Forest products consortium/lignin research

Status, Plans, Connections to NASA's Mission and Vision
and to the Space Architect's Capability Requirements

Organizing principles

NASA 2003 Strategic Plan

Goal 3
Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.
- 3.2
- 3.4*
- 3.5

Goal 4
Explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space.
- 4.1

Goal 7
Engage the public in shaping and sharing the experience of exploration and discovery.
- 7.3*

Goal 8
Ensure the provision of space access and improve it by increasing safety, reliability, and affordability.
- 8.4

Goal 9
Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.
- 9.4

Goal 10
Enable revolutionary capabilities through new technology.
- 10.4
- 10.6*

* These objectives are reflected in the overall Research Partnership Program and thus not connected to specific requirements of any single research program.

Space Architect Perspective
Capability Requirements

- Adaptation and Countermeasures 2.3.6 — 2.3 Habitation and Bioastronautics
- In-Space Laboratory Research Systems 2.7.7 — 2.7 In-Space Instruments and Sensors

OBPR Organizing Questions

2. "What must we know about how space changes life forms, so that humankind will flourish?"
- 2a) Does space affect life at its most fundamental levels, from the gene to the cell?
- 2c) How does space affect the development and life cycles of organisms?
- 2d) How do systems of organisms and their interactions change in space?
- 2b) How does long-term exposure to space affect organisms?

3. "What new opportunities can our research bring to enrich lives on earth and expand understanding of the laws of nature?"
- 3d) What are the fundamental physical, chemical, and biophysical mechanisms that drive the cellular and physiological behavior observed in the space environment?
- 3e) How can we create research partnerships that support national goals, such as contributing to economic growth and sustaining human capital in the areas of science and technology?

Requirements

Requirement: life support: consumable plants. Advanced life support for long space trips requires consumable plants with known crop growth rates and plant regeneration quality.

Requirement: basic research. Further understanding of microgravity or reduced gravity effects when compared to Earth grown plants on mechanisms that control structural and genetic aspects of plants.

Requirements: basic research. tools: Equipment for plant growth in space. To understand the properties of plant growth in microgravity, develop hardware that enables long-duration, healthy plant growth in space. Develop hardware that enables preservation of plants harvested in space.

Requirement: Forest products industry: Understand lignin biosynthesis and cell wall biogenesis in trees of commercial value. Reduce chemical and energy requirements of the pulping process thus reducing environmental pollution emitted from pulp/paper mills.

Requirement: Basic research: Lignin biosynthesis and cell wall biogenesis. The forest products industry is seeking to more clearly understand lignin biosynthesis and cell wall biogenesis in order to improve overall wood properties

Plans

Plan: Plants/trees. More clearly identify control mechanisms for lignin biosynthesis and cell wall biogenesis. On the next two missions to the ISS, PGBA will grow loblolly pine seedlings, a critical step in this important research program. The ability to grow tree seedlings for long periods (90-120 days) in a reduced gravity environment on board the ISS, could help researchers identify the control mechanism involved in lignin biosynthesis and cell wall biogenesis.

Plan: The next experiment for this research program is currently scheduled for flight on board ISS 13A.1. This experiment will grow pine tree seedlings for approximately 90-120 days in space. The seedlings will be harvested by astronauts and preserved for extensive analysis once returned to Earth. It is predicted that this analysis will yield insight into the mechanisms behind plant lignin biosynthesis and cell wall biogenesis when grown in microgravity.

Importance: environmental: chemical and energy use. Understanding lignin biosynthesis and cell wall biogenesis in trees of commercial value and subsequently growing trees with those favorable properties could reduce the amount of pollutants emitted and energy used by pulp mills during the paper making process. Pulp and paper industry is the third largest polluting industry in the world. Improving the feedstock properties used in mills for making paper is one way to significantly reduce the environmental impact of this process. A 10% reduction of lignin in the feedstock used in a mill could reduce toxic emissions by 20-30% and result in a 20% savings in energy usage.

Hypotheses & Projects

Capability: hardware: COMMERCIAL GENERIC BIOPROCESSING APPARATUS (CGBA)
Used for: CGBA can be converted to a cold storage and fixation system for preservation of harvested plant samples from PGBA. It is able to cool samples to and maintain them at –16 degrees C.
Range of future applicability to NASA Research. PGBA is a proven plant growth facility that can be used for almost any plant growth study being conducted by NASA. CGBA as a Freezer system can be used as cold storage for other experiments being conducted on the ISS. CGBA is also used as an incubator for other biological experiments and is described elsewhere.
Available from: BioServe Space Technologies, University of Colorado, Boulder, Colo, a NASA Research Partnership Center.

Capability: hardware: PLANT GENERIC BIOPROCESSING APPARATUS (PGBA)
Used for: PGBA is a space flight plant growth chamber that has a nutrient delivery system, provides temperature, humidity, CO2, and lighting control and can hold up to 120 plants. The hardware is equipped with telescience operations including data acquisition for monitoring plant growth and performance as well as video downlink while in orbit.
Available from: BioServe Space Technologies, University of Colorado, Boulder, Colo, a NASA Research Partnership Center.

Project: FOREST PRODUCTS CONSORTIUM/LIGNIN RESEARCH
Status: next flight 13A.1 (Fall 2003) Space flight hardware (PGBA) fully built and ready to support experiment. PGBA is able to grow pine seedlings for approximately 90-120 days on board the ISS. Space grown trees will be compared to ground controls.
Project description: For this experiment, the trees will be maintained by the apparatus on both ascent and descent on the space shuttle and while on board the ISS. Trees will be harvested and put in cold storage at different intervals during the ISS portion of the flight. A simultaneous ground control will be conducted as well. Once back on Earth the preserved samples (space and ground) will be analyzed using multiple techniques including genetic analysis. Scientists will then begin to study the effects of microgravity on lignin biosynthesis and cell wall biogenesis as well as the effect on secondary compounds produced by the plant.
Project site. BioServe Space Technologies – a Research Partnership Center, University of Colorado, Boulder, CO

Research Partnership Centers Multiple Benefits
Immediate applications on Earth. This research will improve products in the near future for paper pulp industry.
Leverage NASA research funds. Investment by the US Department of Agriculture's Forest Product Laboratory, Weyerhaeuser. and several biotechnology and forest product companies in partnership with NASA enables NASA to stretch its research dollars by not having to pursue this research.

Knowns and Unknowns

Known. On Earth plants have evolved to withstand the force of gravity through the development of a cell wall and production of associated structural compounds such as lignin.

Unknown. The genes that regulate lignin production in response to gravitational loading are unknown.

Status: Prototype, V.6
MacroVU® Analytics

Horn, R. E. Preliminary Thoughts on NASA Strategic Research

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