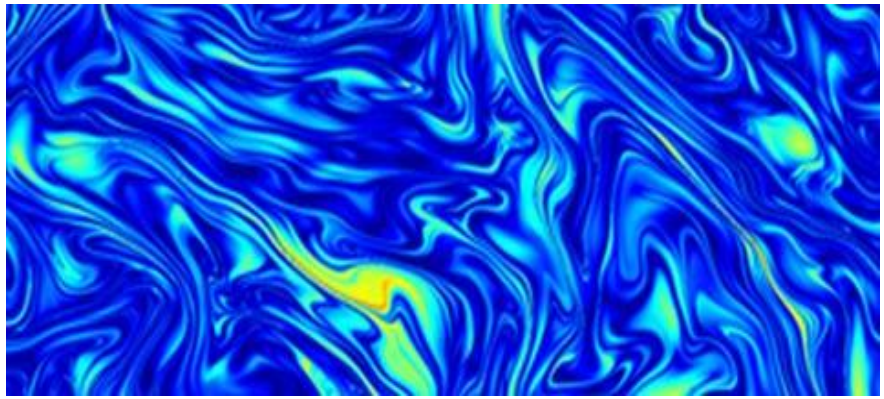
SPRING 2019 MEETING OF THE COMMITTEE ON BIOLOGICAL AND PHYSICAL SCIENCES IN SPACE - The National Academies of ESM

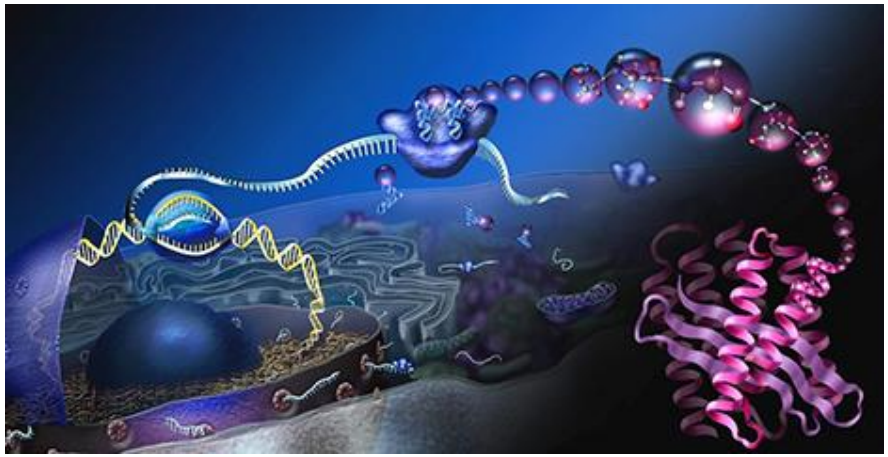
Shahab Shojaei-Zadeh, PhD
CBET Division, Engineering Directorate
National Science Foundation

Panel on Research Interests and Future Needs at Federal Agencies Outside NASA, 3/27/2019

OUTLINE

- **Overview of NSF, ENG, and CBET**
- **NSF-CASIS Collaboration**
- **Selected Awards**
- **Future Directions**





National Science Foundation

FOUNDATION INTRODUCTION

NSF Created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…"

- $7.5B budget (FY2019 request)
- 24% of federally funded basic research at U.S. colleges and universities
- Directorates:
  - Engineering (ENG)
  - Mathematical & Physical Sciences (MPS)
  - Biological Sciences (BIO)
  - Computer & Information Science & Engineering (CISE)
  - Geosciences (GEO)
  - Social, Behavioral & Economic Sciences (SBE)
  - Education & Human Resources (EHR)

NSF Director
France A. Córdova.
Credit: *NSF/Stephen Voss*

NSF's current headquarters in Alexandria, VA
Credit: *National Science Foundation (www.nsf.gov)*

National Science Foundation

ENGINEERING (ENG) DIRECTORATE

ENG Mission: Investing in engineering research and education and fostering innovation to benefit society

Photo Credit: *Joseph Xu*

Assistant Director
Dawn Tilbury

Deputy Assistant Director
Linda Blevins

Emerging Frontiers and Multidisciplinary Activities (EFMA)
Sohi Rastegar

Engineering Education and Centers (EEC)
Kon-Well Wang

Chemical, Bioengineering, Environmental, and Transport Systems (CBET)
Richard Dickinson

