

G2 AND BIOSPHERE II

Greg M. Stanley - Gensym Corporation

Presentation to NASA (Johnson Space Center)

September 2003

archived at

<http://gregstanleyandassociates.com/successstories/Biosphere2/biosphere2.htm>

G2 and BIOSPHERE II

I. Background on Biosphere II

II. G2-based simulations

III. Global monitoring system

- HVAC (Heating, ventilation, air conditioning)
- Air & water analyzer monitor & control
- Network health monitor

VI. HVAC control systems

I. Background on Biosphere II

Goals

- Demonstrate feasibility of life in sealed environment (plants, animals, 8 people) - a miniature earth (Biosphere I)
- Develop technology usable in space or on Earth (e.g., recycling technologies such as soil-bed reactors, algal scrubbers)
- Original focus towards eventual Mars colonization, shifted more towards earth ecology, e.g., effect of global warming & higher CO₂ levels, faster recirculation/recycling of materials
- A "tool", likened to the microscope
 - Best thought of as an engineering prototype

The Biosphere II structure overview

- 3.15 acres (plus basement)
- 85 feet maximum height
- 7 million cu. ft. of air, with peak air recirculation rate of 1 million cu. ft./min.
- Closed to material flow, open to energy and information flows (as would be a space or Mars colony)
 - Energy input from sun, power plant (5.7MW)
 - Energy removal via cooling tower water & chilled water
- Operates at slight positive pressure
 - "Lungs" (1 million cu.ft.) provide constant pressure to avoid blowing out glass due to temperature changes
 - Ensures that leaks are outward, not inward
 - Designed for low leakage rate - about 10%/year

Biosphere II "biomes"

- Organized as connected "biomes"
 - Rainforest (Amazonian, with 50-ft mountain, condensers to generate rain)
 - Savannah (from tropics to thorn scrub)
 - Marsh (Fresh --> Salt, Everglades)
 - Ocean (35 feet deep, 1 Million gallons, with coral reef & tides)
 - Desert (Baja California -- humid)
 - IAB (Intensive Agricultural Biome)
 - Human habitat
- Ponds & streams
- Large number of species (4000) to ensure survival through diversity

The money

- Privately funded (Ed Bass)
- Initial investment guess \$30M
- Typical current guess \$150M - \$200M

- Takes in funds now from tourism - ecology theme park

Some Biosphere II participants

- SBV: Space Biosphere Ventures, and related companies
- HP: prime contractor for computer systems, systems integrator
- Gensym - subcontractor to HP for advanced software, and later, directly to SBV
- Another contractor for sensors & low-level controllers
- Numerous contractors for construction, etc.

Biosphere II project milestones

- Project start: Dec., 1984 with conference
- Basic design & engineering done: 1986
- Construction start: Jan, 1987
- Support buildings completed Mar., 1989
- "Test module" (1/300 scale) closures up to three weeks duration
- Biosphere II closure: Sept, 1991
- Completion of 2-year stay by 8 people: Sept., 1993
- Another crew to start another 2-year stay, in about 5 months

