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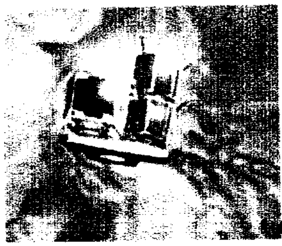


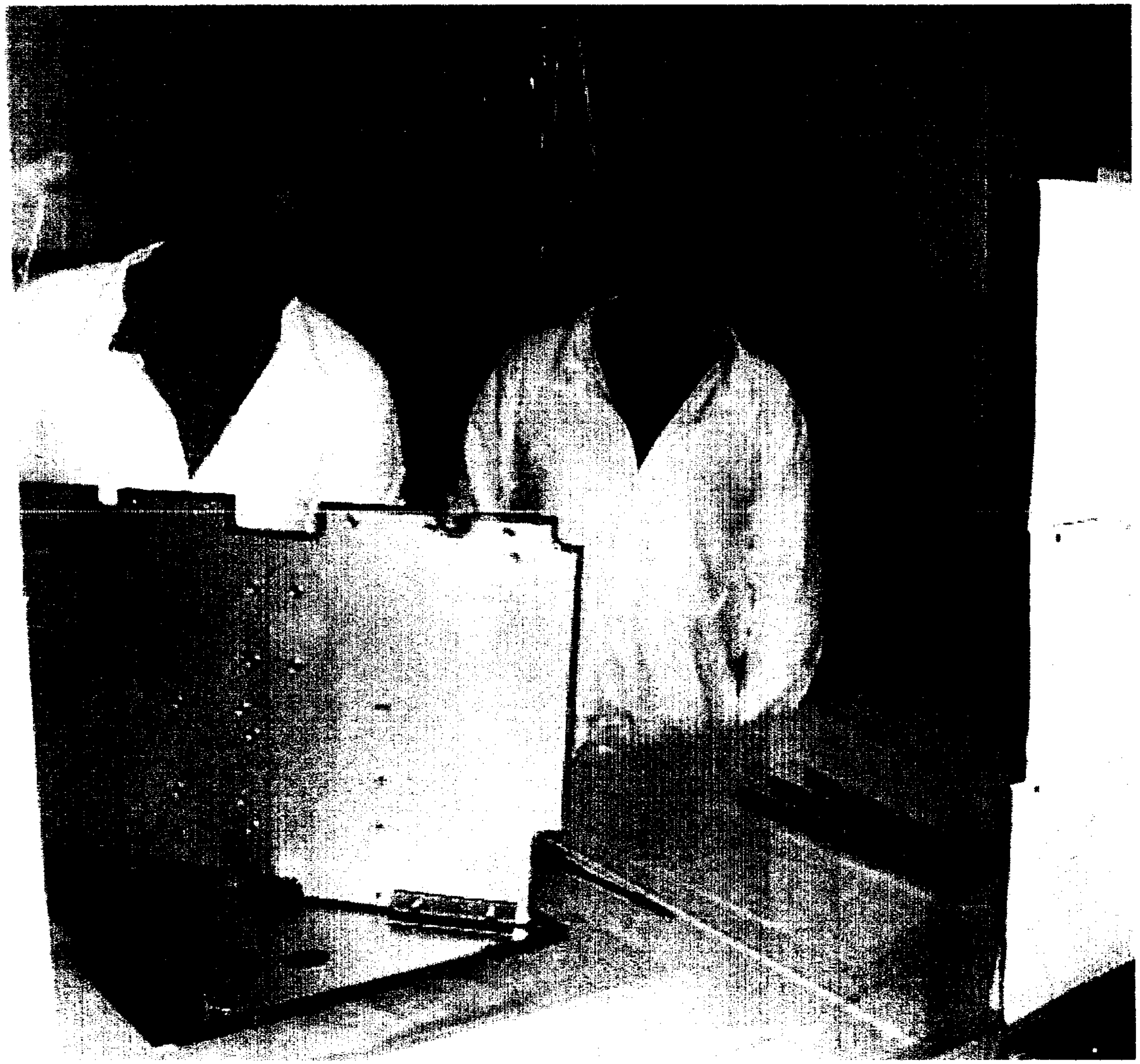
Orion Final Report
for

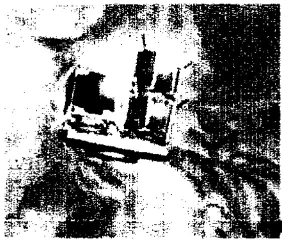
NAG5-9737

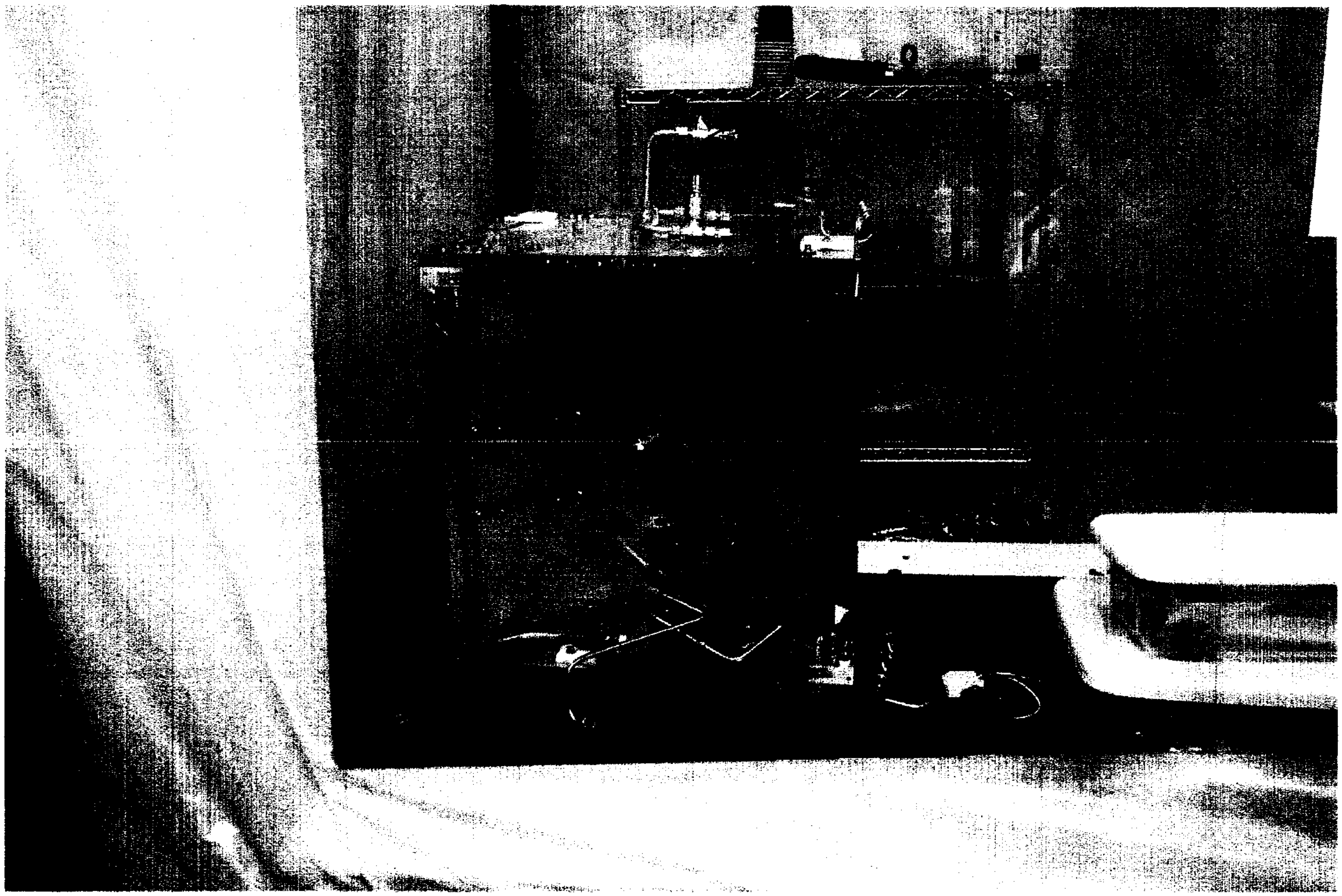
November 22, 2002

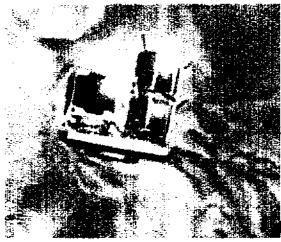
Prof. Robert Twiggs
Stanford University

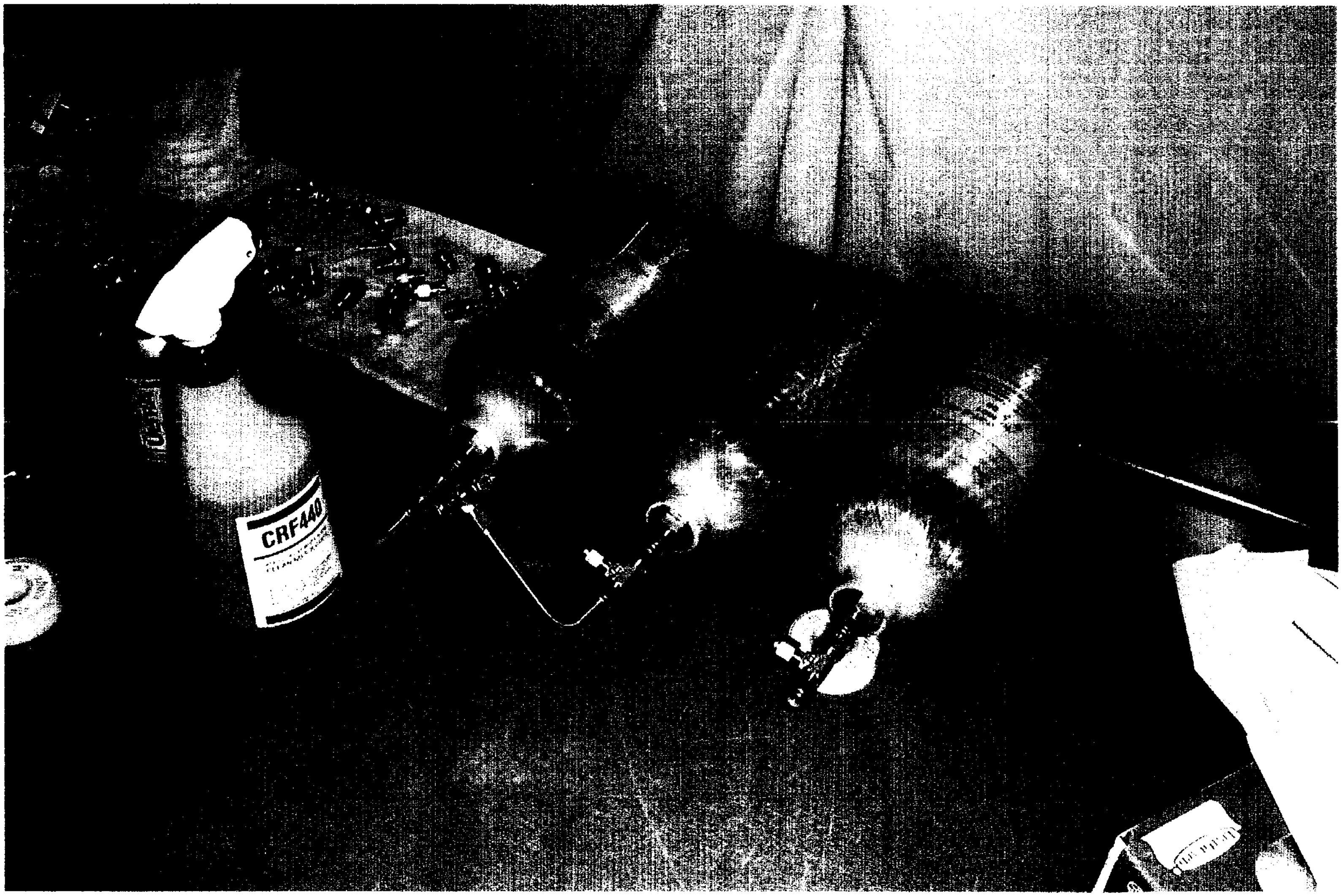
Structure Assembly







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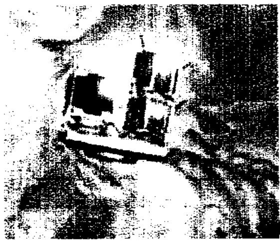
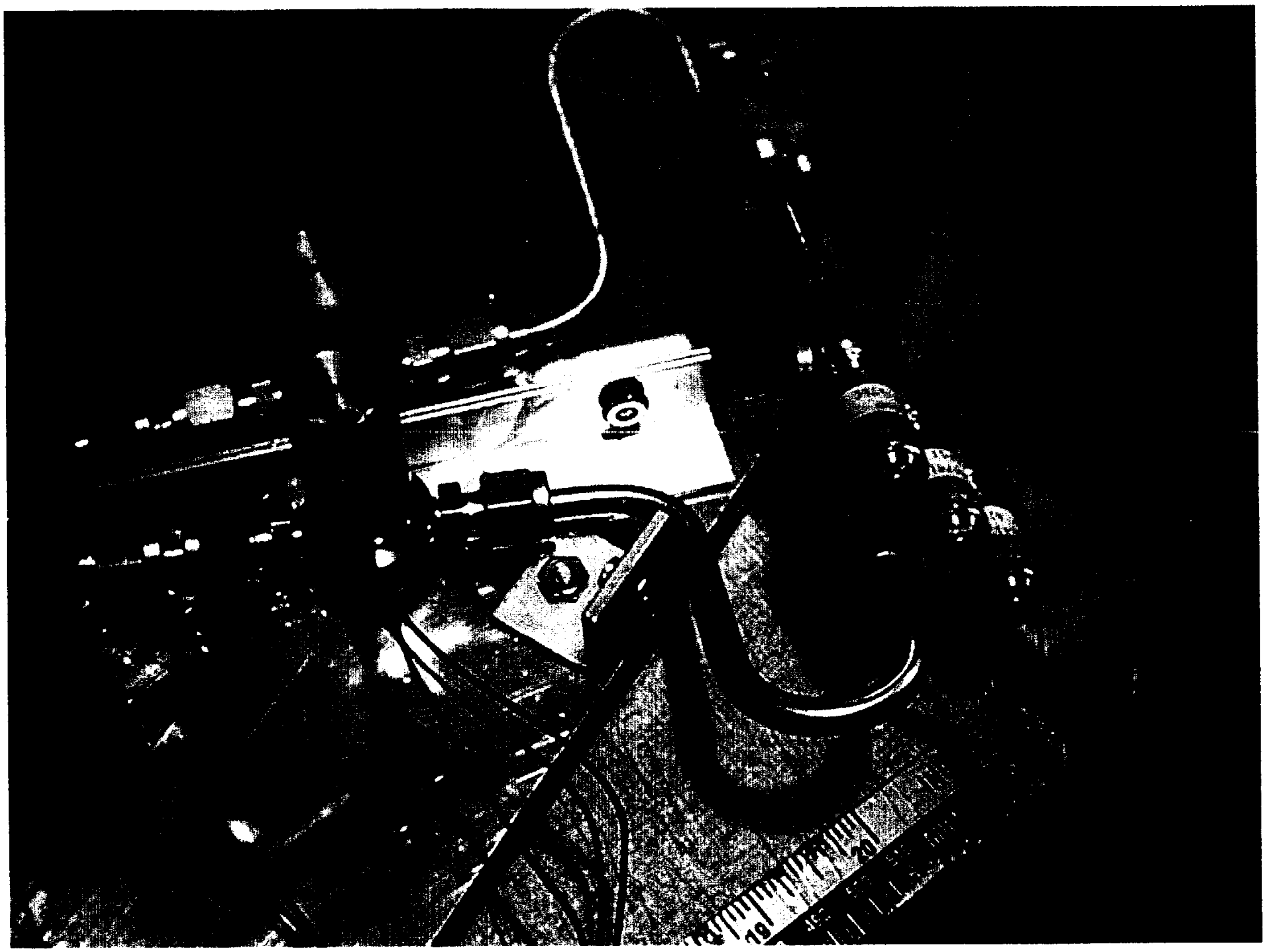
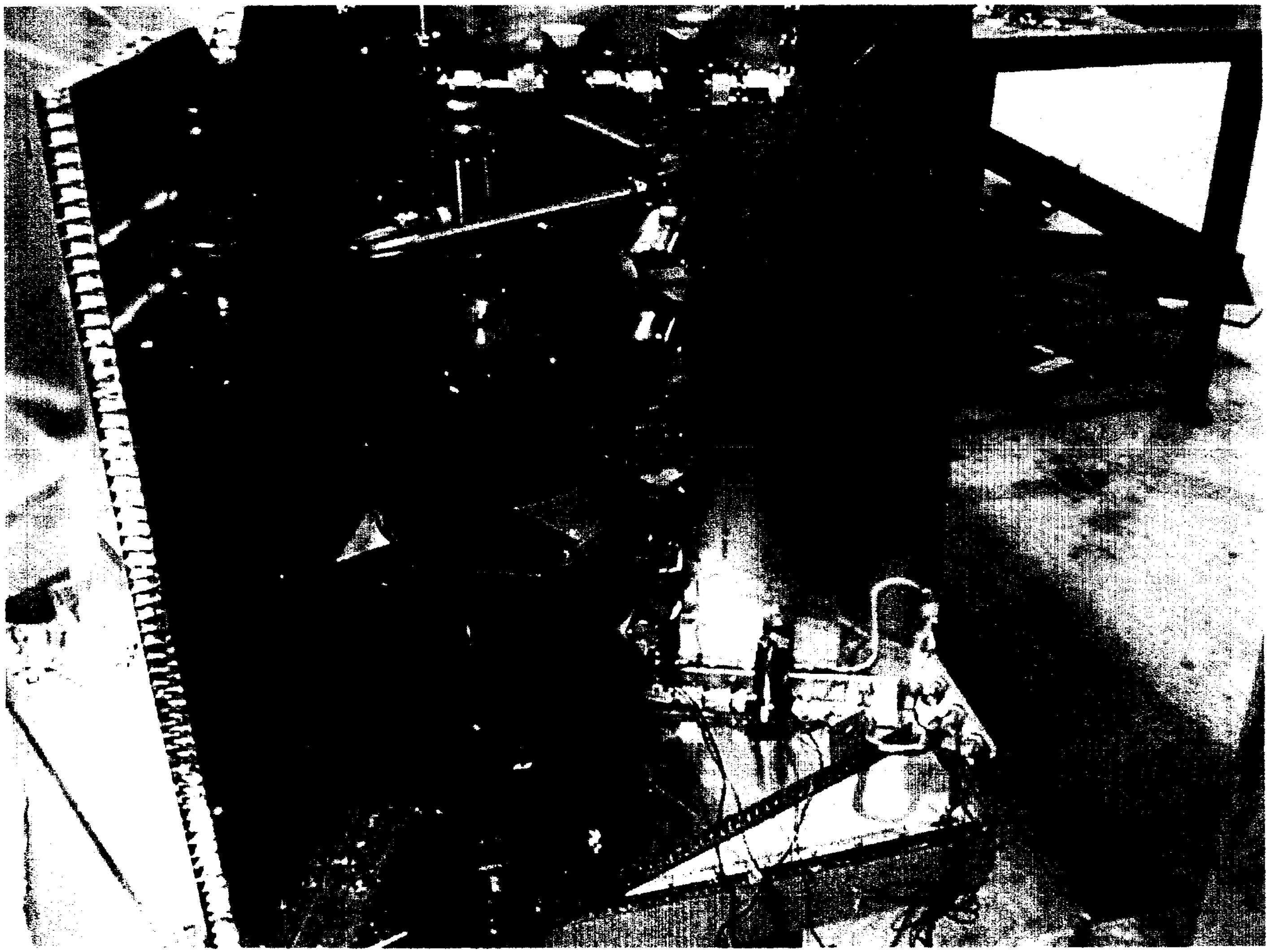
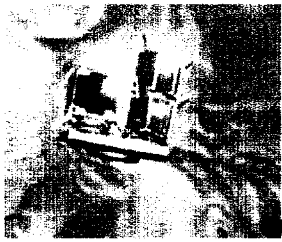
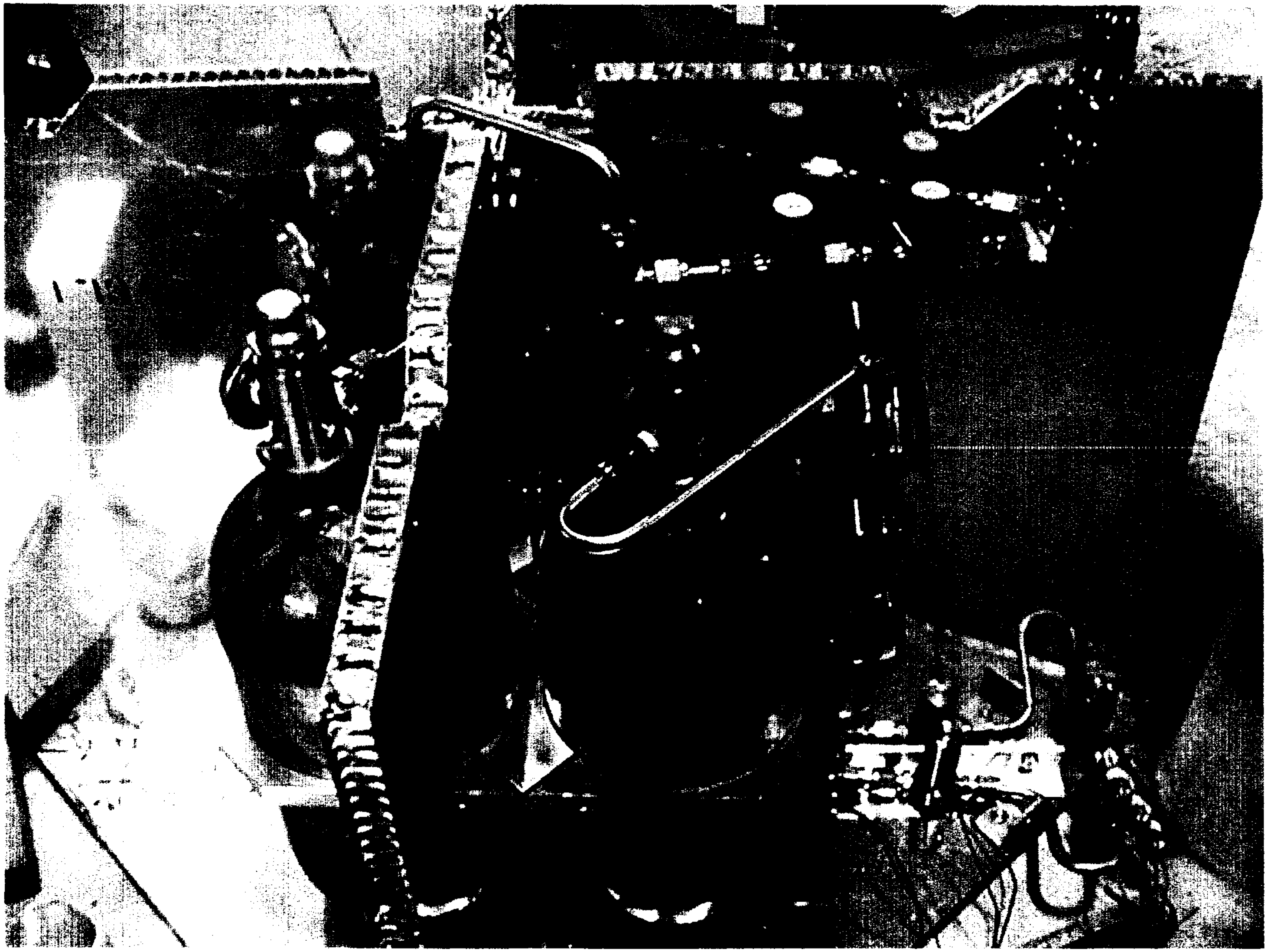
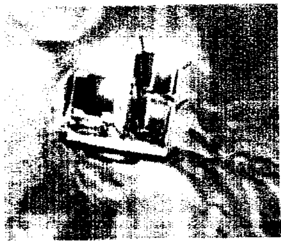


