

CUA: towards
the future of
aerospace
technology





aerospace technologies

CU Aerospace, L.L.C.
www.cuaerospace.com
carroll@cua.space



About CUA

Champaign-Urbana Aerospace develops an innovative range of aerospace technologies, including space propulsion systems, advanced aerospace materials, simulation tools and plasma technology.

Champaign-Urbana Aerospace (CU Aerospace or CUA) is a limited liability company that was founded in 1998.

CUA is located in Champaign, Illinois, minutes from the central campus of the University of Illinois at Urbana-Champaign (UIUC).

Our 10,000 square foot facility contains office/laboratory/ production space to provide an environment where innovative technologies can be developed and produced. Further, CUA's long-term partnership with the University allows us to engage with some of the finest engineering/scientific minds in the world (both Professors and student interns) and stimulate the research and development of visionary concepts.

CUA's Engineering Team

CUA's versatile engineering staff has a very broad range of experience, including spacecraft hardware flight qualification and delivery, and software productization and distribution. CUA is well-positioned for accelerated program efforts and the flexibility to address customers specialized requirements and rapid turnaround. Additionally, CUA personnel excel at state-of-the-art solutions to difficult problems and disruptive innovative technologies

CUA's Laboratories

CUA has 3,400 sq. ft. of laboratory floor space as well as a 300 sq. ft. cleanroom. Its laboratory facilities are accompanied by a wide range

of equipment, diagnostics, vacuum chambers, and chemical processing hardware. Shops equipped with lathes, a CNC-mill, 3D printers, and breadboard electronics fabrication enables CUA's ability to fabricate hardware in-house for rapid prototype testing.



Space Propulsion Systems

New Propulsion Technologies for Evolving Industry Needs

In an effort to provide a “responsible space” option to existing and future satellite manufacturers, CUA has developed five innovative micropropulsion systems that represent tipping point technologies for future integration and flight on micro/nanosatellites. The company takes pride in its ability to innovate and develop quality new solutions for the ever-evolving aerospace environment. The CUA family of micropropulsion systems provide a broad range of capabilities from high thrust to high specific impulse to best suit the needs of the customer.

New Propulsion Technologies for Evolving Industry Needs

Advantages of onboard propulsion:

- Collision avoidance (avoids escalation of orbital debris problem and the Kessler Syndrome)
- Orbit raising and lowering
- Inclination change (some systems)

- Rendezvous (some systems)
- Drag makeup and orbit maintenance
- Deorbiting at end of satellite useful life (avoids escalation of orbital debris problem and the Kessler Syndrome)

SPACE SYSTEMS HARDWARE: HARDWARE FOR THE FUTURE

The CubeSat High Impulse Propulsion System (CHIPS) leverages CUA’s patented compact resistojet technology to provide a high performance self-pressurizing liquid propellant warm-gas system. The CHIPS system design is highly flexible and typically includes attitude control system (ACS) thrusters that can enable up to six degree-of-freedom (6DOF) control of the CubeSat.

CUA’s **Monofilament Vaporization Propulsion (MVP)** system draws from extrusion 3D printer technology to feed and melt spooled polymer propellant prior to evaporation using CUA’s compact resistojet technology. This patented technology

retains performance characteristics competitive with other warm-gas systems, but enables more customer accessibility to micropropulsion via dramatically reduced cost and the elimination of range safety concerns.

The patented **Fiber-fed Pulsed Plasma Thruster (FPPT)** consumes spooled Teflon fiber propellant. FPPT is completely non-toxic with benign exhaust, no range safety concerns, and has on-demand thrust with no warmup time requirement. CUA believes that the FPPT technology is a compelling option to meet many high total impulse micropropulsion needs including deep-space missions.

CUA has tested a proof-of-principle **Monopropellant Propulsion Unit for CubeSats (MPUC)** using a peroxide-alcohol propellant mixture denoted as CMP-X. This monopropellant has zero toxicity, demonstrated no detonation or mass explosion and is recommended for exclusion from the explosives class list. MPUC can be

scaled for very high thrust and has a lower flame temperature than other monopropellants resulting in reduced spacecraft thermal concerns.