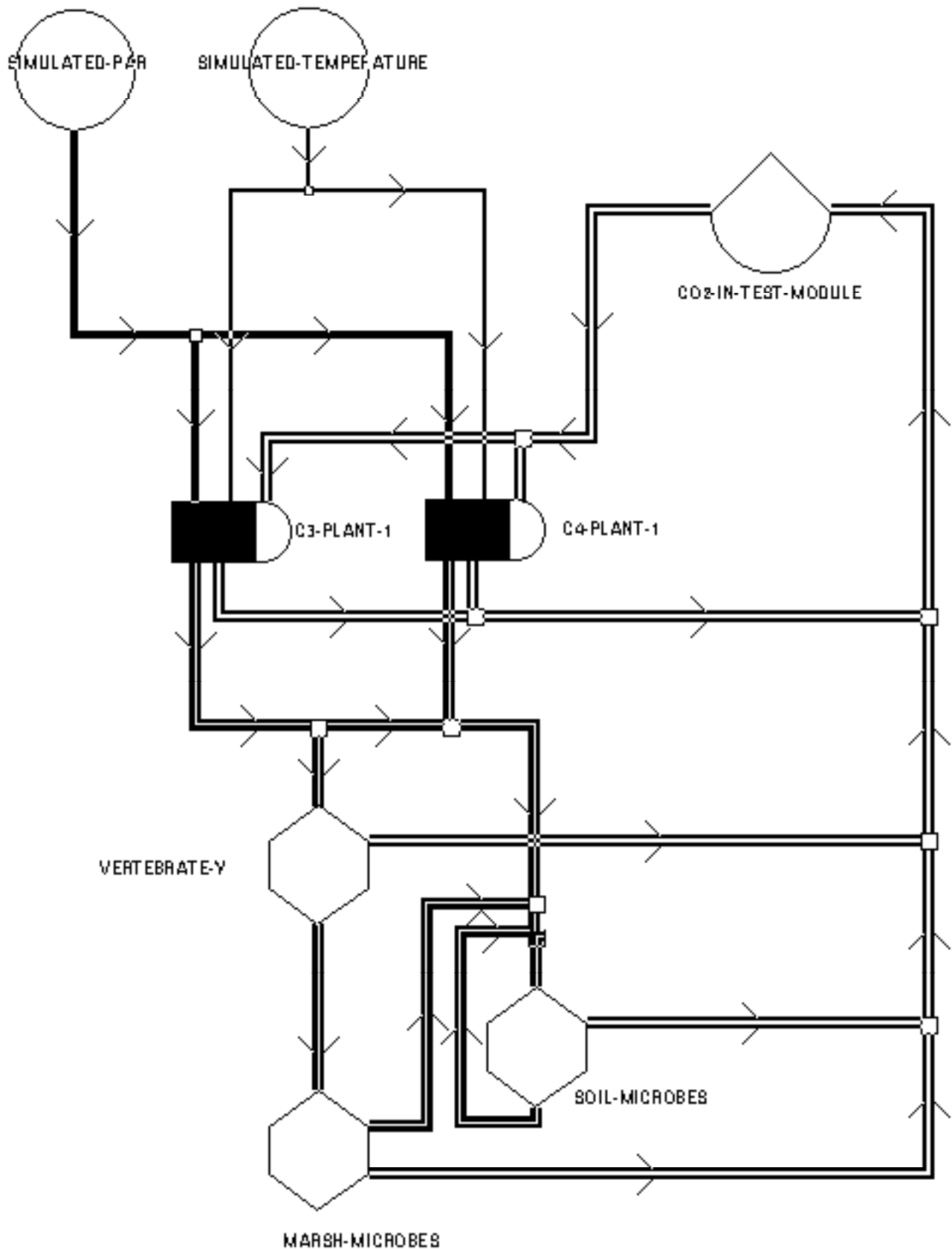
Computer & network architecture

- G2: Supervisory control & monitoring, analyzer control, simulation
- RTAP ("Real Time Applications Platform" - distributed database from HP): short-term data historian
- Oracle data base - archival data storage
- Taylor Mod 30, HP48000 SCADA - low level controls and inputs
- 2500 sensors
- TCP/IP over Ethernet (redundant, broadband cable)
- HP and Sun workstations, throughout Biosphere II and external - about 15 total

II. G2-based simulations

- During design, testing phases
- Biological components
 - Focus on O₂, CO₂, etc.
 - Generic simulation statements
 - Objects/icons as defined by Odum in ecology texts
 - Show material and energy flows as connections
 - Objects such as "primary producers" (plants), "decomposers"
- Used small-scale "test module" to validate (1 person in 1/300 scale, sealed environment for up to three weeks)
- Parameter estimation by trial & error to match test data to simulation
- Work mostly by University of Arizona

Biological simulation example using Odum's symbols



Examples of variables tracked during a simulation

| | |
|---|------|
| C3 photosynthetic rate | **** |
| C4 photosynthetic rate | **** |
| Marsh microbes base respiration | **** |
| Soil microbes base respiration | **** |
| vertebrate-y respiration | **** |
| Night-temperature | **** |
| Minimum day temperature | **** |
| Max daytime temperature increase above mean | **** |
| Minimum day par | **** |
| Max daytime par increase above mean | **** |