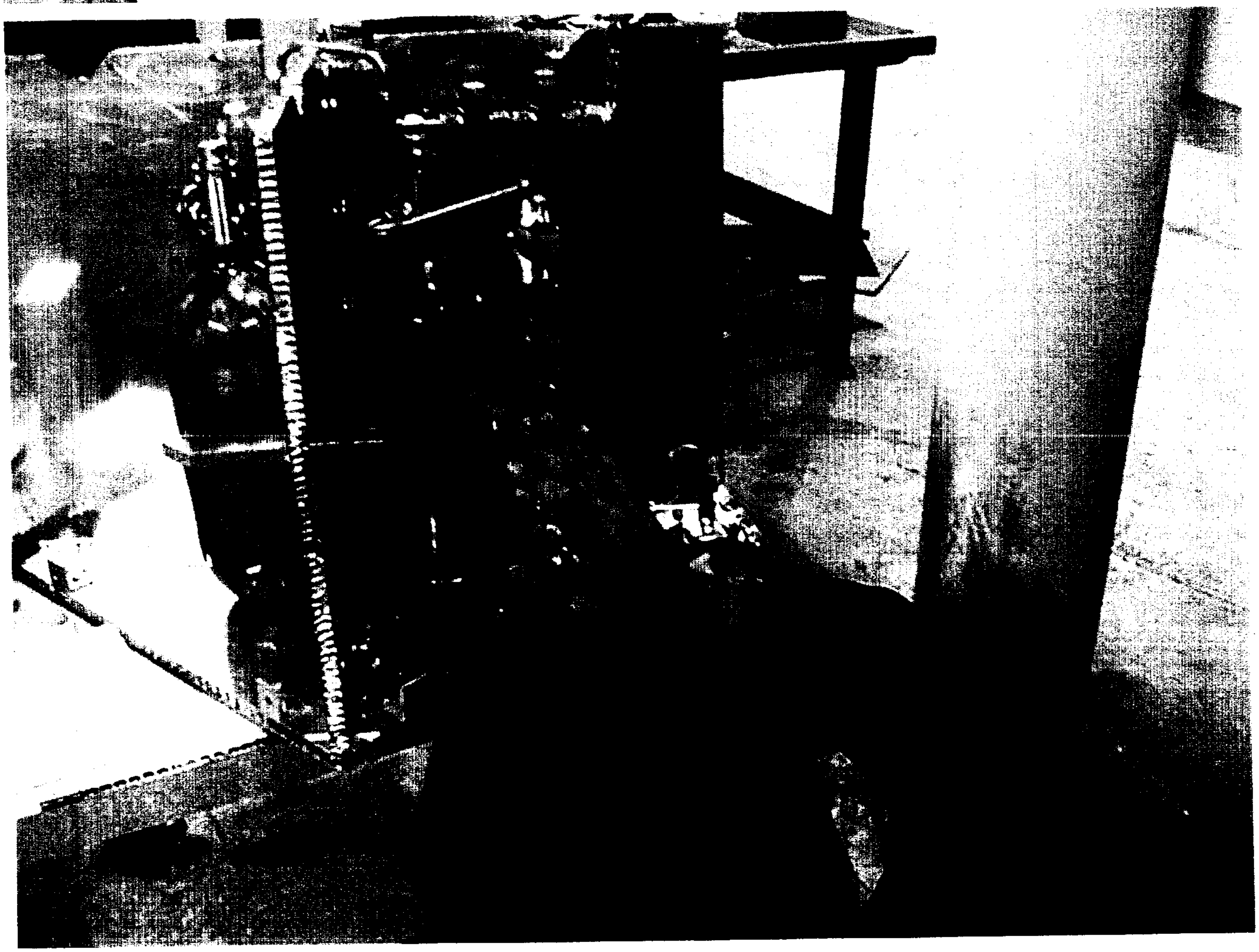


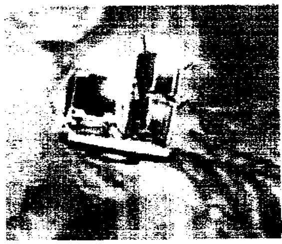


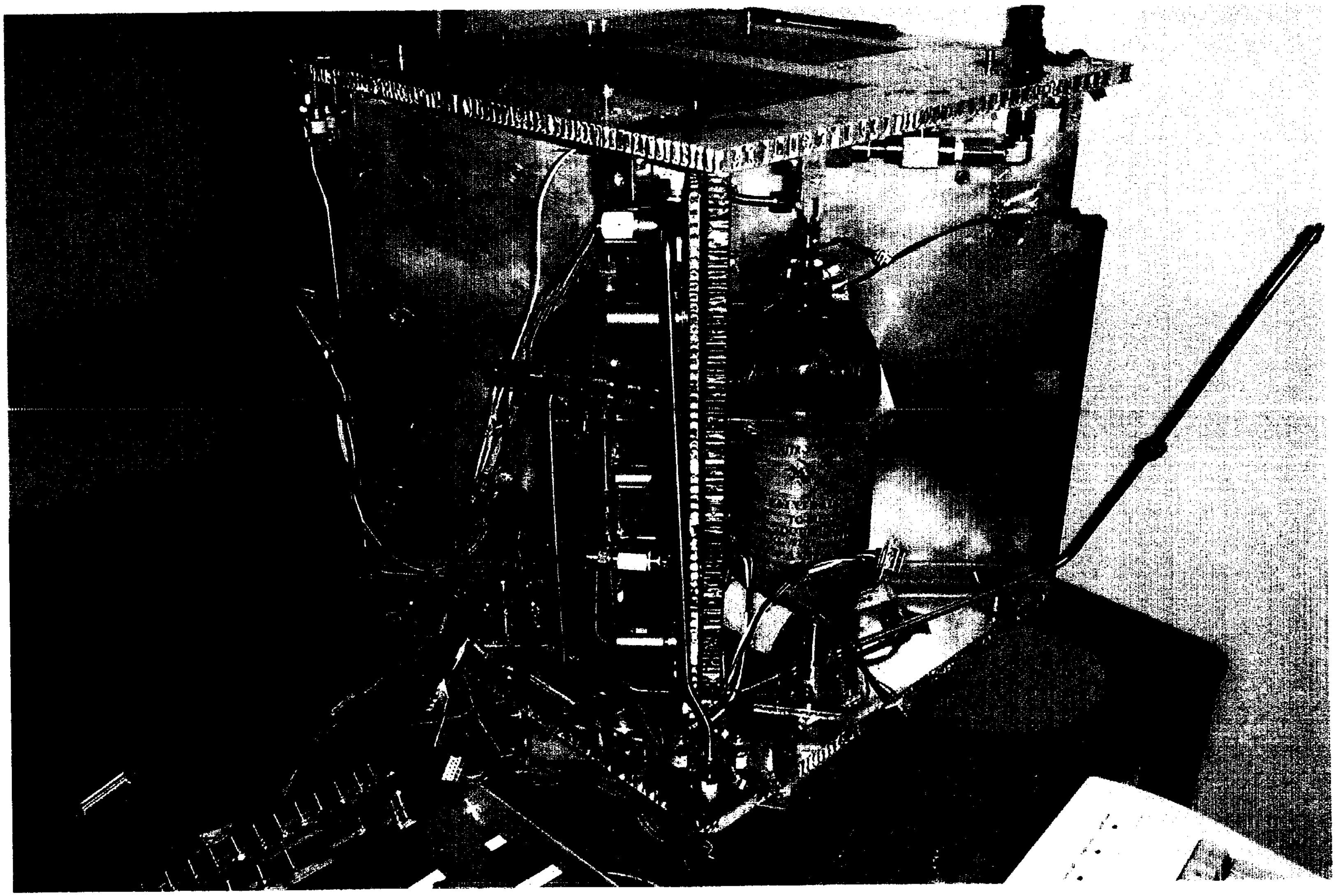


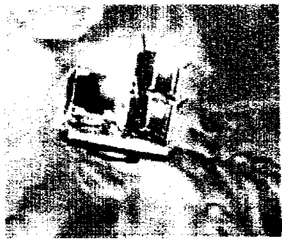


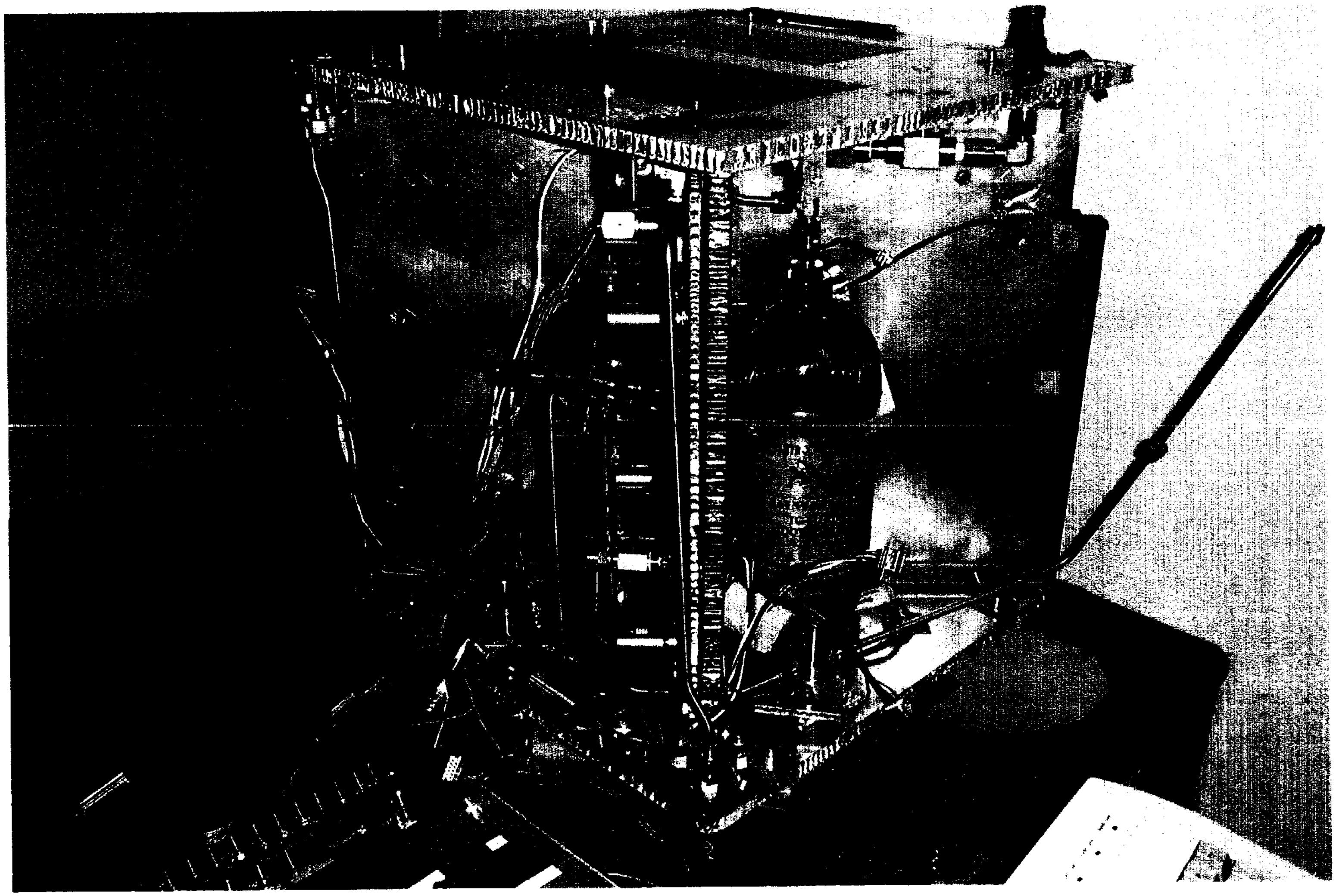


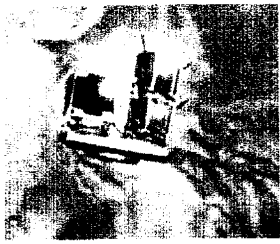


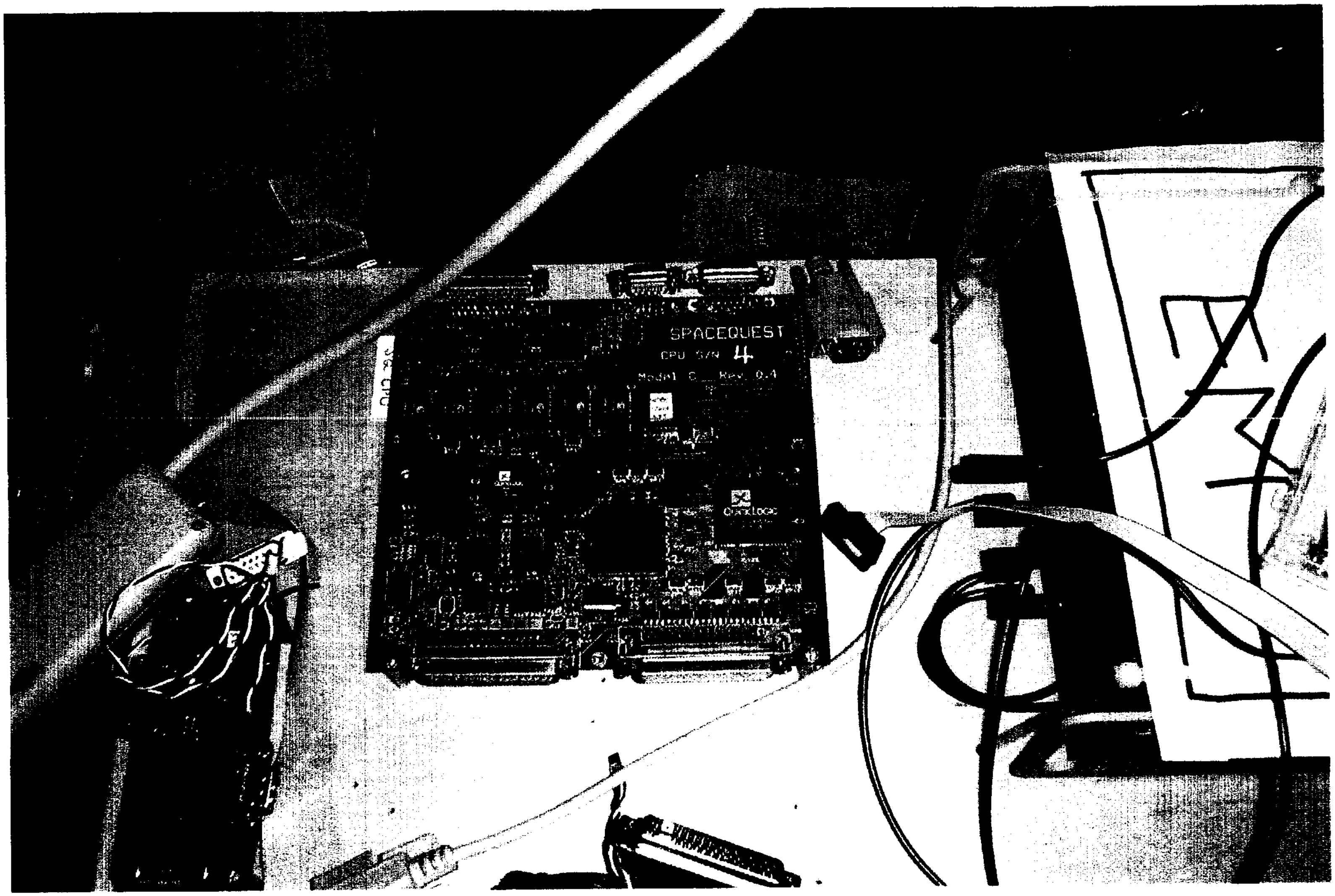


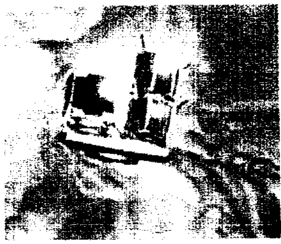


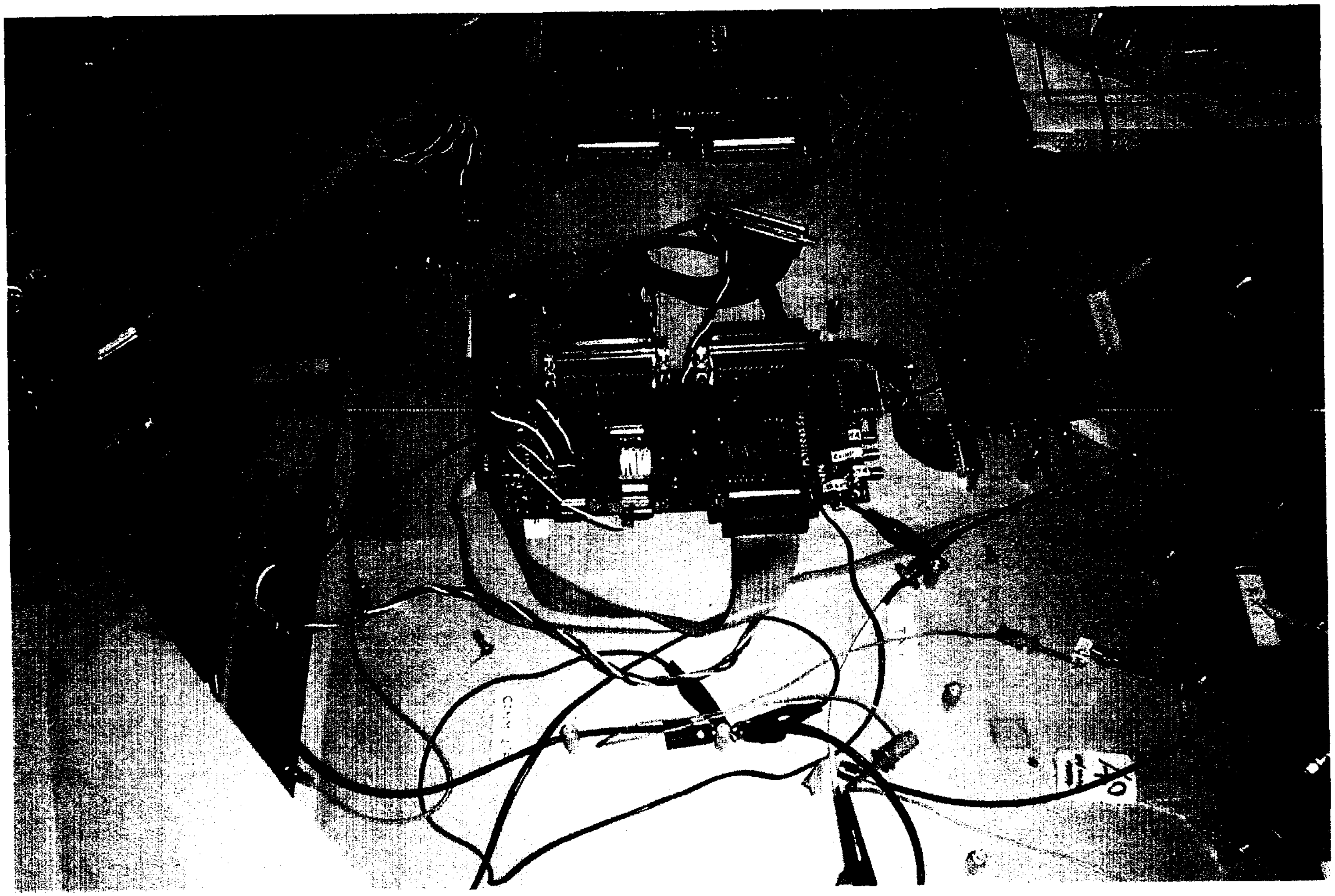


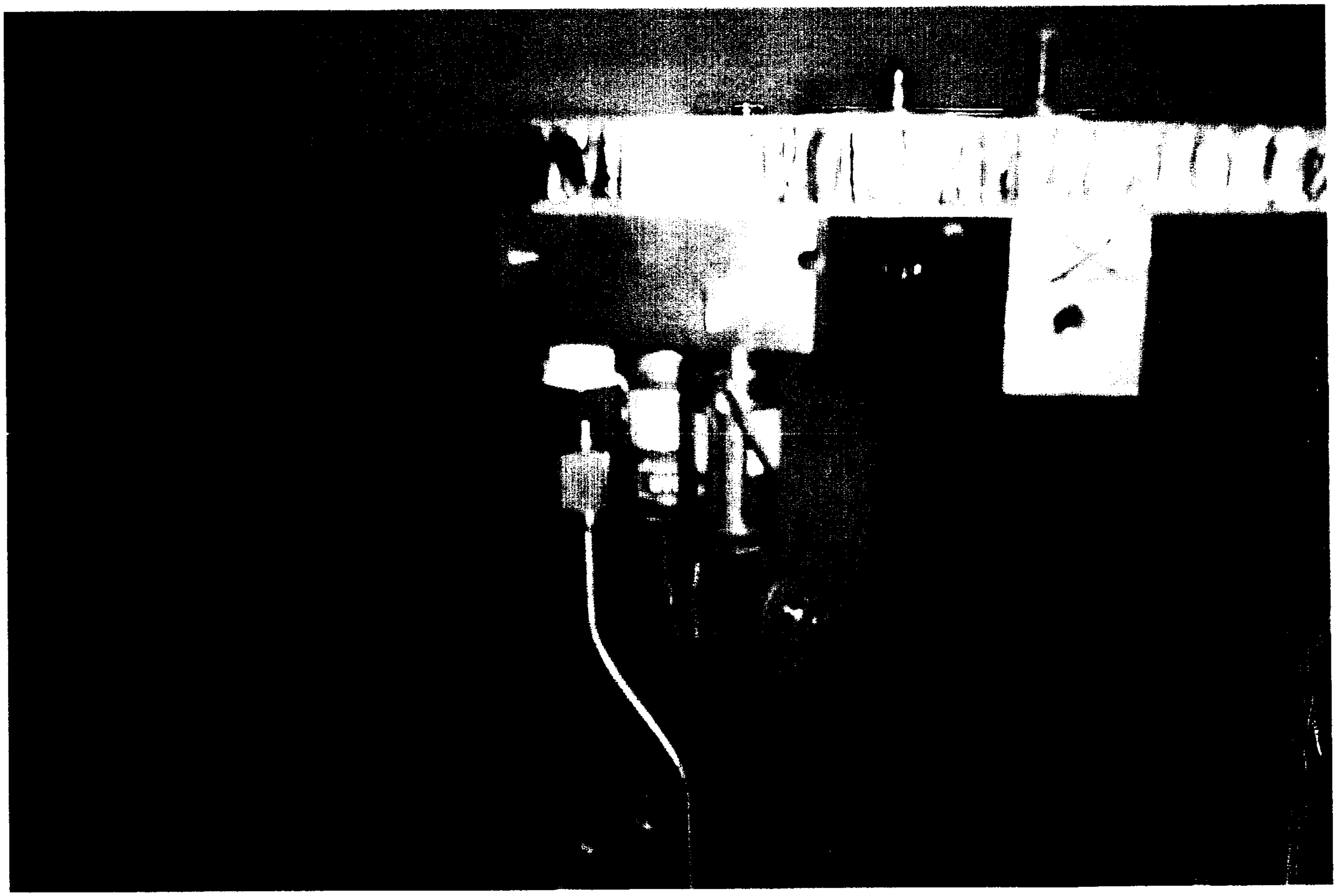


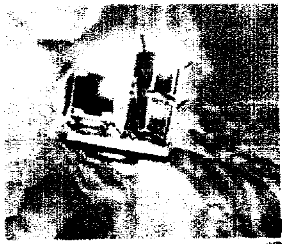
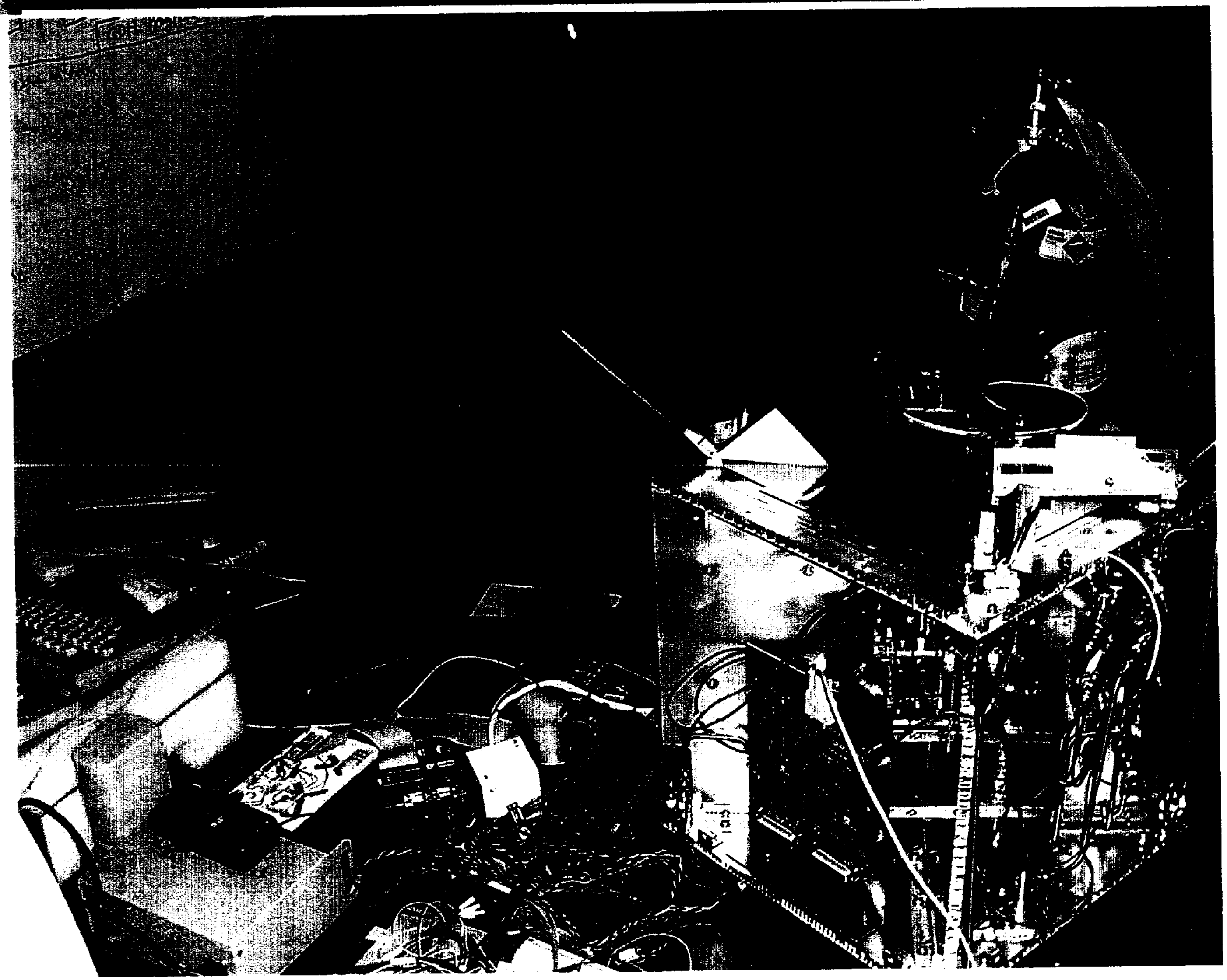



