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Commercial MDA ITA Experiments

Innovative Program Provides Commercial Experiments with Access to Space

A new, innovative program designed to increase commercial access to space will use industry-developed flight hardware to process more than 30 different types of commercial experiments aboard the October 1992 Space Shuttle *Columbia* (STS-52) mission.

The experiments are expected to provide data on how microgravity can aid research in drug development and delivery, biotechnology, basic cell biology, protein and inorganic crystal growth, bone and invertebrate development, immune deficiencies, manufacturing processes and fluid sciences. The experiments should provide scientists and engineers with some 400 data points from which they can focus and expand their research in microgravity.

Collectively known as the Commercial MDA ITA Experiments-1 (CMIX-1) payload, the experiments are sponsored by NASA's Office of Commercial Programs. CMIX-1 is part of a 5-year, five-flight program, resulting from a "value exchange" agreement between Instrumentation Technology Associates (ITA), Inc., Exton, Pa., and the Center for Materials Development in Space (CMDS), one of NASA's 17 Centers for the Commercial Development of Space (CCDS) located at the University of Alabama in Huntsville (UAH).

The CMIX program will provide the CCDS community (through UAH CMDS sponsorship) with an opportunity to conduct microgravity experiments using ITA-developed flight hardware. At the same time, opportunities will be provided on a pay-to-fly basis to ITA's customers.

Under the agreement, ITA will provide four to six Materials Dispersion Apparatus (MDA) Minilabs for each of the five planned Shuttle missions. ITA will exchange 50 percent of the MDA capacity for Shuttle transportation. On STS-52, four MDAs will be flown, two of which will contain experiments developed by the UAH CMDS and the CCDS community, which includes collaborators from industry and academia.

The other two MDAs, commercially marketed by ITA, will contain experiments developed by ITA's customers, which include U.S. biomedical technology and biomaterials companies, international users, university research institutions, and both grade school and high school students.

This represents a truly commercial space venture because the users are directly paying ITA to fly their experiments in the MDA. As a result, the users have no restrictions on their experiments (except for safety and suitability), the sale of the products made in space, or the technology developed. All intellectual property data from the MDA flight experiments are solely owned by the commercial user.

The MDA hardware, developed by ITA with private sector resources, is a commercial space infrastructure element that supports both the Administration's and NASA's Commercial Development of Space initiatives. ITA is a small aerospace company that provides advanced space hardware, flight opportunities and specialized engineering and payload integration to the growing number of technical and scientific entities seeking to take advantage of the microgravity environment of space.

The MDA Minilab is a compact, automated device capable of bringing into contact and mixing up to 100 separate samples of multiple fluids and/or solids at precisely timed intervals using, for example, liquid-to-liquid diffusion, vapor diffusion or reverse gradient diffusion techniques. Since its initial flight on two previous Shuttle missions and several suborbital rockets, the MDA has been improved, and its capabilities have been expanded to allow for microgravity research in a wide range of disciplines, including protein crystal growth, manufacturing processes, fluid sciences and cell biology.

One of the four MDAs flying on STS-52 has been modified by ITA, under contract to the UAH CMDS, to support cell biology experiments. Because some of these experiments use hazardous fluids and require a thermal environment of 37 degrees Celsius (body temperature), ITA has developed a third-level containment vessel that works in conjunction with the MDA to assure crew safety, and maintains a constant temperature in the MDA.

In addition to the MDA equipment, the UAH CMDS will conduct live cell investigations in ten Bioprocessing Modules (BPMs). The BPMs contain 60 to 100 times more fluid volume than the MDAs. The MDAs and BPMs each have a specific advantage to the research being conducted on this flight. The MDAs allow testing of many more samples but provide small volumes, while the BPMs increase volume but allow only one or two tests per BPM.

UAH CMDS Experiment Descriptions

The UAH CMDS and the CCDS community have developed nine different types of experiments to be processed in the MDAs and BPMs. The following is a brief description of these experiments.

