**PROPOSAL NARRATIVE:**

In no more than two (2) pages (excluding references and figures), the Proposal Narrative should include:

* Specific Aims
* Background
* Significance of this work to the origins of life
* Research Design and Methods

Type should be set in legible, 11-point font. All margins should be set at 0.5 inches.

In your Proposal Narrative address one or more of these 10 key questions:

1. **What is the range of possible planetary environments?** How do exoplanets, and the composition of their atmospheres, compare to Earth and other solar system bodies? What factors influence planetary habitability and the course of planetary evolution? How special is the Earth and our solar system? How can space missions help inform these questions?

2. **What chemical processes shaped the composition of asteroids and comets?** How can we explain the diversity of organic compounds present in these primitive bodies? What caused the enantiomeric excesses of compounds found in meteorites? What do patterns of elemental and isotopic differentiation tell us about the genesis of prebiotic materials?

3. **What governed the accretion, supply of water and other volatiles, chemistry and internal differentiation of the planets and the evolution of their atmospheres?** What minerals would have been present on the early Earth and the ancient crusts of other terrestrial planets such as Mars? What role did photochemistry, and bombardment by large projectiles, play in the origin of life? Can we explain certain chemical compounds preserved in the Earth’s early rock record as “prebiotic fossils” of the origin of life? Does Mars serve as an analog for Earth and possibly preserve relicts of prebiotic compounds that have been erased on Earth as a result of plate tectonics?

4. **What sort of chemistry led to the building blocks of biology?** Can reductive homologation chemistry of hydrogen cyanide generate all the building blocks? Are alternative chemistries possible? How and when was homochirality established? Were nucleotides, amino acids and lipids produced simultaneously or sequentially?

5. **How were oligomers of building blocks produced and reproduced?** What was the chemistry of oligomerization? Were RNA and peptides produced simultaneously or sequentially, and how did they co-evolve? Can efficient replication of RNA be demonstrated without peptide/RNA catalysis or is such catalysis essential? How would RNA fitness landscapes be affected by their chemical or physical environments and constrain the evolution of RNA catalysts? Are there alternatives to RNA that could have acted as the central biopolymer of primitive cells and then plausibly given way to RNA?

6. **What was the role of systems chemistry and how** **did cooperating, homeostatic networks form and develop spontaneously?** How do simple, individual chemical reactions self-assemble spontaneously into the dissipative networks that now form the basis of all metabolism? How did chemistry that seems characteristic of different environments (hot brine ponds, lakes, geothermal vents, aerosols of ocean spray, hot sunny rocks?) come together to form simple cells? What fits both plausible chemistry and plausible geochemical scenarios? How did dissipation of energy enable both the operation and (more important and difficult) the *formation* of dissipative and self-improving networks? How did “chemistry” become “life”?

7. **How did primitive protocells assemble and replicate?** What physical and chemical mechanisms drove the growth and division of the earliest protocell membranes? How was the replication of genetic polymers, including RNA, affected by encapsulation? How were other protocell contents replicated?

8. **How did catalysis gain control of early biology?** How did prebiotic syntheses morph into genetically encoded metabolic pathways? How can we explain the origins of biological catalysis in the chemistry of the early Earth? How did the complex process of genetically encoded peptide synthesis emerge? What is the origin of the genetic code?

9. **What can be learned by looking back?** What can deep phylogeny tell us about the history of life prior to the last common ancestor? What constraints can be placed on the time of the earliest possible origin of life on Earth? What are the earliest records of microbial life and how do we evaluate their robustness? What can be done to improve the fidelity of biogeochemical records on the early Earth and, potentially, Mars?

10. **What factors controlled the dominant biogeochemical cycles of ancient Earth and (bio?)geochemical cycles on Mars?** What was the composition of the atmospheres of the Hadean and Archean Earth and of Noachian and early Hesperian Mars? What were the major steps in the early co-evolution of life and environments on Earth, up to and including the Great Oxidation Event?