The Propulsion Unit for CubeSat (PUC) is a complete, high-performance, and compact small-satellite propulsion solution. PUC achieves its high impulse, low-volume capability by employing CUA's patented micro-plasma discharge technology.

CUA's **Cycle Automated Mass Flow (CAMFlow)** system is designed for reliable and well-regulated flow control at an affordable price for the nano-satellite market. CAMFlow is ideal for the low flow rates necessary for sub-kilowatt Hall effect thrusters.

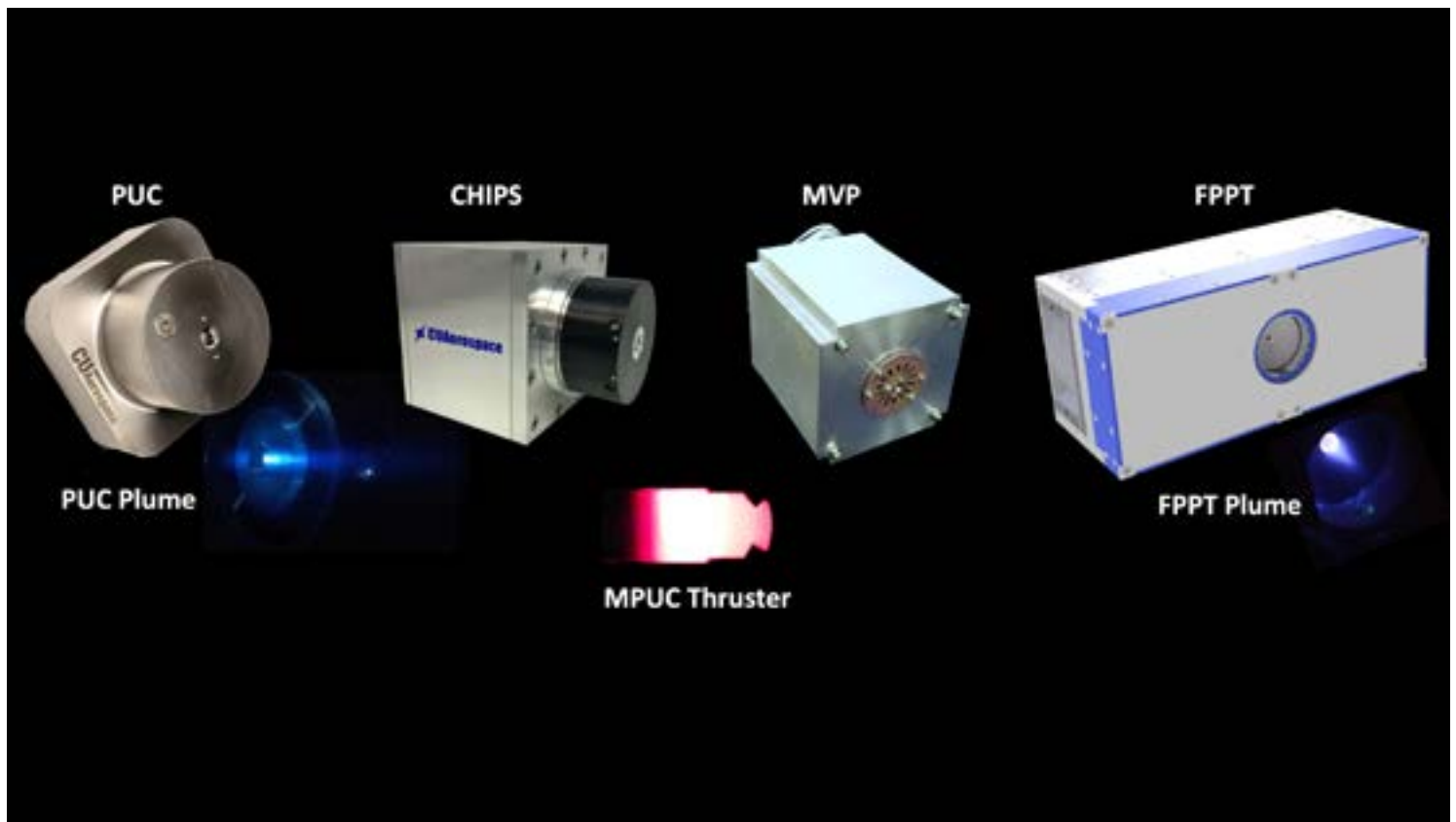
Solar and Drag Sails – Propellantless Propulsion: CUA has developed multiple solar and drag sail technologies (CubeSail, I-Sail, UltraSail,