III. Global Monitoring System

- Monitor and alarm all sensor & status values, e.g.,
 - HVAC temperature, pressure, humidity, wind velocity, various flows, fan status, water levels, pump status, etc.
 - close tracking of daily cycles
- Air & water quality monitoring
- Network health
- Elaborate diagnostics postponed

User Interface

- Typical G2 GUI
- Show alarms, statuses, variable values
- Top-level view of biosphere by Biomes
- Some direct access to key equipment within Biome
- Subworkspaces under each biome icon (or pointed to)
- Generic schematics and tabular displays for AHU's, other repetitive equipment
- Summary of key variables, other overview displays

Generic schematics and tabular displays

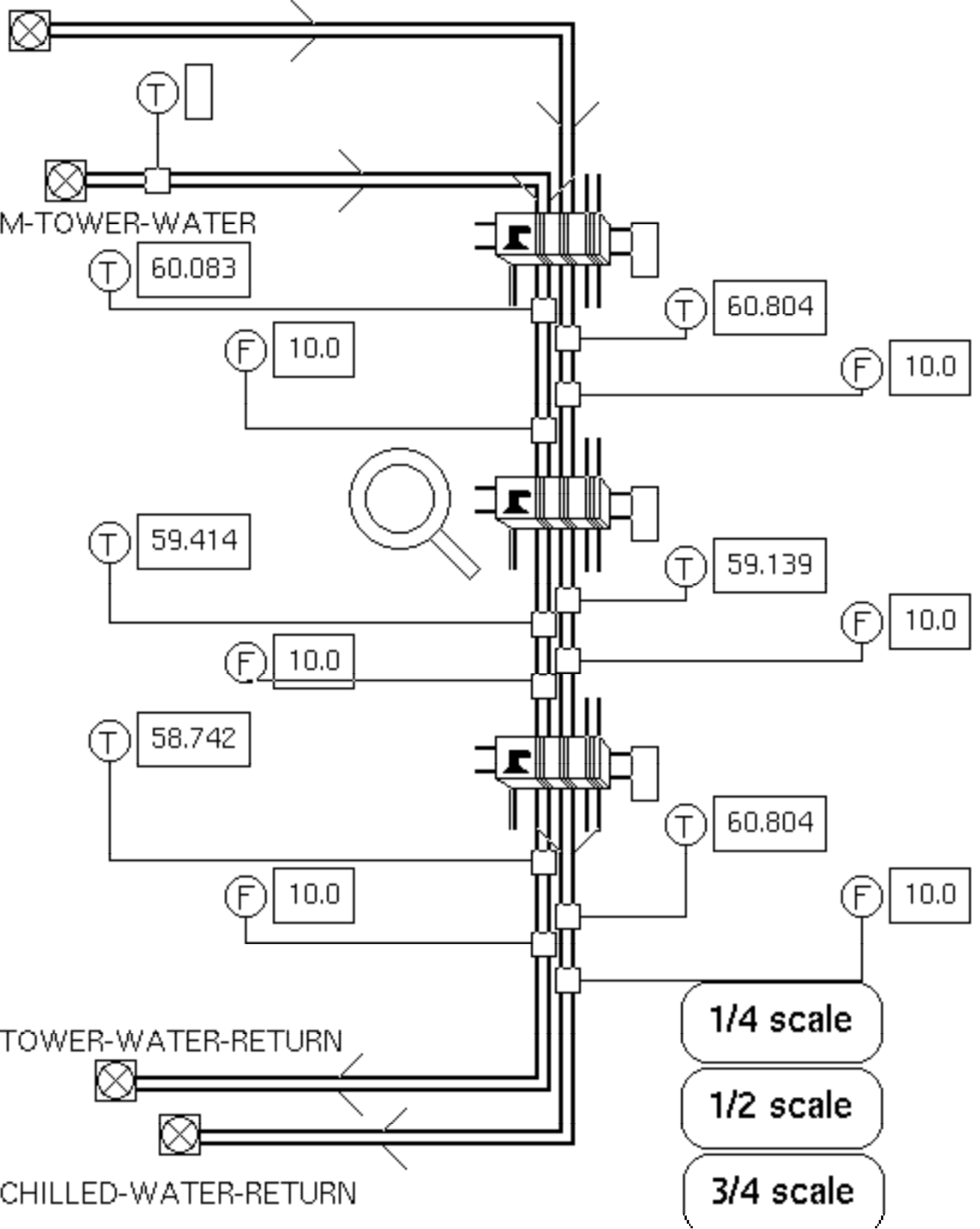
- Take advantage of similarity in equipment
- 30 AHU's, only 2 types of AHU
- One display per generic unit such as AHU
- Extensive use of "view-objects" to allow multiple views of the same object, and for generic use, to be matched at run time
- Relations set at run-time to propagate sensor values