Civil, Mechanical, and Manufacturing Innovation (CMMI)
Rob Stone

Electrical, Communications, and Cyber Systems (ECCS)
Fil Bartoli

Industrial Innovation and Partnerships (IIP)
Andrea Belz

Division of Chemical, Bioengineering, Environmental, and Transport Systems

Division Director
Richard Dickinson

Deputy Division Director
Timothy Patten

Chemical Process Systems

1401
Catalysis
Robert McCabe

1417
Molecular Separations
Christina Payne

1403 Process Systems, Reaction Engineering, & Molecular Thermodynamics
Triantafillos Mountziaris

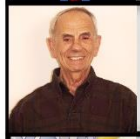
7644
Electrochemical Systems
Carole Read

Chemical Process Systems Cluster
VACANT

Engineering Biology & Health

1491 Cellular & Biochemical Engineering
Steven Peretti

5345
Engineering of Biomedical Systems
Aleksandr Simonian



7236
Biophotonics
Leon Esterowitz

7909
Biosensing
Chenzhong Li

5342 Disability & Rehabilitation Engineering
Aleksandr Simonian

Environmental Engineering & Sustainability

1440
Environmental Engineering
Karl Rockne

1179 Biological & Environmental Interactions of Nanoscale Materials
Nora Savage

7643
Environmental Sustainability
Bruce Hamilton

022Y
INFEWS
James Jones

Environmental Engineering & Sustainability Cluster
Brandi Schottel

Transport Phenomena

1407
Combustion & Fire Systems
Harsha Chelliah

1443
Fluid Dynamics
Ronald Joslin

1415 Particulate & Multiphase Processes
William Olbricht

1406
Thermal Transport Processes
José Lage

Transport Phenomena Cluster
Shahab Shojaei-Zadeh

Division Experts and AAAS Science & Technology Policy Fellows

Engineering of Biomedical Systems Expert
Carol Lucas

Multiple Programs Expert
Geoffrey Prentice

AAAS S&T Policy Fellow
Shanni Silberberg

AAAS S&T Policy Fellow
Thomas Baird

In 2011, NASA chose the Center for the Advancement of Science in Space (CASIS) to be the sole manager of the International Space Station U.S. National Laboratory. The mission of CASIS is to maximize use of this unparalleled platform for innovation, which can benefit all humankind and inspire a new generation to look to the stars.

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NSF-CASIS: RESEARCH IN SPACE TO BENEFIT LIFE ON EARTH

- **Pre-proposal evaluation by CASIS**
  - Feasibility review for operational feasibility and terrestrial economic benefit

Doable on ISS; benefits on Earth

- **NSF provides funding support to**
  - Conduct research, prepare experiments for onboard ISS, collaborate with service providers, provide preliminary analysis to conduct experiments, analyze and interpret data, and disseminate results

- **CASIS will assist grantees in**
  - Translating ground-based experiments and technologies into the space-appropriate hardware

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NSF-CASIS: SOLICITATIONS SO FAR

On Station

News and Views from the International Space Station U.S. National Laboratory.

PUBLISHED ON MONDAY, DECEMBER 14, 2015

CASIS and the National Science Foundation Announce Joint Solicitation in Fluid Dynamics

on the International Space Station

Kennedy Space Center, FL. (December 14, 2015) – The Center for the Advancement of Science in Space (CASIS) and the National Science Foundation (NSF) today announced a joint solicitation wherein researchers from the fluid dynamics community will have the ability to leverage resources onboard the International Space Station (ISS) U.S. National Laboratory. Up to $1.8 million will be awarded for multiple research investigations to support flight projects to the ISS National Laboratory.

NSF 16-518
Fluid Dynamics

NSF 17-517
Combustion & Thermal Transport

NSF 18-521
Fluid Dynamics & Particulate/ Multiphase

NSF 19-525
Transport Phenomena Research

NSF 19-509
Tissue Engineering and Mechanobiology

National Science Foundation

NSF-CASIS: SELECTED AWARDS

Selected Awards

Quantifying Cohesive Sediment Dynamics for Advanced Environmental Modeling

Unmasking contact-line mobility for Inertial Spreading using Drop Vibration & Coalescence

Inertial Spreading and Imbibition of a Liquid Drop Through a Porous Surface

Kinetics of nanoparticle self-assembly in directing fields

Flame Spread in Confined Spaces: Interactions between Flame & Surrounding Walls

Spherical Cool Diffusion Flames Burning Gaseous Fuels

Thermally activated directional mobility of vapor bubbles using microstructured surfaces

