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**Center for Space Power and Advanced Electronics  
Auburn University**

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Manager of Engineering Science**

**Dr. Richard Hopkins  
Manager of Electro-Optical Materials**

**Westinghouse Science and Technology Center**



# VALUE OF PARTICIPATION IN A CCDS TO AN INDUSTRIAL PARTNER

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NASA Office of Commercial Projects  
Washington, DC  
May 14, 1991



Westinghouse  
Science & Technology Center

# Westinghouse Is Involved In Space Activities: Its Commercial Activities Are Expanding As A Result Of Its CCDS Participation

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- Space Division
- Commercial & Civil Space Dept.
- Science & Technology Center
- NASA CCDS's

# The Westinghouse Space Division Applies Its Advanced Electronic Capability to the Analysis, Design, Development Production and Support of Space Related Missions

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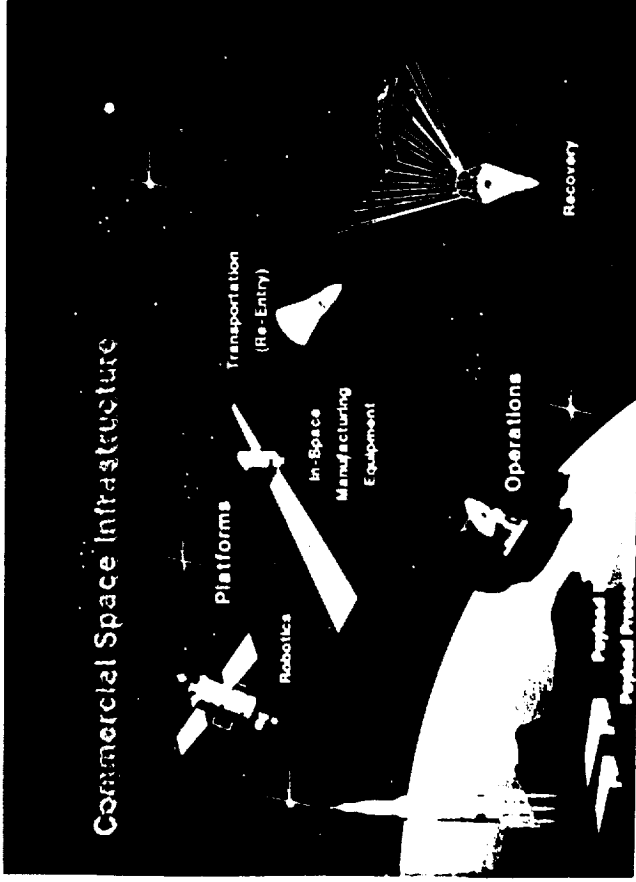


*DMSP (Block VI Operational Line Scan) (OLS) systems combine sensors, on-board data processing and broad-band digital recording to provide wide dynamic range imagery. Block V sensors have successfully demonstrated many years of on-orbit continuous operation.*

- Earth Observation Sensors
- Control and Data Management
- Signal Processing
- Space Defense

# The Westinghouse Commercial & Civil Space Department Is Committed to Development the Infrastructure for Low Cost Access to Space

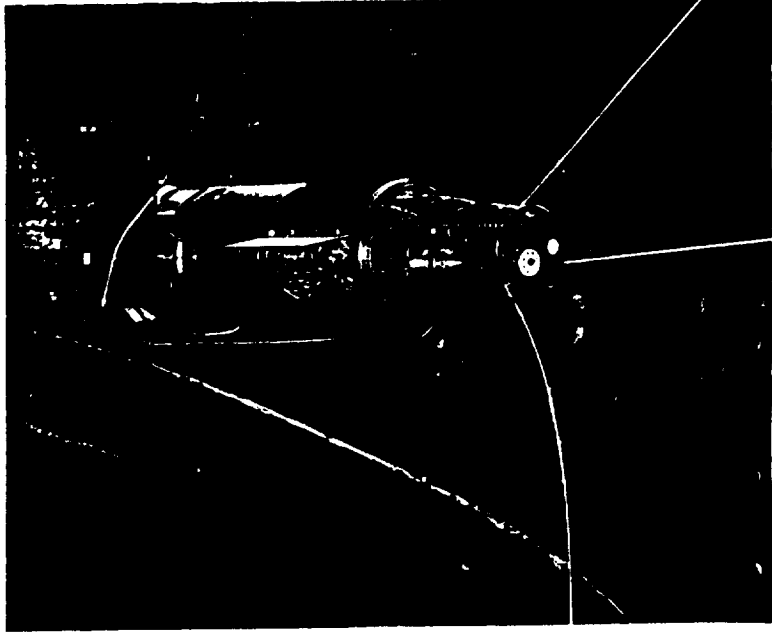
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- Responsible for the Systems Engineering and Service Module for the COMET project.
- Operates Astro Tech for payload processing.
- Will actively pursue all aspects of commercial launch, on-orbit services, and recovery.
- Maintains active interactions with several CCDS's.

