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GAS-GRAIN SIMULATION FACILITY (GGSF)

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ABSTRACT

The goal of the Gas-Grain Simulation Facility project is to provide a microgravity laboratory to facilitate research relevant to exobiology (the study of the origin and evolution of life in the universe). Such a facility will also be useful in other areas of study important to NASA including planetary science, biology, atmospheric science, astrophysics, chemistry, and physics. To achieve this goal, the project will develop and support the GGSF, a modular facility-class payload planned for inclusion on Space Station Freedom. The GGSF will consist of an experiment chamber(s) supported by subsystems that provide chamber environment regulation and monitoring capabilities; sample generation, injection, positioning, and retrieval capabilities; and computer control, data acquisition and housekeeping capabilities. The facility will also provide analytical tools such as light-scattering measurement systems, aerosol size-spectrum measurement devices, and optical imaging systems.

As much as possible, facility components will be designed to be modular, allowing evolutionary growth of the facility capabilities. A modular design will also allow flexibility in facility configuration; provide for on-orbit integration of experiment unique equipment into the facility; and allow GGSF subsystems to be added, removed or exchanged with minimal crew interaction. To further minimize crew interaction requirements, the GGSF and each experiment to be performed on the GGSF are expected to make use of automation, telescience and artificial intelligence, allowing nearly autonomous operation.

Laboratory research enabled by the GGSF involves simulating and studying fundamental chemical and physical processes such as formation, growth, nucleation, condensation, evaporation, aggregation, coagulation, collision and mutual interaction of small (sub-micron to millimeter size) particles (e.g., crystals, powders, liquid droplets and dust grains). Twenty-two potential GGSF experiments involving such processes have been defined to date. Benefits of microgravity and specific potential experiments representative of the various disciplines will be discussed.

Currently, TRW is conducting a Phase A engineering reference design study for the GGSF. This design will be outlined and sketches of the concept shown. The GGSF science community met to discuss science requirements and this reference design at the third GGSF science workshop held in May of 1992 at the Desert Research Institute in Las Vegas, Nevada. The project is currently working toward launch of the GGSF to Space Station Freedom in 1998. GGSF science and hardware concept validation tests both ground and space-based are being planned with precursor experiments scheduled for launch on Shuttle in 1996.

Other work related to GGSF development includes four experiment concept studies for the Aerosol Physics Module, a precursor to the GGSF. These explore potential GGSF experiments dealing with smoke agglomerates, fractal particles, Titan atmosphere aerosols, and organic compound synthesis on growing particles. Another related study involves numerical modeling of coagulation and diffusion effects in the GGSF as a tool for experiment design and data analysis. Also related to GGSF development is an experiment just successfully completed in July on the Space Shuttle mission USML- 1, which studied a method of dispersing solid particles in a microgravity environment.

Gas-Grain Simulation Facility (GGSF)

Space Station Freedom Utilization Conference

Hunstville, Alabama

August 3 - 6, 1992

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Project Goals

- Support exobiology's goal to understand how cosmic, solar system, and planetary evolution have influenced the origin, evolution, and distribution of life and life-related molecules in the universe

- Provide a microgravity laboratory to facilitate research relevant to exobiology, biology, planetary science, astrophysics, atmospheric science, chemistry, and physics

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Project History

1984-85: Workshops propose and develop concept

1987: Physics feasibility study by Martin Marietta

Workshop identifies science community, establishes experiment concept data base

1991: Science Working Group convenes

Phase A concept analysis/definition study begins for GGSF and precursor experiment

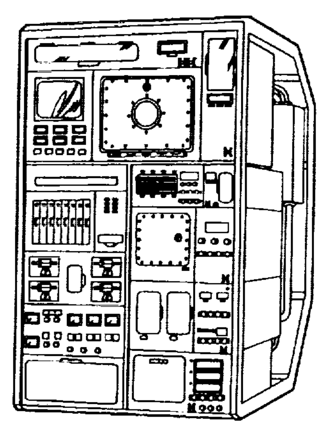
4 Aerosol Physics Module/GGSF concept studies funded

1992: Science Workshop - GGSF community examines Phase A design concept

USML-1 Glovebox Expt. tests particle dispersion method

Payload Data

- Readiness
  - Core Facility (MTC): 1998
  - Mature Facility (PMC): 2001
- Lifetime: > 10 years
- Mass (total): 700 Kg
- Size: 80"H x 42"W x 39"D (1 ISPR)
- Volume: ~ 1 m^3
- Power: < 3 KW peak
- Location: Pressurized Laboratory

