TO THE EDITOR: I appreciate the thought-provoking ideas provided by those who have commented on my Viewpoint article on physiological resilience in astronauts. A healthy discussion can guide the course of research in this area and also help NASA in determining its course of action.

In their commentary, Etheridge and Szewczyk (see Ref. 1) point out that NASA archives already contain a great deal of physiological data relevant to the proposed approach. This is true, to a point. Although much data exist, the data sets are not all from the same subjects or the same experiments, and the measurement methods that provided the data are not all identical. Thus it is a promising start but gaps exist. Their contention misses the crucial point that my proposed approach is personalized and so by its very nature requires multivariate data streams from the same individual at the same time. Furthermore, this personalized signature approach would be relevant to indicating problematic deviations from nominal in any environment, no matter the cause. Thus developing the model in low earth orbit does not prohibit its use elsewhere. Finally, my proposal is not incompatible with the use of molecular, genetic, or metabolic markers. In fact these could be incorporated readily into a personal signature alongside physiological markers. However, I contend that physiological and behavioral/performance markers will in fact be cheaper and can be embedded in normal crew activities, thus allowing for continuous acquisition and little or no acquisition cost in terms of dedicated crew time. The path from genetic markers to behavior and performance, and even physiology, is in many cases so convoluted that an outcome measure might be preferred in an operational setting.

Zuo and colleagues (see Ref. 1) concentrate on respiratory function and propose that improving its strength will increase resilience. I do not disagree, but my broader point is that, although improving the conditioning of any single system is certainly useful in increasing resilience, it is the overall interaction of many such systems that is little understood and that will provide resilience under unusual, dramatic, and unexpected perturbations.

Ward and colleagues (see Ref. 1) suggest that my approach would require extensive amounts of data and be subject to many confounds, and I do not disagree. This will not be a trivial undertaking. They go on to state that astronaut crews are not conducive to the proposed approach because of their lack of homogeneity, but I maintain my stance that the constrained environment, imposed identically on all crew members simultaneously, removes many other confounds that would otherwise be present in a conventional terrestrial population. Finally, I do not discount the importance of radiation effects on crew health and performance. They are, however, not necessarily more pressing than the effects that I propose to measure, and in fact can lead to some of those effects.

Zhang and colleagues (see Ref. 1) point out areas where care is needed in pursuing my approach. I agree completely. This is a daunting task that should include environmental and social variables, among others. This, however, just means that we should start now on this type of work.

DISCLOSURES
No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS
Author contributions: M.S. drafted manuscript; M.S. edited and revised manuscript; M.S. approved final version of manuscript.

REFERENCES

Address for reprint requests and other correspondence: M. Shelhamer, NASA Johnson Space Center, Code SA2, Houston, TX 77058 (e-mail: mark.j.shelhamer@nasa.gov).