IAF-92-0950

THE GAS-GRAIN SIMULATION FACILITY (GGSF) FOR SPACE STATION FREEDOM: DESIGN CONCEPT

N. Gat[1], J.L. Kropp[2]
TRW Space & Technology Group, Redondo Beach, CA, USA

J.L. Huntington[3]
SETI Institute, Moffen Field, CA, USA

M.L. Fonda[4]
NASA Ames Research Center, Moffett Field, CA, USA

Abstract

The GGSF is specifically designed to accommodate µ-g experiments that investigate long-term effects and interactions between submicron to centimeter size particles. The paper introduces the science disciplines and the type of experiments that are currently envisioned for the GGSF. The broad range of science and technology requirements are discussed, and the Space Station Freedom (SSF) accommodations and available utilities are reviewed. Based on the requirements and the available accommodations, a facility conceptual design is outlined. The required subsystems are listed, and the rationale and considerations that lead to the selected approach, delineated. The present GGSF concept is that of a modular facility system comprising a flight rack and an array of fully compatible and interchangeable subsystems that are designed to meet a diverse set of science requirements. The modularity allows for future upgrade of various subsystems as technology evolves and for introduction of new modules to accommodate new or different experiments. These features are essential for a facility that is expected to be in service on board the SSF for 10 years or more.

Introduction

The GGSF is a multidisciplinary facility, scheduled to fly on board the Space Station Freedom (SSF) in late 1998, designed specifically to study interactions between small *grains* or particles and their long-term behavior and characteristics. GGSF will be designed to investigate various physical mechanisms or processes and will allow the simulation of distinct natural systems of interest to several science disciplines as listed in Table 1. This diverse set of experiments objectives was suggested by the results of a workshop conducted by NASA Ames Research Center (ARC) in 1987 and published as a NASA conference publication[1].

The need for a µ-g environment stems from several reasons. First, the forces that are investigated, such as van der Waals, coulomb, *surface* tension, etc. would be totally obscured or dominated by the Earth's gravity. Second, large particles cannot be suspended and investigated for a long enough period to adequately simulate natural phenomena. Third, buoyancy-driven forces are reduced significantly. Finally, unstable and fragile objects such as fractal particles can be investigated in the µ-g environment.

The GGSF is expected to remain on orbit for at least 10 years to accommodate a vast range of experiments. More than 20 strawman experiments have been identified as candidates for the GGSF, reflecting a broad interest within the science community. A brief description of several typical experiment. is given below.

Low-velocity collisions between fragile aggregates. The earlier stage of accumulation of solid bodies in the solar nebula involved low-velocity collisions of aggregates of submicron dust grains held together by weak interparticle forces. In order to understand the time scale of planetesimal formation and its efficiency, the conditions leading to collisional aggregation or erosion/disruption must be determined as a function of particle size, velocity, composition, and physical state. The objective of the experiment would be to determine the velocity regime for coagulation and disruption of aggregates.

Cloud-forming experiments. Many aspects of atmospheric and planetary cloud formation are not well understood and experiments involving crystals and droplets are planned. Micro-gravity studies of the properties of cirrus cloud crystals will help clarify their role in the balance of the earth's atmospheric radiation budget and hopefully answer question on global warming. The rate of growth of droplets at small sizes and how certain parameters affect this growth will also be studied. Various aerosols will be used to form droplets under controlled conditions and condensation (growth) coefficient will be determined.

[1]TRW Program Manager, Applied Technology Division.
[2]TRW Senior Project Engineer, Applied Technology Division.
[3]NASA Project Scientist.
[4]NASA Project Manager.

Table 1. Science Drivers for the GGSF

Science disciplines	Exobiology, planetary science, atmospheric science, biology, chemistry, physics, and astrophysics
Systems to be simulated	Planetary rings, atmospheric clouds, interstellar clouds, planetary atmospheres, Martian dust storms, stellar nebulae
Processes to be investigated	Aggregation, nucleation, accretion, coagulation, evaporation, condensation, collisions, fractal growth, freezing and evaporation, scavenging, UV photolysis, polymerization, longevity of bacteria, crystal growth

Optical properties of low-temperature cloud crystals. The outer planets are covered by clouds which play a key role in many fundamental aspects of these massive atmospheres including temperature structures, radiation budget, and atmospheric dynamics. Knowledge of the microphysical properties of the cloud particles is necessary in order to analyze the role they play. The measurement of optical properties of particles such as crystals of ammonia and methane ice will help in the interpretation of observations of these planets.

Titan atmosphere aerosol simulation. Atmospheric aerosols are important in determining the chemical and radiative properties of planetary atmospheres and hence in determining, for example, atmospheric thermal profiles and planetary surface temperatures. Micro-gravity will extend the ground-based studies by allowing for a longer period of growth and hence larger sizes in studies of organic particle formation and growth, and in measurements of optical, physical and chemical properties.