ISS-CASIS: Quantifying Cohesive Sediment Dynamics for Advanced Environmental Modeling

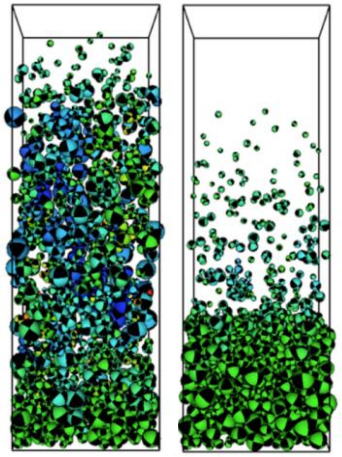
PIS: P. Luzzatto-Fegiz & E. Meiburg, UC Santa Barbara

Background and objectives

- Predicting sediment cohesion and aggregation is essential for modeling ecosystems, pollutant transport, hydrocarbon reservoirs;
- Cohesive forces are much weaker than gravity, and difficult to measure on Earth;
- ISS experiments can observe aggregation in different sediment mixtures over months;
- Comparing ISS experiments to simulations will yield how cohesion depends on composition.

Ground experiments

- Built ground-based replica of BCAT-CS setup aboard ISS;
- Verified that the intended range of sediment concentrations can be measured accurately;
- Chose camera/flash settings for ISS;
- Selected combinations of quartz/clay types and solutes.



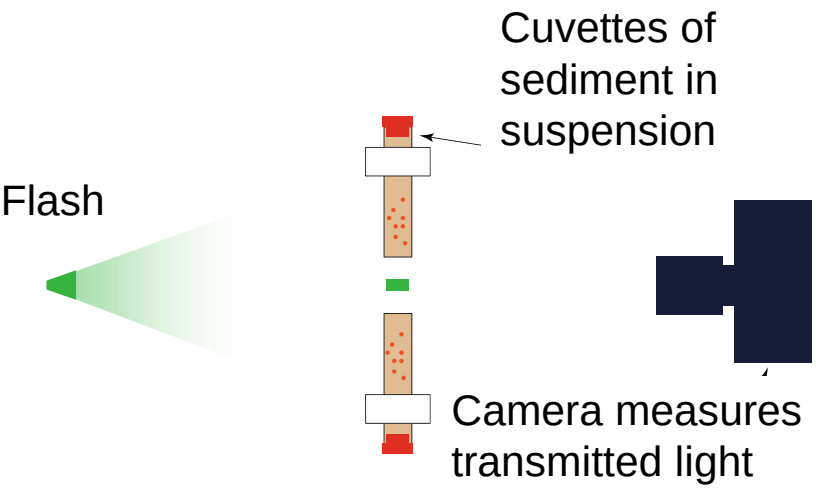
Simulations

- Developed cohesive-particle simulations;
- Use simulations + BCAT data to relate forces to composition + solutes
- Published: Vowinckel *et al.*, *J. Fluid Mech.,* 2019

ISS-CASIS: Quantifying Cohesive Sediment Dynamics for Advanced Environmental Modeling

