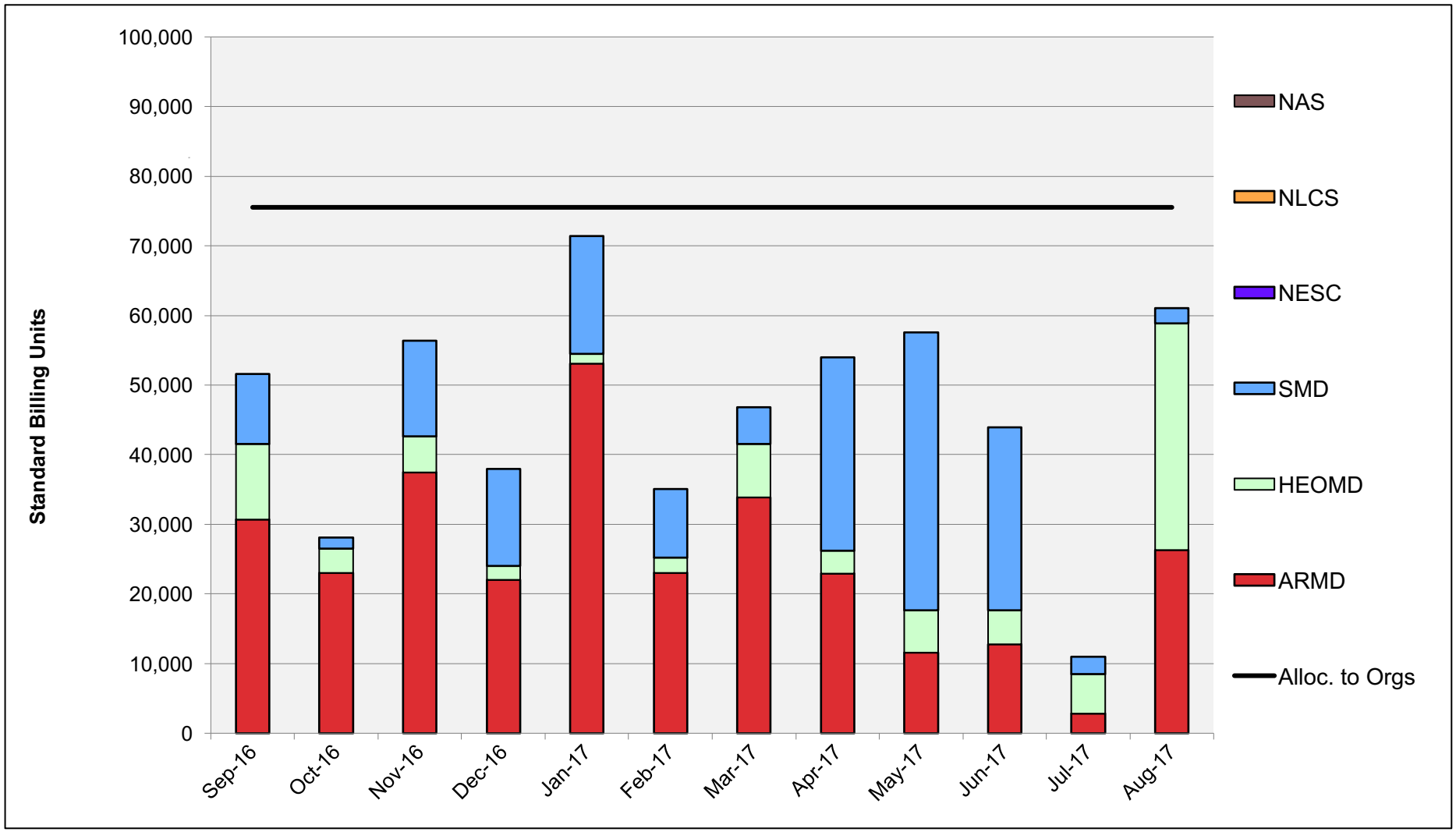
Merope:
Average Time to Clear All Jobs



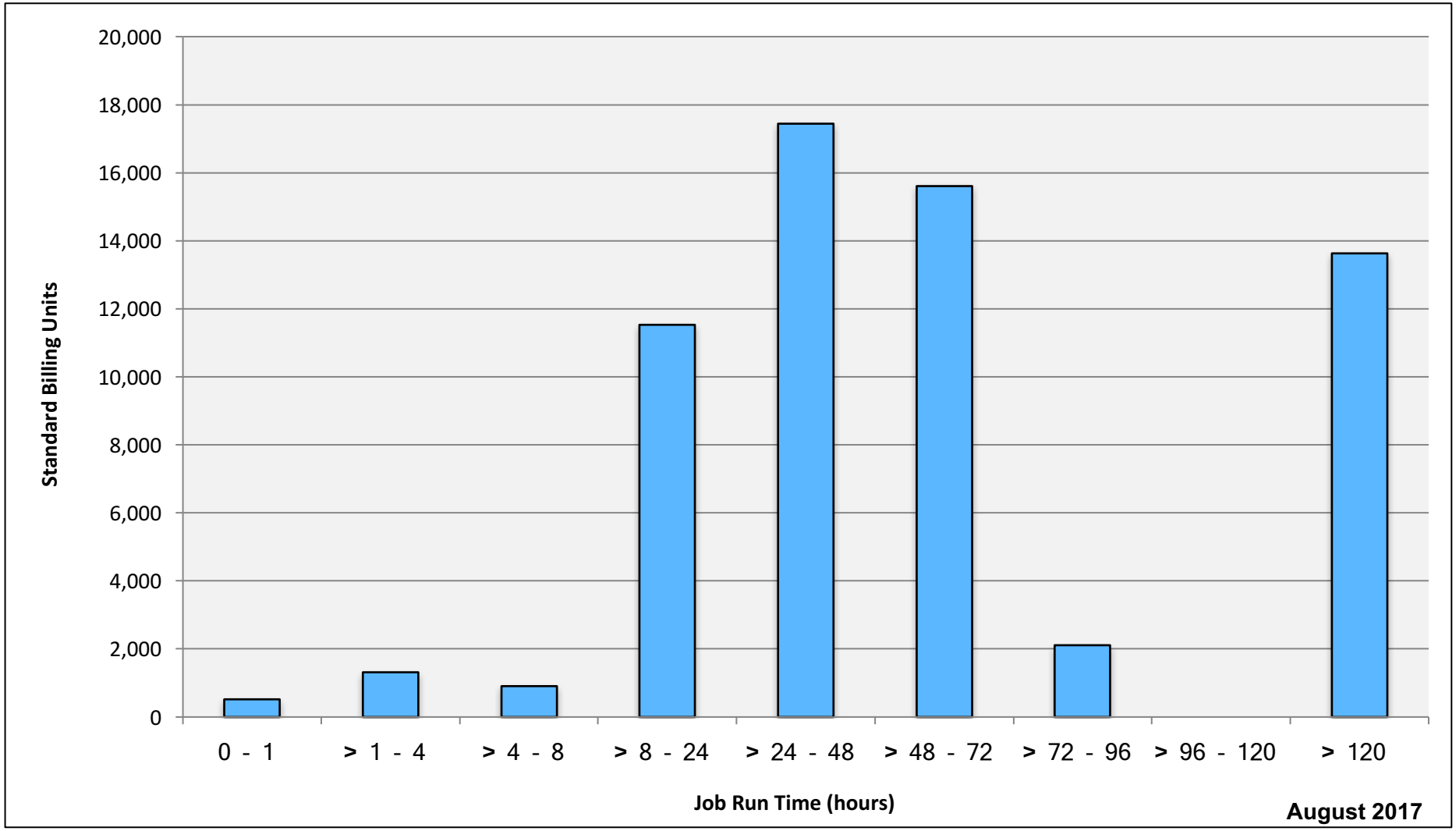
