Research Fact Sheet

Virgin Galactic is the world's first commercial spaceline, pioneering human spaceflight for private individuals and researchers with its advanced air and space vehicles. Its vehicles are suborbital space labs for governments, researchers, and the commercial industry to use in conducting research and testing their innovations in microgravity for the betterment of Earth and space exploration.

Virgin Galactic has flown suborbital research missions on seven flights, including both autonomous and human-tended experiments. It has flown payloads for NASA's Flight Opportunities program since it began spaceflights in 2018. With Italy's *'Galactic 01'* research mission, Virgin Galactic doubled the amount of research payloads flown on its vehicles and demonstrated the ability to use suborbital spaceflights to train astronauts for future orbital missions. *'Galactic 05'* was Virgin Galactic's sixth research mission and took the first private researchers to suborbital space. *'Galactic 07'* further demonstrated the value of suborbital missions as a training platform and research testbed for orbital missions.

Virgin Galactic's piloted, reusable vehicles are designed for humans and research payloads to reach space on frequent, affordable, and safe suborbital spaceflights. Prior to launch, Virgin Galactic's Payload Integration team works closely with researchers to ensure missions are ready for space. Researchers can fly rack-mounted autonomous payloads or travel to space

with their payloads to conduct their experiments in microgravity. Researchers conducting human-tended research receive specialized training and instruction to choreograph the most efficient use of valuable microgravity time. With flights departing from and returning to Spaceport America, researchers can load payloads just before flight and recover them shortly after landing, which provides immediacy and access for time-sensitive missions. Virgin Galactic's configurable cabin and adaptable missions make it uniquely suited to fly high-quality microgravity research missions for the scientific and astronaut community.

NASA Programs

- **Flight Opportunities:** NASA's Flight Opportunities program advances innovative space technologies that support the agency's mission by providing flights on commercial suborbital platforms. These platforms provide access to the microgravity environment as well as bridge the critical gap between laboratory or ground-based testing and demonstration of technical readiness in a mission-relevant, operational environment. By testing technologies on suborbital platforms, NASA and researchers are able to reduce costs and technical risks for future missions.
- Virgin Galactic has worked with Flight Opportunities for over a decade and flown autonomous and human-tended payloads for researchers and industry through the program. Building on this successful flight history, Virgin Galactic was selected for Flight Opportunities' first contracts to fly researchers themselves on suborbital flights. In addition to these missions, Virgin Galactic has been selected to fly more payloads on future missions for Flight Opportunities.
- **SubC:** NASA's Suborbital Crew (SubC) program enables U.S. government agencies to fly their personnel on suborbital research and training missions. NASA is in the process of qualifying Virgin Galactic and its vehicles under the SubC program. The qualification process is analogous to NASA's Commercial Crew program to develop vehicles to transport astronauts to and from the International Space Station. Once qualified under SubC, Virgin Galactic will be able to offer the same research and training opportunities to U.S. employees on suborbital flights that the Italian Air Force and National Research Council of Italy (CNR) received on the *'Galactic 01'* mission.