SPACEQUEST
CPU S/N 4
Model C Rev 0.4



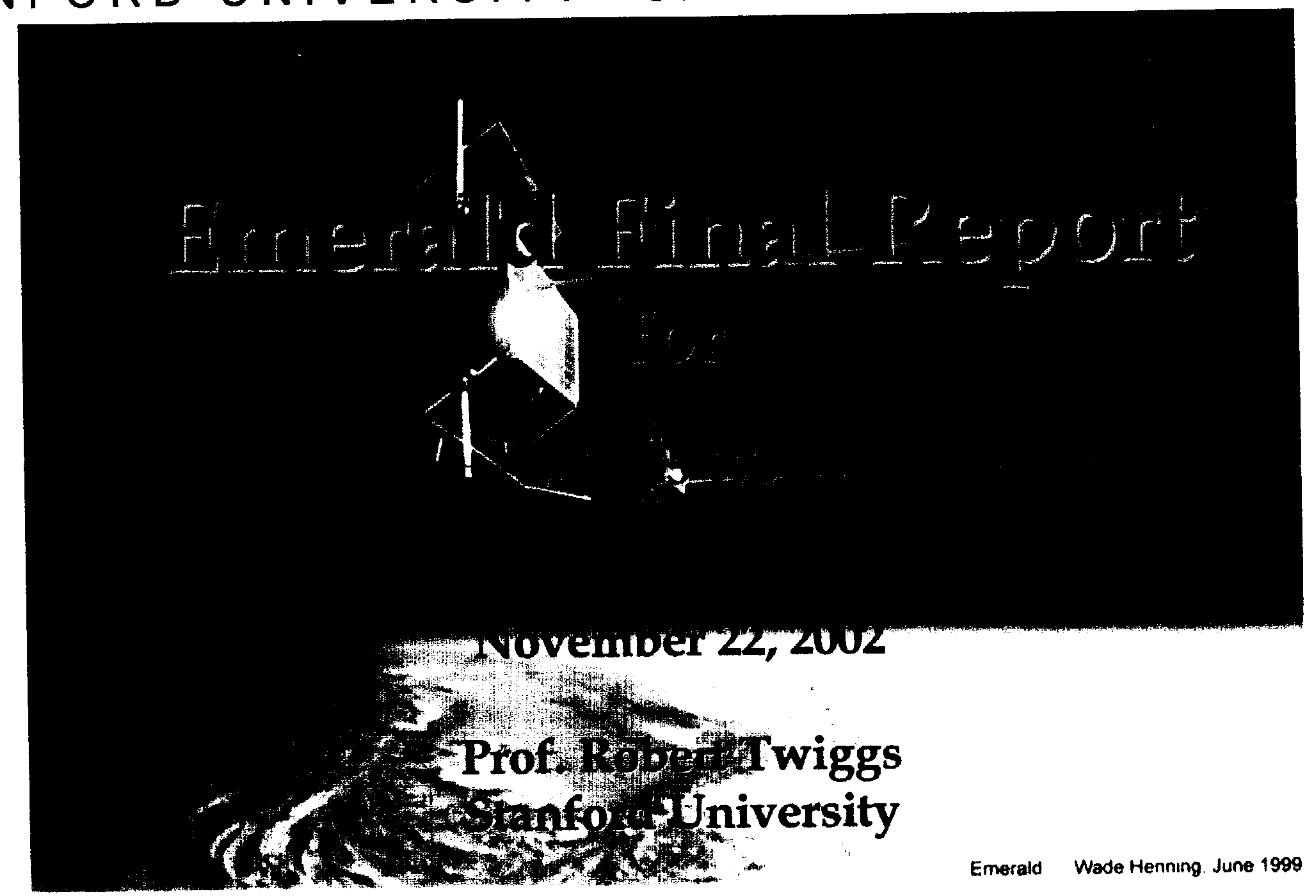




EMERALD NANOSATELLITE

STANFORD UNIVERSITY - SANTA CLARA UNIVERSITY



Emerald Wade Henning, June 1999

University Nanosatellite Program Review

http://ssdl.stanford.edu/Emerald/

University Nanosatellite Program Review

EMERALD MISSION

ROBUST DISTRIBUTED SPACE SYSTEMS

- Integration between Multi Spacecrafts and Ground Station Network
- Demonstration of Component- and System-level Technologies

