CARLOS FERNANDEZ-PELLO

RESEARCH ACTIVITIES (PI or Co-PI, career long)

ON-GOING PROJECTS

Material Ignition and Suppression in Space Environmental Atmospheres (NASA): The next generation of NASA spacecraft will use lower pressures and increased oxygen concentrations than current designs. This environment conditions are known as "Space Exploration Atmospheres (SEA)" Recent research suggests that material ignitability is increased in SEA. These results imply that next generation spacecraft present a greater fire safety hazard than current designs. Currently, there exists no testing methodology specifically designed to determine the fire hazard of materials under SEA environments. The objective of this work is to fill that void with a new test methodology and provide additional information about the effect of SEA on the flammability and suppression of combustible materials. Experiments from this project have been recently conducted (2014) in a GloveBox of the International Space Station (ISS). Further experiments will be conducted in the SoFIE hardware that will be incorporated in the Combustion Integrated Rack (CIR) of the ISS.

Space Fire Safety (NASA): The major goal of this project is to aid in the selection of materials for large-scale material flammability experiments to be conducted onboard of the Cygnus resupply vehicle of the ISS. To this date large-scale flammability testing has not been conducted in microgravity conditions and therefore it has not been possible to validate that current normal gravity flammability testing accurately predicts microgravity flammability. The specific goal of this project is to conduct preliminary flammability testing of thin fabrics. This testing is conducted similar to NASA Standard 6001

Wire Combustion in Low Gravity (NASA/JAXA): The goal of the current work is to study the flammability (ignition and flame spread) of several thin cylindrical materials, particularly single wires and thin thermoplastics, that have the potential to be used in the tests planned in the JAXA project "Fundamental Research on International Standard of Fire Safety in Space". The project seeks to evaluate different aspects of the flammability of materials in microgravity under controlled conditions and compared with the results in normal gravity. The results from both the ground and space based experiments will also be used to verify the predictive capabilities of thin complex materials flammability models.

Tree Mortality: Physical Simulation and Model Revision. (CEC): The objective of the project is to conduct experiments to simulate how wildland dead surface fuels would burn under different environmental condition. Devise an experimental apparatus and test in a laboratory setting the predicted heat release rates across the range of fuel structures and environmental conditions found in wildland areas. Develop and employ a new fuel measurement and mapping system to resolve the essential fuel components and spatial heterogeneity in fuels occurring at multiple scales. Evaluate how to integrate the products into near-term risk forecasts and long-term risk projections with an emphasis on the wildland-urban interface when possible.

PREVIOUS PROJECTS

Natural Fuel Beds Ignition by Hot Metal Particles and Embers: Wildfire Spotting (NSF/UCB): The objective of this work is to develop quantitative predictive capabilities for determining whether or not an ember or hot particle will ignite vegetation based on particle properties, fuel bed characteristics, and ambient conditions. Firebrand (ember) and hot particles fire spotting is the primary vector for spread of wildland and WUI fires under dry, hot, and windy conditions that produce the most devastating fires. Whether or not an ember or hot particle is a competent ignition source depends on its characteristics (size, temperature, flaming, smoldering) and the properties of the target fuel bed. However, the conditions under which embers and hot particles can ignite spot fires are not yet quantitatively understood.

Microwave-Enhanced Ignition (KAUST): Project studies the potential to extend the flammability limits of hydrocarbons, improve combustion efficiency, and reduce pollutant emissions by microwave –enhanced combustion. Electromagnetic fields may be an effective and efficient means of implementing advanced control strategies in energy-conversion systems such as internal combustion engines and gas turbine combustors. Experimental and numerical studies are conducted to reach the objectives of the project.

High Efficiency Thermal Storage of Solar Energy, HELSOLAR (DOE/SENER): The projects is part of a university/industry consortium to carry out a conceptual study of a solar energy steam generation system for a power plant that uses a graphite based energy storage approach. Specifically to develop a computer model that will help to design and optimize the energy storage system, including modeling issues related to heat transfer between the cycle fluid/pipe and storage mass, stagnant inventory volume calculation and system optimization. Detailed behavior material and simulation related to properties, thermal shocks, stress, fatigue and creep in pipes.