and DragSail). A major advantage of a “propellantless” solar sail is that the need for a relatively massive and expensive propulsive device is avoided. Drag sail technologies can also take advantage of propellantless solar sail technology at higher altitude and then ultimately utilize aerodynamic forces to drag a spacecraft down to burn up in the Earth's atmosphere.

DUPLEX
CUA is the recipient of one of 2019's 14 NASA Tipping Point partnership awards for the design, fabrication, launch and in-space demonstration of the Dual Propulsion Experiment (DUPLEX) CubeSat. DUPLEX is a 6U CubeSat that will test two of CUA's micropropulsion technologies in space to provide flight heritage for these innovative new FPPT and MVP thruster systems. This flight demonstration will significantly lower risk for future customers, thereby increasing commercialization potential while

dramatically raising the Technology Readiness Level (TRL). Through the NASA STMD investment, DUPLEX is fully funded from design to launch. Launch of the DUPLEX spacecraft is tentatively scheduled for launch Q3-2022.

GRASP
The GRASP assembly interface provides a preloaded mechanical and electrical interface as a baseline that can be tailored for specific platform/mission requirements. Each baseline interface is equipped with physical connections for both power and data transmission between the different spacecraft/modules, while the flexible design allows for easy reconfiguration and integration of additional interfaces for thermal or fluid transfer. While developed to enable the assembly of a persistent modular space platform, the GRASP interface is extendable to planetary robotics applications.





I-Sail Concept

DISI Kit

DISI Kit is a low-SWaP, COTS-based distributed IMU package containing a motherboard and daughter boards distributed around the spacecraft. Total power draw when operating is estimated to be < 4 Watts and < 200 grams for 5 sensor sets. Capabilities include inertial navigation after system alignment, jitter identification, and DISI Kit in the loop control. Such a system can provide critical information for spacecraft with deployed panels/structures and potentially serve as backup for some attitude control functions.

SPACE SYSTEMS SOFTWARE: SOFTWARE FOR THE FUTURE

CUA has the capability to plan and analyze space missions. Space systems for defence, commercial, and civilian applications are undergoing massive reconfiguration. The utilization of space by the Space Force is seen as a force multiplier in an era of reduced ground and air forces. Commercial space applications, primarily in communications, are on the verge of enormous growth. And NASA continues the development of space missions for studying the earth environment, the solar system, and the universe.

The need for new, highly efficient space systems will increase somewhat over the next several years, leading to more satellite systems and constellations in a variety of low earth orbits (LEO), medium earth orbits (MEO), and geostationary earth orbits (GEO).

CUA operates and in some instances licenses software for use in the aerospace industry. Proprietary computer software that can be used to solve practical spacecraft trajectory optimization problems that include high-thrust and low-thrust propulsion systems have been developed. Additionally, CUA has developed software for the optimization of modular spacecraft architectures.

CUA is currently developing multiple software packages:

- Non-Linear Parallel Optimization (NLPAROPT)
- CUA OpenMP Nonlinear Optimization Tool (COMPNOT)
- Dynamically Leveraged Automated (N) Multibody (DyLAN) Trajectory Optimization Tool
- Satellite Evolvable Tool for Expandability and Reconfiguration (SEPTER)

NLPAROPT

NLPAROPT is a cross-platform (Linux,

macOS, Windows 10) C++ parallel optimization solver for non-linear programs (NLP) on distributed memory architecture systems.

COMPNOT

COMPNOT is a cross-platform (Linux, macOS, Windows 10) C++ parallel optimization solver for NLPs on shared memory computer architectures

DyLAN

DYLAN is a trajectory design optimization software aimed at dramatically enhancing spacecraft mission design capabilities in multiple gravitational body environments (e.g., cislunar). It enables a rapid development of complex trajectories with higher fidelity solutions in reduced computation time in comparison to extant approaches. This software package provides an automated process for searching the global trade space for families of optimal trajectory solutions, thereby significantly reducing labor hours required for impulsive and low-thrust trajectory mission design.