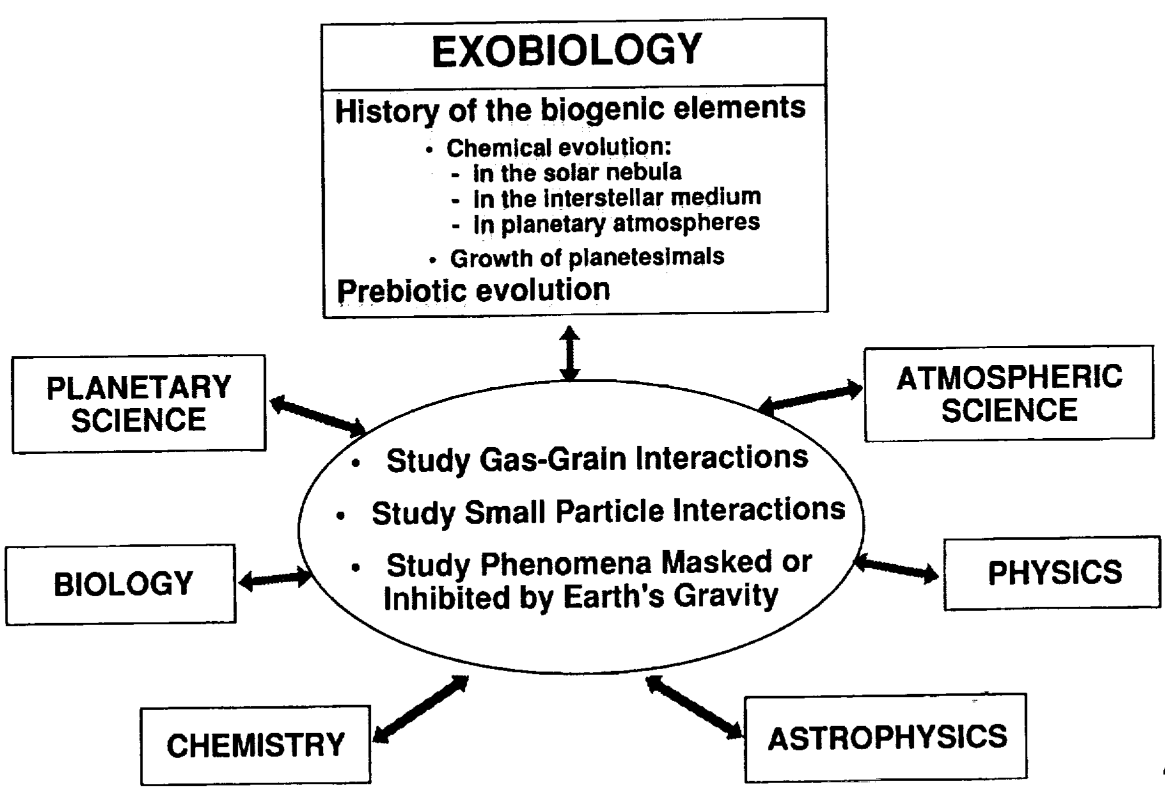


Science Objectives

To investigate fundamental chemical & physical processes involving suspended particles mainly in the sub-micron to millimeter size range (e.g., dust grains, crystals, combustion products, droplets, ...):

- Nucleation
- Condensation
- Evaporation
- Particle/Droplet Formation
- Particle/Droplet Growth
- Aggregation
- Coagulation
- Collisions
- Mutual Interactions

GGSF Science



Exobiology

Question

What can planetary scale atmospheric chemistry reveal about the conditions on early Earth which led to the origin of life?

Potential GGSF Experiment

Titan's Atmospheric Aerosol Simulation

- Simulate formation and growth of organic haze
- Measure optical properties
- Determine chemical composition

Biology/Aerobiology

Question

What is the fate of airborne microbes, and how does microgravity affect aerosol disease spread in a confined space such as Space Station?

Potential GGSF Experiment

Airborne Bacteria in Microgravity

- Examine metabolism and growth, if any, of aerosolized microbes
- Determine the interrelationship between atmospheric trace gases (e.g., NO_x) and airborne microbes
- Determine how being airborne affects microbial pathogenicity

Astrophysics

Question

What are the properties of fractal materials? Do fractals play an important role in circumstellar and interstellar environments as well as in the early solar nebula?