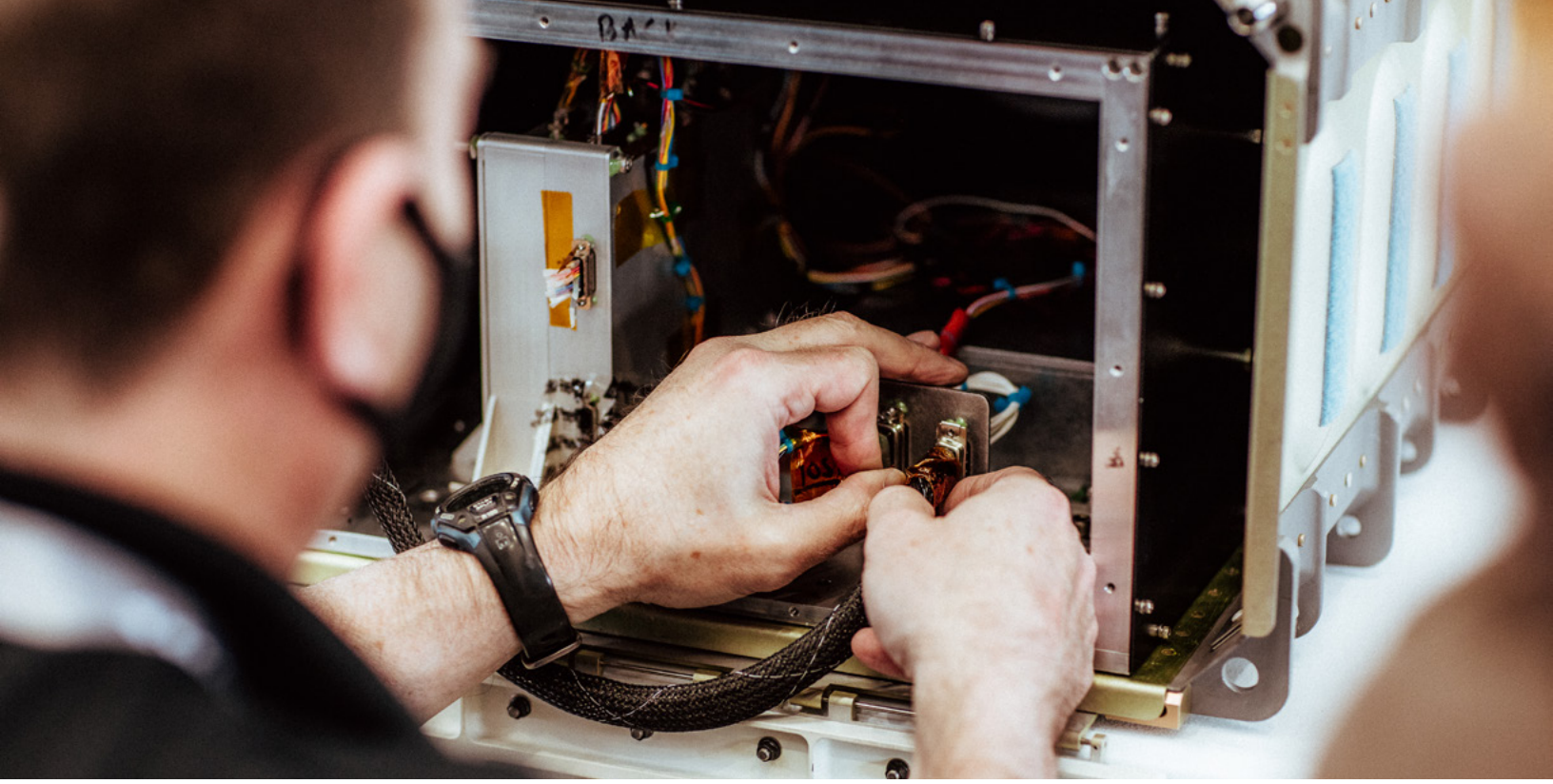
Past Flights – VSS Unity Test Flights

Virgin Galactic's first revenue generating flight was in December 2018 carrying four research payloads for NASA's Flight Opportunities program. Since then, Virgin Galactic has flown more than a dozen payloads over five research flights for the Flight Opportunities program. This includes two flights that were separated by only three months, allowing for quick adjustments in the payloads from one flight to the other and demonstrating the ability to "fly-fix-fly."

Carrying research experiments and supporting programs such as NASA's Flight Opportunities program demonstrates the important relationship between government and commercial industry. A selection of the research payloads flown by Virgin Galactic are summarized below:

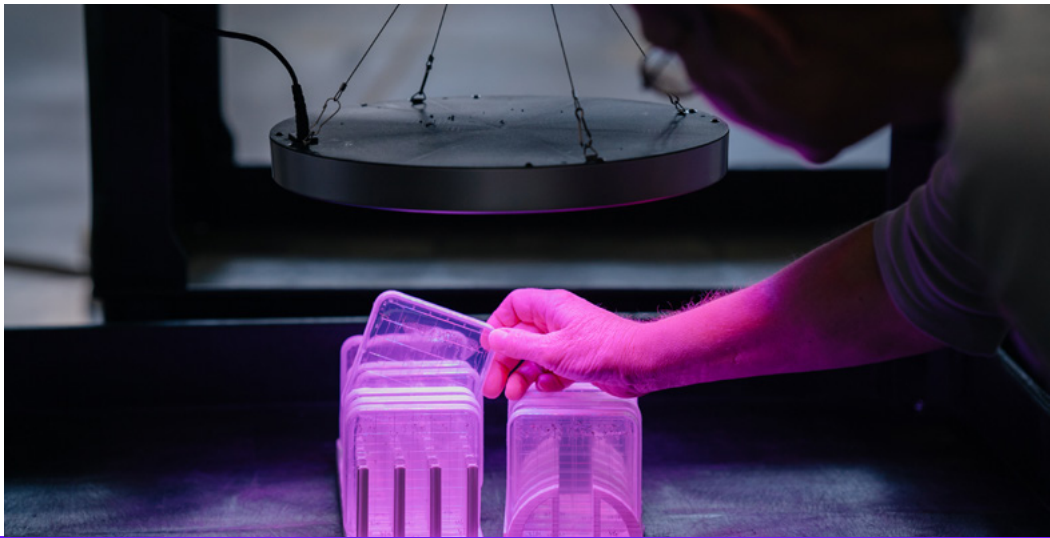
- **University of Florida – UF Flex Imager**
  Principal Investigators: Rob Ferl and Anna-Lisa Paul
  About: The University of Florida's Space Plants program has 20 years of experience studying gene expression in plants on parabolic flight, suborbital, and orbital platforms. This autonomous experiment matured biological fluorescent imaging instrumentation originally developed for the Space Shuttle and International Space Station and calibrated the hardware and data collection capabilities to timeframes optimal for suborbital applications. This biological imaging system has long-term development potential for planetary lander applications and space exploration, in addition to nanotechnology for small satellites.

- **University of Central Florida – Collisions Into Dust Experiment (COLLIDE)**
  Principal Investigator: Josh Colwell
  About: Understanding the behavior of fine particles in dusty environments in response to human and robotic activities is crucial for successful exploration missions to asteroids, the Moon, and Mars. Fine grains may damage optical instruments, coat solar panels, or jam moving parts on spacecraft. The COLLIDE autonomous payload propelled a projectile at a reservoir of simulated dust from one of these planetary systems and observes how the dust moves as a result of the collision. This low-energy impact experiment is a modified version of the COLLIDE experiment that was previously flown on two Space Shuttle missions.



- **Johns Hopkins University Applied Physics Laboratory (APL) – Electromagnetic Field Measurements**
  Principal Investigator: H. Todd Smith
  About: The National Research Council Commission on Physical Sciences, Mathematics, and Applications recommends routine profiles of the electric field between 0-80 km should be made to study the roles of aerosols, global change, and cosmic rays. This region includes the lower ionosphere, which is informally referred to as the "ignorosphere" because its altitude is difficult to explore using in situ instrumentation – it's too high for high-altitude balloons and aircraft and too low for traditional orbiting spacecraft. Reusable suborbital rockets uniquely provide the ability to study this part of the atmosphere and recover payloads. The sensor suite included in this autonomous payload characterized the electromagnetic field environment inside the spacecraft. Applications of this research will help better understand the ionosphere and Earth's complex electrical environment.
- **Controlled Dynamics Inc. – Vibration Isolation Platform (VIP)**
  Principal Investigator: Scott Green
  About: Controlled Dynamics conducting a technology maturation flight to qualify its Vibration Isolation Platform (VIP). VIP is an autonomous vibration isolation platform capable of providing a premium service for future microgravity research experiments flown on suborbital and orbital vehicles. During launch, re-entry, and landing, the research payload was mechanically secured within the payload locker. During parabolic coast, the research payload was automatically released on a free-floating platform. The payload was caged, but otherwise left undisturbed to float freely in the sway space of the VIP. Derivatives of this technology were used as a stabilization platform for optical communications and flown on the Deep Space Optical Communications (DSOC) demonstration on NASA's Psyche asteroid mission.