♦ Colloid Micro-Thruster
♦ Radiation Testbed
♦ Distributed Computing
♦ Distributed System Autonomy
♦ GPS Formation Flying
♦ VLF Ionospheric Science

Presentation Outline

PAYLOAD AND MISSION OPERATIONS

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SYSTEM AND SUBSYSTEM DESCRIPTION

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Julie Townsend
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SAFETY, INTEGRATION AND TESTING

Esther Dutton
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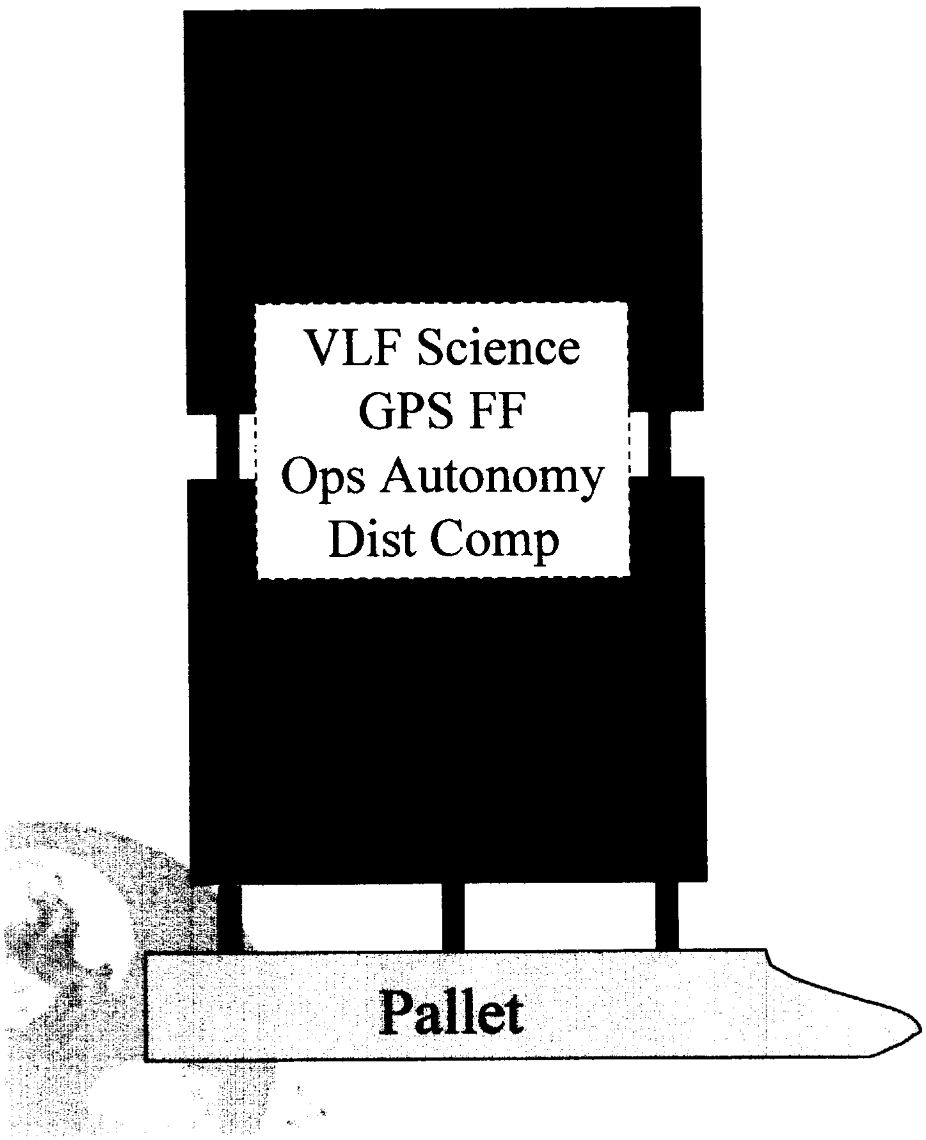
SYSTEM OVERVIEW



- 18” hex, 9” x 13” sides
- 15 kg (each satellite)
- Al honeycomb, stackable trays
- 12 v and 5 v reg. power
- I^2C data & command bus
- Dallas 1-Wire power switching & telemetry
- 9600 baud half-duplex comm. with circular polarization
- 2-axis magnetic stabilization
- Drag panel position control
- GPS relative positioning

COLLOID MICRO-THRUSTER

TECHNOLOGY OVERVIEW

- Simple, Efficient Electrostatic Acceleration of Charged Droplets

EMERALD MISSION

- ~~Survival of the Thruster System~~
- Operational Test Firing
  - Output Stream Measurement
- Technology Demonstration
  - Supporting Traditional Spacecraft Attitude Control
  - Supporting Distributed Space Systems Formation Flying Control

Thruster System

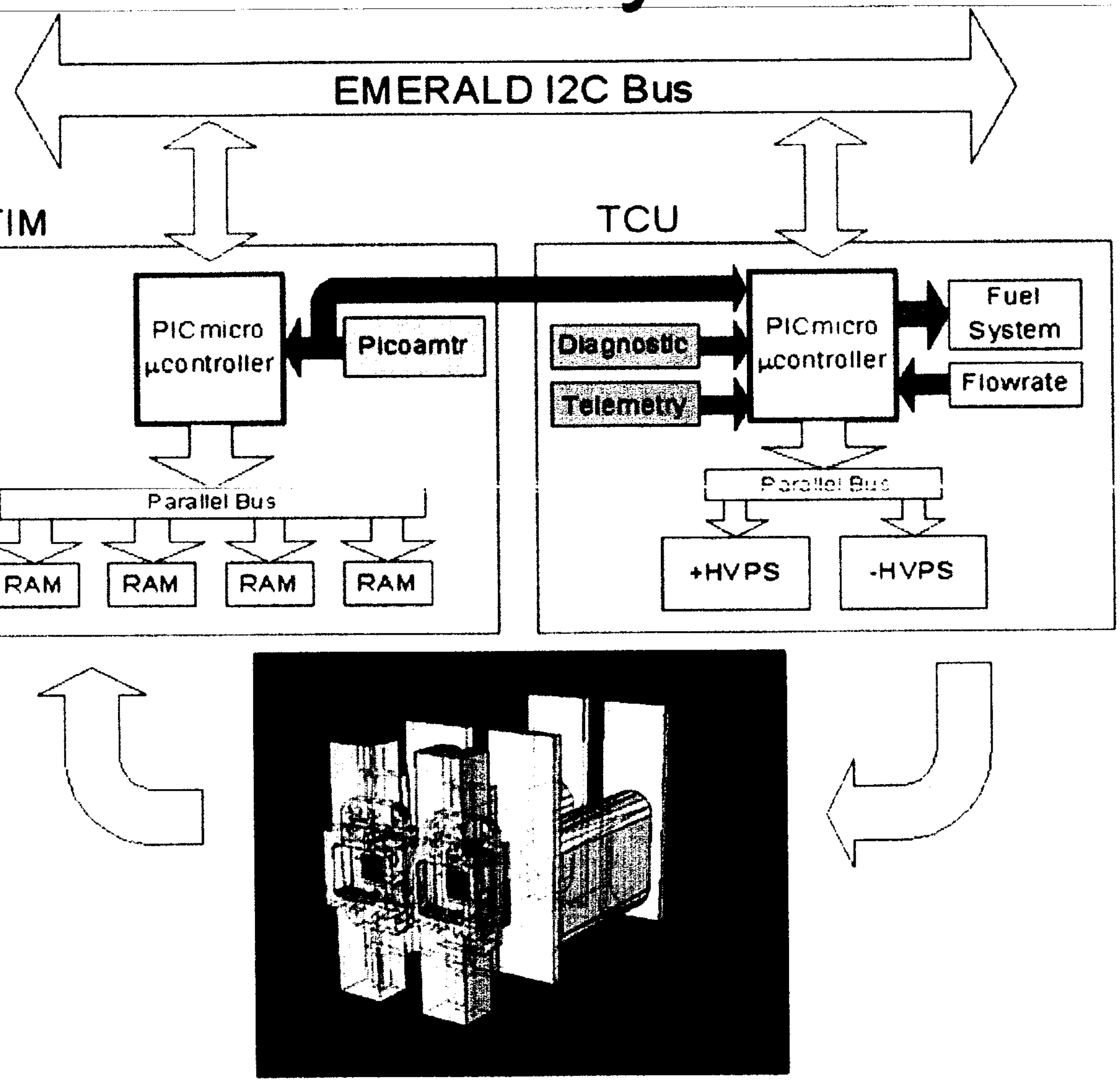
Dual-Polarity Thruster

- Expect 0.1 mN Thrust, ~1000 sec Isp
- 0.5 kg, 10 cm x 10 cm x 20 cm
- 4 Watts max, no-power @ standby

Electronics

- PIC 16F877 for Thruster Control and Data Sampling
- Data sampling module developed by CDH
- Stream output sensor (picoammeter) at 20 kHz sampling at 8 bit, for 30 sec
- EMCO High-Voltage +/- 6kV Power Supply
- Insulin Pump as Propellant Storage and Delivery
- Current propellant choice: Sodium-Iodide / Glycerol

Thruster System



RADIATION TESTBED

OBJECTIVE

- Evaluate effects of radiation on micro electronics

EMERALD MISSION

- Measures Single Event Effects
  - Single Event Upsets (bit-flip)
  - Single Event Latchup
- Measure Total Ionizing Dose
  - Dosimetry

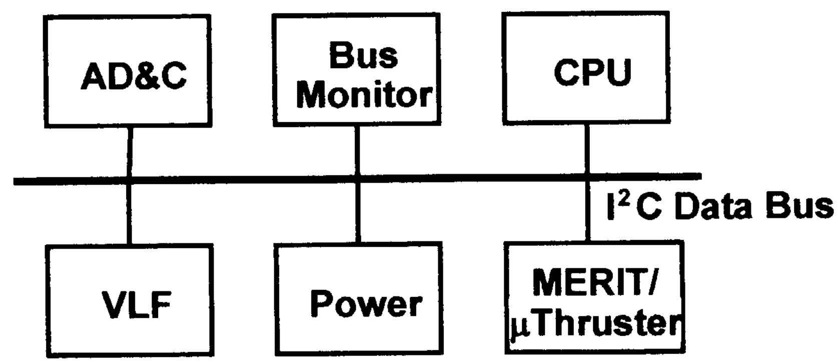
DISTRIBUTED COMPUTING

DISTRIBUTED ARCHITECTURE

- Modular, Standard Data Bus
- Micro-controller enabled subsystems
- Standard Interface = Easy Integration
- On-Orbit Operations Options

EMERALD MISSION

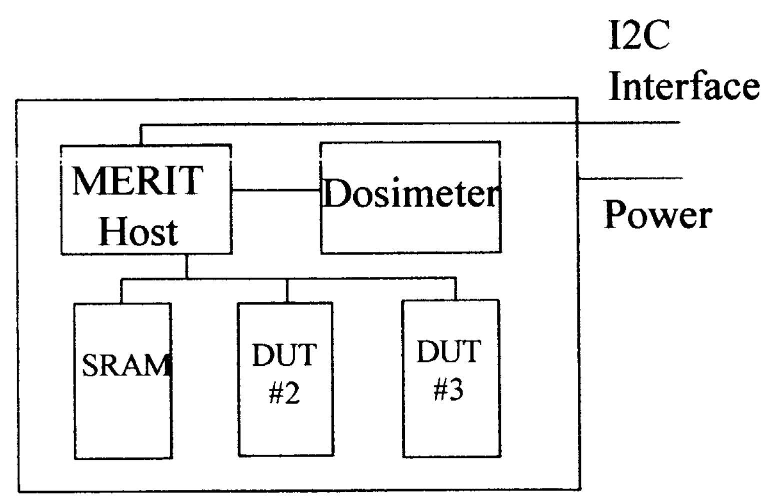
- Inherent in Bus Design
- Integration
- Operations Experiments
  - Simulated CPU Failure
  - Inter-satellite virtual data bus
- Data bus characterization



MERIT System

MERIT (Micro-Electronic Radiation In-flight Testbed)

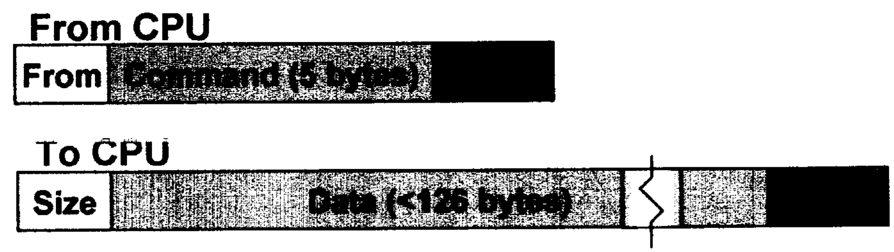
- PIC 16C77 host controller
- PFET Dosimeter
- Device Under Tests
  - SRAM
  - Microchip Technology PICMicro© 16C77
  - Boeing Test Chip
  - GBit DRAM



Dist. Comp. Components

Common Interface

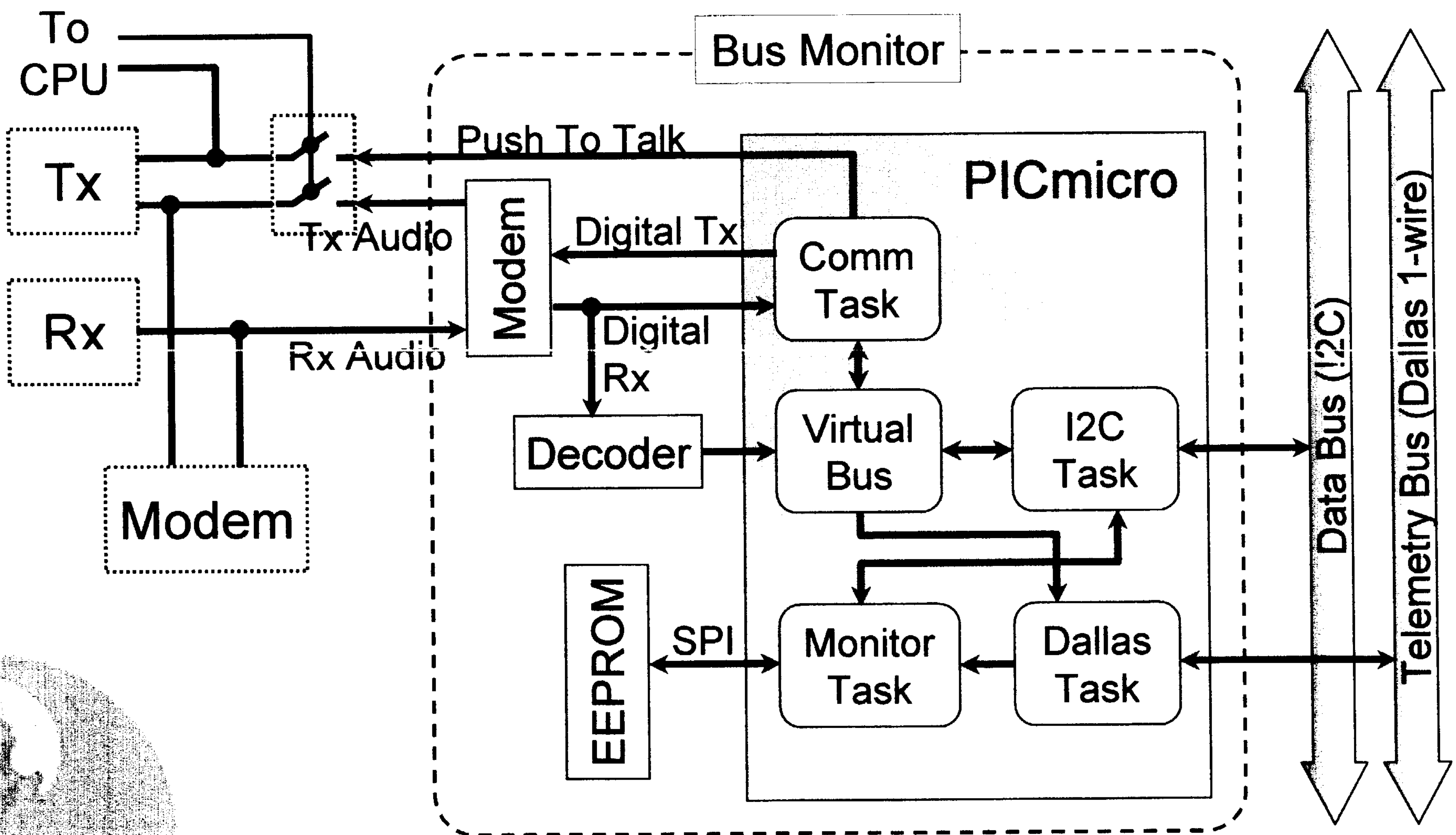
- PIC 16F877 Microcontroller
- “Library” Software: A to D, Memory, I2C, Real Time, etc.
- I2C Serial Data Bus



Bus Monitor

- 0.15 kg, 6 cm x 18 cm x 2.5 cm
- 100 mW, always on (except “Safe” mode)
- PIC 16F877, serial (SPI) EEPROM
- Direct Comm. Link
  - Simple 1200 Baud Modem
  - Enabled by unique bit code

Bus Monitor: Block Diagram



DISTRIBUTED SYSTEM AUTONOMY

AUTONOMOUS OPERATIONS

- Distributed Beacon
- Advanced Science Execution
- Reactive Ground-based Navigation Control

EMERALD MISSION

- Autonomous Operations Experiments supporting Distributed Space Systems Architecture

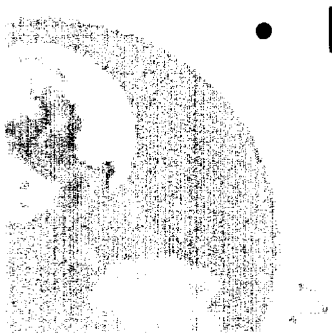
Distributed Beacon

OBJECTIVE

- Multi-satellite beacon monitoring for satellite-to-satellite and fleet-level cases

DESIGN

- Telemetry filter assesses satellite health
- Assessment (a few bits) periodically broadcast
- Ground network automatically notifies operator
- Heavy reliance on heritage



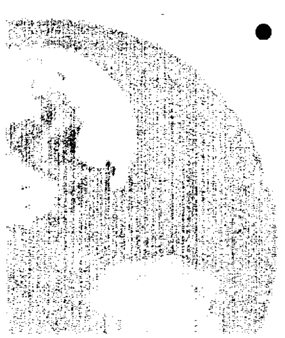
Advanced Science Execution

OBJECTIVE

- Evaluate fleet-level control capability and "opportunistic" science data collection

DESIGN

- Fleet-level control:
  relay time-tagged commands
- Opportunistic Science:
  Threshold filter to recognize periods of interest
- Incorporated into VLF system



Ground-based Navigation

OBJECTIVE

- Automatic calculation and transmission of navigation commands when on-orbit relative navigation system is off (power, failures, range, etc.)