Merope:
Average Expansion Factor



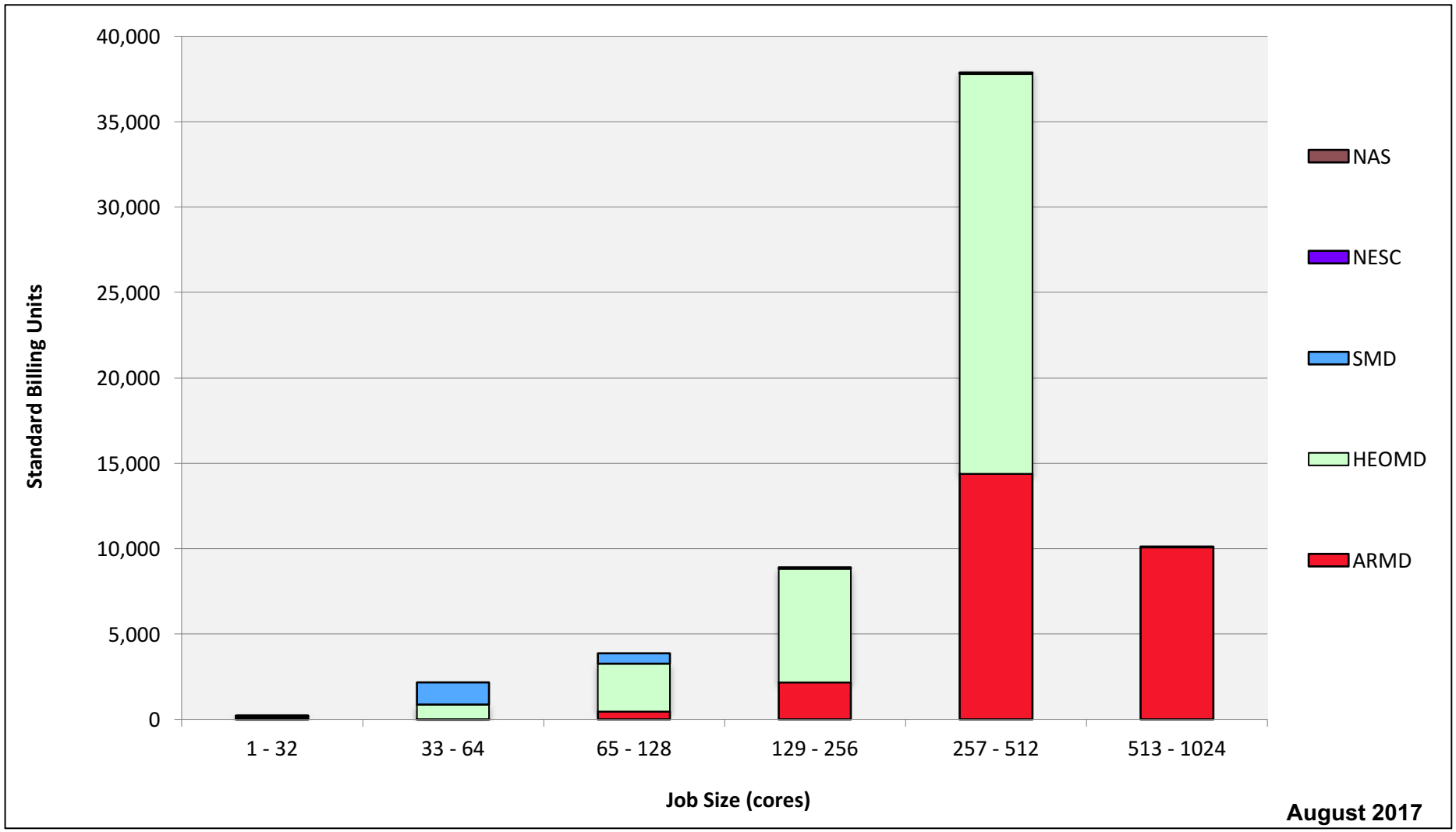
Endeavour:
SBUs Reported, Normalized