- **University of Louisville - Aqueous Immersion Surgical System**
  Principal Investigator: George Pantalos
  About: As human space exploration reaches new destinations and conducts longer duration missions, astrosurgery capabilities need to be developed in the event complex medical procedures need to be conducted far from home. The University of Louisville adapted a neonatal intensive care unit (NICU) incubator into an autonomous glove box payload to house a surgical fluid management system. The system is designed to allow for surgery to be conducted in a weightless environment and could be used on long-term space missions.
- **NASA Johnson Space Center (JSC) – Multi-Phase Flow Experiment for Suborbital Testing (MFEST)**
  Principal Investigator: Kathryn M. Hulbert
  About: NASA JSC is avidly interested in two-phase fluid flow systems for active thermal control and life-support systems for space applications. The autonomous MFEST payload is a pathfinder, suborbital flight experiment for two-phase fluid flow and liquid separation functions. Two-phase fluid flow experiments at partial gravities have been very limited and primarily conducted using special aircraft modified to fly parabolas. A suborbital flight allows longer-duration and continuous operational testing with variable gravity over a wider range.
- **University of Florida – Enabling Suborbital Genomics and Gene Expression**
  Principal Investigators: Rob Ferl and Anna-Lisa Paul
  About: Although changes in gene expression are well characterized between orbital space (like the International Space Station) and Earth, no science has yet been done to capture changes in gene expression during the transition to and from sustained microgravity. To study these gene expressions, Virgin Galactic astronaut Sirisha Bandla activated three Kennedy Space Center Fixation Tubes (KFTs) filled with plant samples at different phases of flight. At the same time, the research team used the flight telemetry to activate identical control tubes on the ground. This first-of-its kind experiment provided new insights into how terrestrial organisms perceive the transition into the novel environment of space.



'Galactic 01' Mission

VIRTUTE 1

The Italian Air Force and the National Research Council (CNR) of Italy's suborbital research flight included 13 payloads. Both autonomous and human-tended payloads flew onboard with the Italian crew of researchers, covering fields of study ranging from biomedicine thermo-fluid dynamics to the development of innovative and sustainable materials in microgravity conditions.

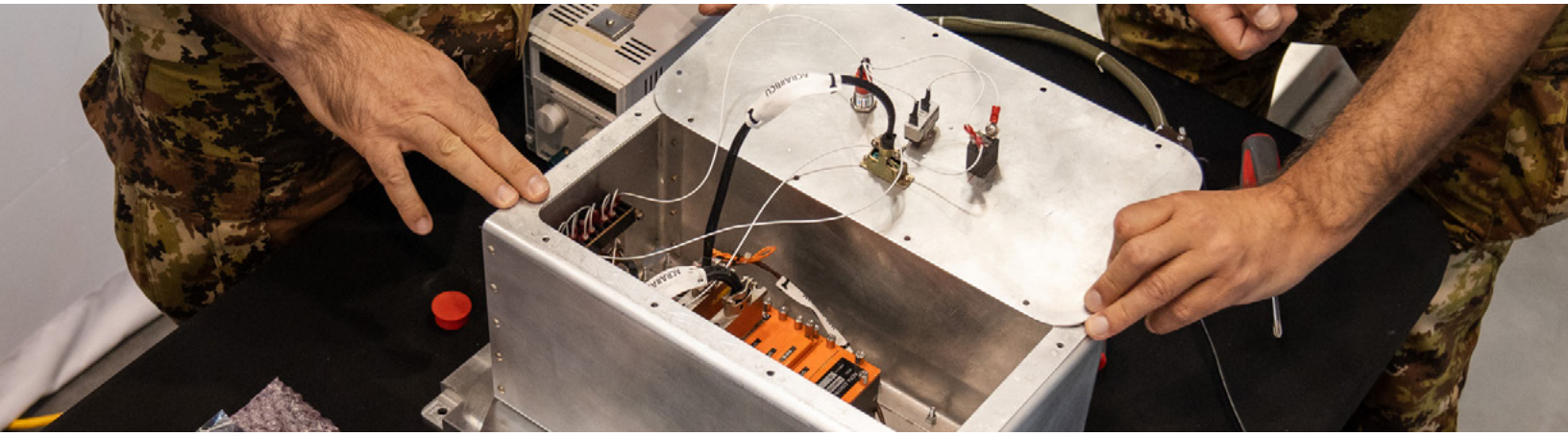
PAYLOADS

1. **Liulin-CNR-VG**
2. **Doosy-CNR-VG**
3. **droP Impact iN micro-Gravity (PING)**
4. **Italian Combustion Experiment – Suborbital Flight (ICE – SF)**
5. **TetRafluoroethAne sPonge (TRAP)**
6. **Cabin Air Quality (CAQ)**
7. **SHApe Recovery of Composite Structures (SUNRISE-VG01-SHARCS)**
8. **TESting in Space (SUNRISE-VG02-TESIS)**
9. **Scientific-Health Area Experiments**
10. **Smart Flight Suit 1 (SFS1)**
11. **ECG Holter Monitoring**
12. **Passenger's Comfortability**
13. **Pre and post flight ground activities**

PAYLOAD DESCRIPTIONS

1. Doosy-CNR-VG and 2. Liulin-CNR-VG

The Doosy and Liulin payloads from CNR's Department of Engineering, ICT and Technologies for Energy and Transport (CNR-DIITET) tested equipment that measured cosmic radiation in the mesosphere (50-100 km), an altitude where limited data has previously been collected. To gather data from Earth to higher altitudes, this mission collected data from two different types of devices, passive dosimeters and a spectrometer radiometer. This data supported the ability to measure radiation levels and profiles in preparation for future space exploration and deep space missions.



3. droP Impact iN micro-Gravity (PING)

Understanding how particle-laden droplets come in contact and stick to different materials has many applications in industrial processes, such as plasma spray, and drop-on-demand coating technologies. The CNR's Institute for Microelectronics and Microsystems (CNR-IMM) autonomous rack-mounted payload expelled droplets from nozzles onto different materials with tuned micro-structured surfaces, to look at how the drops adhere and move around the plates in microgravity.

