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TELEROBOTIC ELECTRONIC MATERIALS PROCESSING EXPERIMENT

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BACKGROUND

The NASA GSFC Office of Commercial Programs (OCP) is currently sponsoring industry and institutional research programs that will utilize GSFC developed robot technologies to facilitate space-based production of microelectronic materials (semiconductors) and devices. The microgravity space environment offers many advantages for microelectronic processing. In the absence of gravity, thermal convection, buoyancy and sedimentation are eliminated. Microgravity also enables containerless material processing, thereby reducing the likelihood of semiconductor contamination. A high vacuum controlled atmosphere, cleanliness and isolation of hazardous materials are other space processing advantages. The objective of the OCP and NASA Headquarters Space Commercialization Office, Code C, is to provide a broad program of technological research and development in support of space-based microelectronic materials processing applications and science programs by matching GSFC capabilities to industry and institutional needs.

Robotics for Commercial Microelectronics Processes in Space Workshop

The GSFC OCP hosted the "Robotics for Commercial Microelectronics Processes in Space Workshop" in December 1987. This was the beginning of a four Phase approach that will lead to a test payload for a space-based processing facility. The objective of the Phase I workshop was to bring together NASA, university, and industry researchers, as well as Space Shuttle carrier personnel, to discuss materials processing, robotics, and commercial automation . Discussed in the workshop was the utilization of robotics and automation to improve microelectronic processing productivity. Phase II of the program was initiated to investigate processes that included bulk crystal growth, wafer manufacturing and device fabrication. A "Telerobotics for Commercial Microelectronics Processes in Space" study report concluded that the utilization of automation and telerobotic technologies was far more cost effective and less hazardous than using a human operator. [Ref. 1]

It has been proposed that Phase III utilize the unique NASA GSFC Development, Integration and Test Facility (DITFAC) testbeds, shown in Figure 1, to identify key features for the material processes and demonstrate robot and automation capabilities. The DITFAC currently supporting the Flight Telerobotic Servicer (FTS) program incorporates three primary testbeds. These testbeds are being used by the GSFC robotics team to create, test and evaluate new and evolving robotic technologies. The testbeds include the FTS Functional Simulator, Engineering Testbed and the Graphics Simulator. These testbeds are being used to evaluate Space Station Freedom mockups, perform robot simulations, research issues such as robot control algorithms and perform graphic kinematic simulations of various robot tasks. [Ref. 2]

The Phase IV proposal represents the development of a Telerobotic Materials Processing Facility (TRMPX). TRMPX is a Shuttle-launched, materials processing test payload using a Get Away Special (GAS) can. The test payload is necessary because key features of the facility cannot be fully tested on earth and will require exposure to the unique environment of space. [Ref. 3]

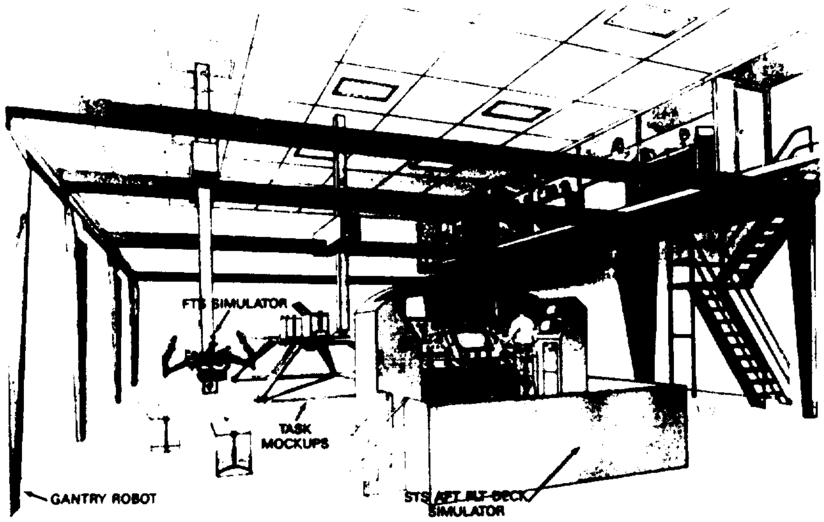

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Figure 1. Development, Integration and Test Facility (DITFAC)