to 30-Day Month



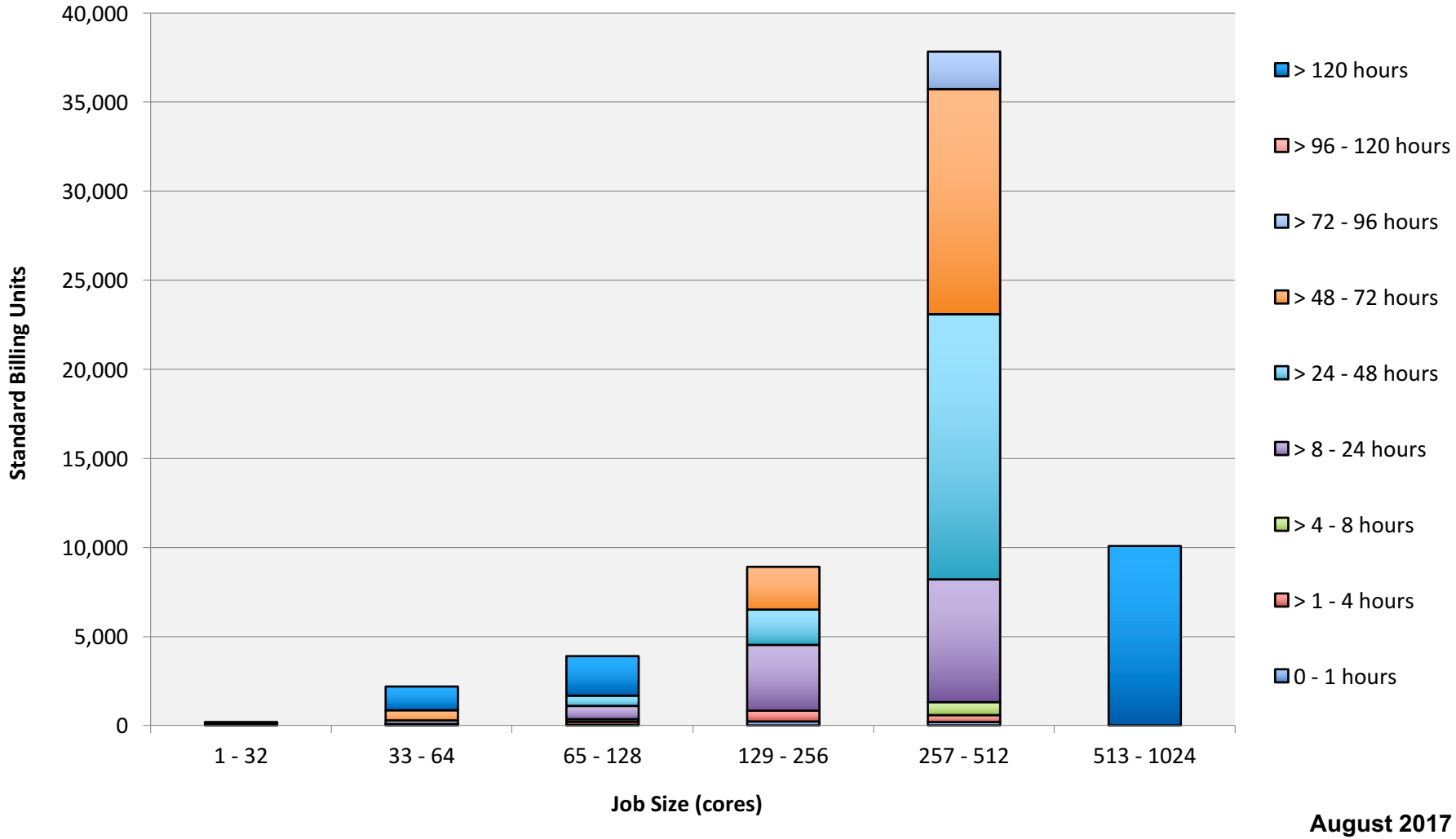
Endeavour:
Monthly Utilization by Job Length