Development of a Generalized Pyrolysis Model and its Application to CFD Modeling of Burning Practical Solid Combustibles (NSF): Project involves the development of a generalized pyrolysis model that can simulate the pyrolysis and burning of real-world materials encountered in fires. Techniques involving automated optimization by genetic algorithms are applied and further developed so that the required material properties can be extracted from existing laboratory-scale tests. A pyrolysis model is developed and coupled to an existing CFD code and used to calculate flame spread on real-world solid combustibles over a range of length scales. The research represents a step toward the development of computational tools that can be used to simulate fire development and how it is affected by the use of alternate materials. The results could aid in cost-effective fire safety design of buildings, and reduce the loss of life and property by fire.

Forced Ignition and Spread Test –FIST. (NASA Space Flight Program): : The objective of the project is the development of a new test method of the fire characteristics of materials used in spacecraft's (plastics, cable jackets, electronic boards, etc.), and the fire properties derived from them. The test would replace the current ASTM E-123 test, since it would better reflect the potential ambient conditions in space-based facilities. If eventually adopted, the test will be used by NASA for fire safety screening of materials to be used in space facilities. The space flight experiments are complemented with theoretical modeling, normal gravity experiments, and reduced gravity experiments that are periodically being conducted in the NASA KC-135 aircraft flying parabolic trajectories. The project has the potential to play an important role in the fire safety procedures used by NASA in its space facilities.

Smoldering and Transition to Flaming in Microgravity (NASA Space Flight Program): The objective of the project is to predict smoldering and the transition to flaming of foams, composite and cellulose materials in conditions expected in space based facilities. It includes experiments in normal gravity and in microgravity. The later are being conducted in the Space Shuttle, and were approved to be continued in the International Space Station. To date five space flight experiments have been conducted in the Space Shuttle. The results of the study are used to predict and prevent the potential onset of smoldering generated fires in ground and space based facilities.

Rotary Internal Combustion Micro-Engine (DARPA/MEMS): Research aimed to develop a rotary internal combustion micro-engine of MEMS scale (mm) and of meso-scale (cm), that would be capable of delivering power using liquid fuels. Major features of such engine would be: planar (wafer) geometry, silicon based ceramic material, high temperature semi-adiabatic cycle, normal or catalytic combustion, direct rotational torque. Because liquid fuels have a much higher power density than batteries, the project aims at the replacements of batteries in cases were weight is critical. Potential applications include propulsion of small devices and portable power generation.

Carbon Monoxide and Soot Formation in Inverse Diffusion Flames (NASA Ground Based Program): The objective of the research is to experimentally and computationally study CO and soot processes in laminar, inverse diffusion flames, which is a special case of underventilated combustion. An understanding of noxious gas formation and flame soot signatures during underventilated fires in spacecraft will be obtained, a goal in line with the Human Exploration and Development of Space (HEDS) objective of achieving earlier, more sensitive fire detection systems for use in microgravity scenarios. The project has additional practical significance for predicting the composition of the intermediate products from fuel-rich zones in practical staged combustors.

Microwave Assisted Fast Pyrolysis Reactor for Conversion of Biomass to Bio-Crude (KAUST): There is great interest in extending the supply of fossil petroleum by additional use of carbon neutral biofuels. One problem of conventional (or slow) biomass pyrolysis is that the resultant gases are not easily stored. One way to resolve this problem is through "fast or falsh:" pyrolysis that produces vapors that can be condensed to liquid bio-crude. This liquid bio-crude can be produced at one location and processed, refined, or used at another. The objective of the work is to demonstrate "proof of concept" for a novel fast pyrolysis reactor that uses micro-waves to enhance the thermal heating of the wood. It will be used to generate liquid bio-crude, which can be hydrogenated to produce green gasoline and diesel.

Smart Sensors for Hazardous Environments (KAUST): Smart combustion sensor technology enables scalable, fuel-flexible and more efficient engines. It will make possible an extension of the petroleum economy by reducing engine emissions and enabling fuel-flexible engine platforms of various sizes. The goal of the two-year program is to develop harsh environment sensors (pressure and oxygen) for in-cylinder monitoring of both small- and large- scale fuel-flexible engines. The monitoring of combustion in-cylinder is important not only for piston engines, but for jet engines and other combustion power sources such as boilers and heaters.