FROM-CHILLED-WATER

FROM-TOWER-WATER

TOWER-WATER-RETURN

CHILLED-WATER-RETURN



Cooling water circuits



FROM-CHILLED-WATER

FROM-TOWER-WATER

59.683

| 3 coil ahu view | |
|-----------------------|---|
| table | |
| move | |
| name | |
| clone | |
| rotate/reflect | ▶ |
| change size | |
| color | ▶ |
| delete | |
| disable | |
| describe | |
| describe restrictions | |
| create subworkspace | |
| select view action | |
| show plot | |

| a 3-coil-ahu-view | |
|-------------------------|-------|
| Notes | OK |
| User restrictions | none |
| Names | none |
| Viewed object name | ahu-1 |
| Identifying object name | none |
| Identifying role name | none |
| Naming text x offset | 40 |
| Naming text y offset | -20 |
| Show name | yes |



a temperature-sensor-view

| | |
|------------------------------|---|
| Options | do not forward chain, breadth first backward chain |
| Notes | TEMPERATURE-SENSOR-VIEW-XXX- 40: OK |
| User restrictions | none |
| Names | none |
| Tracing and breakpoints | default |
| Data type | quantity |
| Initial value | none |
| Last recorded value | no value |
| History keeping spec | do not keep history |
| Validity interval | indefinite |
| Simulation details | no simulation formula yet |
| Initial value for simulation | default |
| Data server | inference engine |
| Default update interval | none |
| Viewed object name | none |
| Identifying object name | none |
| Identifying role name | tower-water-return-temp |
| Value text x offset | 14 |
| Value text y offset | -14 |
| Show value | yes |
| Naming text x offset | 14 |
| Naming text y offset | 14 |
| Show name | no |

Example of a message for generic displays at run time

Description of SMALL-TRANSIENT-MESSAGE-FOR-VALUES-XXX-42.

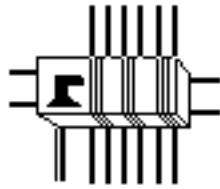
The following items are giving-a-view-value-to this small-transient-message-for-values.

a temperature-sensor-view

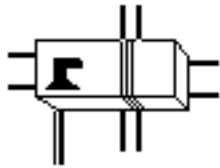
The following items are giving-a-value-to this small-transient-message-for-values.