Effects of NOx on airborne microbial survival. The fate of airborne is a central concern of aerobiology. Do they remain viable and do they multiply? The answers may be critical to the health and safety of a spacecraft crew since microbes may affect air quality significantly in the micro-gravity environment, allowing potential pathogens to spread more readily than in 1-g. These issues, including the effect of NOx on bacterial viability, will be investigated in this experiment.

Science and Technical (S&T) Requirements

The GGSF is required to simulate within a facility chamber various operating conditions to meet the requirements of these diverse science disciplines. These conditions cover a broad range of parameters and are listed in Table 2.

The experiments that investigate the outer planets' atmosphere and interstellar dust require the extremely low temperatures, while experiments interested in the inner planets are interested in the high temperatures. The planetary experiments are also the source for the various

Table 2. Summary of Science and Technical Requirements

Chamber pressure, bar	From 10^{-10} to 3 bars, with a desire to reach 11
Chamber temperature, K	From 10 to 1,200 K, with a desire to reach 4 K
Chamber volume	From 1 cm' to several hundred liters, various geometries
Particulate matter type	Liquid aerosols, solid-powder dispersions, soots from combustion, high-temperature condensates (nucleation of metal and silicate vapors), low-temperature condensates (ices of water, ammonia, methane, or CO_2), a single liquid droplet, a single or a few particles, in situ generated particulates by UV or RF radiation, or by electrical discharge
Particulate size range, µm	from 10 nm to 3 cm
Particulates concentration	a single particle to 10^{10} particles per cm^3
Gases required	air, N_2, H_2, He, Ar, O_2, Xe, H_2O, CO,, CO, NH3, CH4, and more experiment specific gases
Diagnostics required	In-line optical systems and off-line sample analyses, including measurements of the grain size distribution, the number density (concentration), optical properties such as index of refraction, emission and absorption spectra, imaging, measurement of the grain's strength, mass, density, electrostatic charge, and geometry, collisions parameters including particle kinematic parameters before and after the collision
Experiment duration	From a few seconds, for collision experiments. to weeks, for the biology experiments

gases and ices required. The collision experiments that are interested in **planetary** rings generated the requirements for the large particle sizes. The large chamber volume is a requirements of the biology experiments.

SSF Environment and Accommodations

The GGSF will utilize one international standard payload rack (ISPR) and to be installed in the SSF **U.S**. laboratory module. Two modes of operations are anticipated. In the early stages, during the man-tended configuration **(MTC),** the SSF will be visited by the shuttle every 90 to 180 days and the GGSF will operate in an automated or remote-control mode. Later during the **permanently** manned configuration (PMC), the astronauts will be available to assist with the facility and experiment operations.

The physical accommodations of the rack[2"] are shown in Table 3. The level of gravitational acceleration and vibrations on board is expected to be in the range of **10^{-5}g,** for frequencies below 0.1 Hz, and **10^{-3}g,** for frequencies 10 Hz and above.

GGSF Conceptual Design

The broad range of the **S&T** requirements specified for the GGSF, exemplify the need for the design to a ***modular facility system.*** This system will be composed of a flight rack in which a specific hardware configuration is installed for a set of experiments that can take advantage of the hardware commonality. In addition, the system will consist of an array of **fully** compatible, interchangeable, assemblies that can be brought to SSF and installed in the flight rack to meet various other experiment requirements. The replaced assemblies will be returned to Earth for maintenance as necessary. The interchangeable assemblies include various facility chamber configurations, sample generators, diagnostics modules, experiment-specific equipment modules, electronic accessory plug-in units, and consumables such as gas cylinders. The other subsystems making up the GGSF include all the maintenance and housekeeping subsystems such as command and control electronics, data acquisition, power distribution, waste management, and other interfaces indicated in Table 3. A block diagram of the facility and its interfaces with the SSF through the U.S. module is given in Figure 1. This approach will also allow for the system upgrade as technology advances over the lifetime of the GGSF.

In addition to the **S&T** requirements, the facility design is driven by general considerations such as safety-related issues, human engineering factors, and facility lifetime.

In considering the wide range of experiment requirements, several facility constraints become apparent. These can be divided into constraints imposed by the laws of physics such **as:**

- For experiments performed in vacuum, the sedimentation time at **10^{-5}g** for all particle sizes is of the order between 30 to 50 seconds, depending on the chamber size
- For experiments not conducted in vacuum, the very small particles **(e.g.,** submicron) are lost to the chamber wall by Brownian motion induced **diffusion** in a relatively short time. The very large particles **(e.g., 100s** μm) are also lost in a relatively short time by sedimentation.

Constraints imposed by the SSF are:

- Prohibition of cryogenic fluids on board the U.S. module limits the low temperature that can be achieved with mechanical **cryocoolers** to about 40 K for a small chamber and about 150 to 200 K for a large chamber
- Very stringent requirements that limit the dumping overboard of certain gases that are used by the GGSF, creating the need to install a complex waste management subsystem.

The launch of the GGSF is expected to take place in stages. First, a core facility will be launched and installed on board the SSF. This core GGSF will have a broad range, but not all, of the capabilities.