DESIGN

- Beacon indicates on-orbit status
- FreeFlyer navigation software on ground
- Mercury program executes commanding
- Primarily a ground-based system

GPS FORMATION FLYING

OBJECTIVE

- Provide a comprehensive on-orbit demonstration of true formation flying spacecraft

EMERALD and EMERALD-ORION MISSION

- Demonstrate virtual spacecraft bus technologies
- CDGPS for real-time navigation sensing and fleet control
- Demonstrate various control architectures and a real-time inter-vehicle communication link and local ranging systems

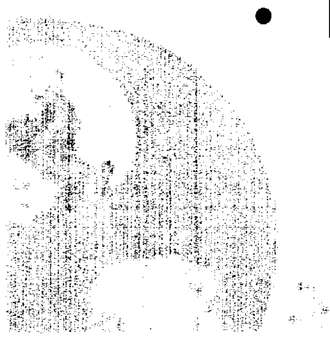
Formation Flying Experiment

Control for a cluster of microsats

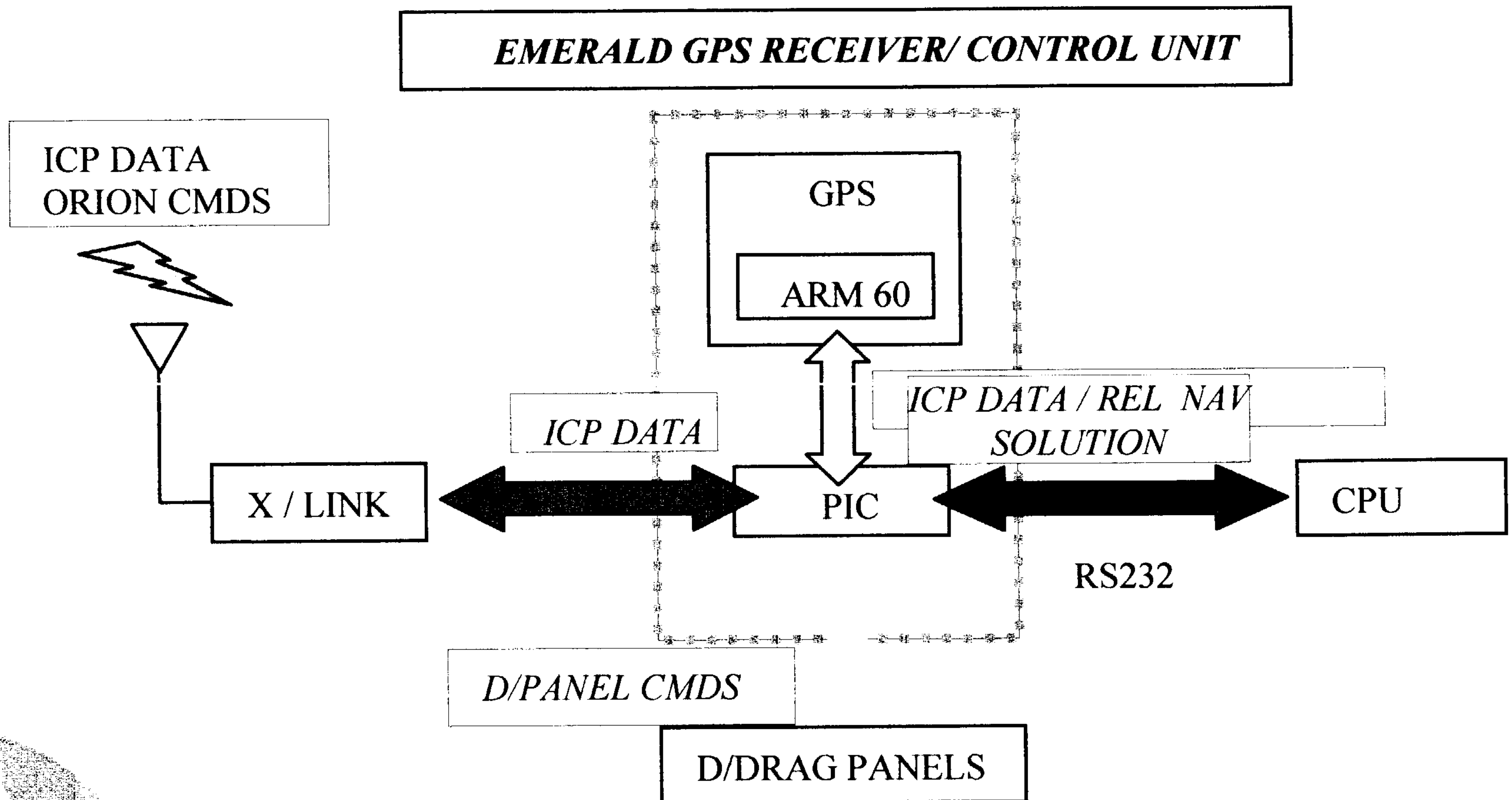
- Real-time autonomous control software
- Formation directed at a high-level from the ground.

CDGPS Receiver

- 2 Antenna
- Expect better than 1 m (relative - radial) for position determination
- Expect better than 5 m (relative - radial) for control
- Low-power, low-cost, attitude capable GPS receiver



GPS Receiver & PIC Controller



VLF IONOSPHERIC SCIENCE

SCIENTIFIC GOAL

- Thunderstorm monitoring and ionospheric science through the reception of lightning-induced VLF waves using multiple spacecraft

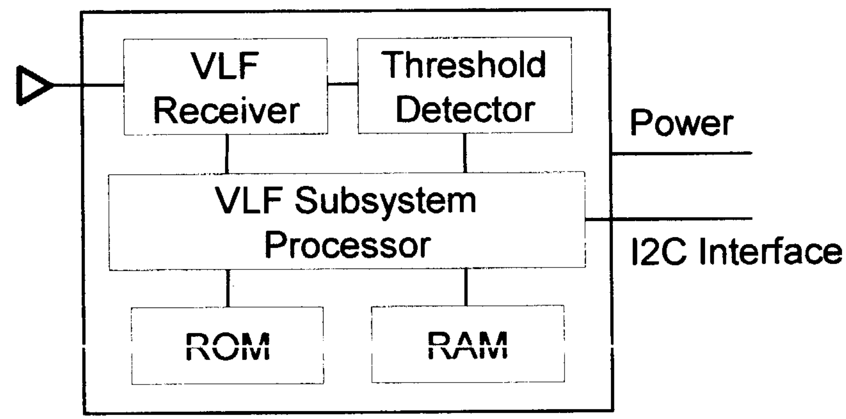
EMERALD MISSION

- Lightning Count Survey
- Science to Demonstrate and Validate Distributed Space Systems

VLF Receiver System

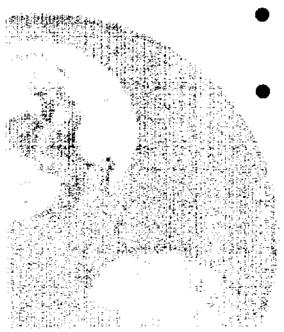
VLF Receiver

- Active Filter and Amplifier
  - Peak amplification at 5kHz
- Threshold detector
  - Triggers comparator to count strikes above a programmed level



PIC Processor

- Sample VLF receiver data and store to science memory
- Read science memory and send out data through I2C Bus
- Science Data Tagging (Time, Attitude, Absolute and Relative Position)



MISSION OPERATIONS

MAJOR MODES OF OPERATIONS

1. Launch and Verification
2. Stacked Flying
3. Stack Separation
4. Distributed Operations
5. Non-Distributed Operations
6. Downlink
7. Safe Mode

Driving Requirements

- Shuttle Requirements
- MSDS and SHELS Requirements
- System Resources

Mode 1: Launch and Verification

- Launch from Space Shuttle
  - Separation controlled from Shuttle
  - Emerald will be powered off while on Shuttle
- Initial Acquisition
  - Power turned on when separated
  - Use beacon or orbital data to acquire satellite from Ground Station
  - Ground Station command to initiate Emerald system boot-up

Mode 2: Stacked Flying

- Emerald satellites will orbit for undetermined time stacked
  - Time between Shuttle separation and satellite separation
  - May be limited by attitude requirements, downlink access and/or waiting for Orion
- Perform System Checks
- Can Run Experiments

Mode 3: Stack Separation

- Short but Critical operational mode
- Separation initiated from Ground Station
  - While in an optimal pass
- Satellite attitude critical
  - Driven by Experiment and Mission Requirements

Mode 4: Distributed Operations

- Experiments that require adequate satellite cross-link and relative position knowledge
  - Distributed Computing
  - Distributed System Autonomy
  - EMERALD Formation Flying
  - EMERALD/ORION Formation Flying
    - ORION with 1 Emerald
    - ORION with 1 Emerald, Emerald responds to ORION
  - Multi-Spacecraft VLF Experiment

Mode 5: Non-Distributed Operations

- Experiments that can be run independent of the other satellite
  - Colloid Micro-Thruster
    - Test Firing
    - Attitude Control Experiment
    - Formation Control Experiment
  - Radiation Testbed
  - Single-Spacecraft VLF

Mode 6: Downlink

- Any Inclination
- Altitude 325km minimum
- Stanford Ground Station
- Distributed Ground Station Network
  - Provisions to use other ground stations will greatly increase on-orbit data collection and storage limits

Mode 7: Safe Mode

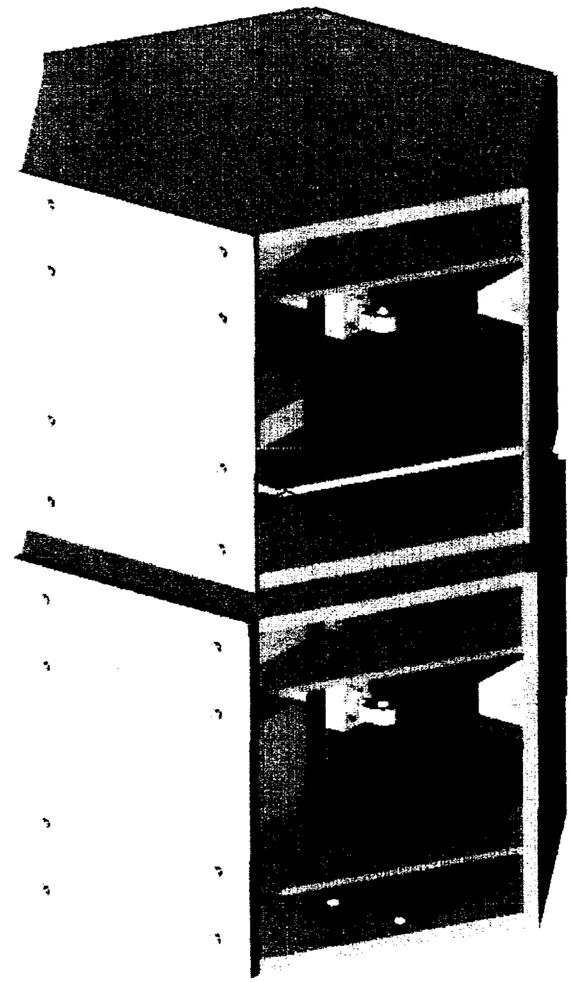
- Emerald to revert to Safe Mode during periods of low power or immediately upon experiencing an on-orbit anomaly
  - Only critical subsystems left on, all experiments terminated
  - Health and Maintenance Monitoring (HMM) subroutine will perform checks on all systems and experiments
  - HMM Information to be sent over beacon
  - Ground Station(s) will use beacon to diagnose and correct problems

EMERALD SYSTEM

- Structure and Mechanical Systems
- Thermal System
- Power System
- Command and Data Handling System
- Communications System
- Attitude Determination and Control System

Structure Design

- Heritage design
- Aluminum honeycomb hex plates & side panels
- Longerons
  - Stainless steel all-thread, aluminum spacers
- L-brackets
- Layout
- Subsystem boxes as necessary

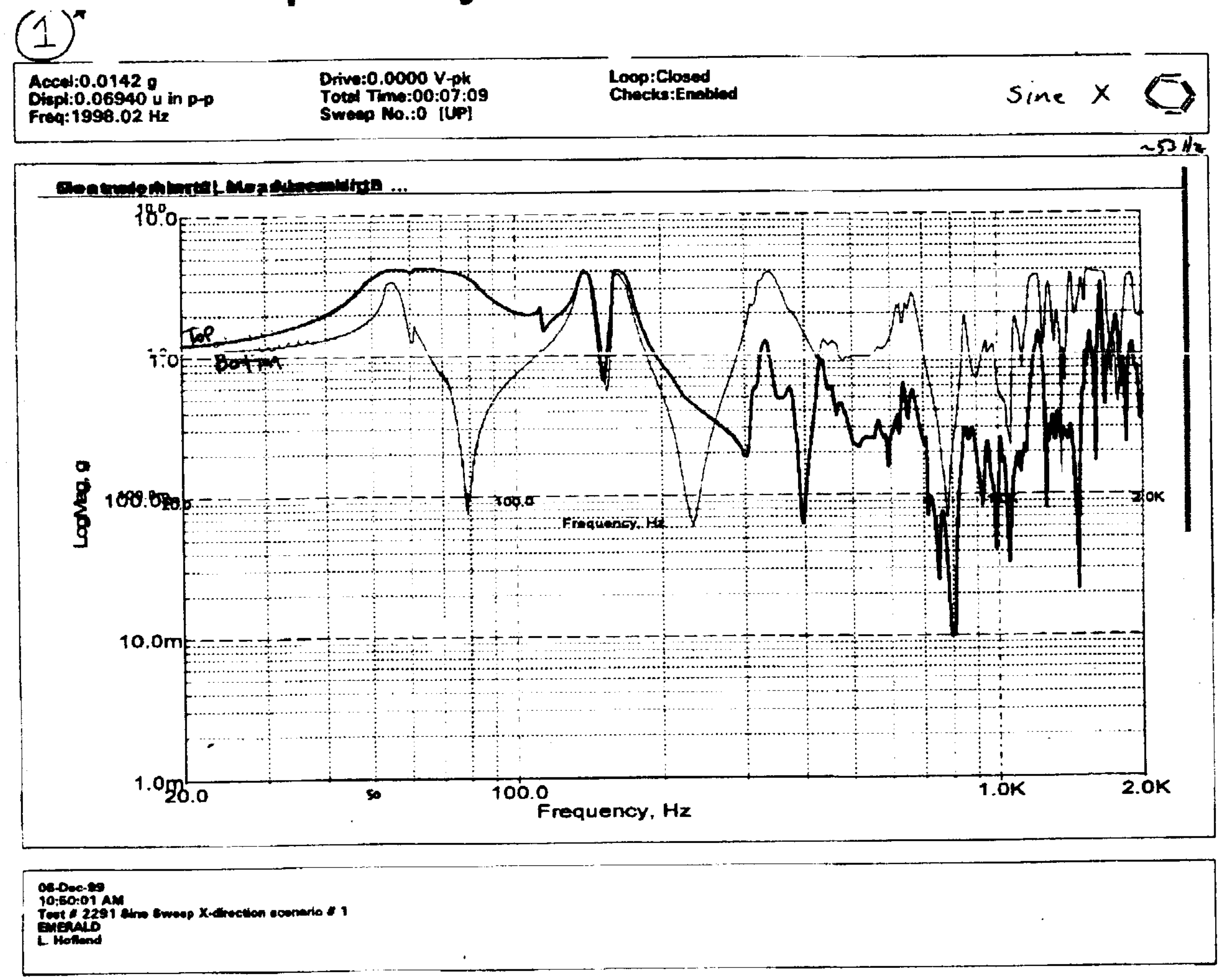


Vibration Testing

- Vibe Test @ NASA Ames on Dec 6, 1999
- EM Structure with Subsystem/Experiment mass simulators
- Sine Sweep in X, Y, & Z @ 20 Hz. to 2 KHz
- Random Vibe in X, Y, & Z @ 11g's
- Multiple L-bracket & side panel configurations were tested
- Natural frequency of satellite stack > 50 Hz
- Natural frequency of individual hex >100 Hz

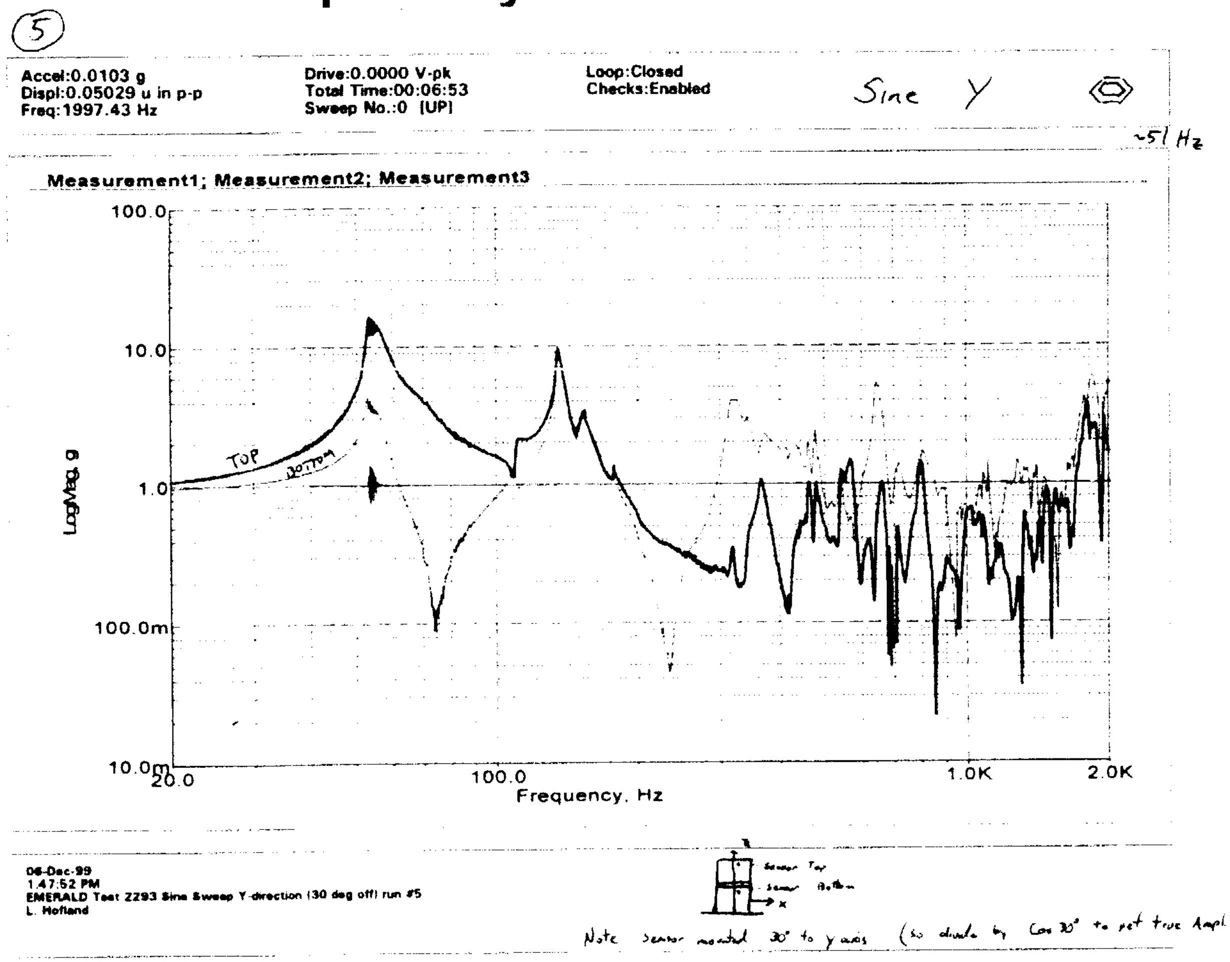
Vibration Testing

- Natural Frequency in X dir. = 53 Hz.