AHU1-TOWER-WATER-RETURN-TEMP, a
gsi-temperature-sensor

Generic sbv equipment

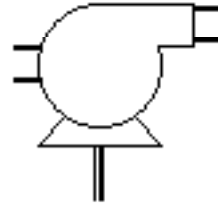


GENERIC-3-COIL-AHU

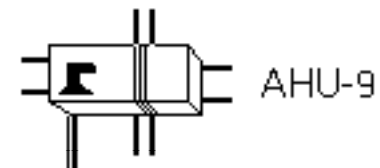
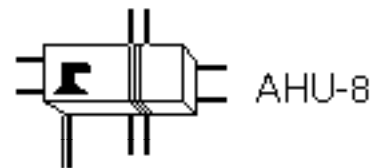
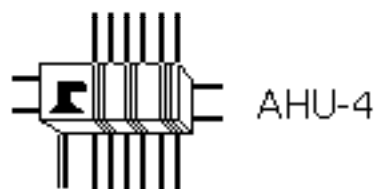
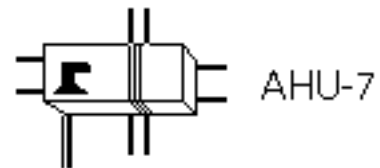
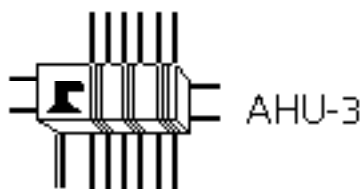
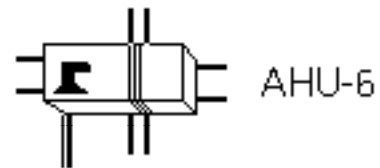
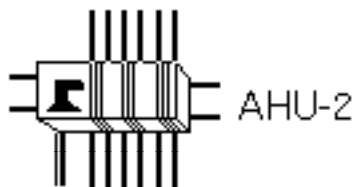
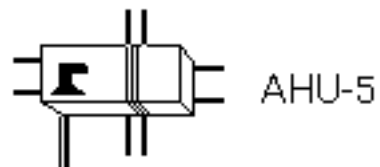
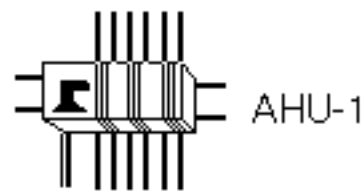


GENERIC-1-COIL-AHU

GENERIC-AHU-FAN



Specific AHU objects



AHU-1, a 3-coil-ahu

| | |
|--------------------------------|--------------------|
| Notes | OK |
| User restrictions | none |
| Names | AHU-1 |
| Associated generic object name | generic-3-coil-ahu |

Sensor Library

- Essential to have one, mergeable library, from both development and maintenance standpoint
- Provided a scheme to automatically build the sensor library from standard patterns (per AHU, per biome), to minimize the development time
- "Identifying-object-name" and "Identifying-role-name" used to match sensors between units, and to displays
- Consistency checks done (missing/ duplicate names, legal codes for RTAP, etc.)

SBV GSI Interface Library













Last update: July 16, 1990






Consistency check

Make ID lists





Clean up after checks

-  IAB-GSI-INTERFACES
-  DESERT-GSI-INTERFACES
-  RAINFOREST-GSI-SENSORS
-  OCEAN-GSI-SENSORS
-  MARSH-GSI-SENSORS
-  SAVANNAH-GSI-SENSORS
-  HABITAT-GSI-SENSORS

-  GLOBAL-GSI-VARIABLES-AND-SENSORS
-  EXTERNAL-GSI-SENSORS
-  MISCELLANEOUS-GSI-SENSORS

-  GSI-OBJECT-DEFINITIONS
-  UTILITY-ICONS-SUBSET-FOR-GSI-LIB
-  CONSISTENCY-CHECKING-GSI-SENSORS
-  MISCELLANEOUS-GSI-SENSOR-LIBRARY-STATEMENTS
-  KB-WORKSPACE-FOR-SENSOR-CLONING

Documentation:

-  HOW-TO-USE-THIS-SENSOR-LIBRARY
-  SBV-COLOR-STANDARDS
-  REVISION-INFO
-  ALARM-VALUES-AND-PRIORITIES

Temporary tests, etc.