Table 3. International Standard Payload Rack Features

Physical dimensions	2 side-by-side 19" racks per EIA RS-310-C Maximum depth 75 cm, height 164 cm, **width** 93 cm
Payload volume	-1.13 **m^3** out of **1.55** m^3 total
Miscellaneous	Fire suppression system using **CO_2**
Configuration	**4-post** or **6-post** racks available
Weight capacity	Cpost rack weighs ~ 58.5 kg, supports 700 kg 6-post rack weighs ~ 68.2 kg, supports 700 kg Structural augmentation is required for payloads > 400 kg for stiffness.
Construction	Composite **(graphite/epoxy)**
Electrical Power	Up to 3 or 6 **kW** depending on the location
GN2 Supply	Through a 318-inch line at a pressure between 90 and **110 psia** (0.621 to 0.759 **MPa)**
Vacuum exhaust	**Waste m**anagement under strict control of **allowable** waste gases and contaminants
Vacuum vent	Provide vacuum down to about **10^{-6}** bar
Avionics air	About **1kW** cooling capacity
Cooling water	Two loops of cooling water, one at a low temperature
Communications	Communications interfaces via a **MIL-STD-**1553 and an FDDI buses

Additional hardware and enhancement will be launched and installed at later times to accommodate additional experiments.

Facility Chamber

Numerous requirements drive the chamber design considerations and approach. Because many of the requirements create conflicting engineering considerations, no single chamber can meet all the S&T requirements. At least four chambers are required to meet all the experiment conditions. The chambers are listed in Table 4. A fifth chamber that has no active temperature control may be useful for initial experiments over a limited range of the parameter space. A typical chamber design is shown in Figure 2.

The chamber is of a double-walled, vacuum-jacketed construction to reduce the thermal conductive heat loads. Radiation shielding between the two chamber shells is used to reduce radiative heat loads. Each chamber is equipped with a number of ports, interfaces, and windows that also provide conductive and radiative paths for thermal heat loads. The ports include CCD camera windows (2), illumination windows for the CCD cameras (2), diagnostic light port (2), sample generator port (2), gas vent and fill (1), power feedthrough (1), sensor data feedthrough (1), cryocooler interface (1), and internal mounting provisions for additional optical detectors or experiment-specific hardware. Each chamber is designed with a large removable lid for both shells for maintenance and clean up. The rack can accommodate only one chamber at a time.

Table 4. GGSF Chambers

Purpose	Volume, liters	Pressure, bar	Temperature K
Large volume	67	10''- 1	150 - 400
Low temperature	4.2	lo^{4}-3	60 - 400
High temperature	8.2	10''- 1	300 - 1,200
High vacuum	4.2	10^{-10} - 1	60 - 400

Cooling of the chamber is accomplished with a mechanical cryocooler. The cooler must have sufficient cooling capacity, minimum power consumption, and small size and weight. The baseline design has selected a water-cooled cryocooler with 15-watt heat rejection capacity at 77 K with about 700 watts electrical power.

Because of the thermal loads, the limited cooling capacity, and the size of the chamber, the large-volume chamber cannot be cooled to below about 150 K, and even that temperature is reached with a cool-down period of several hours. In order to reach the lower temperatures, a smaller chamber was selected, as shown in Table 4.

In order to reach pressure below that supplied by the SSF vacuum line, a special chamber equipped with an integral high-vacuum pump is designed. The pump is directly mounted to the chamber to maximize the conductance. Either a turbomolecular or a getter-type pump may be appropriate. The SSF vacuum line serves for roughing the high-vacuum pump.