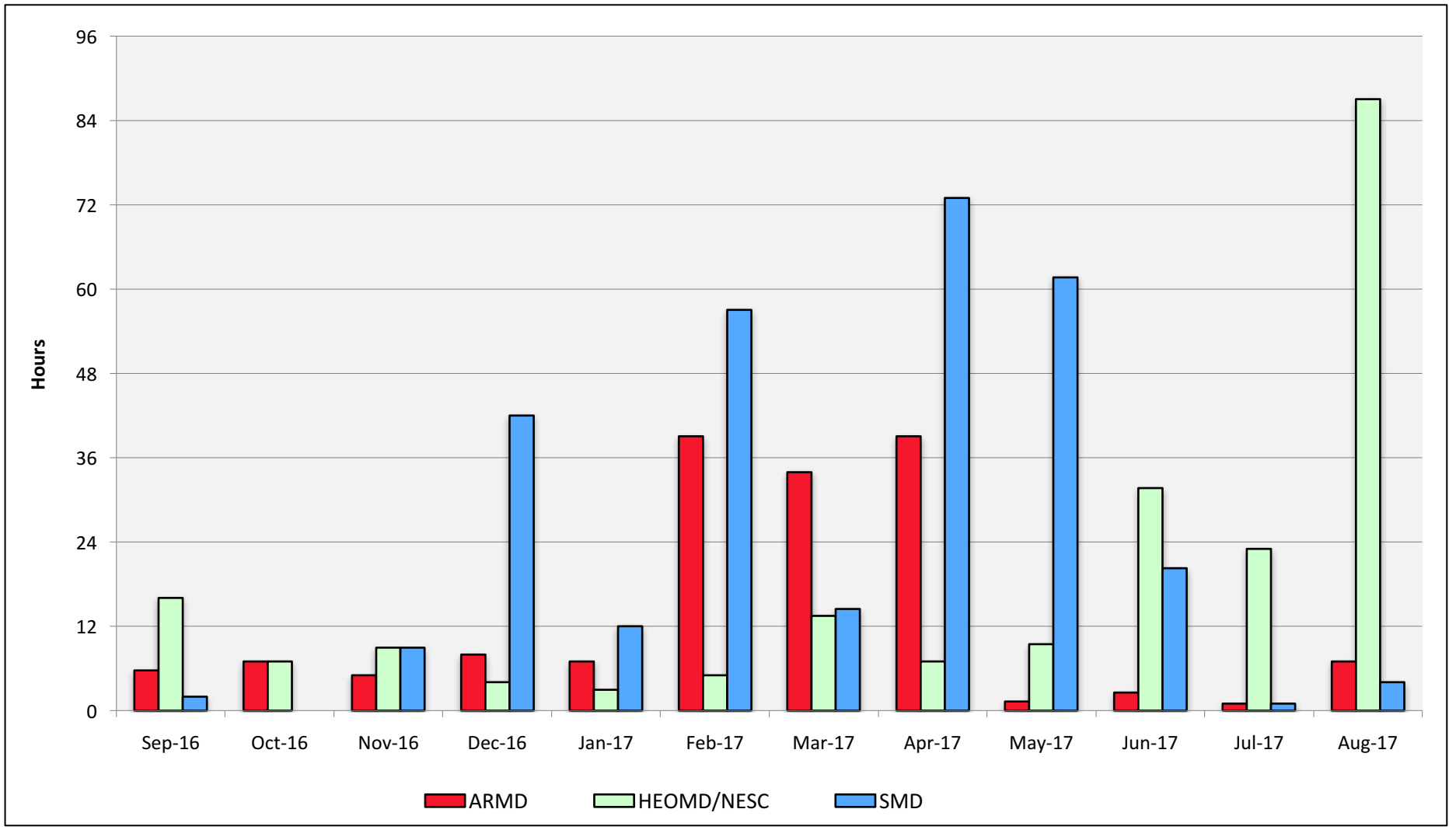
Endeavour:
Monthly Utilization by Size and Mission



Endeavour:
Monthly Utilization by Size and Length



Endeavour:
Average Time to Clear All Jobs



Endeavour:
Average Expansion Factor