4. Italian Combustion Experiment – Suborbital Flight (ICE – SF)

ICE - SF experiment from the CNR's Institute of Sciences and Technologies for Sustainable Energy and Mobility (CNR-STEMS) studied the combustion characteristics of renewable liquid biofuels and the behavior of complex fluids at high temperature. Examining these fluids at normal and high pressures in microgravity can contribute to research on efficient technologies for eco-sustainable energy and propulsion systems, such as industrial gas turbines and aircraft engines. This research is based on an Italian experiment conducted on the International Space Station in 2013. For this suborbital flight, the autonomous payload had three distinct experimental apparatuses operating simultaneously, each designed to perform a specific experiment on biofuel droplets.

5. TetRafluoroethAne sPonge (TRAP)

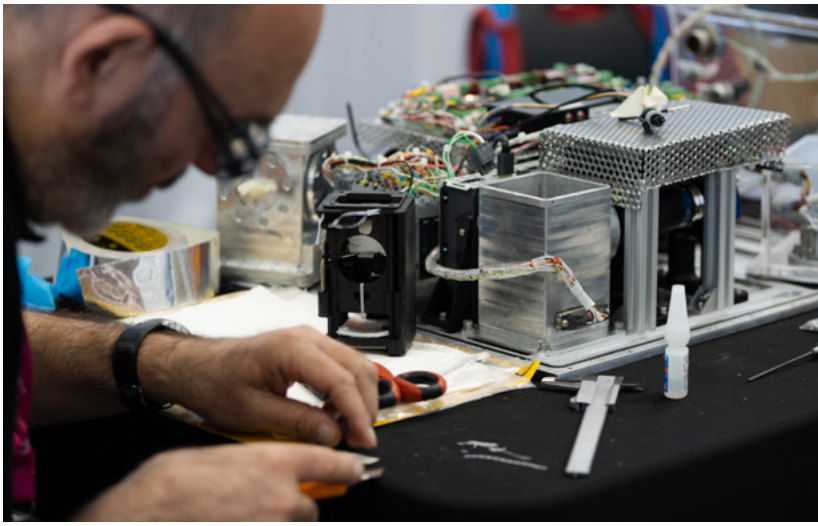
The University of Padova and Italian company Technology for Propulsion and Innovation (T4i) tested the design of a highly-innovative evaporator. This evaporator transformed liquid into a gaseous phase, similar to how fluid transfer is done in an air conditioner, but in a microgravity environment. This flight allowed for the testing and qualification of this new technology, which could be applied in cold gas propulsion systems for microsatellites. This rack-mounted payload was turned on by a member of the Italian crew during the microgravity phase of the spaceflight.

6. Cabin Air Quality (CAQ)

As commercial suborbital space travel becomes more frequent, there is a need for innovative adaption of Earth-based technologies that may also be used in space. Air quality within commercial aircraft has been highly analyzed over the past decades, and as people spend more and more time in space with commercial orbital flights, technologies for monitoring and evaluating the quality of the environment becomes critical. This autonomous payload from CNR's Institute of Atmospheric Science and Climate (CNR-ISAC) used a small nanoparticle monitor to measure the indoor air quality of suborbital flights to apply to future long duration missions. Specifically, the payload evaluated the sources and levels of any ultrafine particles that are present.

7. SHApe Recovery of Composite Structures (SUNRISE-VG01-SHARCS)

The University of Rome Tor Vergata's SHApe Recovery of Composite Structures (SHARCS) experiment was a human-tended rack-mounted payload. The experiment consisted of the deployment of a small composite boom made of a shape memory polymer composite (SMPC). The experiment began with the boom curled in a spiral. Once the payload entered the microgravity phase and a member of the Italian crew turned it on, the boom heated and the spiral returned to its original shape as a flat boom. A camera in the payload observed how quickly the boom returned to its original shape in microgravity. This is only possible in microgravity because the boom would bend in Earth's gravity. This research has many applications for building composite structures in space, such as booms for solar sails and ultra-light deploying systems.



8. TESting in Space (SUNRISE-VG02-TESIS)

The University of Rome Tor Vergata's TESting in Space (TESIS) experiment studied the effect of microgravity on liquid mixing. Different mixtures were placed in syringes, which the researcher activated once microgravity was reached. Of particular interest is the production of foams from materials with very different densities, as these foams are very difficult to produce on Earth. This research has future applications for in-space manufacturing and biomedical applications.

9. Scientific-Health Area Experiments

The scientific team of the Italian Air Force Medical Corps in collaboration with University of Milan, Policlinico Foundation of Milan, Sapienza University, University Politecnica delle Marche, and Italian Andremacon Biotech launched biology experiments in orbit, aimed at improving

performance and the physical efficiency of future astronauts for space missions. The information obtained allow to prevent and diagnose early and improve the treatment of widespread diseases in the population, starting with the most aggressive of cancers up to aging. The studies sent live human cells into space and collected biological samples before, during and after the astronauts' flight. Mission specialists underwent pre and post flight high-definition MRI scans as well. The match between molecular and imaging data throughout omics technologies and artificial intelligence offers strategic information to improve personalized therapy approaches. The added value of this project can be achieved thanks to two aspects of Italian scientific excellence: A "field research laboratory" and a high-level multidisciplinary scientific team.

10. Space Motion Sickness

The ItAF's Official Flight Test Center is studied vibrations in spaceflight vehicles and their link to motion sickness in people flying to suborbital space. This autonomous payload was connected to accelerometers under the researchers' seat. Low frequency acceleration data from the seats was used to map the vibration profile transmitted to the passengers during flight.

11. Smart Flight Suit 1 (SFS1)

Spacewear Smart Flight Suit 1 was a technology demonstrator and prototype of a new class of flight suits for space activities. The flight suit consisted of innovative equipment designed with ergonomic criteria to provide comfort with breathable and fireproof-class fabrics that can withstand over 6 G of acceleration. The suit included a t-shirt with an integrated device to collect biomedical data from the researcher during each phase of flight. The data was collected in real time without the use of cables or electrodes. During the flight, the researcher wearing the flight suit also tested the ergonomic criteria of shape and function. Feedback on the design and construction of the suit along with an analysis of the biomedical data was conducted post-flight.