SEPTER

Spacecraft modularity is seeing rapid growth in the industry. The SEPTER software package was created to design optimized reconfigurable spacecraft architectures. The software

Cyclotron Arc Plasma Actuator (CAPA) UAV Flight Demo

Onboard Camera: CAPAs On



considers desired orbit, module form factors, module capabilities, and mission requirements. The package outputs component selections, sizing, and an optimized configuration (including saved near-optimal configurations for comparison). Features include pointing constraints, field-of-view, and keep-out zones. The software package is Python compatible.

PLASMA SYSTEMS TECHNOLOGY: THE FOURTH STATE OF MATTER

Solids, liquids, gases, and plasmas. As the world's understanding of the fourth fundamental state of matter and complex plasmadynamics expands, new technologies are being invented to solve modern problems. CUA is developing multiple plasma-based technologies to address emerging needs.

Plasma Sterilization

Plasma-generated Reactive Oxygen Species (ROS) technology has strong potential for low-temperature sterilization needs in the healthcare industry, and others such as wearable consumer electronics, where decontamination is necessary. CUA

has developed the Sterilizing Plasma Afterglow Reaction Chamber (SPARC) to address these needs. A target application of our SPARC system is a compact sterilization chamber for medical equipment and personal protective equipment (PPE). Also being explored is the use of SPARC technology for decontamination of NASA sample collection equipment for future space missions.

Plasma Actuators

CUA's active Cyclotron Arc Plasma Actuator (CAPA) technology (co-patented with the University of Illinois) can be flush mounted into an aircraft wing to eliminate the drag penalty of passive vortex generators while having active safety control. Testing with a UAV demonstrated improved stall characteristics. These "on-demand" actuators are also being investigated for use with plasma assisted combustion and sterilizer applications.

Plasma Assisted Combustion

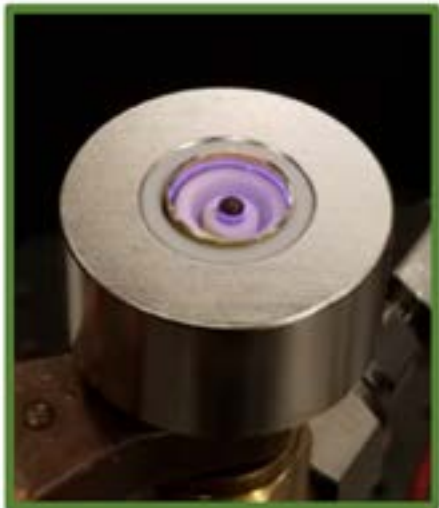
Plasmas have demonstrated the ability to improve flame stability and extend lean flame blow-off limits to lower fuel-to-air equivalence ratios (reduced fuel consumption). Plasma-assisted

combustion (PAC) techniques may also reduce acoustic noise. Application of matured plasma-assisted combustion and ignition technology may be a route to cleaner and more efficient use of fossil fuels and variants of our Cyclotron Arc Plasma Actuator (CAPA) technology are being investigated for these purposes.

GAS PHASE LASERS: PROVEN HIGH QUALITY POWER

CUA has decades of experience with efficient high energy laser (HEL) technologies. Personnel at CUA can perform experiments, modelling, and systems analyzes for many HEL technologies.

CUA invented and demonstrated an exciting variant of the chemical oxygen-iodine laser (COIL) system that draws its power from electrical rather than chemical energy (ElectricOIL or EOIL), thereby improving its safety and mass-scaling characteristics. Additionally, CUA co-invented a variant of the diode pumped alkali laser (DPAL) called the exciplex pumped alkali laser (XPAL).



COIL and ElectricOIL are high power chemical lasers that are unique because of their strong coupling to most materials and their ability to transmit through the atmosphere as well as through common fiber optics. CUA personnel also have decades of experience with older hydrogen-fluoride (HF) and deuterium-fluoride (DF) laser systems.

Applications for gas phase high energy lasers are primarily tactical and missile defense for the military. The chemical laser technologies remain as the highest performing laser systems in terms of power, beam quality at high

power, and demonstrated ability to destroy missiles at a distance.