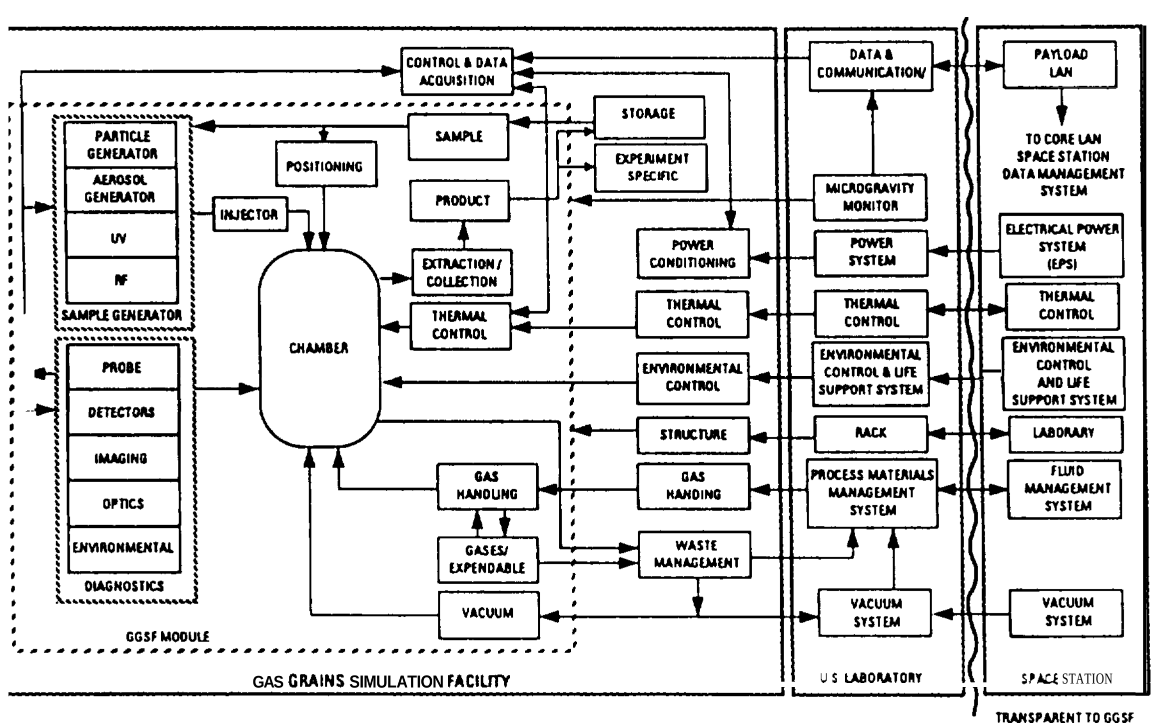

Figure I. GGFS Block Diagram and SSF Interfaces

Sample generation

A summary of the sample generation requirement is given in Table 5, in which the list is divided according to the type of sample. Here again, as with the chamber, no single technique can meet all the requirements. The challenge is to identify techniques that would minimize the number and type of generators required to fulfill the broadest range of the requirements.

Generation techniques in each of the categories listed in Table 5 were reviewed and several concepts selected based on their operating principle, which include insensitivity to gravity, reliability, range of applicability (i.e., particle sizes, size distribution, etc.). For those experiments that require vacuum, the sample generator cannot use a carrier gas. Similarly, some experiments that require a precise composition of the chamber atmosphere cannot tolerate the introduction of the sample with a carrier gas. Other issues related to the introduction of the sample into the chamber relate to the uniformity of the initial distribution throughout the volume and to the velocity at which the particles are introduces. Vacuum experiments cannot tolerate any velocity, since all particles introduced with an initial velocity would impact the wall. The sample generation techniques that were reviewed are listed in Table 6. Laboratory testing of several techniques are underway and a final selection will be made on the basis of the test results and verifications tests to be conducted using ground-based low-gravity facilities such as NASA's KC-135 or the 0-g Facility.

Each of the sample generators is to be designed with standard mechanical and electrical interfaces so that each generator can be mounted into any of the chambers and any of the two sample generation ports on each chamber. This approach allows for future growth and development of new generation techniques.

Diagnostics

The diagnostics are divided into the following categories. In-line systems that perform measurements on samples in the chamber, including extinction measurements, angular and spectral scattering, diffraction, and imaging. Off-line systems that remove samples from the chamber for analysis, including various particle counters (condensation nuclei counter, diffusion battery, electrical mobility analyzer, etc.) and filters and impactors for mechanically capturing the samples. The third category of diagnostics includes the environmental diagnostics that monitor the pressure, temperature, humidity, gas composition, and g-level. All diagnostic systems are to be fully interchangeable and compatible with all chambers, but not all the techniques can be used in a given facility configuration.