Microgravity Production of Nanoparticles of Novel Materials Using Plasma Synthesis (NASA Ground Based Program): The overall objective of the research is to study the formation in reduced gravity of particulate of novel materials, in the nano-meter size, and of high quality, using plasma synthesis. Particular emphasis will be placed on non-oxide materials like SiC, SiN, c-BN, etc. The interest is to determine how microgravity synthesis can improve the quality and yield of the nanoparticles and synthesized powder. The particulate could be applied to the growth of nano-systems, such as MEMS based combustion systems, catalytic nano-reactors, fluidized bed reactors and heat exchangers, or to build nano-structures.

Compact Fluidized Nano-particle Reactor for Photocatalytic Reduction of Carbon Dioxide to Methanol (ITRI): The objective of this project is the development of a photocatalytic fluidized bed reactor that will utilize solar UV radiation to transform atmospheric carbon dioxide (CO_2) and water (H_2O) to methanol (CH_3OH). Methanol is a conventional fuel that can be reformed into a feedstock for a hydrogen fuel cell, or directly oxidized to produce power in an engine or heat in a furnace. The result would be a carbon neutral energy generation approach that could have the advantages of fossil fuels without the adverse impact on the environment.

Flame Spread over Solid Fuels in Opposed and Concurrent Oxidizing Flows (NIST): Research aimed to the determination of the mechanisms controlling the spread of fire in convective oxidizer flows. Includes theoretical and experimental studies of the effect of the oxidizer flow velocity, turbulence intensity, and oxygen concentration on the rates of flame spread and steady burning, of solid combustible materials. The results are used in the development of fire models and of materials flammability tests.

Ignition and Extinction of Condensed Fuels (NSF): Research includes theoretical and experimental studies of ignition and diffusion flame extinction in boundary layer oxidizer flows established over the surface of solid and liquid fuels. The results provide fundamental information about the limiting conditions of condensed fuel burning.

Liquid Fuel Spray Ignition (ARO/TACOM): Study of the mechanisms of ignition and combustion of liquid fuel droplets and sprays under supercritical conditions. The project includes theoretical and experimental tasks. The results aim to improve the combustion efficiency and reduce emissions of diesel engines and gas turbines.

Stability of Gaseous Fuel Flames (NASA LeRC): Project to study the effect of buoyancy on the stability of premixed and diffusion flames. It includes experimental studies conducted at normal and reduced gravity in the NASA 2.2 seconds drop tower. The results are used to improve our understanding of the mechanisms controlling flame propagation and stabilization.

Flight Path of Metal Particles and Embers Generated by Power Lines in High Winds (SDGE): Development of a computer code to calculate trajectories, and lifetimes of metal particles generated by power lines and embers of different sizes for various wind conditions and terrains. The results predict the potential for fire spotting by metal particles and embers in wildland fires.

Liquid Fuel Pool Fires and Boilover Burning of Fuels Spilled on Water (CNRS, France): Collaboration with LCD-ENSMA, University of Poitiers, France, to study the burning characteristics (boilover) of liquid fuel spills, particularly the conditions leading to the nucleate boiling of the sub-layer water and the subsequent explosive burning of heavy hydrocarbon fuels (diesel oil, heating oil, etc.) floating on the water.

Flame Characteristics of Solid Fuels in Microgravity Conditions and Very Small Flow Velocities (ESA/Spain): Collaboration with the ETSIA, Universidad Politecnica de Madrid, Spain to study the flammability limits, surface flame spread, flame characteristics and stability limits of the combustion of solid fuels in oxidizer mixtures in microgravity, low velocity flows. The project was approved by NASA to be conducted in the International Space Station

Flame Spread over Discontinuous Fuels in Microgravity (NASA/NEDO): Collaborative project with Tohoku University, Japan, to study the propagation of flames over discontinuous fuels in reduced gravity. The microgravity experiments are to be conducted in the JAMIC drop tower facility in Saporo, Japan

NOx reduction in Diesel Engines by Ammonia Injection (Extengine Transport Systems): Study of the feasibility and performance of adding ammonia in the exhaust manifold of diesel engines to reduce NOx emissions. The results of the project could result in the implementation of the method in stationary and moving power plants using diesel to reduce emissions.

High Efficiency, Low Nox, Natural Gas Burner (UERG): Feasibility study of a two stage, ultra-low Nox and CO natural gas burner. It consists of a first stage with a premixed flame anchored at a porous burner with a highly radiant surface, and a second stage with a lean turbulent diffusion flame. The burner could be developed for use in appliances and small boilers