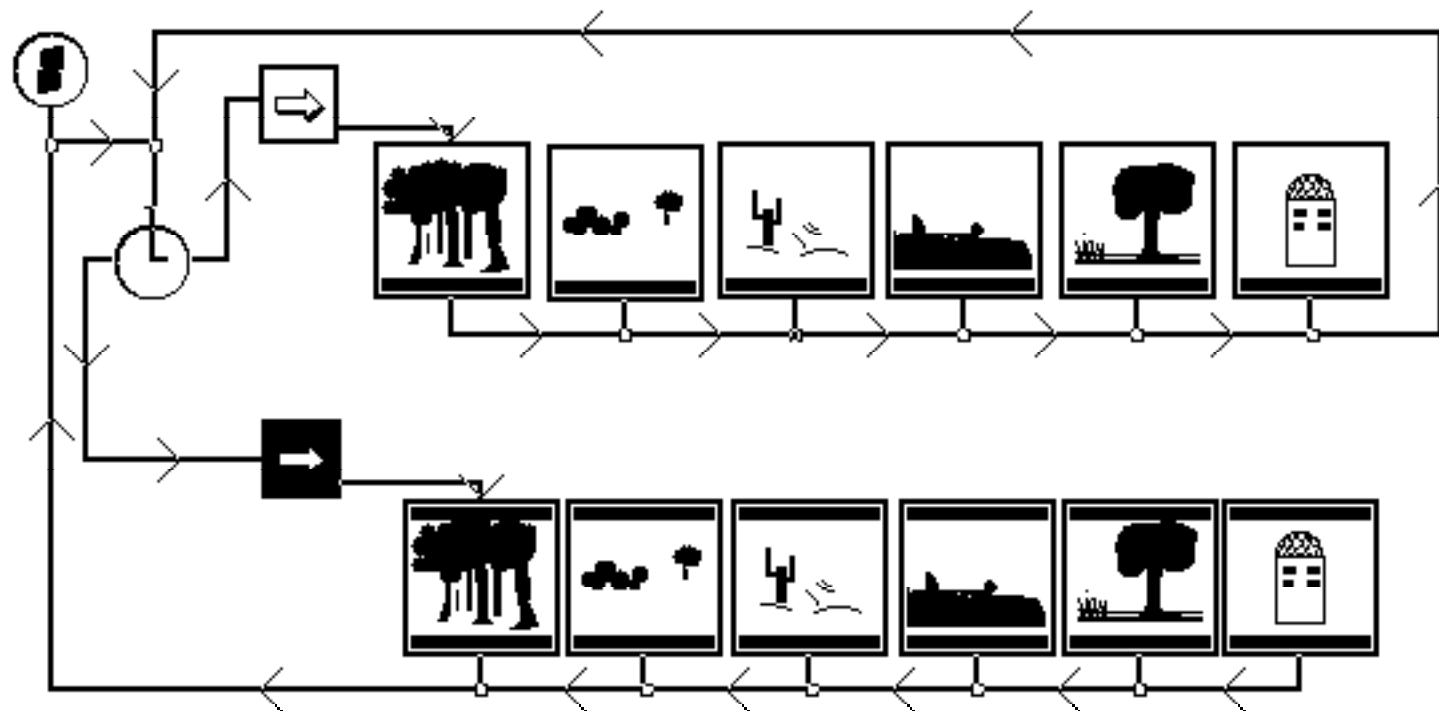
Continuous Air Quality Monitoring System (CAQMS),



alias "Sniffer" system.



Go



Initialize

Cleanup

Start

Stop

Graphs

Manual

Main

Toplevel

Meters

Next



auto



step



skip

Time: 4.033



Manual Sampling

- Rain Forest Main
- Rain Forest H2S
- Rain Forest NH3
- Cal. Rain Forest

Rain Forest **R**

- Marsh Main
- Marsh H2S
- Marsh NH3
- Cal. Marsh

Marsh **R**

Calibration

- O3 Generator
- Span Gas (mix)
- Span H2S
- Span NH3
- Dilution Air
- Span O3
- Air & N2 to 146

Reset All

O3 Span

- Savannah Main
- Savannah H2S
- Savannah NH3
- Cal. Savannah

Savannah **R**

- IAB Main
- IAB H2S
- IAB NH3
- Cal. IAB

IAB **R**

Miscellany

- CO2 GC Activate
- Cal. Sample Man. 1
- Cal. Sample Man. 2
- Cal. Sample Man. 3
- Cal. Gas to analyzers
- Cal. Gas to Scrubber