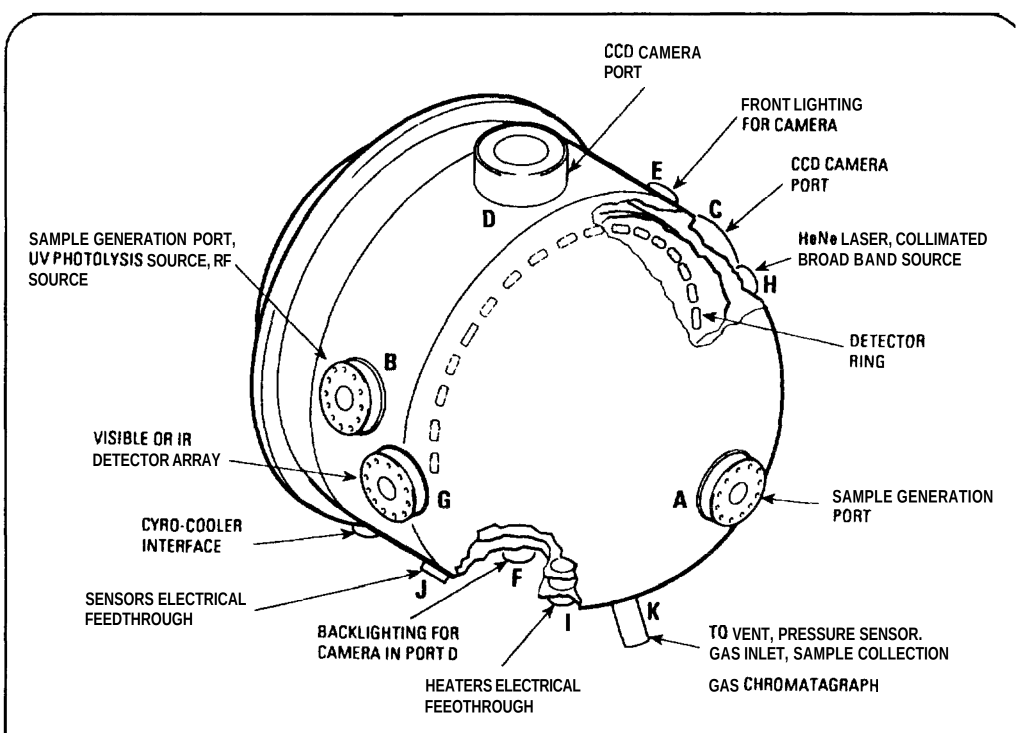

Figure 2. GGSF Typical Chamber

In-line diagnostics. These include nonintrusive optical diagnostics that utilize a transmitted light beam and determine various sample characteristics on the basis of the interaction between the incident light and the particles. The transmitted bean may be either a monochromatic laser light, or, interchangeably, a broadband source (e.g., tungsten filament lamp) for FTIR-type characterization. The broadband source can also be sent through a filter wheel to select a specific spectral range, or through a monochromator for a higher resolution in the selection of the transmitted light. Other sources available, include continuum or line emitters in the UV, visible, and IR.

The specific types of in-line measurements include extinction, angular scattering with detectors placed at various angular positions from 0 to 180°, polarization, and diffraction. These measurements allow the determination of the particle size distribution, their number density, and various optical properties.

Finally, imaging using two CCD cameras can view the experiment sample at 90' to each other, allowing the

Table 5. Summary of Sample Generation Requirements

Sample Type	Materials	Size, µm	Concentration no./cc	Pressure, bar (desired)
Solid particles	Silicate grain, salt, quartz, basalt, carbon, olivine, pyroxene, alumina, TiO_2, MgO, microspheres	0.01 - 1000	$1 - 10^8$	$10^{-10} - 1$ (10)
Liquid aerosols	Organic solutions, microbes in nutrient solution, others TBD	0.1 - 50	$300 - 10^5$	0.05 - 1 (11)
Single particle1 drop	Silicates and ice coated silicates, tholin, ices of NH_3, CO_2,	$1 - 10^4$	One or two only	$10^{-6} - 1$
Soot and smoke	Hydrocarbon combustion soot, MgO, PAH	0.0005 - 10	$1 - 10^8$	$10^{-10} - 1$
In situ samples	From gas mixtures using RF, UV, E-discharge, E-fields	0.005 - 10	$10^5 - 10^8$	0 - 1
Low-temperature condensation and nucleation	Ices of H_2O, CO_2, CH_4, NH_3	0.01 - 2,000	$1 - 10^8$	$10^{-6} - 3$
High-temperature condensation	Bimetallic elements, metal-bearing gases, metals, silicates	0.01 - 100	$10^6 - 10^{11}$	$10^{-6} - 1$

measurements of the velocity vector of moving particles. RS-170 video output may be recorded on an analog VCR, or the signal may be sent directly to a frame grabber for digitization. The cameras can be driven at the standard RS-170 mode or at a faster data rate up to 100 frames per second. This data rate is sufficient to resolve the particle kinematic parameters for the collision experiments. A zoom/macro lens allows to adjust the field of view and resolution of the cameras. The system will be able to operate with various high-resolution CCD arrays, if necessary.

The option of overall cloud behavior imaging is provided by various lighting schemes, including front- or back-lighting the cloud and introduction of a light sheet created from the laser beam via anamorphic optics.

Off-line diagnostics. For those experiments in which the particle size and concentration falls outside the region of operations for in-line methods (e.g., extinction below ~5% or above ~95%) off-line methods are provided. These include for the very small particles (down to 0.001 µm) a combination of an electrical mobility analyzer, diffusion battery, or a condensation nuclei counter. For the large particles, filters and impactors are available for capturing sample.

In considering the off-line diagnostics, experiments that operate in low pressure or vacuum may not be amenable to these techniques because of the difficulty of withdrawing a sample from the low-pressure environment in the chamber. Furthermore, in some cases the required flow rate and duration of flow into the diagnostic instrument is such that cannot be tolerated by the experiment. And finally,

Table 6. Sample Generation Techniques Considered for the GGSF

Solid Dispersion	Blast deagglomeration, exploding wire, fluidized bed feeder, aspiration feeder, auger feeder, atomization of hydrosols, atomization of dissolved solids
Liquid aerosol	"Spray can," squeeze bottle, pressure atomizers, electrostatic atomizers, thermal ejector (ink jet), various nebulizers, vibrating orifice, spinning disk
Hi temperature vapors	Radiation heating, electric arc, gas furnace, electric furnace
Soot generation	Diffusion flame, premixed fuel-rich pyrolysis
Single droplet	Syringe, thermal ejector (ink jet)
Single solid particle	Mechanical
In situ generation	UV radiation source, RF coil, super saturation and nucleation, heterogeneous nucleation

another issue to consider is the nonisokinetic sampling from the chamber.