Bone Cell Function in Microgravity (MDA): Loss of mineral from bone is common in older persons who suffer from osteoporosis, and in astronauts who experience spaceflight. Mouse bone cells will be flown to evaluate how well the cells grow and produce collagen, a bone precursor, in microgravity. Information gained from this experiment will contribute to a database on potential areas for drug treatment of osteoporosis. Potential commercial applications (3-10 years) include developing ways to enhance bone cell growth and prevent bone deterioration in astronauts and the elderly.

Phagocytosis (MDA): In order to fight infection, one of the body's defenses is to rid itself of invading organisms, such as bacteria, by the process of phagocytosis (a means by which certain cells engulf and destroy foreign materials). The purpose of this investigation is to evaluate the phagocytic function of certain cells in microgravity. The expected long-range benefit is a better understanding of the behavior of these disease-fighting cells.

Immune Cell Response (MDA): Previous flight experiments have demonstrated a difference in the sensitivity of certain cells, especially the immune system cells of the body. Compared to ground controls, these cells are less responsive during and after spaceflight. An objective of this experiment is to gain information on why some cells, such as lymphocytes, are more sensitive to microgravity than others. Once this is understood, techniques may be developed to stimulate immune system cells.

Potential commercial applications include development and testing of drugs to reduce some of the undesirable effects of microgravity. In the future, a small, but significant, market can be expected for such drugs for use by astronauts and space travelers. However, a larger commercial market is expected in the Earth-based use of space-developed pharmaceuticals. There also is commercial potential in the culture of specific cells based on natural selection. These cells may be selected for culture in microgravity to increase production of certain commercially-important cells and cell products.

Mouse Bone Marrow Cells (MDA): These cells will be used to investigate use of the microgravity environment to select for stem cells, the type of cells from which the cell of the immune system and red blood cells develop. A concerted effort to culture these cells on Earth has met with only limited success.

The market for human bone marrow stem cells — which are used for bone marrow transplantation and reconstituting the immune system after radiation therapy and chemotherapy treatments for leukemia, lymphoma and breast cancers — is estimated at close to $10 billion, if the cells could be grown in large numbers. Because microgravity appears to select against the growth of some cell types in the bone marrow mixture, investigators believe that this will give the stem cells in the culture an opportunity to expand. The preliminary experiments on this flight will evaluate mouse bone marrow cell survival and response factors which cause them to develop into different types of immune cells and blood cells.

Nerve/Muscle Cell Interactions (MDA):
Using frog cells, this experiment will study the effect of microgravity on the development of nerve cell communication which is essential for brain function. Results from this experiment may be relevant to the ability of higher organisms to undergo normal brain development in space. The value of this experiment lies in collecting information and increasing the database on nerve cell development in space, which will help to identify future potential commercial applications.

Diatoms (MDA): Minute plant cells (diatoms) are encased in a silicone coating and can be used to generate oxygen. It is important to know how microgravity affects these one-celled plants, and to determine if they can be useful commercially to regenerate oxygen.

Other experiments conducted in the MDA will evaluate invertebrate and bone development. Commercial applications of these experiments include developing a database for potential commercial processes and services, which use individual cells to determine the effects of microgravity and to develop and test drugs in space. As the database on cell response and control is enlarged, growth of commercial applications can be expected.

As part of the CMIX program, the UAH CMDS is working with RANTEK, Inc., a scientific and biotechnology research and development company in Coral Gables, Fla. The company is interested in research leading to the development of marketable medical and pharmaceutical products for space and Earth-based uses such as those described above.

Live Cell Investigations (BPMs):
Experiments conducted in the BPMs are designed to gain information on how cells of the human immune system may be induced to grow when exposed to certain compounds. Once scientists discover how cells respond to these compounds in microgravity, techniques may be developed to select for certain desirable cell types.

These cells types produce factors (e.g., interferons) that stimulate other cells to grow and are used to treat certain types of cancer. On Earth, this is a multimillion dollar industry. Previous space research indicates that these cells produce more factors than ground-based cells. The value of this lies in selecting those cell populations which have increased production for potential commercial development in space.

ITA Commercial Experiment Descriptions

ITA and its commercial customers have developed 17 commercial and six student-designed experiments for processing in the MDAs. The following is a brief description of these experiments.