TELEROBOTIC MATERIALS PROCESSING EXPERIMENT (TRMPX)

The objectives of the GSFC managed and OCP sponsored TRMPX program are to define, develop and demonstrate an automated materials processing capability under realistic flight conditions. GSFC has proposed to accomplish this using small test payloads launched on the Shuttle as a Hitchhiker attached GAS payload experiment. TRMPX will fit inside the 19-3/4" diameter x 28-1/4" length GAS can interior. The Hitchhiker avionics and electronics interface will provide the necessary power and data handling to operate TRMPX. The process of utilizing the GSFC laboratory to develop and demonstrate robot capabilities, and the knowledge accrued from this experiment, reduce the risk in developing a space-based materials processing facility. A concept drawing of a proposed TRMPX is shown in Figure 2. [Ref. 4]

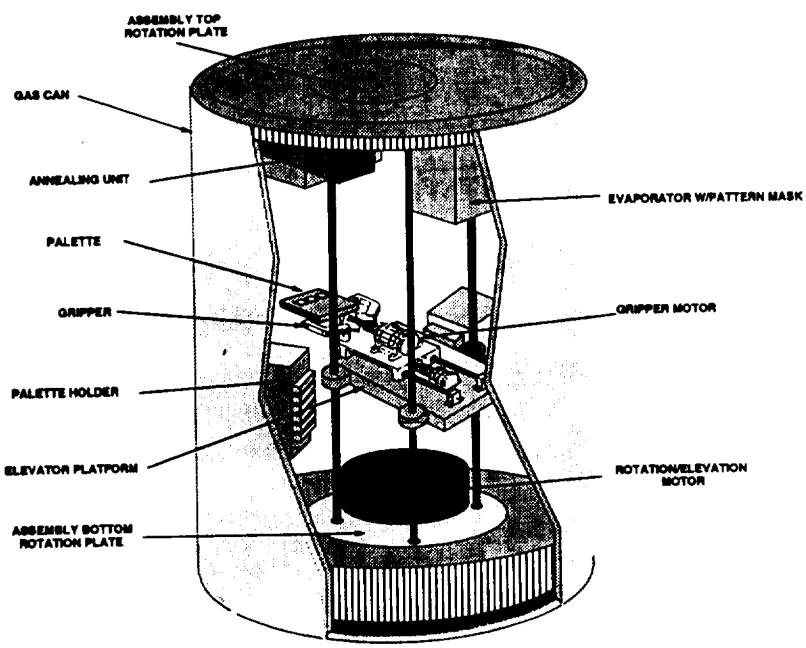


Figure 2. Telerobotic Materials Processing Experiment (TRMPX) Concept

Materials Processing Experiment

TRMPX will provide the capability to test the production processes that are dependent on microgravity. The processes proposed for testing include:

- the annealing of amorphous silicon to increase grain size for more efficient solar cells,
- thin film deposition to demonstrate the potential of fabricating solar cells in orbit, and
- the annealing of radiation damaged solar cells.

Robot Handling Equipment

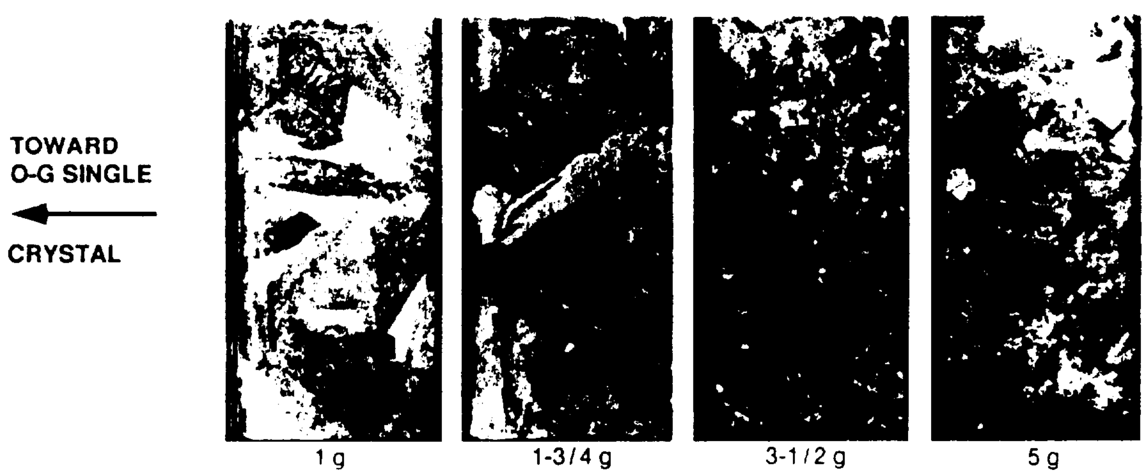
TRMPX robot-process testing will include:

- three axis robot manipulation,
- the gripper/grasping and robot manipulation of palette with sample materials, and
- robot control using autonomy as well as teleoperation from the ground.

Mission Characteristics

The proposed materials processing mission for the initial TRMPX is the post fabrication recrystallization annealing of poly and amorphous Silicon (Si) to increase microcrystal grain size for the production of high efficiency solar cells based on inexpensive materials.

Figure 3 shows the effects on grain size for metal crystals grown in a centrifuge. It is theorized from this data that one can approach a single crystal configuration and therefore improve solar cell efficiency by processing in a microgravity environment.



GRAIN VS. G-FORCE

Figure 3. Micro Gravity Effects

The robot interaction would include:

- substrate exchange from holding carriages to annealing area and back again,
- in-flight analysis and robot control to adjust the annealing cycles during the course of the experiment.

Robot tasks will further evolve as the experiment design is solidified.

The definition of TRMPX mission and robot design requirements will be completed during the second quarter of FY 91. A prototype Flight TRMPX will be available during the third quarter of FY 92 with a launch by the first quarter FY 93. These time lines assume continued funding support and STS availability.

Centers for Commercial Development of Space - CCDS

The TRMPX program utilizes in-house engineering support as well as contractors. Commercial Centers for Development in Space (CCDS) was established to provide for commercial involvement in requirements definition. The CCDS consists of universities and industry which conduct research and development of technologies with applicability to space-based materials processing. Clarkson College and Batelle Corporation are researching materials such as zeolite ampoules. They also plan to flight test GSFC silicon samples on-board a KC-135 aircraft. Flying at a high altitude, a free falling KC-135 can duplicate a weightless environment for short durations. Similar samples may be supplied to GSFC for the TRMPX experiment. The University of Wisconsin Center for Space Automation and Robotics (WCSAR) has been established to conceive, demonstrate and simulate space and terrestrial commercialization technology. The WCSAR has been involved in robot automation and sensor development and is considering joining the TRMPX team.

TELEROBOTICS MATERIALS PROCESSING FACILITY (TRMPF)

Goals and Objectives

GSFC engineers have begun to define requirements and concepts for a free-flyer telerobotic materials processing facility (TRMPF). The objective of the TRMPF program is to evolve TRMPX to a fully self contained free flyer materials processing facility. TRMPF will utilize enhanced materials processing and robotic capabilities used on TRMPX.

Mission Scenario

The TRMPF facility, shown in Figure 4, will be approximately 30" diameter and 76" long. Initially, TRMPF would be an attached payload on the Shuttle evolving to a permanent facility on Space Station Freedom or a free flying spacecraft. The geometry and size of TRMPF make it a good candidate for launch on an expendable launch vehicle (ELV). The facility can be serviced by the Shuttle or an ELV with re-entry capability. Both would supply new materials for processing and remove processed samples and return to earth as shown in Figure 5. Another concept being considered is to launch multiple facilities that would be attached to each other by using an autonomous robot walker to form a TRMPF train as shown in Figure 6. Facilities that have completed their missions will be detached and returned to earth.