PIS: P. Luzzatto-Fegiz & E. Meiburg, UC Santa Barbara

Setup onboard ISS: BCAT-CS



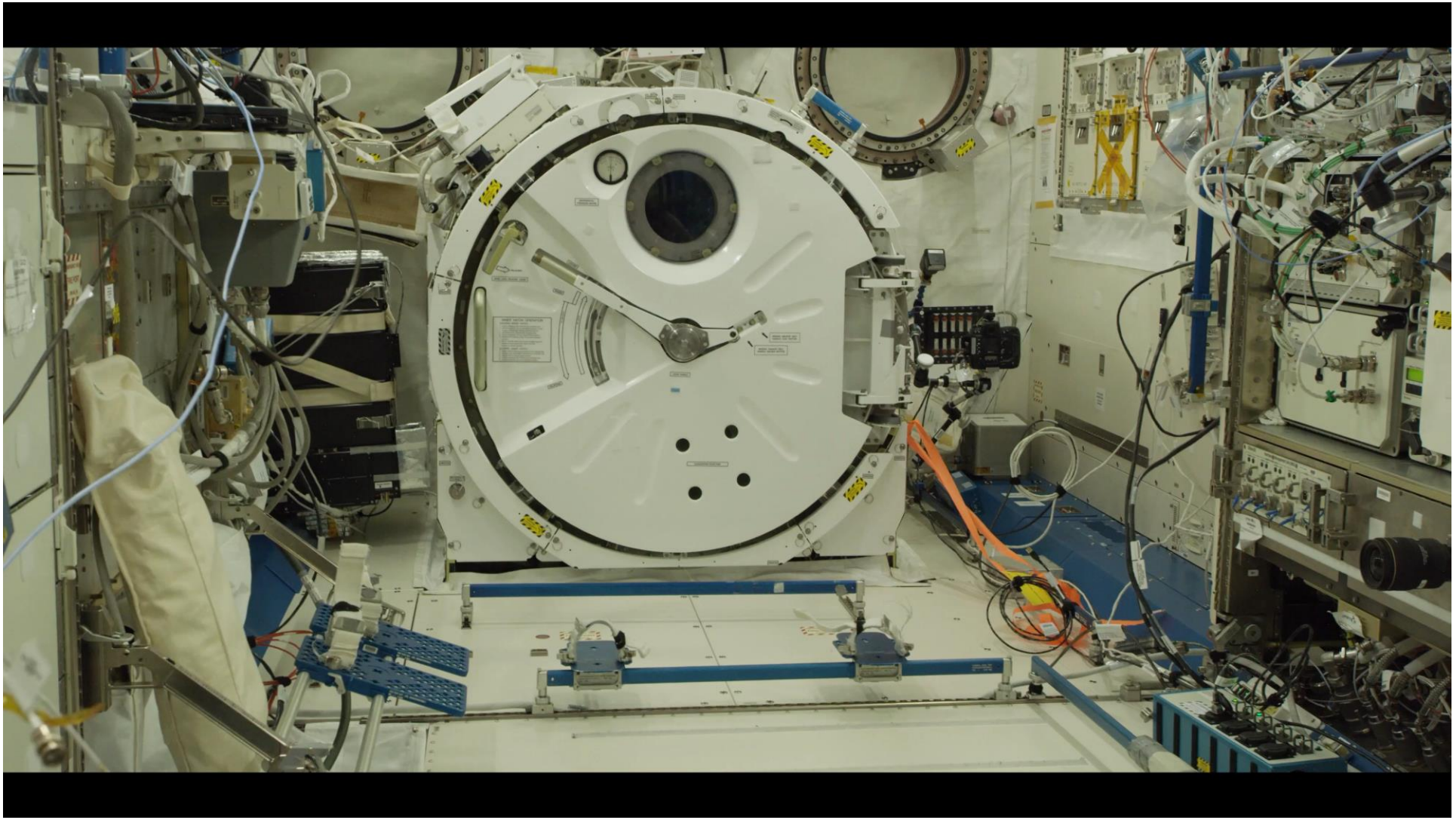
Serena Auñón-Chancellor & Alexander Gerst set up and operate BCAT-CS

Launch to ISS

- Launched: SpaceX-15, 6/29/2018;
- Experiment start: 7/26/2018;
- Re-start due to equipment issue: 8/13/2018;
- Completion: 11/20/2018;
- Two extensions granted to investigate long-term behavior;
- Samples returned: SpaceX-16, 1/14/2019

ISS-CASIS: Quantifying Cohesive Sediment Dynamics for Advanced Environmental Modeling