Urokinase Protein Crystal Growth: ITA and a researcher from NASA's Johnson Space Center will conduct this experiment using three separate growing techniques available in the MDA. Urokinase is important because it is an enzyme used to dissolve blood clots in the treatment of thrombotic diseases. It also is a key enzyme that cancer cells accumulate and use as part of their mechanism of invasion and metastasis. Researchers believe that understanding the enzyme's three-dimensional structure may lead to the development of a blocking or therapeutic drug for preventing the spread of breast cancer.

Urokinase crystal growth is very difficult both on Earth and in space. More than 1500 ground-based experiments, some lasting more than 3 years, have resulted in only a few small, fragile crystals. On a previous Shuttle flight (STS-43 in 1991), the MDA was used to grow small, rod-shaped crystals in less than 8 days (unfortunately, they were too small for X-ray analysis studies).

The MDAs on this mission, however, will vary the urokinase concentration levels using three growth techniques to repeat earlier results and to grow a larger crystal.

Bacterial Aldolase and Rabbit Muscle Aldolase Crystal Growth: The University of Montreal, Canada, will use aldolase enzymes to grow protein crystals, which will be subjected to X-ray analysis studies to determine the enzyme's three-dimensional structure. This will provide information and knowledge for research on genetic illnesses. This experiment is a follow-on to similar experiments conducted on STS-37 and -43 in 1991, in which a researcher from the university developed a new technique, using the MDA, to grow very large, high-quality protein crystals.

Enzyme Assembly: ET&T, ITA and the Alberta Research Council in Canada will conduct a joint experiment of enzyme assembly. A large number of proteins, including enzymes, have the ability to form two-dimensional arrays on surfaces. In normal gravity conditions, these assemblies are imperfect. Imperfections in the arrays are caused by thermal convection, which should be absent if the assemblies are produced in extended periods of free fall or microgravity. Potential commercial applications of optimal enzyme assemblies include the development of improved, biologically-based semiconductor materials for computer chips and other electronic applications.

Collagen Polyester Alloy: The Kensey Nash Corp., Exton, Pa., a developer, manufacturer and marketer of high-technology, proprietary medical products, is conducting this experiment to determine what new properties can be imparted to biopolymers by processing them in space. In particular, the company is looking at the preparation of unusual polymer alloys that are impractical to prepare on Earth. The hope is that these new materials will have extraordinary physical properties, thus enabling them to be used in commercial biomaterials applications (proprietary).

Other experiments being conducted in the commercial MDAs include inorganic assembly (proprietary), protein crystal growth, dye and yeast cell diffusion, and engineering tests. Potential commercial applications are expected in areas such as environmental sciences, drug research and development, and cell pharmacology. Engineering tests will be performed to obtain data on liquid-to-liquid diffusion and magnetic mixing rates to verify normal MDA operations and provide "baseline" diffusion data.

Student Experiments

ITA initiated a Student Space Education Program which will run for the life of the CMIX program. For STS-52, ITA has donated 5 percent of its MDA capacity to high school students in Florida, New Jersey, Pennsylvania, Virginia and Washington, D.C. Former NASA Astronaut Robert Cenker coordinated the student experiments for ITA, which include:

Human Fibrinogen Clotting: The experimenters will attempt to clot human fibrinogen (a blood plasma protein) with an enzyme found in snake venom from the *Bothropes Atrox*, a tropical American highly venomous viper (commonly referred to as the fer-de-lance). The experimenters hope to gain further knowledge on the clotting process as it occurs in microgravity. The schools responsible for developing this experiment include T.C. Williams High School, Alexandria, Va.; Jeb Stuart High School, Fairfax, Va.; and Dunbar Senior High School, Washington, D.C. Additional assistance for the experiment is being provided by the National Space Society and the National Institutes of Health.

***Coreopsis* Seed Germination:** Seeds from Florida's official state flower, the *Coreopsis*, are intended to germinate in space, after which they will be distributed to classrooms for comparison with seeds germinated at the Space Florida Authority experiment facility. Students will prepare reports detailing any differences in growth between the two groups of seeds. Three Florida schools are responsible for developing this experiment, including Citrus High School in Inverness, Wakulla Middle School in Crawfordville, and Tate High School in Pensacola.