Zero Air

Mix Gas Span

- Desert Main
- Desert H2S
- Desert NH3
- Cal. Desert

Desert **R**

- Habitat Main
- Habitat H2S
- Habitat NH3
- Cal. Habitat

Habitat **R**

Spares

- Relay 61
- Relay 62
- Relay 63
- Relay 64
- Relay 65
- Relay 66

Zero N2

NH3 Span

| | |
|-------|-----|
| CH4 | 999 |
| nmHC | 999 |
| CO | 999 |
| CO2-1 | 999 |
| CO2-2 | 999 |
| CO2-3 | 999 |
| SO2 | 999 |
| O2 | 999 |
| O3 | 999 |
| NO | 999 |
| NO2-2 | 999 |
| NOx-2 | 999 |
| N2O | 999 |
| NH3 | 999 |
| NOx-1 | 999 |
| NO2-1 | 999 |
| H2S | 999 |

Schematic



7 Aug 93 6:00:58 p.m. - SAMPLING
RAIN-FOREST: COLLECTING DATA

| | N2O | NOX-2 | CO | CO2-1 | CO2-2 | CO2-3 |
|-------------|-----|-------|-----|-------|-------|-------|
| RAIN-FOREST | *** | *** | *** | *** | *** | *** |
| | *** | *** | *** | *** | *** | *** |
| DESERT | *** | *** | *** | *** | *** | *** |
| | *** | *** | *** | *** | *** | *** |
| IAB | *** | *** | *** | *** | *** | *** |
| | *** | *** | *** | *** | *** | *** |
| MIN | *** | *** | *** | *** | *** | *** |
| MAX | *** | *** | *** | *** | *** | *** |

| | NOX-1 | NO2-1 | CH4 | H2S | NO2-2 | NMHC |
|-------------|-------|-------|-----|-----|-------|------|
| RAIN-FOREST | *** | *** | *** | *** | *** | *** |
| | *** | *** | *** | *** | *** | *** |
| DESERT | *** | *** | *** | *** | *** | *** |
| | *** | *** | *** | *** | *** | *** |
| IAB | *** | *** | *** | *** | *** | *** |
| | *** | *** | *** | *** | *** | *** |
| MIN | *** | *** | *** | *** | *** | *** |
| MAX | *** | *** | *** | *** | *** | *** |



SBV GLOBAL MONITORING
Network Health Subset

- Ensure that all key processes are running
- Watch error log files
- Watch for proper creation/deletion of files for file-based interfaces (e.g., RTAP/Oracle)
- Watch CPU statuses, loads, performance
- Watch disk capacities
- Detect network problems
- Interfaces to system-level routines (RPC)