12. ECG Holter Monitoring

An electrocardiogram (ECG) Holter monitor is a small, battery-powered medical device that measures the heart's activity, such as rate and rhythm. Electrodes were placed on the researcher's chest with leads connecting them to the monitor. The passive, wearable monitor recorded 12 signals from the researcher during the suborbital spaceflight, assessing cardiac responses to acceleration. The data was used to evaluate the cardiovascular effort exerted during the spaceflight. This research may help validate risk assessment for future spaceflight participants with cardiovascular disease, continuing to open space travel accessibility for a wider population.

13. Passenger's Comfortability

To study cognitive conditions during spaceflight, Italian crew members performed working memory exercises during flight with devices measuring the body's response. To conduct this experiment, the researcher had three devices. The first was a tablet strapped to their leg so they could perform tests on mental workload and sustained attention. The second was an electroencephalogram (EEG) cap worn on their head to measure brain activity. Finally, they had a sensor on their hand to measure the galvanic skin's response. The collective measurements from the devices assessed potential cognitive and/or emotional changes induced by the suborbital flight.

14.Pre and post flight ground activities

a. Effects of Microgravity on Oxy-Inflammation Related to Circadian Clock

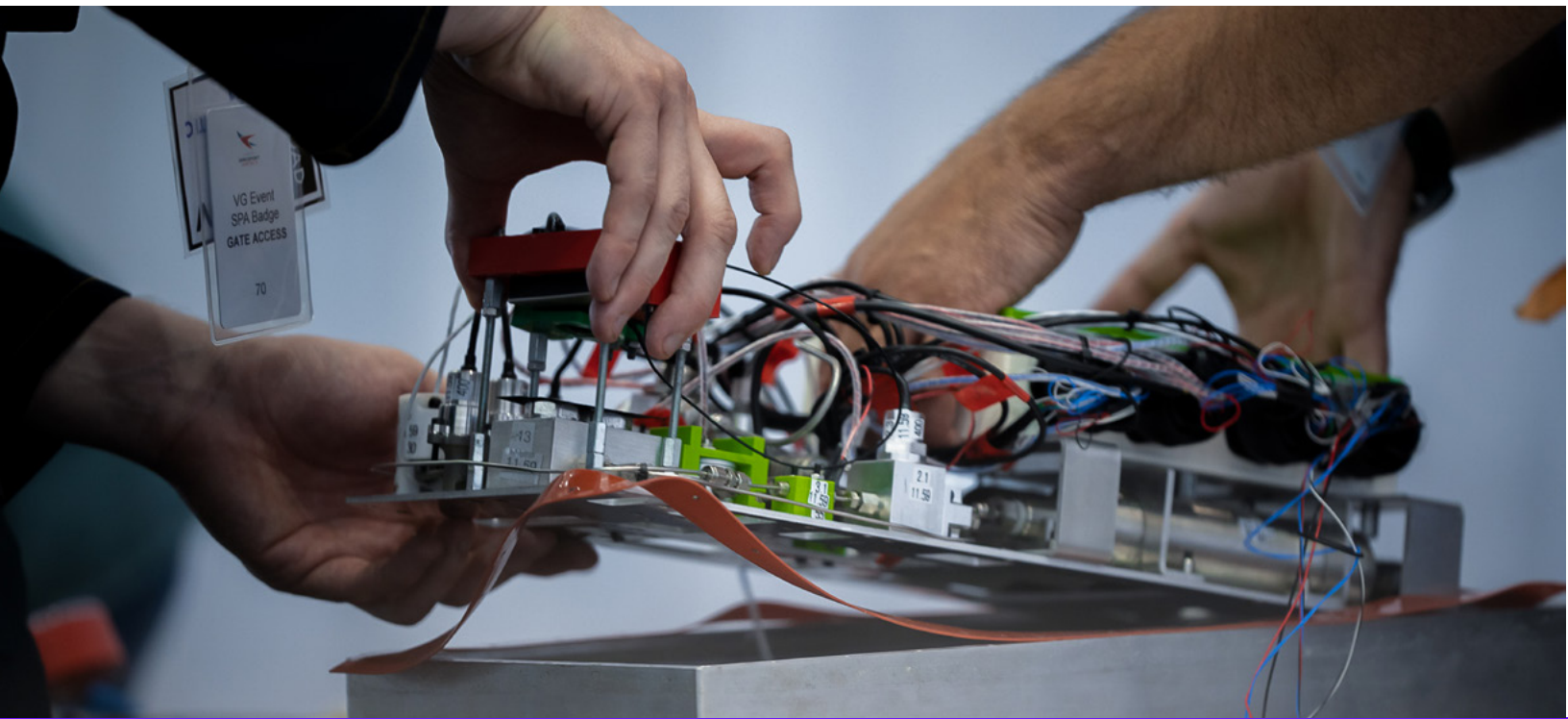
The study evaluated the linkage among oxidative stress, circadian rhythms and neuroplasticity during exposure to a microgravity environment. The researcher collected saliva samples before and after the flight, which were analyzed by the onsite research team post-flight.

b. Spaceflight MRI Project

This study evaluated the potential effects of suborbital flight on the human organism. The Italian crew underwent heart and skull MRIs days before the flight. The same exams were performed after the suborbital flight. The data was then compared with biohumoral-laboratory parameters, electrocardiogram (ECG) data, cognitive tests and clinical parameters.

c. Evaluation of Endothelial Function in Personnel Exposed to Microgravity During Suborbital Flight Activity

This study evaluated the impact to endothelial tissue function (flow-mediated dilation – FMD) in the Italian crew as a result of suborbital flight. Ultrasound Doppler acquisitions were performed pre-and-post flight to understand the impact of traveling to a rarely studied altitudes and observing any transient alterations.



GALACTIC 05 MISSION

SUMMARY & OVERVIEW

- *'Galactic 05'* was Virgin Galactic's sixth spaceflight carrying microgravity and space-based research and second in 2023.
- The two experienced researchers on board, Dr. Alan Stern and Kellie Gerardi, conducted a total of five research experiments during the suborbital spaceflight.
- Alan's mission, sponsored by the Southwest Research Institute (SwRI), was to train for a future NASA-funded suborbital flight in which he will perform two NASA experiments in space.
- Kellie, sponsored by the International Institute for Astronautical Sciences (IIAS), flew three payloads developed through extensive reduced-gravity flight campaigns with the National Research Council of Canada (NRC).
- The pursuit of scientific discovery has driven Virgin Galactic from the beginning, and the company offers a range of high-quality and reliable microgravity and space-based research opportunities. The flexible nature of the spaceship's cabin lets the company tailor flights to accommodate the diverse needs of private passengers and scientific experiments.