Environmental diagnostics. Two types of pressure transducers are provided. An ionization gauge is used for the vacuum range and a conventional diaphragm with a bonded-strain-gauge-type transducer is used for the higher range. The selected technique must be insensitive to the gas composition or to the gravity so that gauges that measure pressure by detecting the thermal conductivity (and rely on free convection) of the surrounding gas (e.g., Pirani) are inappropriate.

The temperature is measured in the facility chamber and at several locations on the walls of the chamber using RTDs.

Gas composition is measured with a gas chromatograph (GC) that is connected directly to the facility chamber and to the gas mixing chamber. Humidity can be measured in the GC or with a solid-state relative-humidity sensor located in the gas mixing chamber.

g-level. The g-level monitoring could be done with the SAMS, an instrument developed by NASA/LeRC for the measurement of accelerations down to the 10^{-6}g along three axes.

Storage

A limited volume is defined within the GGSF for the storage of sample material pre- and post-test and for some of the interchangeable GGSF subsystems.

Gas handling and mixing

The gases for the various experiment mixture could be provided in two ways: premixed and pure gas cylinders. The premixed gases may be used to fill the chamber directly with the premixed composition. If new compositions are required or modifications to the initial composition is needed, then the pure gases are used. A mixing chamber equipped with a fan is available for preparing gas mixtures. The chamber is also equipped with pressure transducers that allow the filling of the chamber with the individual constituents according to their partial pressures.

The gas bottles are positioned on a pallet for easy removal and replenishment operations.

Waste management system

The function of the waste management subsystem is to clean up the experiment waste to a level compatible with the SSF waste and vent lines specifications. Particulate matter and toxic gases must be treated and removed from the effluents and any significant concentration cannot be dumped overboard.

The subsystem consists of a series of treatments as follows:

- Removal of particulates via a coarse and a fine mesh filters
- Gas scrubbing beds, including activated and impregnated charcoal for the removal of hydrocarbons, and basic gases, and other beds (e.g., LiOH) for the removal of acid gases
- Catalyst beds for the oxidation of H_2 and CO.

Additional treatment may be necessary for various experiments. The flow treatment system is packaged into a removable canister. The system may include a circulating fan to run the waste through the treatment several times until the desired level of cleanup is achieved. The removal of substances occurs via adsorption and chemical reaction, which in some cases is exothermic. In those cases, active cooling of the canister may be required, depending on the amount of waste products.

In addition to the plumbing and valving associated with the waste management subsystem, a monitoring system (e.g., pressure drop) is utilized for "health monitoring."

Electrical and electronics

The electrical and electronics subsystems consist of two general elements. The first element includes those components that are interchangeable and support/control other interchangeable hardware modules such as sample generators, various chambers, diagnostics units, etc. These elements contain local capability for control and data acquisition and may have the capability to digitize signals for noise reduction. The second element is "fixed" in the GGSF and provides communications and control, interface with the operator, interface to the U.S. laboratory and the utilities, and transmission of image and data to and receiving commands from the U.S. laboratory module or ground control (through the U.S. module). These elements include the display monitors, other user interfaces such as keyboard or touch panels, and the computer. An electrical block diagram is shown in Figure 3.

Electrical. The SSF provides 120 Vdc and the payload is responsible for power conditioning and distribution within the payload facility. The GGSF power management system consists of three converters as shown in Table 7.

The preliminary analysis indicates that both the primary and secondary converters will be rated for a maximum load of 750 watts and a steady-state average of 500 watts at a conversion efficiency of about 80 to 87%.

Electronics. Because of the longevity requirements of the GGSF, a modular payload computer system is planned. The rapid evolution in microprocessors is expected to continue to double the CPU speed every four to five years as in the past decade. Therefore, a CPU upgrade built-in capability is necessary. In addition, various types of I/O modules may be required for different experiments. For