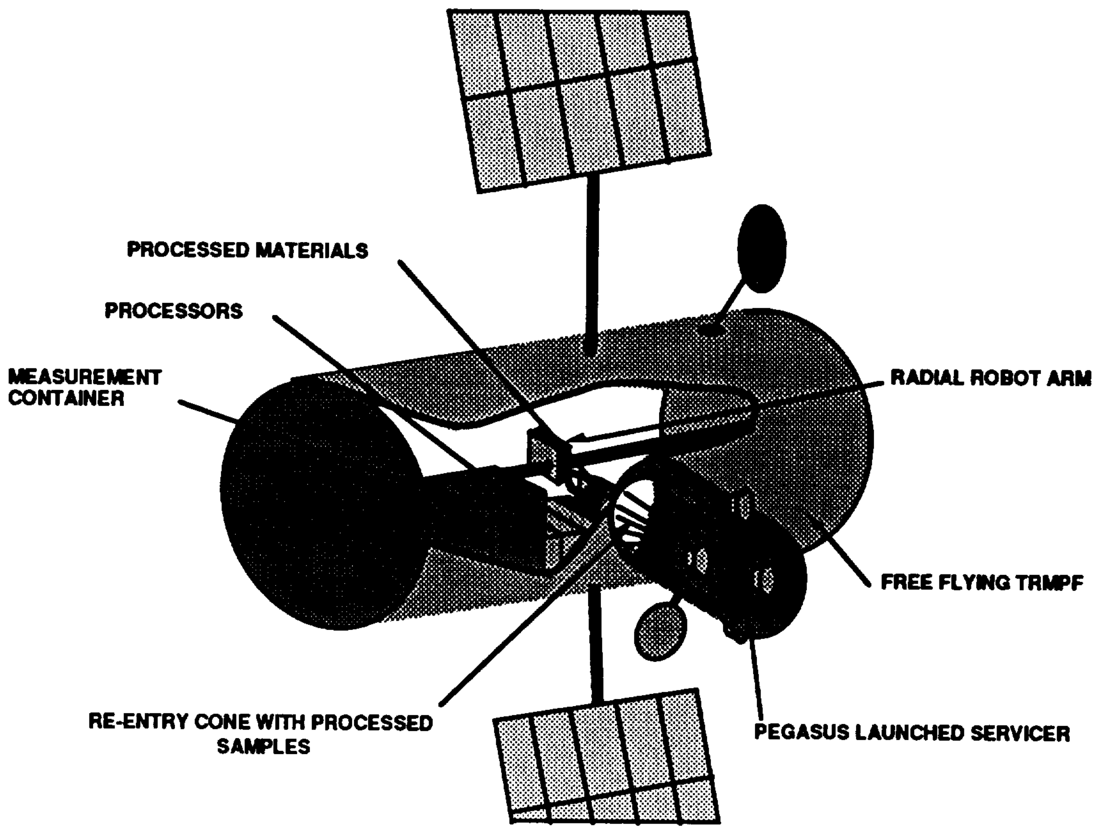


Figure 4. TRMPF Concept

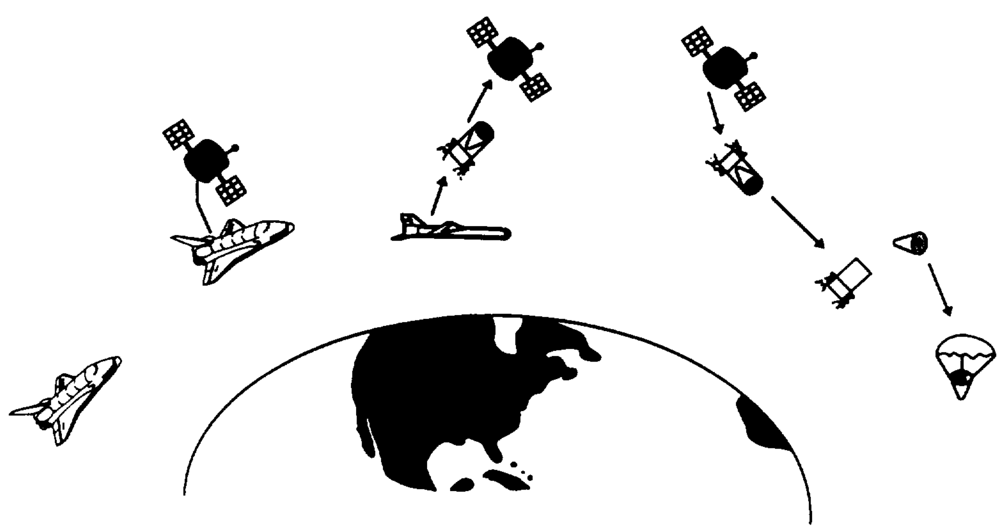


Figure 5. TRMPF Servicing

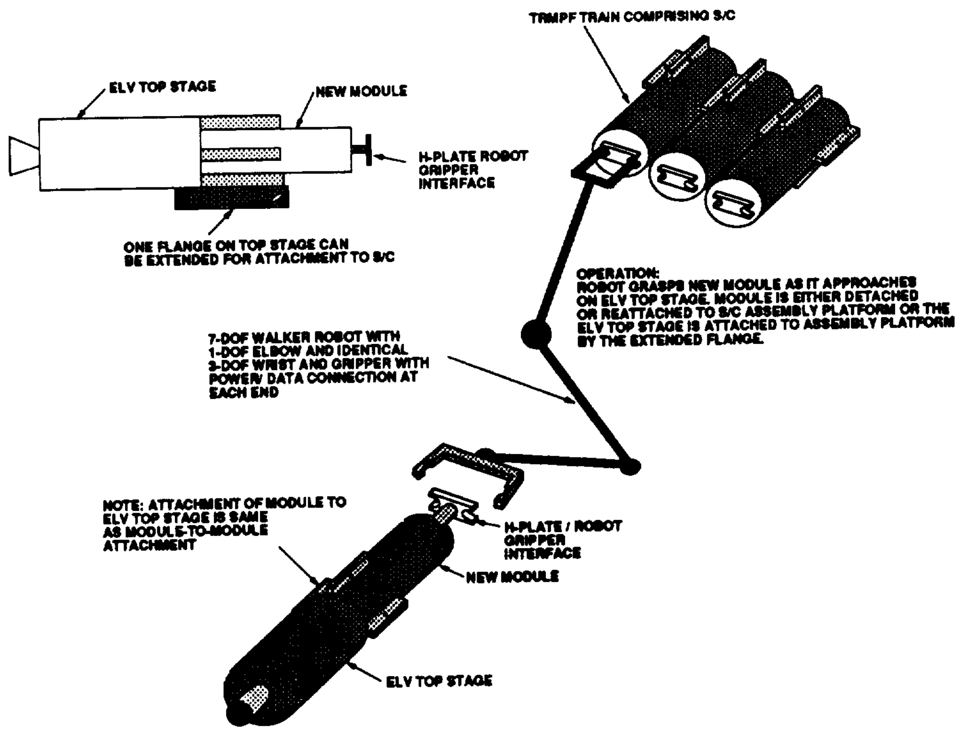


Figure 6. TRMPF Train

SUMMARY AND CONCLUSIONS

The Office of Commercial Programs (OCP) working in conjunction with NASA GSFC engineers is supporting research efforts in robot technology and microelectronics materials processing that will provide many spinoffs for science and industry. The environment of space provides a number of potentially significant advantages in regard to commercial microelectronic processes. To provide for an environment by which these emerging technologies can be tested and demonstrated, GSFC has developed and implemented a Development, Integration and Test Facility. The OCP is sponsoring universities and industry to participate in this tremendous opportunity to contribute to the development of microelectronic processing and robotic applications in space.

TRMPX is being designed as an attached Shuttle payload to demonstrate an automated materials processing capability under realistic flight conditions. TRMPF will evolve using the knowledge gained from TRMPX to form a stand-alone self-supporting free-flyer materials processing facility in space.

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1. "Telerobotics for Commercial Microelectronics Processes in Space." NASA GSFC, 1987.

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3. "Telerobotic Electronic Materials Processing Experiment (TREMPX)." Systems Concept Review. NASA GSFC, December 21, 1989.

4. "Get Away Special (GAS) Small Self Contained Payloads - Experimenter Handbook." NASA GSFC, 1989.