RESEARCHERS

DR. ALAN STERN, Astronaut 020
Dr. Alan Stern is best known as the principal investigator of the New Horizons mission to explore Pluto and the Kuiper Belt. He is a vice president at SwRI and a planetary scientist with experience leading or playing key support roles in 30 suborbital, orbital and planetary space missions. He previously served as NASA Associate Administrator, leading all its space and Earth science programs. A long-time advocate for commercial suborbital research platforms, he has published over 500 peer-reviewed scientific papers and, as an experienced general aviation pilot, conducted research missions with F-18s and other high-performance U.S. Air Force, NASA and commercial aircraft.

KELLIE GERARDI, Astronaut 021
Kellie Gerardi is an aerospace and technology professional, a bioastronautics researcher, and payload specialist. She leads Mission Operations for Palantir Technologies, serves on the Defense Council for the Truman National Security Project, and served on the board of directors for The Explorers Club, whose esteemed flag she carried during a crew rotation at the Mars Desert Research Station. With nearly a million followers across her social platforms (@kelliegerardi), Kellie is a popular science communicator and the author of Not Necessarily Rocket Science and acclaimed children's picture book series Luna Muna, which was read from the International Space Station by Commander Peggy Whitson as part of the crew's STEM outreach in 2023.

EXPERIMENT DETAILS

DR. ALAN STERN

Alan's mission is a privately funded training flight for a future suborbital spaceflight through NASA's Flight Opportunities program and is sponsored by SwRI. Alan flew two human-tended experiments in preparation of his future NASA-funded flight.

His experiments included:

- A biomedical harness to collect physiological data related to human spaceflight.
- Training for future flight demonstration of astronomical observation capabilities on commercial suborbital flights.

Southwest Research Institute – Xybion Camera Mockup

Principal Investigator and Co-Investigator: Alan Stern and Dan Durda, respectively
About: Human-tended astronomy missions from suborbital platforms are largely unexplored with great potential for Earth observation and imagery of objects in space. The Xybion camera is an innovative wide-field visible and ultraviolet imager used for astronomical experiments on two Space Shuttle missions. On a future NASA-funded suborbital flight, Alan will operate the camera to compare the efficacy of doing onboard astronomy on VSS Unity to its efficacy on the Space Shuttle. For the 'Galactic 05' mission, Alan flew with a full-sized foam mockup of this camera for training and risk-reduction practice purposes before the NASA-funded flight.

Southwest Research Institute – Biomedical Harness Evaluation

Principal Investigator and Co-Investigator: Alan Stern and Dan Durda, respectively
About: Throughout extensive flight-test campaigns, SwRI has used a biomedical harness to test researchers' responses to high-g and microgravity environments. Alan flew with a commercial-off-the-shelf Accutracker-II biomedical harness sensor, which measured the researcher's vital signs with accurate time stamps while it was worn. The device has flight heritage from 68 Space Shuttle spaceflights and has been used by Alan and principal investigator Dan Durda for flights on high-performance F-104 and parabolic aircraft. Alan will also fly with the bioharness on his future NASA-funded suborbital flight and used 'Galactic 05' as a risk-reduction mission for this human spaceflight technology.

KELLIE GERARDI

As the first IIAS suborbital payload specialist to fly on a suborbital spacecraft, Kellie flew three human-tended payloads on behalf of IIAS. Her research has been developed through extensive reduced-gravity flight campaigns with the National Research Council of Canada (NRC) and has now been advanced through a suborbital spaceflight.

Her experiments included:

- Examining how a confined fluid behaves in low gravity to help inform technologies such as spacecraft life-support systems and syringe designs for administering medication in space.
- Collecting biometric data with the Astroskin biomonitoring device, marking the first time this technology was used during the launch, re-entry and landing portions of spaceflight.
- Wearing a continuous glucose sensor to gather data and insight on blood glucose changes over the course of a suborbital spaceflight.

IIAS – Configuration of a Confined Fluid in a Low-Gravity Environment

Principal Investigator: Kellie Gerardi and Aaron Persad

About: The question of how a confined fluid behaves in a low-gravity environment is of scientific, technological, and safety importance, but not yet thoroughly understood. This was dramatically illustrated in July of 2013, when a clogged filter caused more than a liter of water to flood the helmet of Italian astronaut Luca Parmitano during a spacewalk. Kellie operated a fluid cell designed to help better predict and control the shape and location of fluid within a container in microgravity. During spaceflight, she collected data about where in the container the liquid settled and how difficult it was to dislodge the liquid from that location. This data can be used to help inform novel technologies ranging from spacecraft life-support systems to new syringe designs for administering medication in space.

IIAS – Astroskin

Principal Investigator: Kellie Gerardi and Aaron Persad

About: The commercial spaceflight industry is opening a new era of access to space, which presents an opportunity to build more comprehensive human health frameworks for human spaceflight. Kellie collected a wide range of biometric data during her flight with the Astroskin biomonitoring device, a lightweight smart shirt and all-in-one sensor suite developed by Canadian company Carré Technologies with the support of the Canadian Space Agency (CSA). Electrical signals received through the sensors detected a range of relevant biomonitoring parameters including 3-lead electrocardiogram (ECG), heart rate, breathing rate and volume, and skin temperature. The Astroskin is currently in use by astronauts aboard the International Space Station, and this flight was the first time that data was collected during the launch, re-entry, and landing portions of flight.