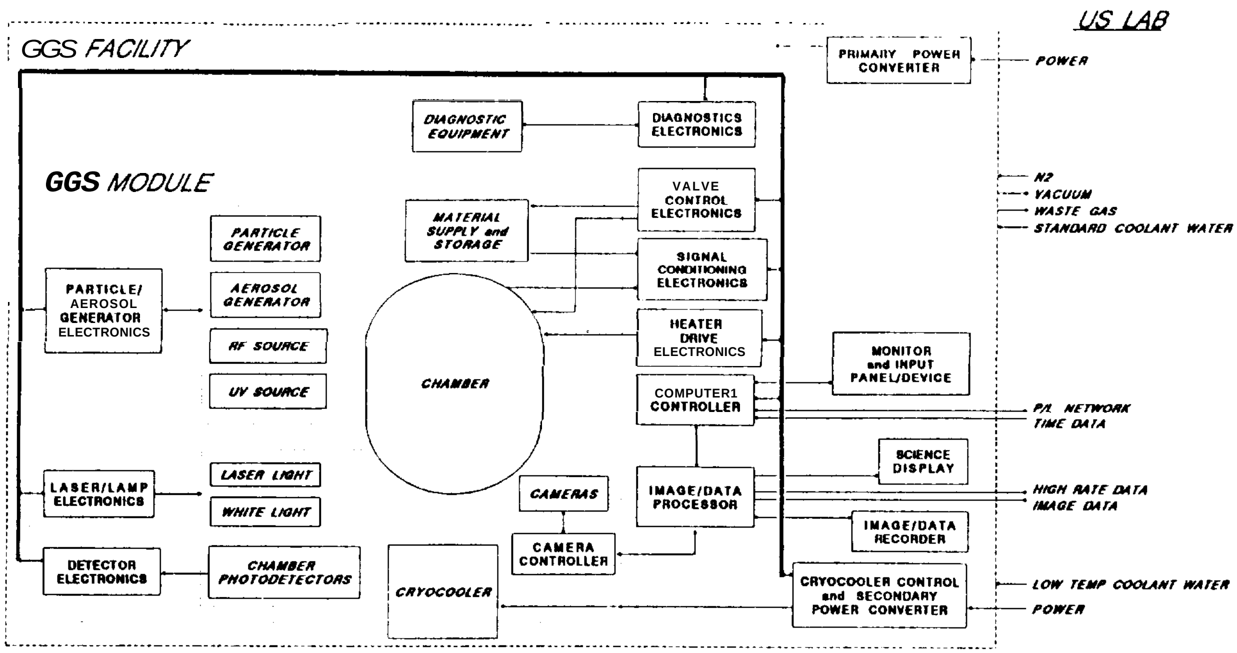

Figure 3. Electronics Block Diagram

instance, valve controllers, a frame grabber, thermocouple modules, preamplifiers, other A/D and D/A units, heater drivers, etc. These modules could be independent plug-in boards that are installed into a passive backplane or a card-cage configured system as required by the experiments.

The modular computer will provide communications capabilities via the MIL-STD-1553 and the FDDI buses via similar plug-in modules. For heavy computational loads a DSP module may be provided.

Table 7. GGSF Power Management

OUTPUT	APPLICATION
Converter 1, Primary Conversion form 120 Vdc to:	
115 Vac, 50/60 Hz	Use of "off-the-shelf" instrumentation and equipment
+28 Vdc	MIL-level relays, wide equipment selection, existing hardware design
+8 Vdc	To permit local regulation for logic supplies, etc.
±18 Vdc	To permit local regulation for amplifiers, signal processing circuits
Converter 2, Secondary Converter from 120 Vdc to:	
15 Vac, 60 Hz	For c applications, e.g., cryocooler
Filter	
120 Vdc	For low-level distribution to allow for presently

Automation, robotic, and AI

During MTC, the SSF will provide the most quiescent period of time while the shuttle is not docked. That time is ideal for those experiments that require a long duration quiescent environment. The down side of the MTC period is that the facility will require extensive automation for operating.

Various modes of GGSF operations have been defined and are listed below in order of increasing complexity level.

1. Manual or remote control: uses a man-in-the-loop (on board or via down/up link)
2. Open-loop operations: based on time sequencing or some trigger to start or stop certain operations
3. Simple closed-loop operations: utilizes simple sequencing or trigger to initiate certain operations and sensors with feedback control for other activities.
4. Action based on a simple quantitative decision tree using a numerical algorithm or another logic device control: uses sensors, a data acquisition system, and digital control (for example, if pressure is >P and if temperature is < T and experiment duration is > t, then do X).

5. Action based on a complex set of conditions, qualitative and quantitative considerations, all of which can be anticipated in advance: experiment control utilizes an expert system based on heuristic inference engine possibly in conjunction with numerical models. This option requires a good understanding of all the possible experiment outcomes in order to develop a knowledge-based set of rules.

6. Action based on a complex set of conditions not anticipated in advance but that can be extrapolated from previous experience: the control system may utilize an adaptive neural network initially in a "supervised learning" mode that is "trained" to control the experiment.

The level of control complexity appropriate depends on the level of maturity of the experiment. The GGSF modular computer will allow for the implementation of AI and artificial neural network if necessary. The control rationale and software will be developed in the laboratory and loaded into the computer.

Level 1 in the list above may not be available during MTC and may be better suitable for PMC. In general, levels 2 through 4 will be appropriate for most experiments. The capability to upgrade the experiment control into levels 5 and 6 is provided by the GGSF modular computer concept.

Mission Operations.

During MTC, the space shuttle docks every 90 to 180 days, for 7 to 10 days. During that time the astronauts must perform any required maintenance operation. These occasions will also be used for hardware reconfiguration and replenishment of consumables as required. Due to such activities this is a nonquiescent time and it must be considered whether experiments are affected by the induced environments. Because of their assignments to such activities, it is unclear how much time the astronauts will actually have to dedicate to operating the facility and conducting experiments. The quiescent environment between such Shuttle docking provides a better experiment environment. During the quiescent period there is no operator to operate the payload and full automation or remote control is required.