# The Westinghouse Science & Technology Center Develops Products & Technologies for Westinghouse Divisions

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## Major Space Activities

- SPEAR Program
- Hyper-Conductor Generator
- TEM-Pump for SP-100
- Space Furnaces
- SMES Program
- Participation in CCDS's
  - Auburn
  - Clarkson

# Westinghouse, In Conjunction With The Auburn CCDS, Is Developing Space Related Products and Technologies

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## Products:

- Intelligent fault protection system based on neural network technology
- Critical element of adaptive (autonomous) controls for electrical power systems and components.
- Terrestrial applications can expedite commercialization.

## Technologies:

- High temperature, radiation-hard electronics based on SiC
- Enabling technology for highly reliable and long-lived space based electronics.
- Extensive commercial and military applications.

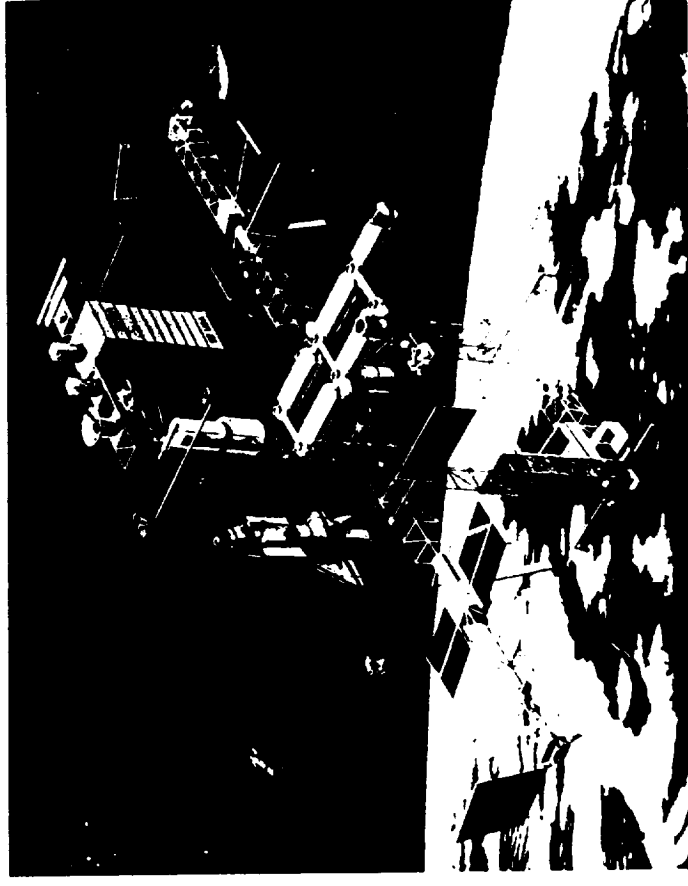




# Intelligent Adaptive Controls Can Improve The Reliability of Space Power Systems

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- Minimizing human response time and errors in correcting faults, and properly interpreting fuzzy sensor signals.
- High level autonomous operation
- Detecting incipient faults
- Impact
  - Improved availability
  - Reduced fault severity
  - Reduced maintenance time