IIAS – Continuous Blood Glucose Monitoring in Suborbital Flight

Principal Investigator: Kellie Gerardi and Shawna Pandya

About: There is growing evidence that long-duration spaceflight induces insulin-resistance, a pre-diabetogenic state, but there is still uncertainty as to how quickly these changes are induced. A new generation of implantable sensors that can continuously sample blood glucose offer a way to easily and continuously monitor blood glucose levels for populations in need, including astronauts. Kellie deployed and wore a continuous glucose sensor to measure and store glucose readings during spaceflight. The blood glucose data gleaned from this study may offer insight as to how quickly insulin-resistance develops during spaceflight. This was one of the first deployments of a continuous glucose monitor to the spaceflight environment.

GALACTIC 07 MISSION

- *'Galactic 07'* was Virgin Galactic's seventh spaceflight carrying microgravity research and third since it entered commercial operations.
- The suborbital spaceflight included Turkish Space Agency (TUA) astronaut and Axiom Mission 3 (Ax-3) Backup Mission Specialist, Tuva Atasever, who flew with three wearable payloads. In addition, Purdue University and the University of California, Berkeley had two rack-mounted autonomous payloads aboard through support from NASA's Flight Opportunities program.
- In addition to Tuva's wearable payloads, he also participated in four human physiology research investigations carried out by Turkish researchers.
- Tuva's experiments further demonstrated the value of suborbital missions as a training platform and research testbed for orbital missions.
- Purdue University's experiment studied propellant slosh for spacecraft propulsion applications.
- UC Berkeley's payload 3D printed and post-processed parts manufactured while in microgravity.
- The flexible nature of Virgin Galactic's commercial business model and spaceship design enables it to fly U.S. and international partners alongside industry customers and academia.

RESEARCHER

TUVA ATASEVER, Astronaut 027

Tuva Atasever is an aerospace and technology professional, who was competitively selected to be one of the first two Turkish astronauts as a part of TUA's first-ever astronaut selection campaign. After completing his master's degree in photonics at the University of California, Irvine, Tuva founded two virtual reality startups, Blue Dot VR and HyperSight, Inc. He then worked for ROKETSAN, Inc., a leading Turkish aerospace company, as an avionics systems engineer on the Micro Satellite Launch Vehicle (MSLV), Türkiye's first orbital launch vehicle. He also served as the payload integration manager for ROKETSAN's Space Sounding Rocket (SSR), Türkiye's first domestic launch vehicle. After more than a year of astronaut training with Axiom Space, Tuva was honored to serve as the Ax-3 Backup Mission Specialist for the historic all-European commercial astronaut mission to the International Space Station (ISS).

EXPERIMENT DETAILS

AXIOM SPACE

Tuva's flight was contracted through Axiom Space, the Houston-based company building the world's first commercial space station. Tuva flew three human-tended experiments from Türkiye and the U.S. and participated in four Turkish physiological research investigations. Three of the Turkish physiological research investigations were also conducted as part of the Ax-3 mission.

TUA's experiments included:

- Testing a smart and active personal dosimeter developed by two Turkish universities and adapted for spaceflight.
- Studying multiple aspects of human performance and physiology during all phases of suborbital spaceflight using a physiological monitoring system.
- Examining the ability to administer accurate doses from insulin pens in microgravity.
- Investigating the effects of suborbital spaceflight in gene expressions and their impact on the immune system response against cancer.
- Identifying the metabolic and transcriptomic changes that occur as a result of a suborbital spaceflight.
- Analyzing the effect of microgravity and radiation exposure on the concentration of myeloid derived suppressor cells within peripheral blood.
- Isolating and analyzing extracellular vesicles after suborbital spaceflight to further investigate the potential of exosome therapies for future astronauts.

Middle East Technical University The Research and Application Center for Space and Accelerator Technologies (METU IVMER) – IvmeRad

Principal Investigator: Prof. Dr. M. Bilge Demirköz, Middle East Technical University and Asst. Prof. Dr. Selcen Uzun Duran, Karadeniz Technical University

About: "IvmeRad" is a wearable, smart, and active personal ionizing radiation dosimeter adapted to spaceflight for this mission. IvmeRad was designed with support from The Scientific and Technological Research Council of Türkiye (TÜBİTAK) for use for use at hospitals and radiological centers, where patients are actively threated by radiopharmaceuticals. Radiopharmaceuticals are agents used to diagnose various medical problems or treat certain diseases, such as cancer. IvmeRad applies Internet of Things (IoT) technologies to dosimetry to create an affordable, lightweight, and easy to use device that actively tracks exposure and identifies potential hazards faster than traditional methods.[1] IvmeRad flew in a custom-built pocket of Tuva's TUA flight suit. IvmeRad is designed and produced by METU IVMER, supported by Karadeniz Technical University, and tests and logistics are supported by TÜBİTAK UZAY.

Center for Space Medicine Research (CSMR) in the Department of Psychiatry at Massachusetts General Hospital and Harvard Medical School—in collaboration with Louisiana State University (LSU), Massachusetts Institute of Technology (MIT) Media Lab, Northeastern University, and the Health Sciences University (Türkiye)—BEACON-R (Behavioral, Affective, Cognitive and Neurophysiological Responses to Spaceflight)

Principal Investigators: Dr. Vladimir Ivkovic and Ms. JoAnna Pollonais

About: Part of BEACON-R saw Tuva wear NINscan during the Galactic 07 mission. This was the first spaceflight for NINscan: A custom developed brain and physiological monitoring system originally developed for NASA and used in extreme environments, including parabolic flight. NINscan headgear secured brain activity-monitoring sensors to Tuva's head and had electrode pads and leads for monitoring heart activity, allowing researchers to complete the first-ever continuous monitoring of blood and cerebrospinal fluid flow in all phases of spaceflight. This 'first' is essential for understanding the mechanics behind spaceflight associated neuro-ocular syndrome (SANS)—a major biomedical risk to astronauts involving changes in brain pressure and vision—and studying emotional and physiological responses associated with the 'Overview Effect', as well as spaceflight-induced changes in stress and immune function that will be assessed via blood and salivary biomarkers. Collaborators Dr. Gary Strangman, Dr. Aleksandra Stankovic, and Dr. Quan Zhang from CSMR/MGH/HMS, Dr. Guillaume Spielmann and Ms. Heather Quiriarte at LSU, Dr. Nataliya Kosmyna from the MIT Media Lab, Lab, Dr. Lisa Feldman Barrett, Dr. Karen Quigley and Dr. Jordan Theriault at Northeastern University, and Dr. Nazim Ata from the Health Sciences University of Türkiye will supported BEACON-R to provide insight on mitigating spaceflight biomedical risks and managing neurological and psychiatric disorders in clinical practice on Earth.