Potential GGSF Experiment

Study of Fractal Particles

- Measure coagulation coefficients of silicates & metal grains
- Measure scattering & extinction efficiencies of aggregates
- Measure cohesive strength
- Study fractal structure
- Look for signatures to distinguish fractal aggregates from a distribution of particles

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Planetary Science

Question

How do low energy collisions influence the behavior of ring structures such as those of Jupiter, Saturn, Uranus, and Neptune?

Potential GGSF Experiment

Planetary Ring Dynamics

- Study collision dynamics
- Measure energy loss in low velocity collisions
- Determine coefficients of restitution
- Analyze the transfer of linear to angular momentum

Atmospheric Science

Question

What are the properties of cirrus cloud crystals and what role do they play in the the balance of the Earth's atmospheric radiation budget? What is their effect on global warming?

Potential GGSF Experiment

Ice Scavenging and Aggregation: Optical and Thermal IR Absorption and Scattering Properties

- Study crystal growth
- Study aggregation
- Measure optical and thermal IR scattering and absorption properties
- Study scavenging of aerosols by ice crystals

GGSF Strawman Investigations

1 Low-Velocity Collisions Between Fragile Aggregates

2 Low-Energy Grain Interaction/Solid Surface Tension

3 Cloud Forming Experiment

4 Planetary Ring Particle Dynamics

5 Aggregation of Fine Geological Particulates in Planetary Atmospheres

6 Optical Properties of Low-Temperature Cloud Crystals

7 Ice Scavenging and Aggregation

8 Synthesis of Tholin and Measurement of its Optical Properties

9 Metallic Behavior of Aggregates

10 Organic Compound Synthesis on Surfaces of Growing Particles

11 Crystallization of Protein Crystal-Growth Inhibitors

12 Dipolar Grain Coagulation and Orientation

13 Titan Atmospheric Aerosol Simulation

14 Surface Condensation and Annealing of Chondritic Dust

15 Studies of Fractal Particles

16 Emission Properties of Particles and Clusters

17 Effect of Convection on Particle Deposition and Coagulation

18 Study of Smoke Agglomerates

19 Airborne Bacteria in Microgravity

20 Infrared Emissivity of Extraterrestrial Particles

21 Radiation-Induced Rotation of Interplanetary Dust

22 Dynamics and Evaporation of Clusters of Drops in Vortical Flows

GGSF Strawman Experiment Investigators

1 Weidenschilling, *Planetary Science Institute*

2 Sievers and Thompson, *Cornell University*

3 Hudson, *Desert Research Institute*

4 Bridges, *U.C. Santa Cruz*

5 Marshall, *Arizona State University*

6 Pope, *ARC* and Tomasko, *U. of Arizona*

7 Hallett, *Desert Research Institute*

8 Khare, *Cornell University*

9 Traver, *Johns Hopkins University*

10 Oberbeck, *Ames Research Center*

11 Raymond, *U. of South Alabama*

12 Freund, *SETI Institute*

13 Scattergood, *S.U.N.Y.* and McKay, *ARC*

14 Rietmeijer and McKinnon, *U. of New Mexico*

15 Nuth, *Goddard* and Stephens, *Los Alamos Lab.*

16 Allamandola, *Ames Research Center*

17 Rhim, *Jet Propulsion Laboratory*

18 Mulholland, *NIST*

19 Mancinelli, *SETI Institute*

20 Goebel, *Ames Research Center*

21 Misconi, *Space Research Institute*

22 Bellan, *Jet Propulsion Laboratory*

Benefits of Microgravity to GGSF

- Suspension times increased
  - Permits long duration aerosol studies
  - Enables low-velocity collision experiments
- Buoyancy-driven convection reduced ($\Delta T_{cr} \propto 1/g$)
- Allows low energy interactions that are masked by gravitational forces on Earth
- Fractals and other gravitationally unstable (at 1 g) objects may be studied

Modular Design Concept (Phase A)