During MTC phase the sequence of experiments will be to conduct one experiment repeatedly or to perform more than one or a few experiments. If more than one experiment is performed, all interfaces to the chamber must be validated prior to the start of automated operations. Only experiments that are compatible with the hardware configuration and selected (interchangeable) subsystems can be performed in one sequence. The timeline of each experiment must be developed to determine the appropriate sequence.

Overall GGSF layout

Figure 4 shows the GGSF conceptual design layout.

References

[1] Gas Grain Simulation Facility: Fundamental Studies of Particle Formation and Interactions. Vol. 1 and 2. Edited by G. Fogleman, J.L. Huntignton, D.E Schwartz, and M. L Fonda. Proceedings of a workshop held at NASA Ames Research Center. NASA Conference Publication 10026, 1989.

[2] NASA/ESA/NASDA Agreement, Amended. Payload Interchangeability. Undated.

[3] SSP 30426, Rev. B. July 1991.

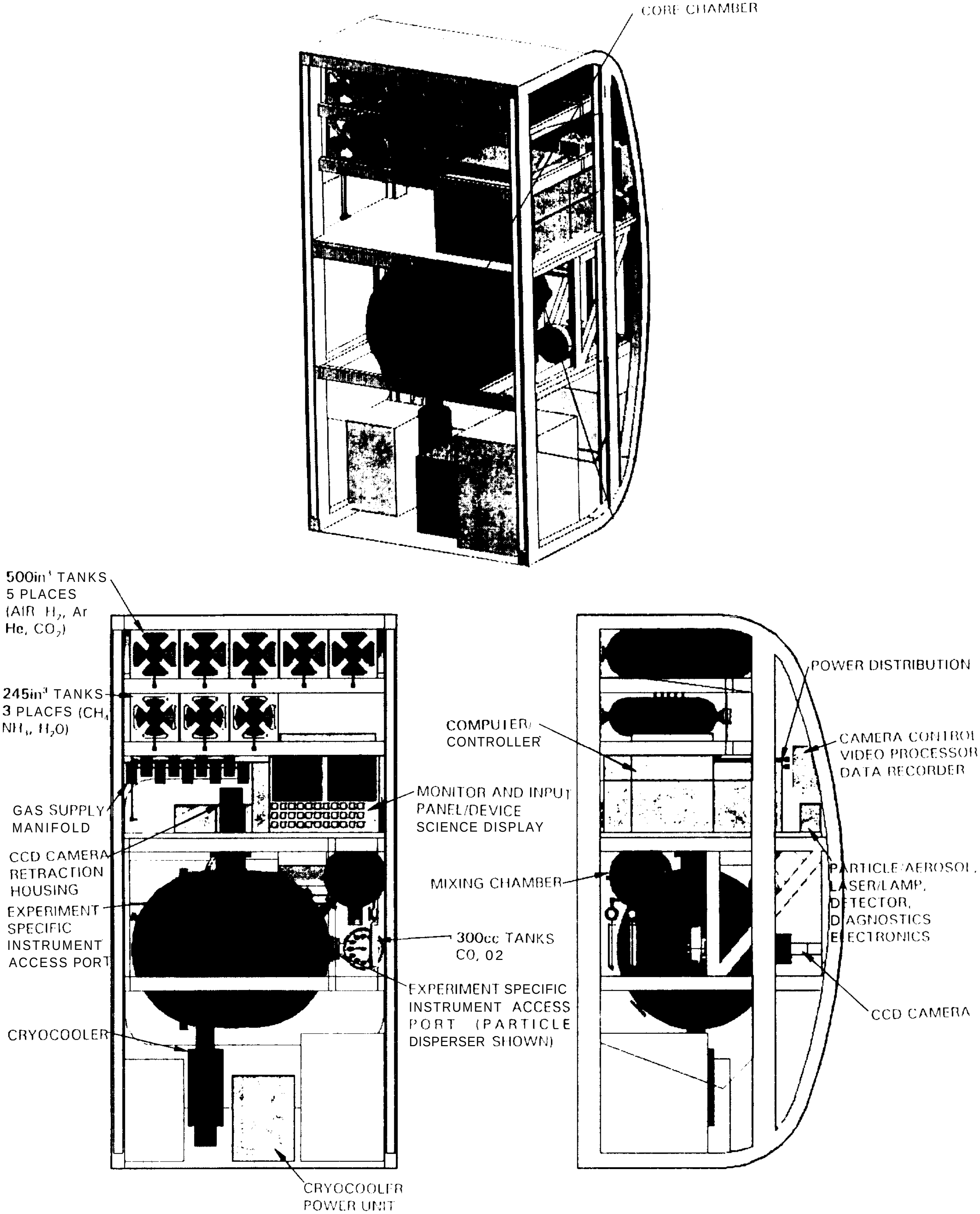

Figure 4. Overall GGSF layout