# The Development of the Product Need, Concept and Implementation Has Utilized Significant University Participation

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## W - STC

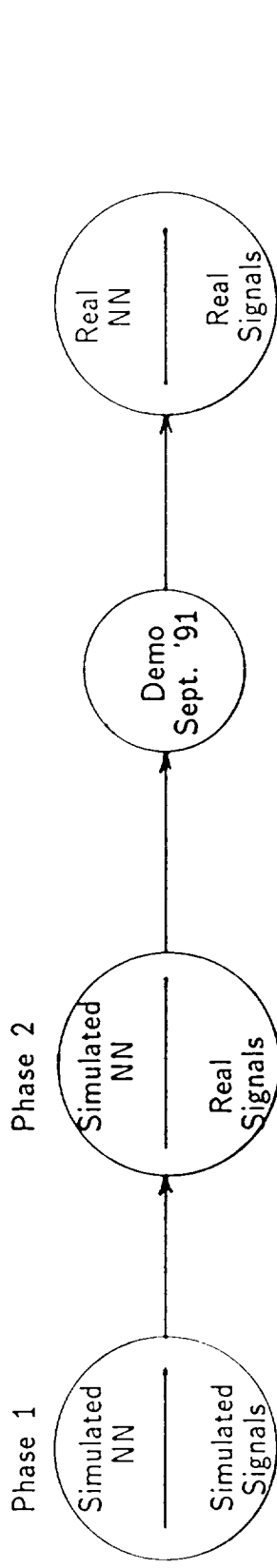
- Selection of neural network applications
- Integration of neural network with hardware
- Training of neural network with data
- Laboratory set-up and demonstration
- Commercialization

## Auburn U

- Consultation on neural network techniques
- Development of user-friendly neural network software
- Development of parallel processor computer system on card
- Awareness of current developments in neural network hardware and paradigms

# Intelligent Fault Protection Development Accomplishments and Status

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Applied To:

- Power System
- Power Component (Motor Controller)
- Power Source Motor Controller Motor
- (W) Commercialization Maritime Industry
- Space Applications
- Central Control Systems

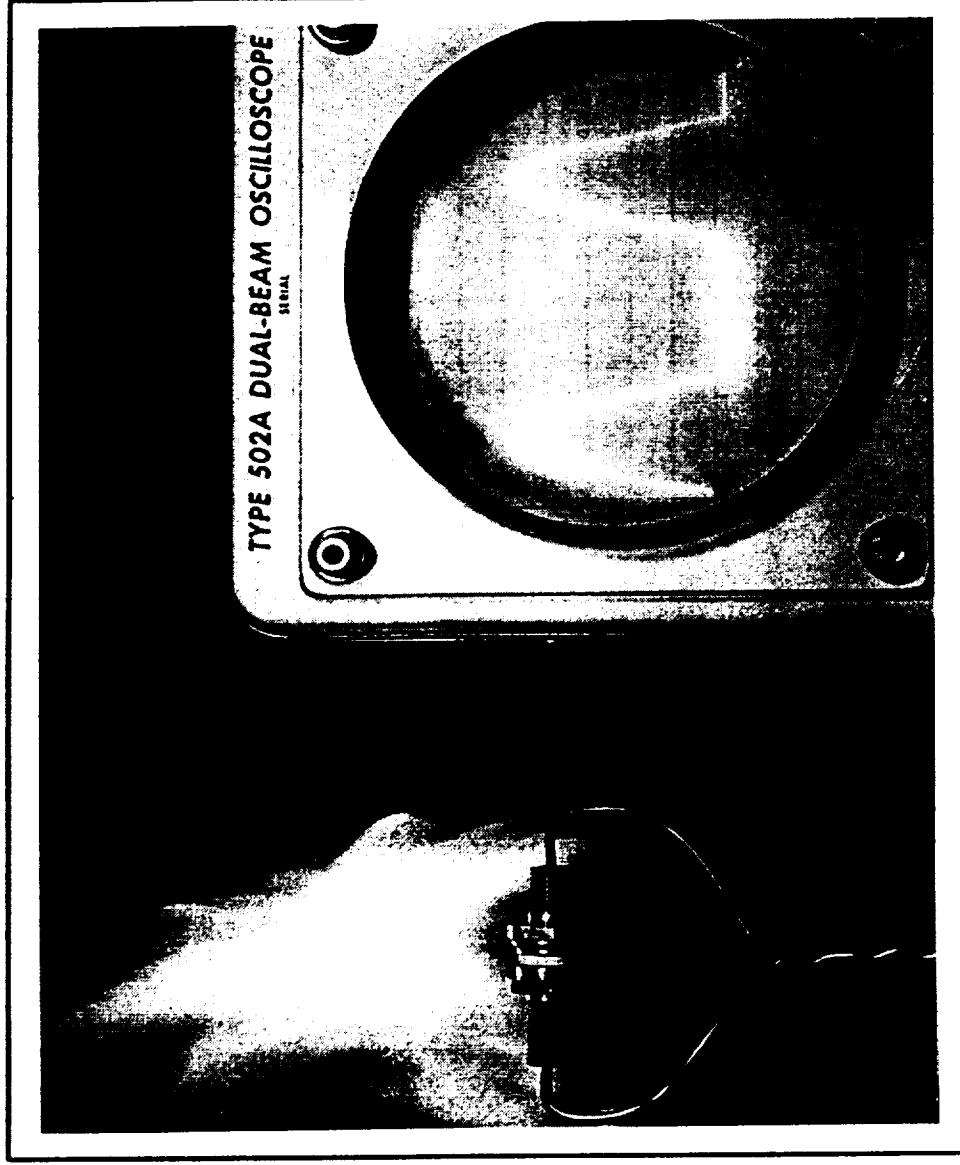
Features:

- Proof of concept via fault classification
- Real-world interface
- C-language program (fast)
- Realistic input signals
- Flexible design choices
- Fault Detector/Classifier Plug In Board
- Real-time response

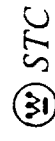


# Silicon Carbide (SiC) - The Semiconductor With the Right Stuff

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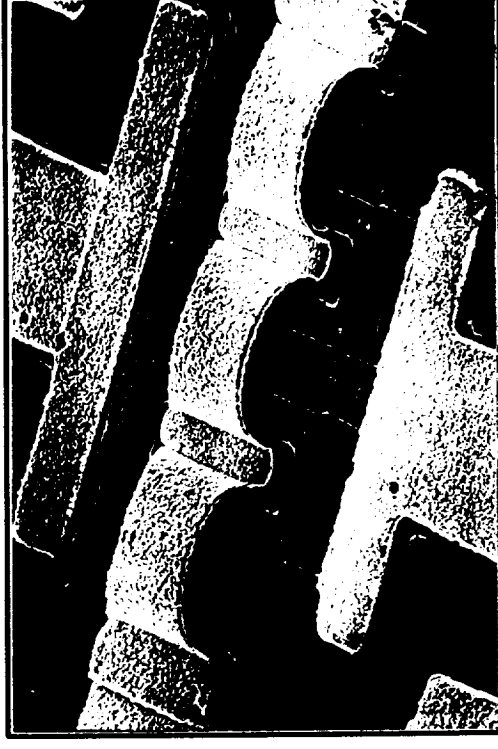


**Rectification in a  
Hot, Chemically  
Active  
Environment**



# SILICON CARBIDE ELECTRONICS

- **High Temperature, RAD Hard Devices are an Enabling Technology for Advanced Ultrareliable Space Electronics**
  - **Secure, Uninterrupted Satellite Communications**
  - **Significant Reduction in Satellite Payload Cooling and Weight**
  - **Compact Reactor Diagnostics and Thrust Controls for SEI Missions**



- **Silicon Carbide is a Pervasive Technology with Many Commercial Applications**

# Silicon Carbide Beats Nearest Competitor

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## High Power

- 10X Power Density
  - Reduced Parts, Size, Cost
  - New Capabilities: Stealth Detection

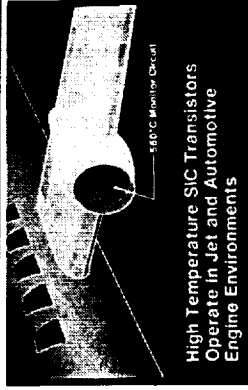
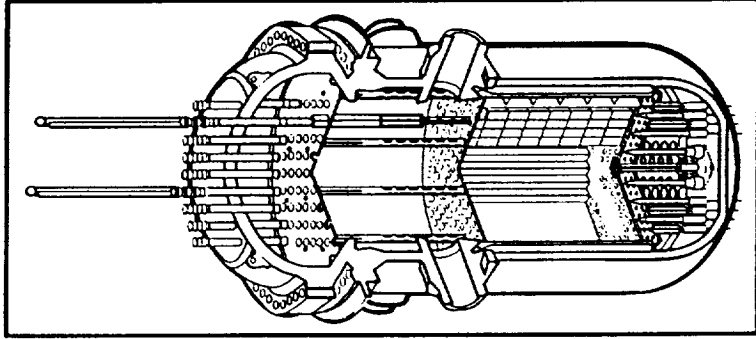
## High Temperature

- 650° Operation vs. 150°
  - Less Cooling, Weight, System Cost
  - 1,000X Reliability