Advantages of gas phase (high energy) lasers include:

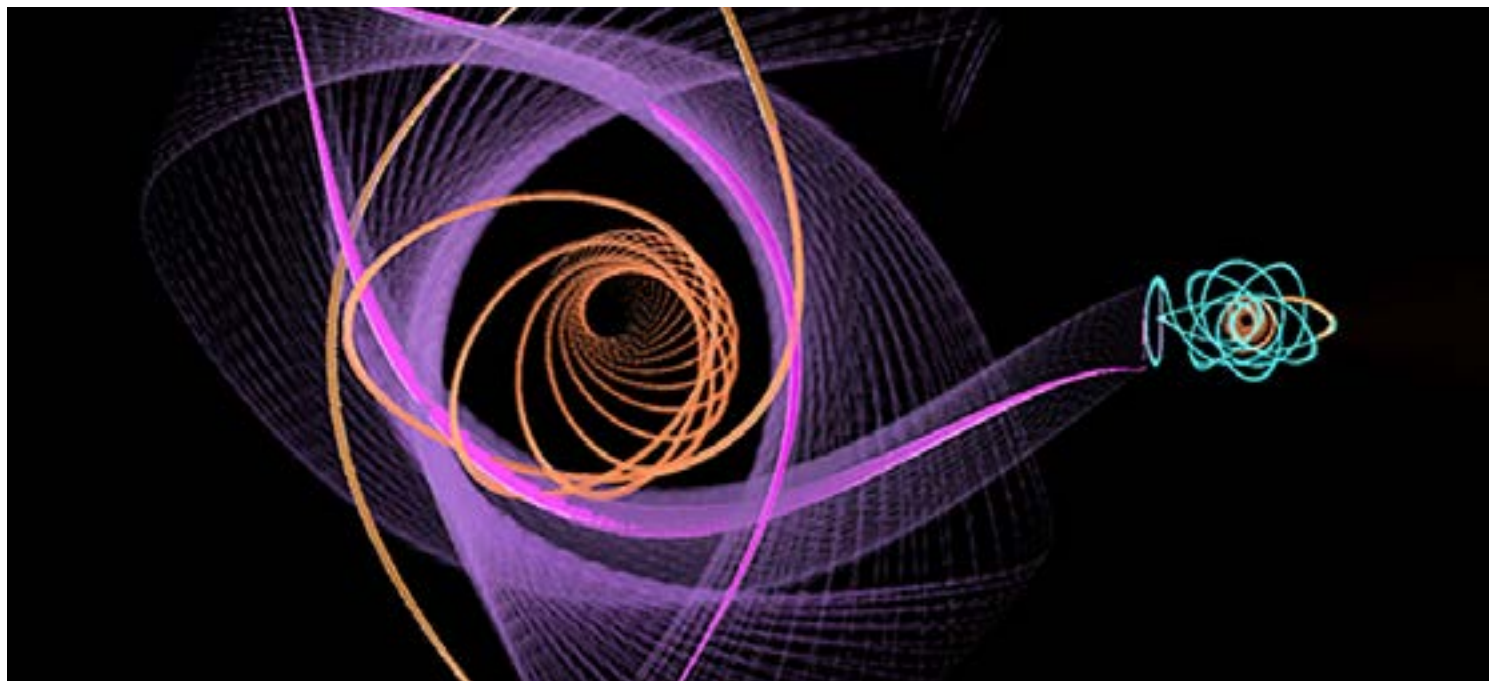
- Demonstrated scalability
- Excellent beam quality
- Chemical-based lasers don't require high electrical power

AIR VEHICLE SYSTEMS: AIRCRAFT SAFETY

Icing Hazard Mitigations

The accretion of ice onto an aircraft's wings or rotor blades in poor weather conditions can lead to critical and tragic failure. Maintaining all-weather

operation of vertical lift aircraft with detection and avoidance of icing hazards is a crucial mission, where flight safety implementation in Urban Air Mobility (UAM) is a critical gap. For example, this problem is growing more pronounced with the emerging realities of Unmanned Aerial Vehicles (UAVs) to deliver packages to the home and more importantly maintaining passenger and crew safety in air taxis. Prevention of rotorcraft icing, as well as the associated mitigation strategies and tools are a key challenge that CUA and our partner the University of Illinois are investigating for the future enhancement of air vehicle safety.