Axiom Space and TUA – Suborbital Testing of Insulin Pens

Principal Investigators: Dr. John Marshall and Mr. Alex Rubin

About: This experiment served as a stepping stone to support astronauts with insulin-dependent diabetes and demonstrates a capability necessary for maintenance therapy and hyperglycemic states in insulin-dependent people with diabetes. This human-tended experiment included two commercially available insulin pens, which were each secured in a custom 3D-printed container during flight. During the flight, Tuva retained the insulin pens in his flight suit, dialed an insulin dose, and dispensed insulin from each pen into a collection container to study the accuracy of dose dispensation in microgravity. Commercial spaceflight and the research flown on these missions are opening space to people with diabetes and those who previously have not been eligible to fly to space.

Bilkent University National Nanotechnology Research Center (UNAM) – YUVA

Principal Investigator: Dr. Fatih İnci

About: Extracellular vesicles (EVs) are "lipid shuttles" secreted from parental cells and contain a diverse array of biomolecules. As part of the YUVA experiment, researchers collected blood and urine specimens from TUA's astronaut pre- and post-flight to isolate circulating EVs with their state-of-the-art microfluidic chip. This chip is able to isolate EVs from low-volume of samples by minimum instrumentation. Downstream proteomic and transcriptomic analyses scrutinized the isolated EVs, detecting variations in expression levels to unveil microgravity-induced alterations in EV-based communication. As the next step of the investigation, researchers aim to apply space-travel-induced EVs to healthy human cells to show that cellular adaptation occurring during space travel could be transferred to the healthy cells, and potentially in the future, could be employed to prepare astronauts for space missions long before reaching space conditions.

Üsküdar University – MESSAGE

Principal Investigator: Dr. Cihan Taştan

About: In this human physiology experiment, researchers aimed to analyze the whole transcriptome profile of a blood sample collected from TUA's astronaut before and after the suborbital spaceflight. This allowed them to determine the genes effected by microgravity whose expression is either up-regulated or down-regulated. After discovering these genes, the research team aims to determine microgravity effect of these gene expressions in in immune system cells in terms of anti-cancer activity.

Ankara University – METABOLOM

Principal Investigator: Prof. Dr. Emel Emregül

About: The main purpose of this study was to better understand the molecular mechanisms that occur in the human body as a result of a suborbital spaceflight through metabolomic analysis of biological samples collected from TUA's astronaut and data received from the blood plasma transcriptome. The investigators looked at the physiological and biochemical changes in gene expression and metabolism of the astronaut under the influence of space environment conditions, namely the exposure to hyper gravity, microgravity, and increased

radiation. Furthermore, this study provided important data for future research on topics such as gravitational physiology, aviation, and space medicine, as well as to contribute to the creation of new therapies and preventive measures for diseases that exist on Earth.

Hacettepe University – MIYELOID

Principal Investigator: Prof. Dr. Güneş Esendağlı

About: Myeloid-Derived Suppressor Cells (MDSCs) are formed when the bone marrow allows the immature cells needed after chronic inflammation and/or acute inflammation to enter circulation and these cells gain immune suppression ability. Within the scope of this investigation, the distribution and concentration of sub-populations of MDSCs within peripheral blood were determined using the pre-flight and post-flight blood samples taken from TUA's astronaut were the effect of radiation exposure due to the suborbital spaceflight was analyzed. For the first time, myeloid-derived supporessor cells in peripheral blood samples of a suborbital spaceflight participant after radiation exposure were analyzed. By understanding the characteristics and function of MDSCs after a spaceflight, investigators are hoping to develop therapeutic interventions for both terrestrial and space applications.[1]

NASA FLIGHT OPPORTUNITIES

NASA has been flying experiments with Virgin Galactic since our first spaceflight in 2018. Virgin Galactic was recently selected as a contracted Flight Provider by Flight Opportunities for the next five years. NASA's Flight Opportunities program provided support for two autonomous, rack-mounted payloads on Galactic 07.

NASA-funded experiments included:

- Investigating how liquid moves in spacecraft propellant tanks after executing maneuvers.
- Testing new 3D printing techniques that could significantly reduce printing time.

Purdue University School of Aeronautics and Astronautics – Rotational Slosh

Principal Investigator: Dr. Steven Collicott

About: When spacecraft are accelerating in space, such as during a pointing maneuver, re-orientation burns for docking, or to transfer to a new trajectory, it sets the liquid in propellant tanks in motion. After the thruster firing ends, the liquid motion slows down in the zero-gravity environment. This experiment studied the rate of damping of liquid motion after a rotational maneuver. The results will use this additional understanding of low-g propellant slosh to improve spacecraft pointing and mission operations. With the ongoing small satellite revolution, this experiment can use actual propulsion tank sizes for small satellites, rather than sub-scale mock-ups of tanks for larger satellites. The research can be furthered by studying how green propellants movements may differ from traditional propellants, like hydrazine, in zero-g.

University of California, Berkeley – Space Computed Axial Lithography (SpaceCAL)

Principal Investigators: Hayden Taylor, Taylor Waddell

About: Computed axial lithography (CAL) is a new type of additive manufacturing. Unlike conventional 3D printing where objects are formed layer by layer, CAL forms objects all at once by rotating a vial of photopolymer while exposing it to a complex set of projected images, very similar to a CT scan. Since parts are formed all at once, they typically form in minutes or less, much faster than other printing processes. This process can enable printing into high-viscosity fluids or even solids as well as around preexisting solid objects. The SpaceCAL payload has conducted two parabolic flights and Galactic 07 was its first spaceflight. Given the sensitive light needed to image and cure the 3D printed objects, Virgin Galactic will be built a dark room in its hangar for the team to conduct its pre- and post-flight work.

[1]*Dosimeters flown on VSS Unity during its flight test program determined that passengers do not experience radiation levels high enough for exposure risk.*