Vibration Testing

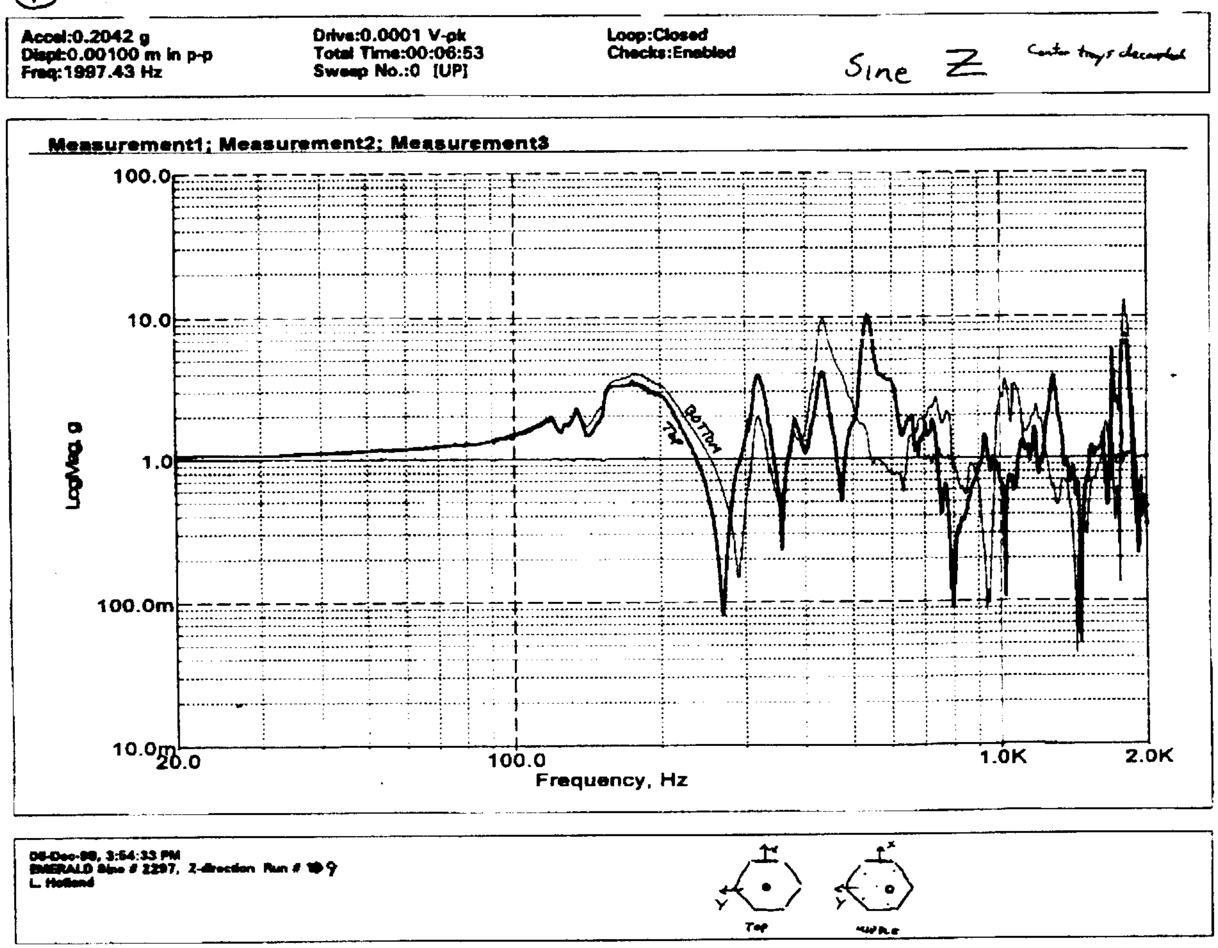
- Natural Frequency in Y dir. = 51 Hz.



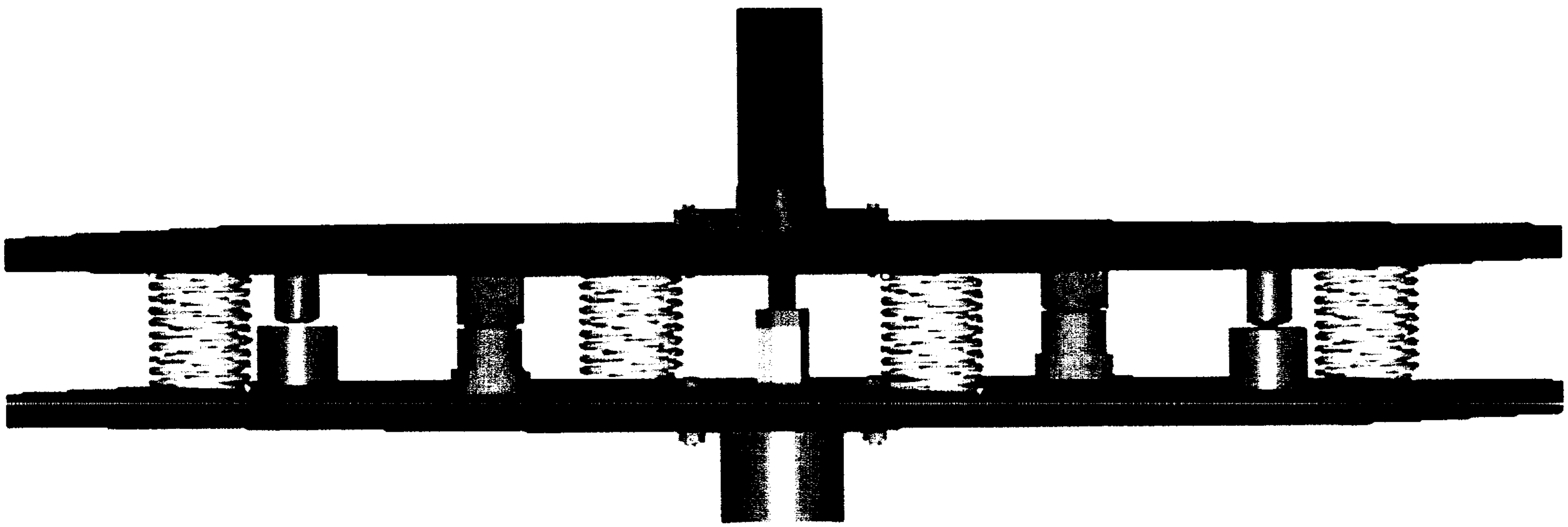
Vibration Testing

- Natural Freauencv in Z dir. = 106 Hz.

9



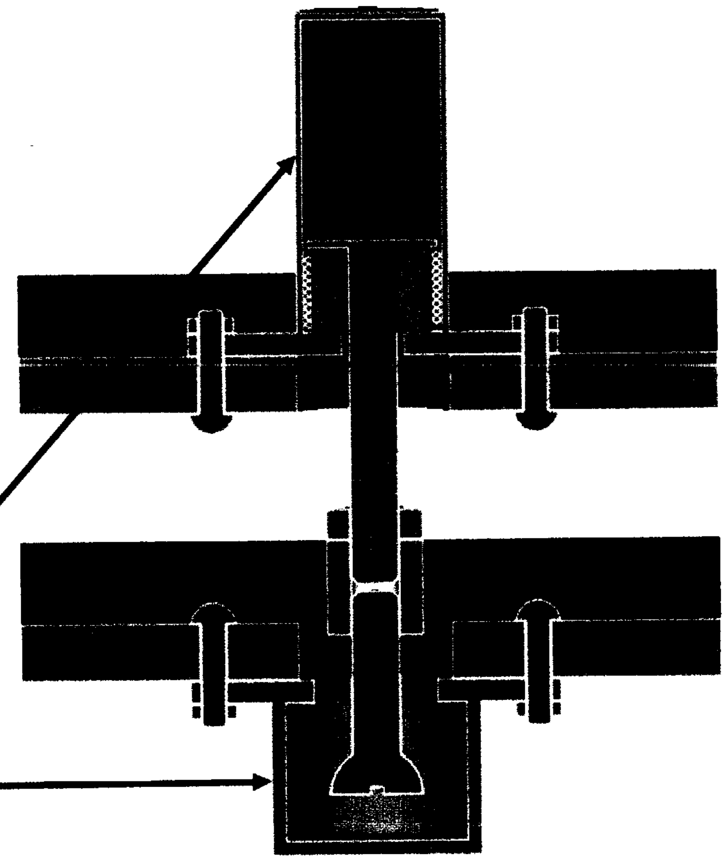
Separation System



- Starsys Qwknut Actuator (1 min. re-settable)
- Bolt Catcher/Retractor (with load sensor)
- 1 cup/cone interfaces (torsion, shear)
- 2 V-slot/cone interfaces (compression, bending)
- 1 spherical button/post interfaces (compression, bending)

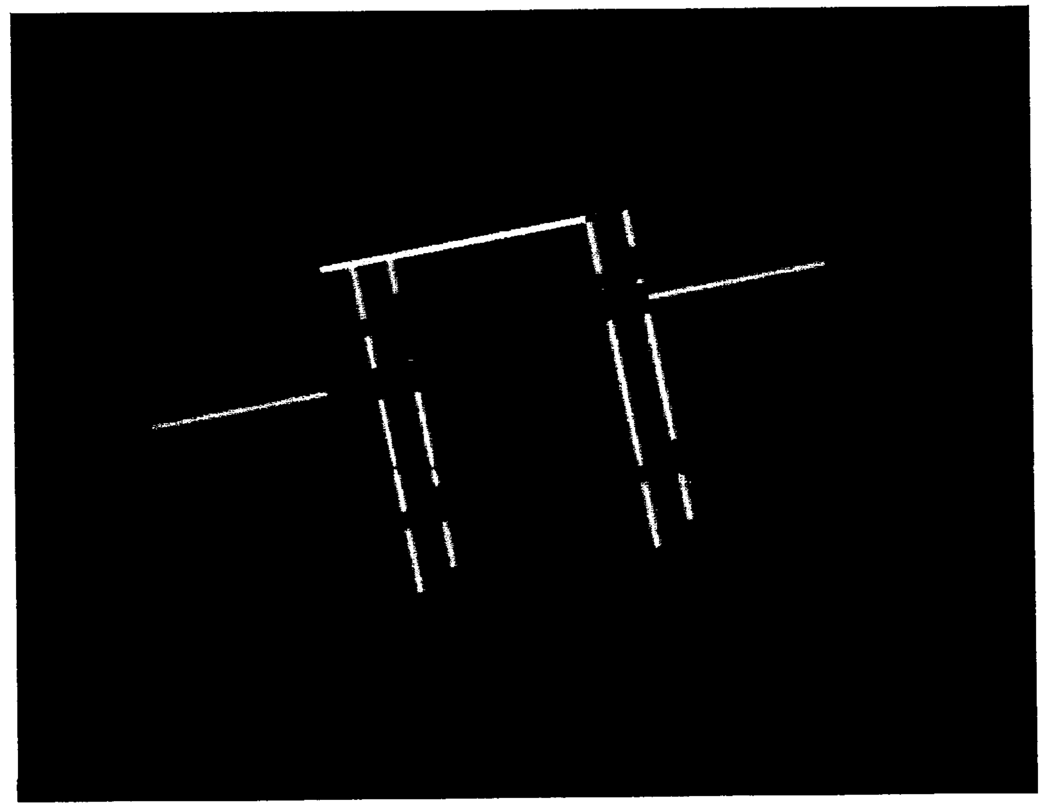
Separation System Mechanisms

- Bolt Retractor/Catcher
- Starsys Qwknut Actuator



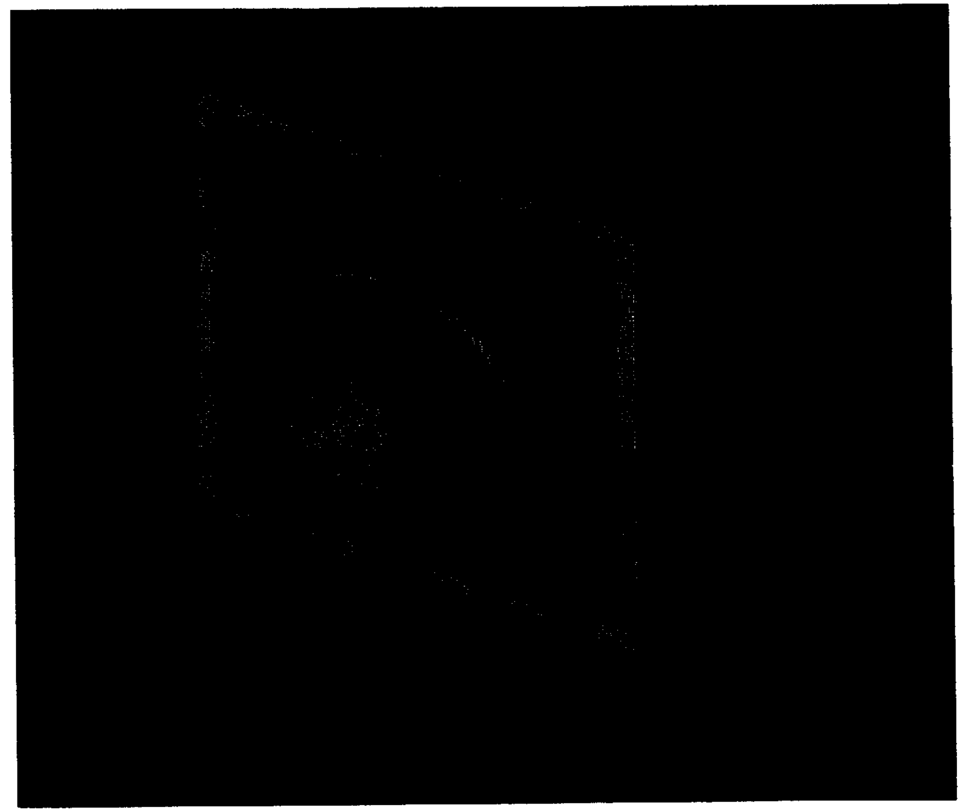
Drag Panel Mechanism Design

- Linear Actuator System
- Linear Guides on Drag panels
- Rigid Hinges



VLF Antenna Mechanism Design

- 3 meter long, 1/2" wide carpenter's tape
- Reverse Tape Measure Mechanism
  - Coiled tape's tendency to expand outward drives it
  - Pin Puller Actuators

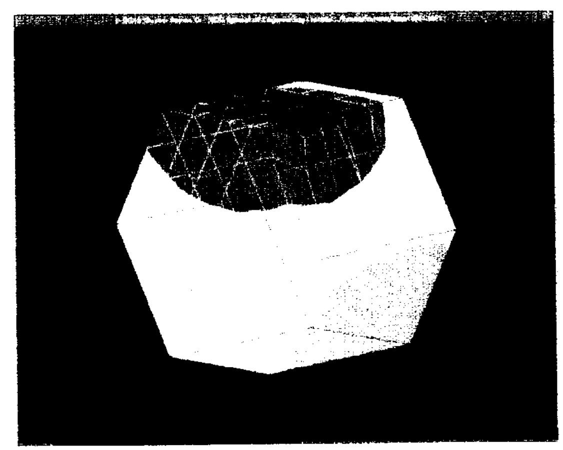


Structure and Mech. Status

- Development status
  - Engineering model components manufactured
  - Engineering model intersatellite separation system complete (minus springs)
  - Drag panel prototype & actuator selection underway
  - VLF deployment mechanism prototyped
  - Actuator circuits prototyped
- Outstanding structural issues
  - Natural frequency

Thermal Analysis

- Preliminary "back-of-envelope" calculations
  - Assumed single node, steady-state, worst-case
  - Hand calculations and spreadsheet
  - Results: ~ 10 ºC to 50 ºC
- I-DEAS FEM Thermal Analysis Package
  - 36 node model
  - Industry mentors
  - Expect results in 1/00