SBV Nerve System Network



TEMP-WORKSPACE

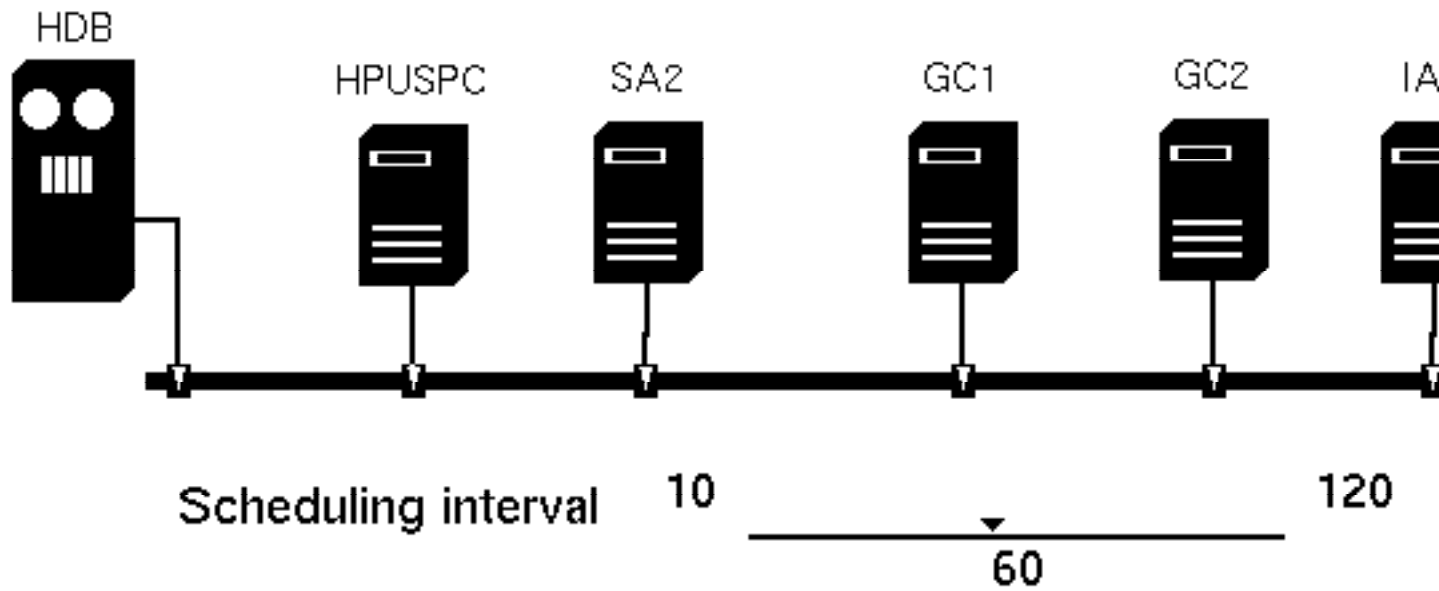
7 Aug 93 6:10:52 p.m.

1/4 scale

1/2 scale

3/4 scale

Full scale

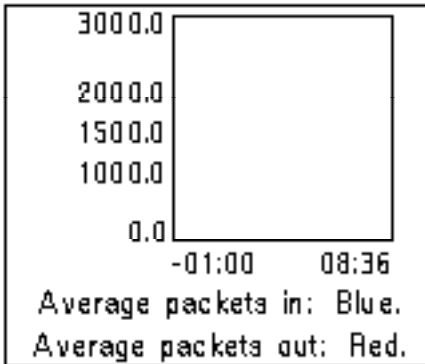
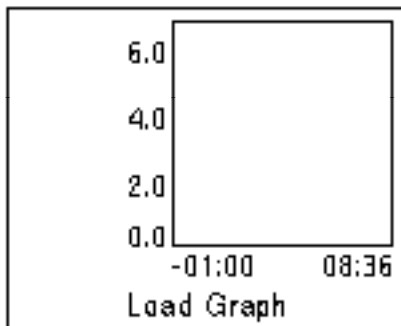


Network Monitor - sa2 Details



- F** File Systems
- P** Processes
- L** Log Files
- Q** Message Queues
- S** Semaphores
- M** Shared Memory

| | | | |
|---------------------|----------|----------------|-----|
| Computer Status | up | | |
| GMS Server Status | shutdown | | |
| Average Load | 0 | Load Threshold | 1.9 |
| Average Packets In | 0 | | |
| Average Packets Out | 0 | | |
| Number of Users | 0 | | |
| Uptime (hrs) | 0 | | |
| Packets In Errors | 0 | | |
| Packets Out Errors | 0 | | |
| Packet Collisions | 0 | | |



Control Systems

- Control temperatures, humidities, wind velocities
- Control via "Air Handling Units" (AHU's) with cooling tower water, chilled water, steam heat, and throttling of inlet air flow to blowers
- Challenges
 - significant variations across biomes, heights
 - sun/shade variations inside
 - weather variations outside (sun/shade, day/night)
 - interactions between AHU's, biomes
 - sensor and valve reliability
- Initial proposal was extensive, but traditional industrial-style feedback controls with cascades, BTU feedforward for solar input, constructed as clones of a generic scheme
- Strategies recognized economics and constraints
 - humidity maximum, wind velocity minimum
 - economics of cooling tower vs. chilled water

- Final configuration more a set of "templates" (cases), mainly because the subcontractor couldn't get sensors, valves, and low-level controls to work