Additional Products & Services

THERMOSYS MATLAB Toolbox

The THERMOSYS v.5.1 Toolbox for MATLAB/Simulink® is a suite of simulation tools for analyzing the behaviour of air-conditioning and refrigeration systems (both steady-state and time-dependent). It was developed at the University of Illinois at Urbana-Champaign through sponsorship by the Air-Conditioning and Refrigeration Center (ACRC) and is distributed by CU Aerospace.

Key benefits include:

- Nonlinear models suitable for simulation and control design of multi-phase fluid dynamics associated with subcritical air-conditioning and refrigeration systems

- Capability to simulate transient dynamics, including start-up-shutdown dynamics
- Built-in refrigerant properties for 12 different refrigerants
- Open architecture code suitable for customisation

ADVANCED AEROSPACE MATERIALS

VascTech (Vaporisation of sacrificial components Technology) is a unique process to imbue composites with three-dimensional multifunctional vasculature. This enabling technology has been commercialised by CUA and expanded from high strength fibres to include filament for fused

deposition printers and 3D sacrificial templates. CUA is currently examining several applications such as thermal management, self-healing, reconfigurable antenna, but the possibilities are endless.

Thermal Management

The construction of a prototype microvascular composite heat exchanger was undertaken for use as a counterflow Joule-Thomson cryocooler for infrared cameras, superconducting electronics, gamma ray detectors, etc. Microvascular heat exchangers that are low cost, compact, and highly efficient will enable a new class of cryocoolers.



DragSail Concept

Small spacecraft rarely have volume for thermal control, while the few who do have control rely on low-complexity systems. These simplistic techniques are sufficient for low power missions in Low Earth Orbit (LEO) but are not capable of dumping heat produced by increasingly advanced subsystems such as propulsion systems or high-power antennas. A novel VascTech control system utilized a deployable radiator composite panel with a microvascular circulatory system for coolant.

Self-Healing Composites

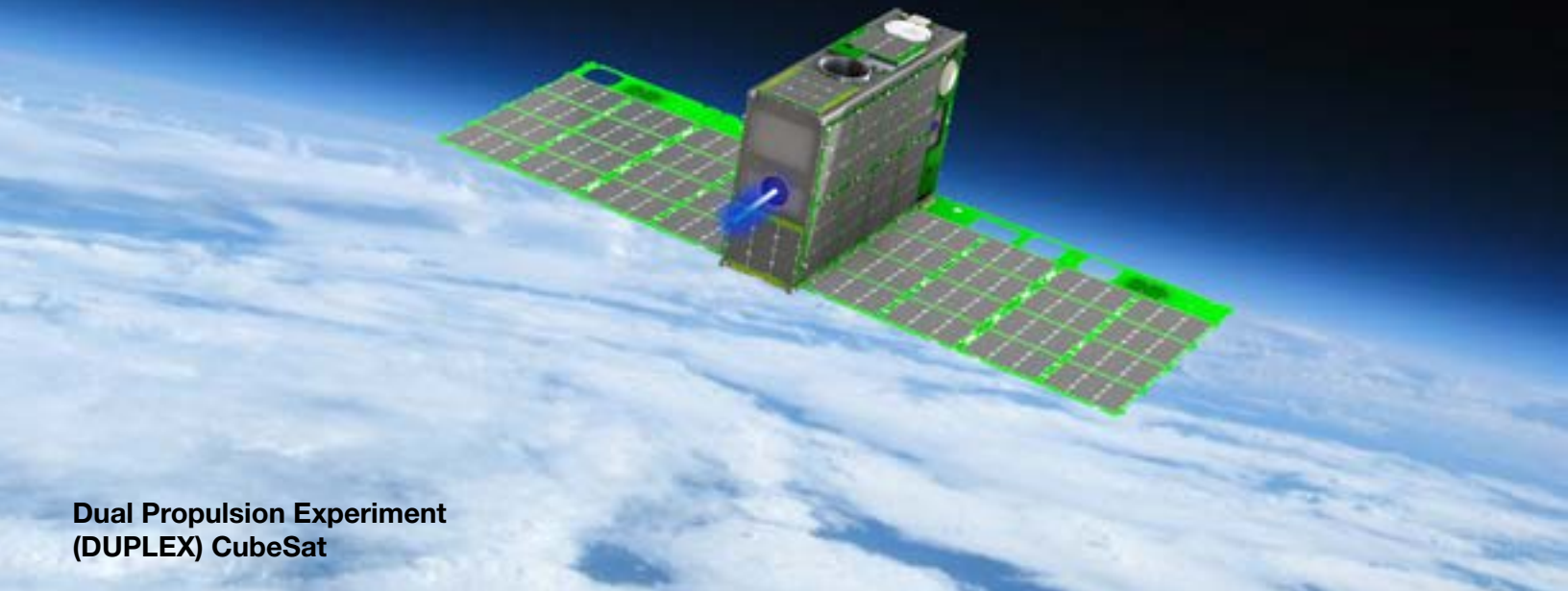
Delamination damage in fibre-reinforced composites is difficult to