Brine Shrimp Development: Brine shrimp development will involve hatching tiny *Artemia Salina* shrimp eggs in space to observe how microgravity will effect their early development. After the Shuttle lands, the hatchlings will be returned to the students for observation and comparison. Titusville High School in Florida developed this experiment, with additional assistance provided by the Spaceport Florida Authority.

Tin Crystal Production: This experiment will attempt to grow pure tin crystals in space using a zinc strip immersed in stannous chloride solution. It is expected that the delicate space crystals will be larger and have less imperfections than ones grown on Earth. This experiment was developed by Haliah-Miami High School in Miami, Fla., with additional assistance provided Spaceport Florida Authority.

***Brassica Rapa* (mustard seed) Germination:** Seeds and newly developing reproductive tissue (from either stamens, ovary or both) of *Brassica Rapa* will be flown. The seeds will be flown dry, while the tissue will be immersed, during flight, in an inert culture medium. The materials returned will be used to propagate successive generations of the plant to assess any long-term effects on heredity patterns. This experiment was developed by J.P. McCaskey High School in Lancaster, Pa.

Spinach Mustard Seed Germination: Spinach mustard seeds will be immersed in different growth mediums both in ground control experiments and in flight, to ascertain any differences due to being exposed to microgravity. Data will be compared with similar experiments on earlier Shuttle missions. A fixative will be added shortly after the Shuttle lands to isolate the microgravity development state. This experiment was developed by the Peddie School in Hightstown, N.J.

On-orbit Operations

Throughout STS-52, the four MDAs, each consisting of an upper and lower block, will remain in the thermally-controlled environment of a Commercial Refrigerator/Incubator Module (CRIM), developed by Space Industries, Inc., Houston, Texas.

Each MDA has upper and lower blocks that contain an equal number of wells or reservoirs filled with different experiment samples, including fluids and solids. During pre-flight loading, the MDA blocks are offset to prevent the experiment samples from coming into contact prematurely.

The MDA units will be activated on the first day in orbit by Astronaut Lacy Veach. Veach will give a command to each MDA so that each block will be moved in relation to the other, and the self-aligning reservoirs will align to allow dispersion (or mixing) of the different substances.

To complete microgravity operations, the blocks will be moved to bring a third set of reservoirs to mix additional fluids or to fix the process for selected reservoirs. The system is designed so that a light comes on when the MDA blocks are in the correct microgravity and reentry positions. A prism window in each MDA also will allow Veach to determine alignment of the blocks.

To activate the MDAs, Veach will open the CRIM door to access the MDAs and the MDA Controller and Power Supply. Activation of the four MDAs will occur simultaneously and is required as early as possible in the mission, followed by minimum microgravity disturbances for a period of at leas 8 hours. The crew will operate switches to activate each MDA and, once activated, the CRIM door will be closed.

Deactivation of each MDA will occur automatically at different intervals. For example, one MDA will be deactivated within 10 to 15 minutes of being activated, whereas one will not deactivate at all. Deactivation of the other two MDAs will occur later in the mission.

Veach also will activate the BPMs, which consist of four plastic syringes. The syringes are interconnected by tubing to a four-way valve attached to an aluminum tray. The first syringe of each BPM will contain live cells. The second syringe will contain a mediator of cell growth or function (e.g., an activator), and the remaining two syringes will contain a chemical fixative.

To activate the BPMs, Veach will open the BPM valve to mix the cells with growth mediator. After specified times in microgravity, he will terminate each BPM test by turning the valve to mix cells with fixative to preserve cellular structures in space before returning to Earth. Post-flight analyses will be done to evaluate cell growth and production of materials, including interferons.

Once the Shuttle lands, the MDAs and BPMs will be deintegrated and the samples will be returned to the researchers for post-flight analyses. Principal investigator for the CMIX payload is Dr. Marian Lewis of the UAH CMDS. Dr. Charles Lundquist is director of the UAH CMDS. John Cassanto, president of ITA, Inc., is program manager for the commercial MDAs.

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The CMIX-1 Payload on STS-52 Will Use Four MDA Units