Fiscal Year:	FY 2020	**Task Last Updated:**	FY 06/21/2021
PI Name:	Chaikin, Paul M. Ph.D.		
Project Title:	The Control and Dynamics of Hard Sphere Colloidal Dispersions		
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	COMPLEX FLUIDS/SOFT MATTER--Complex Fluids		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	10003	**Congressional District:**	8
Comments:	NOTE: PI moved to NYU (from Princeton U) in 2005 per A. Hollingsworth in PI's dept (7/2009). Changed email 3/30/2009 (chaikin@princeton.edu no longer valid).		
Project Type:	FLIGHT	**Solicitation / Funding Source:**	98-HEDS-03
Start Date:	09/06/2013	**End Date:**	09/05/2021
No. of Post Docs:	3	**No. of PhD Degrees:**	4
No. of PhD Candidates:	5	**No. of Master' Degrees:**	
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:		**Monitoring Center:**	NASA GRC
Contact Monitor:	McQuillen, John	**Contact Phone:**	216-433-2876
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Flight Program:	ISS		
Flight Assignment:	NOTE: End date changed to 9/5/2021 per NSSC information (Ed., 11/5/20) NOTE: End date changed to 9/5/2020 per NSSC information (Ed., 11/12/19) NOTE: End date changed to 9/5/2019 per NSSC information (Ed., 10/2/19)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Hollingsworth, Andrew Ph.D. (New York University)		
Grant/Contract No.:	NNX13AR67G		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	NOTE (Ed., March 2014): Continuation of "The Control and Dynamics of Hard Sphere Colloidal Dispersions--NNX08AK04G", grant # NNX08AK04G with the same Principal Investigator (PI), Dr. Paul Chaikin. Colloid science is entering a new era. Over the past 15 years, our NASA-sponsored research has mainly dealt with monodisperse suspensions of colloidal particles interacting via well-known forces. Using spherical particles and observations with light scattering and microscopy, we have gained a great deal of fundamental knowledge about different phases of matter and the dynamics and thermodynamics of their formation. In particular, our experimental results in microgravity have led to a basic understanding of why crystals and glasses form and their properties. During the past decade, we have made great strides in synthesizing new classes of particles with different shapes and specific, reversible or irreversible, variable range interactions. We have also found new ways to manipulate the particles with flow, electric and magnetic fields, and light. We are therefore positioned at the threshold of a new technology, assembling equilibrium and non-equilibrium macroscopic structures with function and activity from well designed particles on the nano to micron scale. Of course, there are still fundamental scientific questions which we can and will address including a host of new ordered phases, frozen configurations, frustration and glasses, and the process of self-organization itself. In particular, we plan to use the microscopy and light scattering instruments, in collaboration with our European colleagues, to study particles that we prepare through emulsion and dispersion polymerization. Physical lithographic techniques will also be employed, and the particles will be modified chemically for controllable interactions. We plan to use different phoretic techniques--electro-, dielectro-, and thermo-phoresis--to control the particles density and orientation. These will also serve as the driving forces to establish the rheological properties of these new systems.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Characterization of crystal formation in the microgravity environment of the ISS (International Space Station) can lead to a greater understanding of how gravity affects many kinds of colloidal materials, including monodisperse ellipsoids and cubes, colloidal clusters of silica or polymer microspheres, DNA-functionalized colloidal spheres, and 'lock-and-key' colloids. By performing these experiments in reduced gravity, we intend to accomplish the desired characterization without gravitationally-induced inhomogeneities that affect both the dynamics and equilibrium state on Earth. Understanding these complex materials should enable new ways of forming ordered phases, such as those sought for photonic devices to be used in optical communication systems. With the ability to make particles of different shapes, i.e., non spherical, we also have the possibility of having directionally dependent particle interactions. For example, we could take tetrahedral clusters of particles and attach DNA to them. The complementary single-stranded DNA 'sticky ends' can associate/dissociate via thermal activation. This arrangement could lead to tetrahedral bonding as found in diamond or in amorphous glass structures. Another approach utilizes depletion interactions. Since we can lithographically prepare particles of any shape we design in two dimensions and many shapes in three dimensions, we can fabricate lock-and-key colloids which only bind to their complementary shape. In this case, the binding is also directional since the congruent surfaces must match. We can also make such lock-and-key particles through emulsion chemistry. Our goal is to produce some simple processes with such ‘designer particles’ and interactions, to lay the foundations for self-assembly and perhaps self-replication of this new class of materials.
Task Progress:	Progress Report, Year 6: Sept. 1, 2019 to August 31, 2020 [Ed. note: compiled from report sent to NASA Glenn Research Center] The program’s principle goal is the understanding and explanation of the fundamental microscopic mechanisms of self-organization in model complex fluid systems. The experimental samples are composed of specially synthesized colloidal particles with well understood, well controlled, and sophisticated interactions. Our experiments feature recently developed colloidal systems with directional, specific, and externally controlled inter-particle interactions and motility. During the past grant period we have been preparing ellipsoidal and spherical particles for temperature and temperature gradient experiments for the NASA Advanced Colloids Experiment (ACE) presently on the International Space Station. We have also been performing ground based experiments on these samples to compare with the upcoming microgravity experiments. In addition we have published several results on ground based colloidal experiments. Two recent publications are directly connected with antibody tests related to combatting the Covid-19 pandemic. They use optical detection of proteins bound to colloids where in their medical application the colloids would be covered with antigens complementary to the antibodies found in patients blood. The holographic detection method is capable of observing size changes in colloids’ radii of much less than a monolayer of antibody. We have also pursued experiments on the effects of non-equilibrium organization of colloids. In particular we have studied the formation of non-crystalline colloidal structures that exhibit a new form of order, hyperuniformity, the vanishing of long range density fluctuations. As we have demonstrated in previous work, hyperuniformity may be useful in making isotropic complete photonic bandgap materials. Isotropic hyperuniform structures cannot be made by any equilibrium self-organization. However, as we demonstrate, they can be made using a dynamic phase transition Random Organization at its critical point. We implement and study this transition by driving a system of controlled volume fraction with a specially constructed shear cell with optical access to a confocal microscope.
Bibliography Type:	Description: (Last Updated: 06/21/2021)
Articles in Peer-reviewed Journals	Wilken S, Guerra RE, Pine DJ, Chaikin PM. "Hyperuniform structures formed by shearing colloidal suspensions." Physical Review Letters. 2020 Oct 2;125(14):148001. https://doi.org/10.1103/PhysRevLett.125.148001 , Oct-2020
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Articles in Peer-reviewed Journals	Snyder K, Quddus R, Hollingsworth AD, Kirshenbaum K, Grier DG. "Holographic immunoassays: direct detection of antibodies binding to colloidal spheres." Soft Matter. 2020 Nov 18;16(44):10180-6. https://doi.org/10.1039/d0sm01351j ; PMID: 33057563 , Nov-2020

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NASA Technical Documents	Chaikin P, Clark N, Nagel S. "Grand Challenges in Soft Matter Science: Prospects for Microgravity Research. [Proceedings of a NASA Glenn Research Center virtual meeting--Grand Challenges in Soft Matter and Opportunities for Microgravity Research at 2020 American Physical Society (APS) March Meeting Virtual Event, March 26, 2020.]" Cleveland, Ohio: NASA Glenn Research Center, 2021. NASA/CP-20205010493. https://ntrs.nasa.gov/search?q=20205010493 , Mar-2021