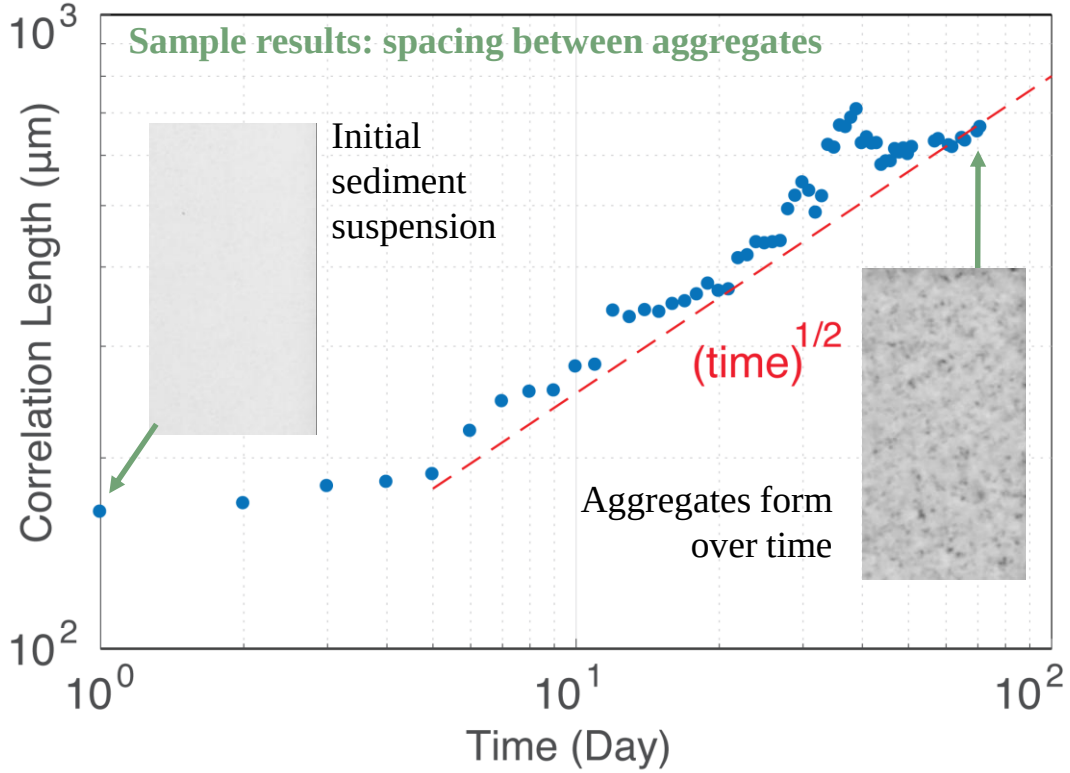
PIS: P. Luzzatto-Fegiz & E. Meiburg, UC Santa Barbara



PIS: P. LUZZATTO-FEGIZ & E. MEIBURG, UC SANTA BARBARA

Preliminary findings from ISS experiment

- Aggregation rates successfully measured as a function of sediment composition;
- Aggregation observed also for sediment traditionally considered very weakly cohesive;
- Long-term experiments reveal power-laws for aggregation, enabling development and testing of theoretical models.



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FUTURE INTERESTS: INPUT FROM CURRENT AWARDEES

Combustion

Current fire experiments are conducted in Microgravity Science Glovebox

Larger facility for burning solid materials

- How does scale play a role in fire behavior?
- Enabling new research areas (e.g., water droplets for fire suppression in microgravity)

State-of-the-art diagnostic techniques (other than cameras, radiometers,…)

Multiphase Flows

Contact line dynamics in two phase flows: μg provides larger deformation/slower dynamics

Dynamics of low-Re turbulent liquid-gas flows (gravity dominates such flows on earth)

Heat Transfer

Extending the CVB (Constrained Vapor Bubble) experiments

How do loop heat pipes (HP) perform in microgravity?

- Fabricate transparent HP to observe behavior rather than just measure temperature
- Optimal internal geometry for microgravity wickless HP?

Colloids and Surfactants

Currently BCAT (binary colloidal alloy test) & ACE (advanced colloids experiments)

Host of experiments on colloidal assembly in the absence of gravity

Emerging area: Study of photo-surfactants (surface tension – Marangoni forces/ buoyancy)

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EMERGING AREAS WITHIN THE ENG & ACROSS DIRECTORATES

Emerging Frontiers in Research and Innovation

EFRI seeks to support multi-/inter-disciplinary and potentially transformative research at the frontiers of engineering research that addresses a national need or grand challenge

Some recent EFRI topics

Flexible Bioelectronics Systems (BioFlex)

Origami Design for the Integration of Self-assembling Systems for Eng. Innovat.(ODISSEI)

CBET-Proposed EFRI topics

Plastic-Eradicating Technologies

Distributed Chemical Manufacturing

Curbing Atmospheric CO2

Sensing and Understanding the Microbiome in Soil

Synthetic Biology for Engineering Solutions

Designing Materials to Revolutionize and Engineer our Future

DMREF seeks to accelerate discovery/development of materials with specific and desired functional properties from first principles.

Topics: Catalysis, 2D Materials and Membranes, Photonics, etc…

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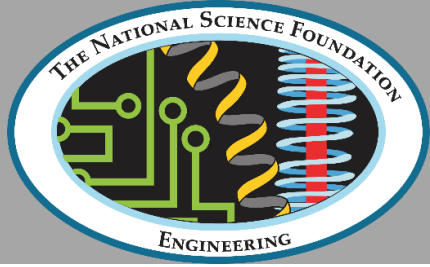
TEN BIG IDEAS!



Thank you!