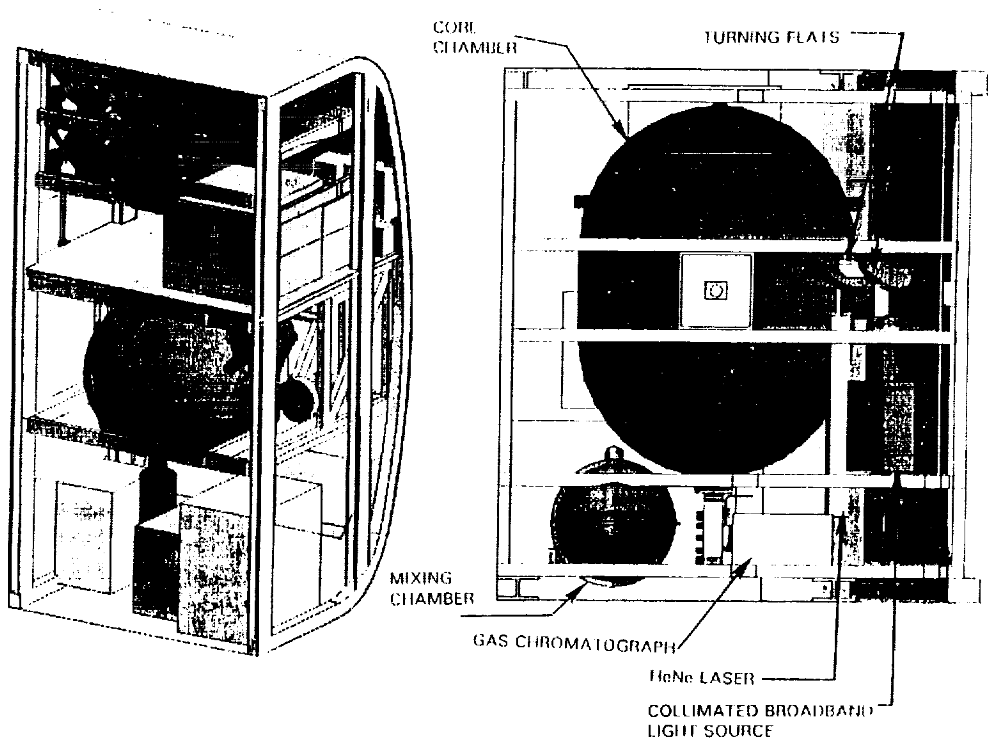
- Interchangeability of subsystems accommodates a broad range of experiments
- Allows for new experiments and technology upgrades
- Four interchangeable chambers

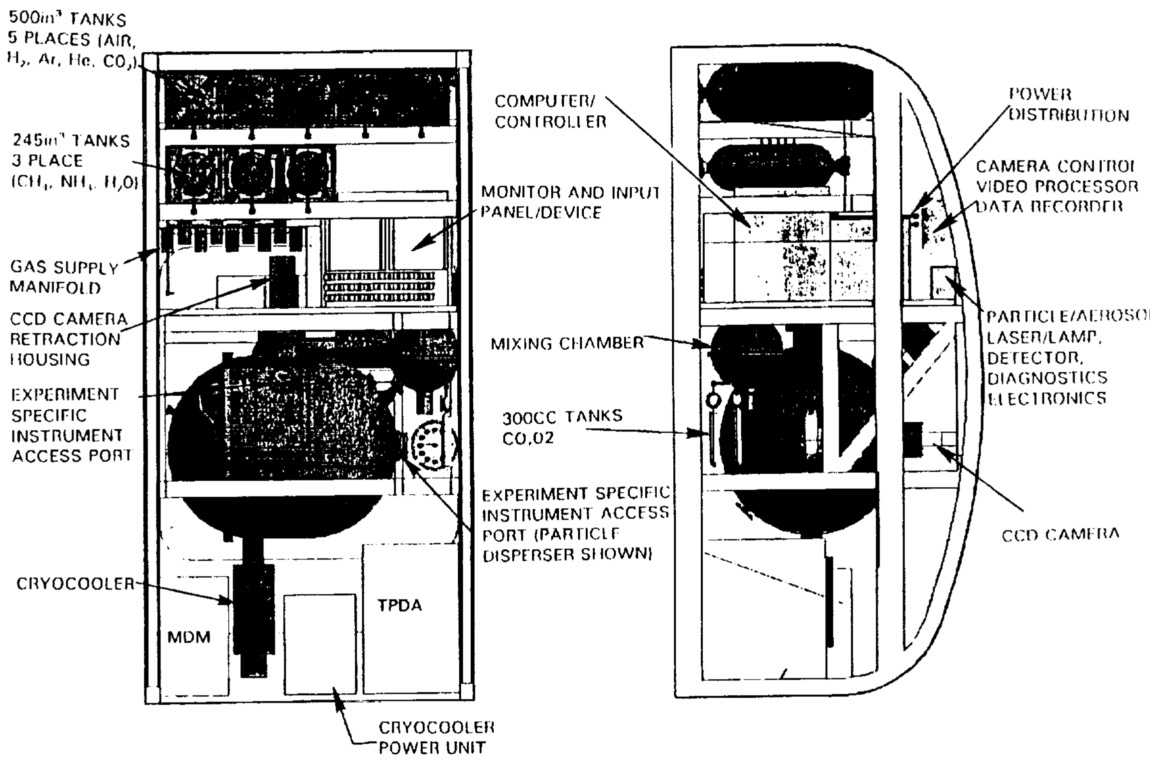
Function	Temperature (K)	Pressure (bar)	Volume (Liters)
Core	150 to 400	10^{-6} to 1	67
Low Temp.	40 to 400	10^{-6} to 3	4.2
High Temp	300 to 1200	10^{-6} to 1	8.2
High Vacuum	60 to 300	10^{-10} to 1	4.2