detect and nearly impossible to repair. This failure mechanism remains one of the most significant factors limiting reliability and leads to conservative designs. A recent publication reported multiple cycles of in situ delamination healing (>100%) achieved through microvascular delivery of sequestered, reactive healing chemistries thus demonstrating the potential for improved safety and durability

Structurally Embedded Liquid Metal Antennas

Embedding patterned metallic objects within fibre composites yield structurally integrated and

conformal electromagnetic devices. Additionally, the use of liquid metal as the primary conductor for antennas reduces dependence on fragile solid conductors while enabling reconfigurability. The proof of concept for reconfigurable EGaln antennas has been demonstrated for single channel systems but VascTech allows complex conductive paths in two and three-dimensions in multifunctional (structural / flexible / actively cooled) materials.



Dual Propulsion Experiment (DUPLEX) CubeSat

OPTIMIZATION BASED UPON SURVIVAL OF THE FITTEST

What is a Genetic Algorithm?

A genetic algorithm is a search/optimization technique based on natural selection. Successive generations evolve more fit individuals, as according to the Darwinian theory of survival of the fittest. The genetic algorithm is a computer simulation of such evolution where the user provides the environment (function) in which the population must evolve.

CUA distributes a free FORTRAN GA front end driver code that can be coupled with other codes for optimization problems. GAs have historically proven to be versatile optimizers, especially for highly multi-modal problems. The “securGA”, which stands for small elitist creeping uniform restarting GA, has proven superior to other standard GAs.

ENGINEERING SERVICES AT CUA Need Help With an Engineering Problem?

CU Aerospace (CUA) offers experienced engineering services with a very diverse range of capability. In addition to our core areas of expertise (spacecraft propulsion/software, high energy lasers, modelling and simulation, and advanced materials), during our 20+ year history we have also successfully tackled problems in plasma/discharge engineering, robotics, controls, diode lasers, fuel cell technology, oxygen extraction from lunar regolith, and software toolbox development, among other technologies. CUA additionally offers management services for special situations (for example, new start-up companies requiring guidance and support). Overall, our depth of multi-disciplinary knowledge enables CUA to address complex engineering problems in a cost-effective and time-expedient manner that few other businesses are able to manage.

Modeling & Simulation

CUA has in-house modelling and simulation tools such as THERMOSYS for design of refrigeration systems, DyLAN for astrodynamics simulations, BLAZE Multiphysics for complex fluids/plasma/laser problems, and SEPTER for the design of modular spacecraft architectures. Additionally, CUA has multiple cluster machines for its high-performance computing (HPC) needs.

Design

CUA has licenses to a number of mathematical and mechanical design tools including multiple computer aided design (CAD) software packages. These CAD and mathematical physics capabilities are supported by numerous in-house specialty design tools for systems and mission engineering.

Get in Touch

To learn more about our services for your application(s), please contact us.



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**CU Aerospace, L.L.C.
www.cuaerospace.com
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+ 217-239-1701**

**3001 Newmark Drive
Champaign, Illinois
61822
USA**