Thermal Design & Test

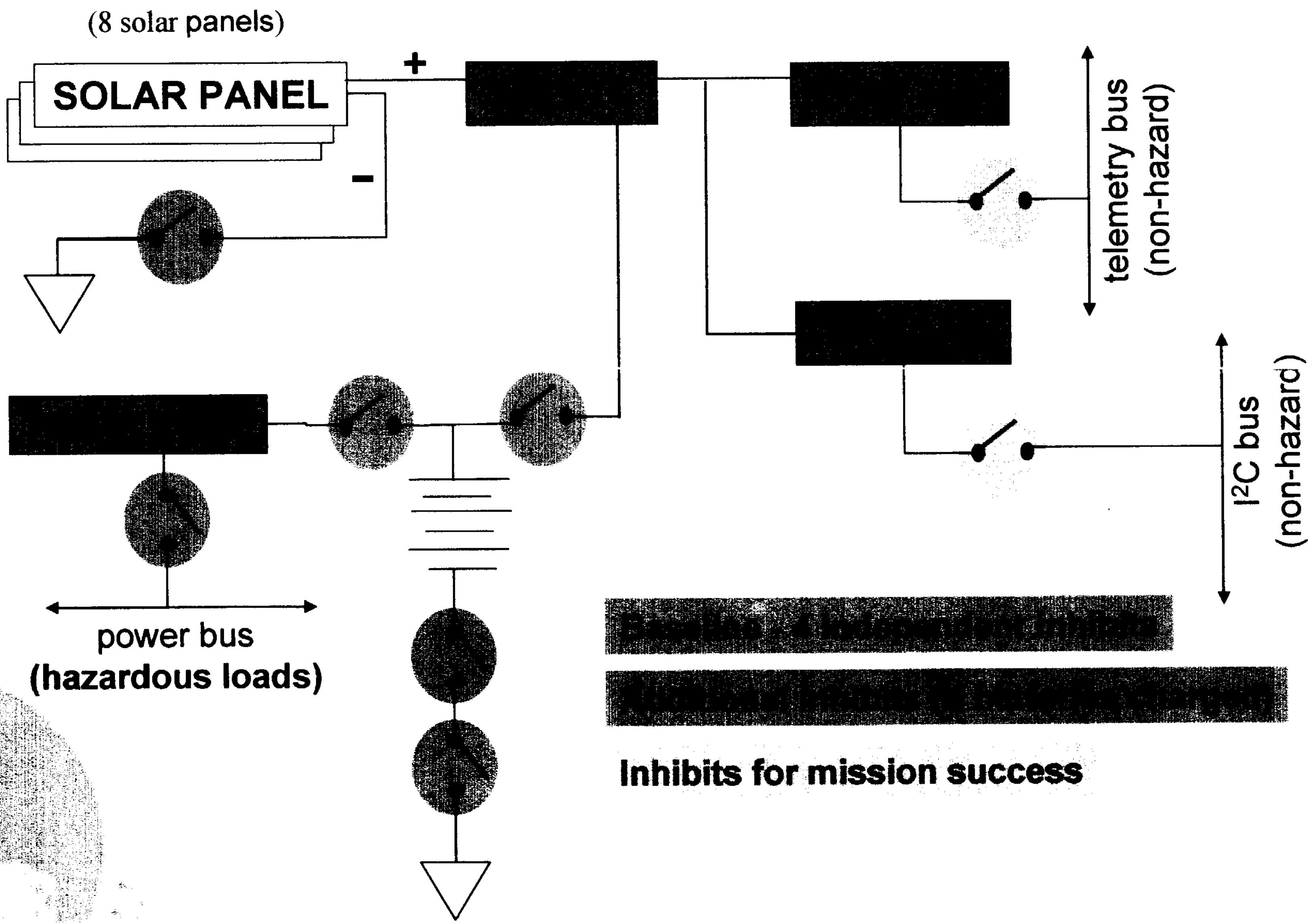
- Planned passive compensation techniques
  - Thermal coatings
  - Insulation
  - Modification of conductive paths

- Planned testing
  - Rudimentary in-house component level tests
  - System-level thermal-vacuum test
    - Lockheed Martin
    - Target date 11/00

Power Design

- Generation and Storage
  - Spectrolab triple-junction Ga As solar cells
  - Two 8-cell strings per panel
  - 9.3 W average power
  - 10 5AH Sanyo CADNICA NiCd Battery
- Power Regulation and Distribution
  - Regulated 12V and 5V using Vicor Regulator
  - Unregulated 11-14V Battery Voltage
  - Dallas 1-Wire serial bus for Power Switching
- Telemetry
  - Voltage and Current Telemetry via Dallas 1-Wire

Power Diagram w/Inhibits



Power Status

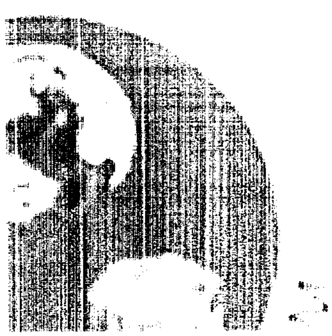
- Regulation circuitry
  - Prototype complete
  - EM PCB being manufactured

- Batteries in-house

- Solar Panels
  - Layouts designed
  - First fabrication meeting with Spectrolab 1/00

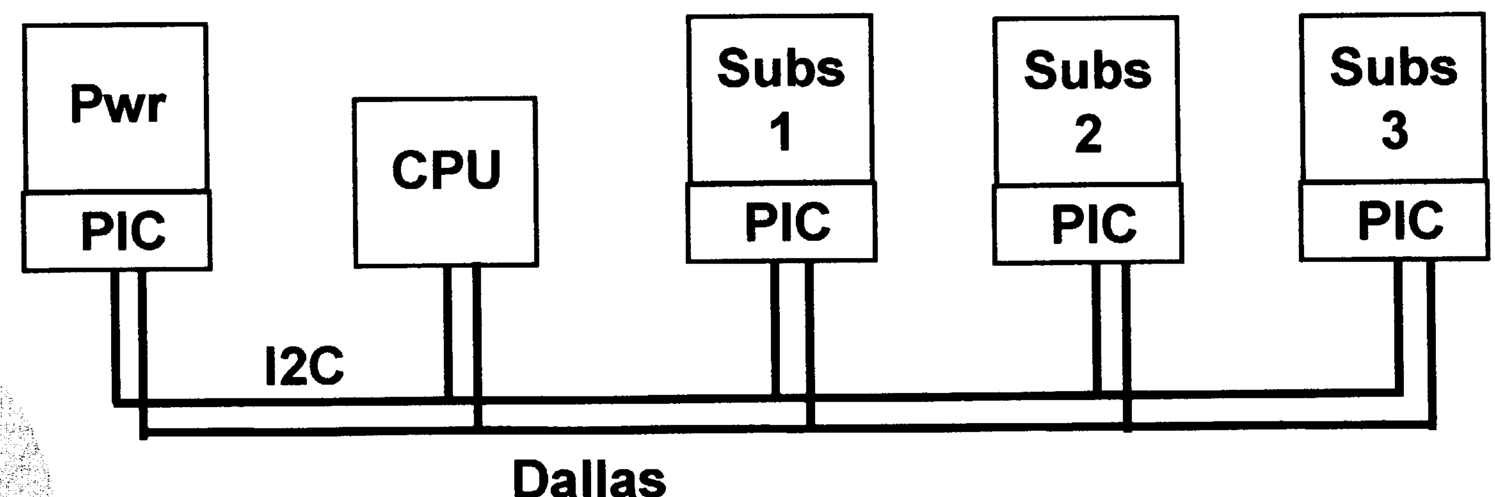
C&DH Design

- CPU
  - SpaceQuest V53 Based
    - 10MHz Processor
    - 6 Built-In Serial Channels
    - 1MB EDAC RAM
    - Built-In H/W to support S/W TNC
- Operating System
  - BekTek OS
    - RAM-based file system
    - Multi-tasking and multi-user
    - Includes S/W for TNC using AX.25
    - Includes H/W and S/W Debugging Utilities



C&DH Data Bus Design

- I2C serial bus
  - Commanding
  - Data transfer
  - PICMicro interfaces
- Dallas 1-wire
  - Telemetry
  - Power Switching



C&DH Status

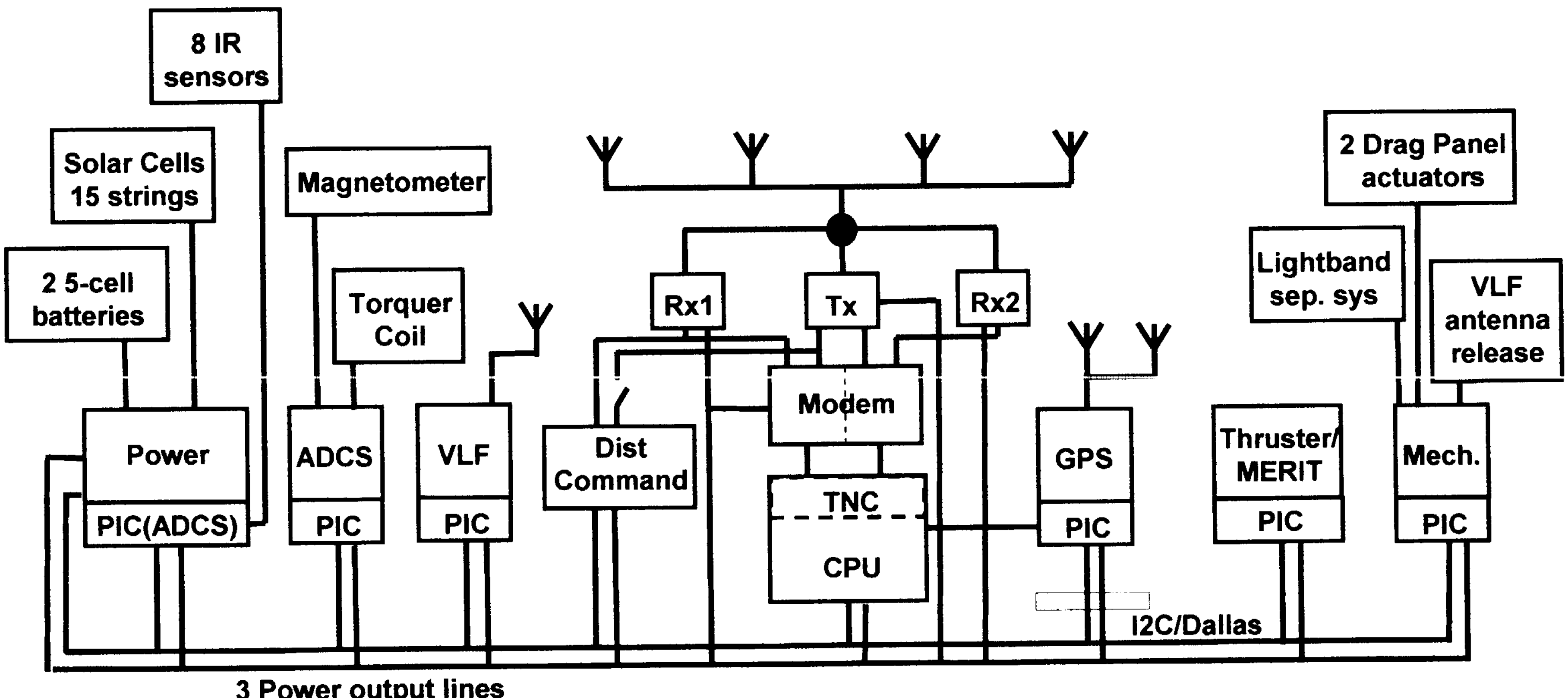
- PICMicro
  - Visual Basic testing suite (CoolTools™)
  - Bus and functionality libraries created for subsystem use
- Software
  - Architecture laid out
  - Dependencies defined
  - Development underway
- Main CPU
  - First EM in-house
  - Functional testing in progress using ARTIC board and EM
- Also…
  - Integration with communications system has begun

Communications Design

- Transmitter
  - 437 MHz
  - Hamtronics kit (SAPPHIRE heritage)
  - Modified to transmit at multiple power levels
- Receivers
  - 437 MHz and 145 MHz (backup)
  - Hamtronics kit (SAPPHIRE heritage)

- SpaceQuest modem
- SpaceQuest software TNC
- Circular antenna polarization
- Beacon based on Sapphire heritage
  - On/Off keyed status report of vehicle

System Block Diagram

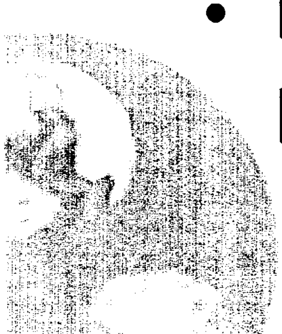


Communications Status

- Architecture and hardware finalized
- EM transmitter and receiver
  - Assembled and tested
  - Successfully communicate between computers
- Isolation/polarization circuitry
  - Prototypes complete
  - EM PCB being manufactured

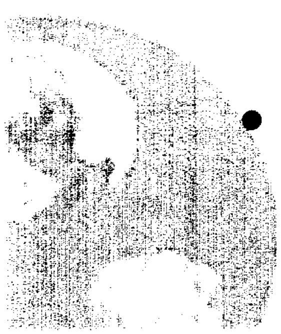
Attitude Determination

- Requirement: 10 deg, 1 deg/sec
- Light/IR sensor (SAPPHIRE heritage)
  - Array of phototransistors
  - On/off or linear analog differential configuration
- Honeywell HMC2003 3-Axis Magnetic Sensor
- ODDSS (Virtual Sun Sensor):
  - Estimates sun angle via solar panel currents
- Dedicated PICMicro® for onboard signal processing



Attitude Control

- Requirement: 15 deg (vel. dir.), 3 deg/sec
- Magnets & hysteresis rods
  - Sized for separation orientation
  - Designs and sizing techniques based on SSDL/Amsat heritage
- Aerodynamic drag stabilization
  - VLF antennas and drag panels
  - Sized to dominate magnetic torques
- Colloid thruster option



ADCS Status

- Behavior simulations via STK
- Determination hardware in-house
- Circuit & PICMicro® prototyping underway
- Magnets sized
- Additional drag body TBD

Safety, Integration, and Test

- Safety
  - hazards
  - hazard controls
  - inhibits
- Integration
  - satellite integration
  - stack integration
  - interfaces
  - ground equipment and servicing
- Test

Emerald Safety

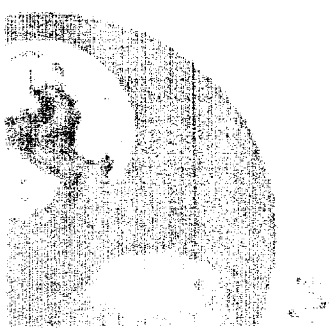
Hazards

- Power Subsystem
  - Hazard
    - NiCd batteries
    - provides power to deployable mechanisms and communication subsystem
  - Hazard Controls
    - battery box design (leakage, inadvertent short)
    - trickle charge mode prevents batteries from overcharging
    - switches to prevent solar power from reaching batteries
  - Inhibits
    - four independent and verifiable inhibits to prevent power from reaching hazardous loads
    - external port for inhibit verification
    - inhibit control tied to stack separation signal

Emerald Safety

Hazards

- Microthruster
  - Hazards
    - high voltage power supply
    - liquid propellant
    - thruster misfire
  - Hazard Controls
    - systems are discharged and off while on MSDS
    - clearance around power supply impedes arcing
    - very low-pressure propellant tanks
    - inert and stable propellant (NaI/Glycerol)
    - full testing of materials and assemblies to confirm structural integrity, material characteristics, etc.
    - not enough thrust for recontact with Shuttle



Emerald Safety

Hazards

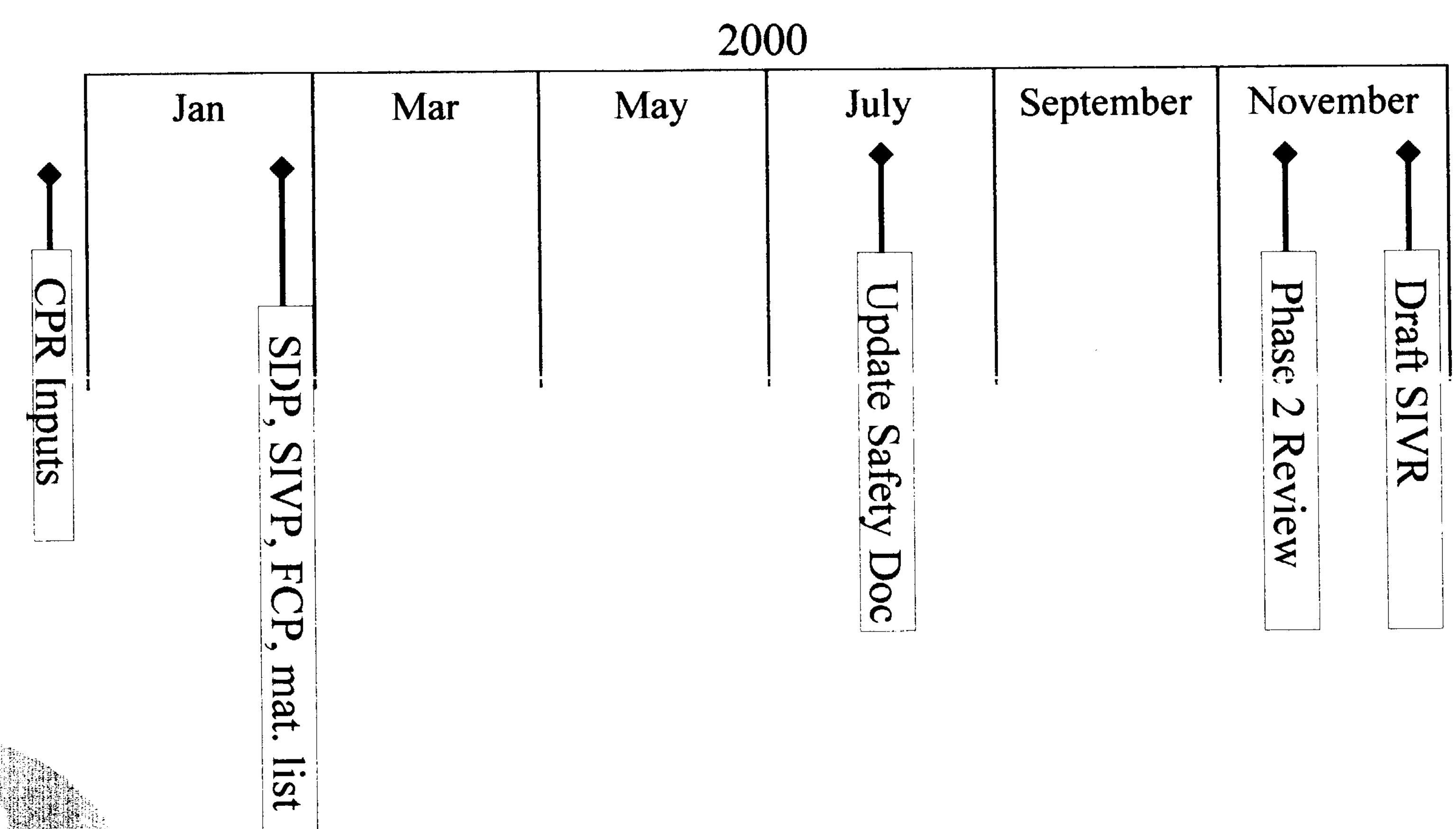
- Communication Subsystem
  - Hazard
    - inadvertent RF transmission
  - Hazard Controls
    - maximum transmission levels well below limits
  - Inhibits
    - two inhibit “requirement” satisfied by power subsystem
- Command/Control Subsystem
  - Hazard
    - EMI
  - Hazard Controls
    - worst-case interference is 20 MHz
    - boxes shield noise from MSDS and Space Shuttle