The 4 Chambers Accommodate the Following:

Physical Objectives
Aggregation
Biological
Condensation/Nucleation
Crystal Formation
Particle Dynamics/Collisions
Spectral/Optical Properties
Synthesis of Compounds

Generation Methods
Low Temp. Nuc./Condensation
High Temp. Vapor Formation
Solid Particle Dispersion
• Single/Small Number
Combustion (Smoke/Soot)
Liquid Aerosol Dispersion
• Single/Small # of Drops
Radiation-Induced Synthesis





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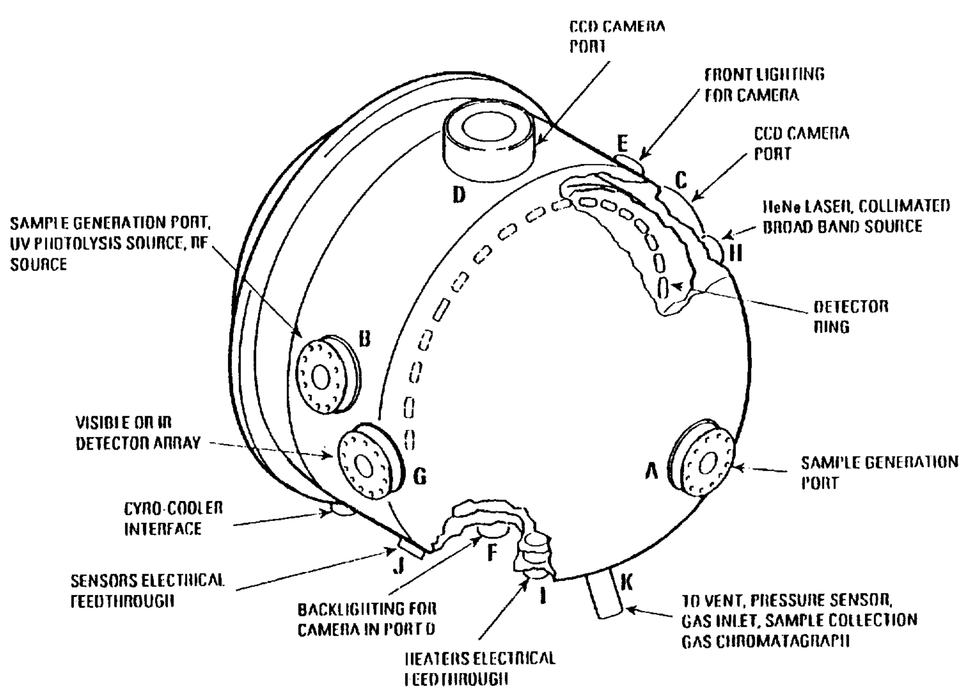
Core Chamber



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Future Plans

- Science and Hardware Concept Validation
    - Ground-based KC-135, drop tower; space-based Shuttle middeck and Spacelab opportunities
    - Reduces hardware development risks
    - Provides early science return
- GGSF Technology Workshop
- GGSF Science Workshop

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