Emerald Safety

Hazards

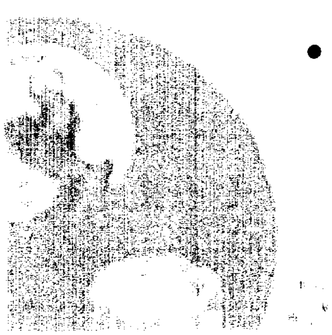
- Structure and Mechanisms
  - Hazards
    - structural failure
    - inadvertent deployment of mechanisms
  - Hazard Controls
    - full analysis and testing to show compliance with structural integrity requirements
    - full documentation of design, analysis, test, assembly, and integration
    - deployment actuators will not function without power
    - actuators can be treated as structural members (no credible failures)

Safety Documentation Schedule



Safety Documentation

- Deliverables
  - Flight Safety Data Package (22210 FSDP)
    - will comply with the following generic Hitchhiker payload hazard reports:
      - "Damage to STS Electrical Systems"
      - "Electromagnetic Interference with Space Shuttle Operations"
      - "Ignition of a Flammable PLB Atmosphere"
      - "Flammable Materials"
      - "Failure of Hitchhiker Payload Structure"
    - other hazard reports
      - deployable mechanisms
      - battery leakage/rupture



Safety Documentation

- Deliverables (cont.)
  - Structural Integrity Verification Plan (SIVP)
    - will report mass properties in English and metric units
    - will include Fastener Integrity Report and Fracture Control Plan in SIVP
  - Fracture Control Plan (FCP)
    - pressurized system fracture control (microthruster)
    - fracture control of mechanisms
    - transportation and load points
    - no composites

Safety Documentation

- Deliverables (cont.)
  - Ground Safety Data Package (22220 GSDP)
    - will comply with generic Hitchhiker payload hazard reports for Ground Support Equipment (GSE)
      - "Structural Failure of Ground Lifting/Handling Equipment (GHE)"
      - "Inadvertent Movement of Payload or GSE"
      - "Electrical Shock"
      - "Electrical Failure Causes Fire"
      - "Purge Pressure System Failure" (if needed)
      - "Use of Hazardous Materials/Substances" (RTV)

Safety Documentation

- Deliverables (cont.)
  - Materials List
    - will report mass properties in English and metric units
    - will submit Material Usage Agreement for all non-standard materials
      - no non-standard materials have been identified thus far
      - possible exception: NaI/Glycerol propellant
      - materials checked against MSFC-HDBK-527 (via MAPTIS)
      - critical fasteners will chosen from GSFC stock
      - many fasteners exempt from requirements

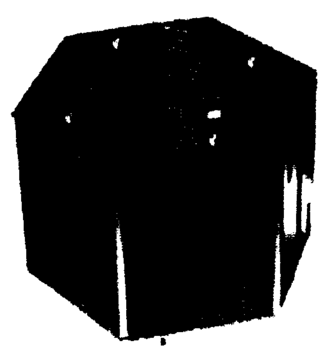
Emerald Integration

- Part 1
  - integration of subsystems into Beryl and Chromium
- Part 2
  - integration of Beryl and Chromium into Emerald stack
- Part 3
  - integration of Emerald stack with MSDS

Emerald Integration

Part 1 Flow

Mechanical Assembly → Power Verification → C&DH/I^{2}C System Verification → Communications System Verification → ADCS System Verification → Experimental Systems Verification → Primary/Secondary Structure Assembly → Functional/Sequence Test → Thermal Cycling & Thermal Vacuum Tests → Helmholtz Chamber Test → Functional/Sequence Test →



Emerald Integration

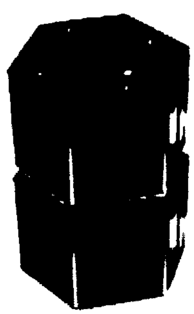
Part 1 Documentation

- 21110 Nanosatellite Assembly Document
  - structure
  - power/electrical
  - thermal
  - communications,command, and data handling
  - guidance, navigation, and control
  - payload/experiment
  - safety
- Assembly logs included in 21110

Emerald Integration

Part 2 Flow

1. Mechanical Assembly
2. Power Verification
3. C&DH/I²C System Verification
4. Communications System Verification
5. ADCS System Verification
6. Experimental Systems Verification
7. Primary/Secondary Structure Assembly
8. Functional/Sequence Test
9. Random Vibration Test
10. Sinusoidal Vibration Test
11. Shock Test
12. Functional/Sequence Test



Emerald Integration

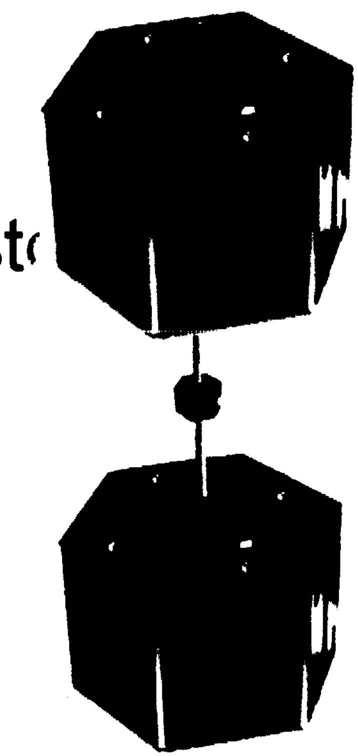
Part 2 Details

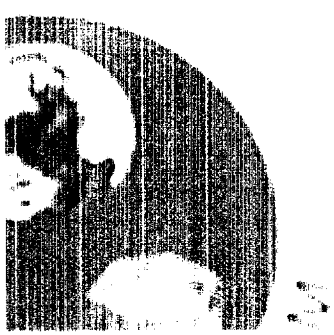
- Stack Integration
  - assembly of Emerald to be performed at Stanford
  - microthruster propellants will be loaded at Stanford
  - assembly logs at satellite and stack level
  - satellites shipped without charged batteries and with inhibits in place
  - manufacturing processes documented prior to assembly
  - assembly teams trained in handling procedures and fabrication skills

Emerald Integration

Part 2 Documentation

- 21100 Stack Assembly
  - assembly logs included in 21100
- 21120 Intersatellite Separation Syst
- 21200 Stack Interfaces
  - mechanical interface
  - electrical interface
  - ground support equipment interface





Emerald Integration

Part 3 Details

- Interfaces
  - no interface between Emerald and ORION
  - signal indicates separation of stack from MSDS
    - MSDS timing of separation signal
    - investigating use of Emerald timers (backup)
    - number of orbits before stack separation
  - external port on each Emerald satellite provided for
    - battery charging
    - external power
    - inhibit verification
    - debugging

Emerald Integration

Part 3 Details (cont.)

- Ground Equipment and Servicing
  - load points
    - currently designed for dual handles attached to the top of the stack through four load bearing members
    - willing to accommodate any ground handling equipment
      - eyebolts, etc. can be attached to the four load points
    - no special requirements for equipment

Emerald Integration

Part 3 Details (cont.)

- Ground Equipment and Servicing
  - battery charging
    - trickle charging method
    - 10 hour charge time
    - 0.5 A charge current
    - 16.5-17 V charge voltage
    - can be accomplished at Goddard or KSC
    - <u>no</u> on-orbit battery charging prior to MSDS separation
  - propellant
    - no need for fueling or de-fueling at Goddard or KSC
    - propellant will be stable during transport and delays

Mechanical Test Plan

MECHANICAL TESTS	Component	Satellite	Stack
Strength	analysis	analysis	analysis
Sinusoidal Sweep Vibration	analysis	NASA Ames	NASA Ames
Random Vibration	required 7002	NASA Ames	NASA Ames
Acoustics			NASA Ames
Self-Induced Shock	required 7002	required 7002	required 7002
Externally-Induced Shock			America West
Modal Survey		NASA Ames	NASA Ames
Pressure Profile	Stanford		
Appendage Deployment		Stanford	Stanford

- Dec 1999 - mass model sine sweep, random vibe
- Jan 2000 - mass model externally induced shock
- Early 2000 - component and appendage testing
- Summer 2000 - stack testing

Thermal Test Plan

THERMAL TESTS	Component	Satellite	Stack
Thermal/Vacuum Thermal Cycle	Stanford	Loral	Loral
Ambient Pressure Thermal Cycle	Stanford	Loral	
Thermal Balance			Loral
Temperature-Humidity			
Bakeout	Stanford	Loral	Loral
Leak Test (sealed components)	Stanford		

- Early 2000 - EM thermal tests at Loral or LMMS
- Testing to verify thermal model in IDEAS

EMI Test Plan

EMI TESTS	Component	Satellite	Stack
Conducted Emissions			
Radiated Emissions	Stanford	Stanford	
Conducted Susceptibility			
Radiated Susceptibility	Stanford	Stanford	

- Power off prior to MSDS separation, no conducted susceptibility

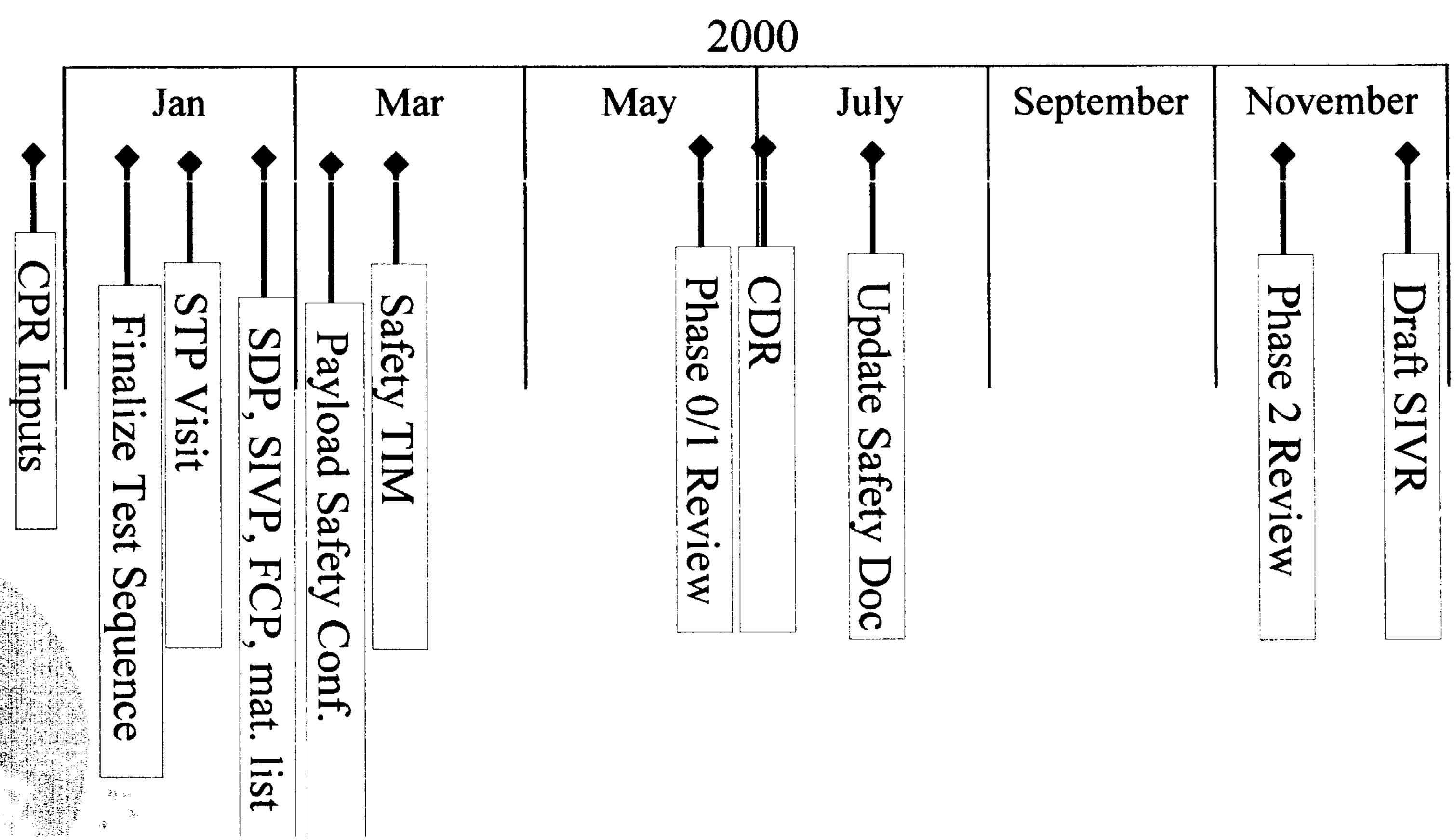
Functional Test Plan

FUNCTIONAL TESTS	Component	Satellite	Stack
Electrical Interface	Stanford	Stanford	Stanford/AFRL
Comprehensive Performance	Stanford	Stanford	
Failure-free Performance	Stanford	Stanford	
Mechanical Interface	Stanford	Stanford	Stanford/AFRL
Calibrations	Stanford	Stanford	
End-to-End Compatibility Tests & Mission Simulations			Stanford
Life Test	Stanford		
Mass Properties Verification	Stanford	Stanford	analysis

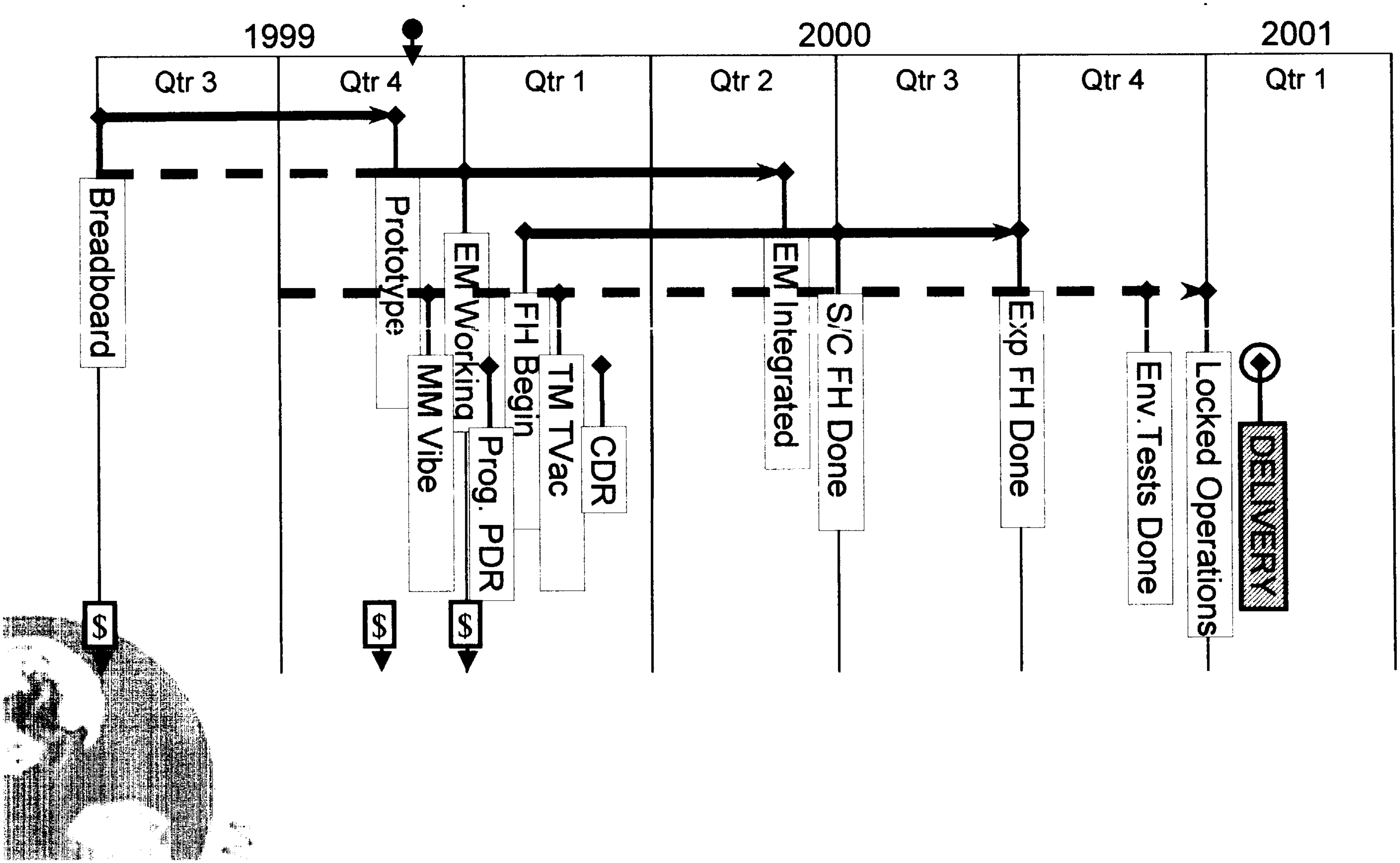
Overall Schedule

Safety, Integration, and Test

- Phase 0/1 Safety Review
- Safety Documents: SIVP, FCP, FSDP, GSDP
- Phase 2 Safety Review



Master Schedule



More Information

http://ssdl.stanford.edu/emerald/safety