## Radiation Hard

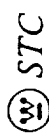
- 20X Gamma, 50X Neutron Resistance
  - First In-Core Electronics for Protection and Control
  - Reduced Cabling, Penetrations and Cost
  - New Services

Transistors for  
Long-Range  
Surveillance



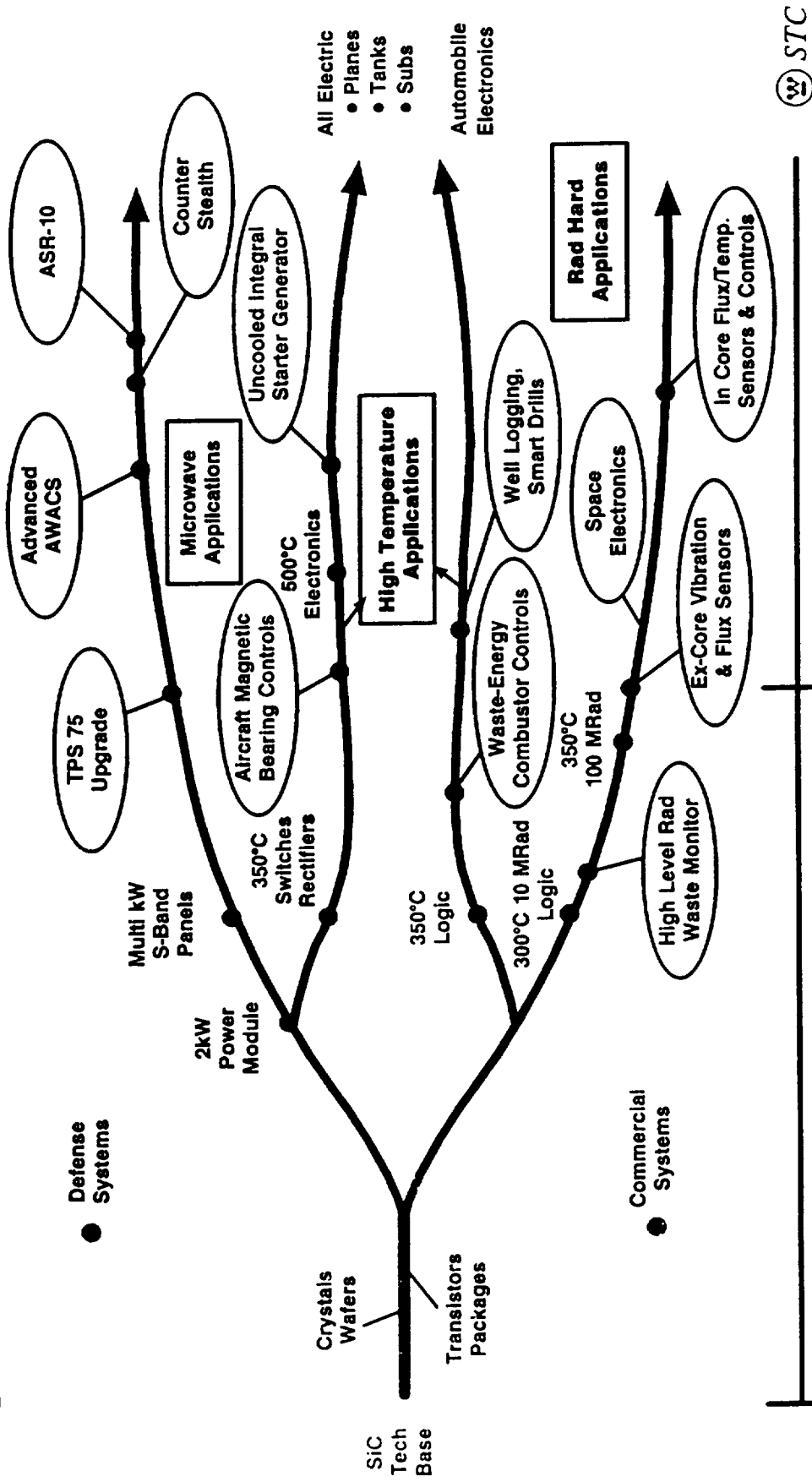
Electronics in  
Severe Environments:  
All-Electric Vehicles

In-Core Flux and  
Temperature Measurements  
at 100 MRad 350°



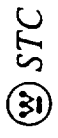
# Silicon Carbide Payoff

## Significant New Business



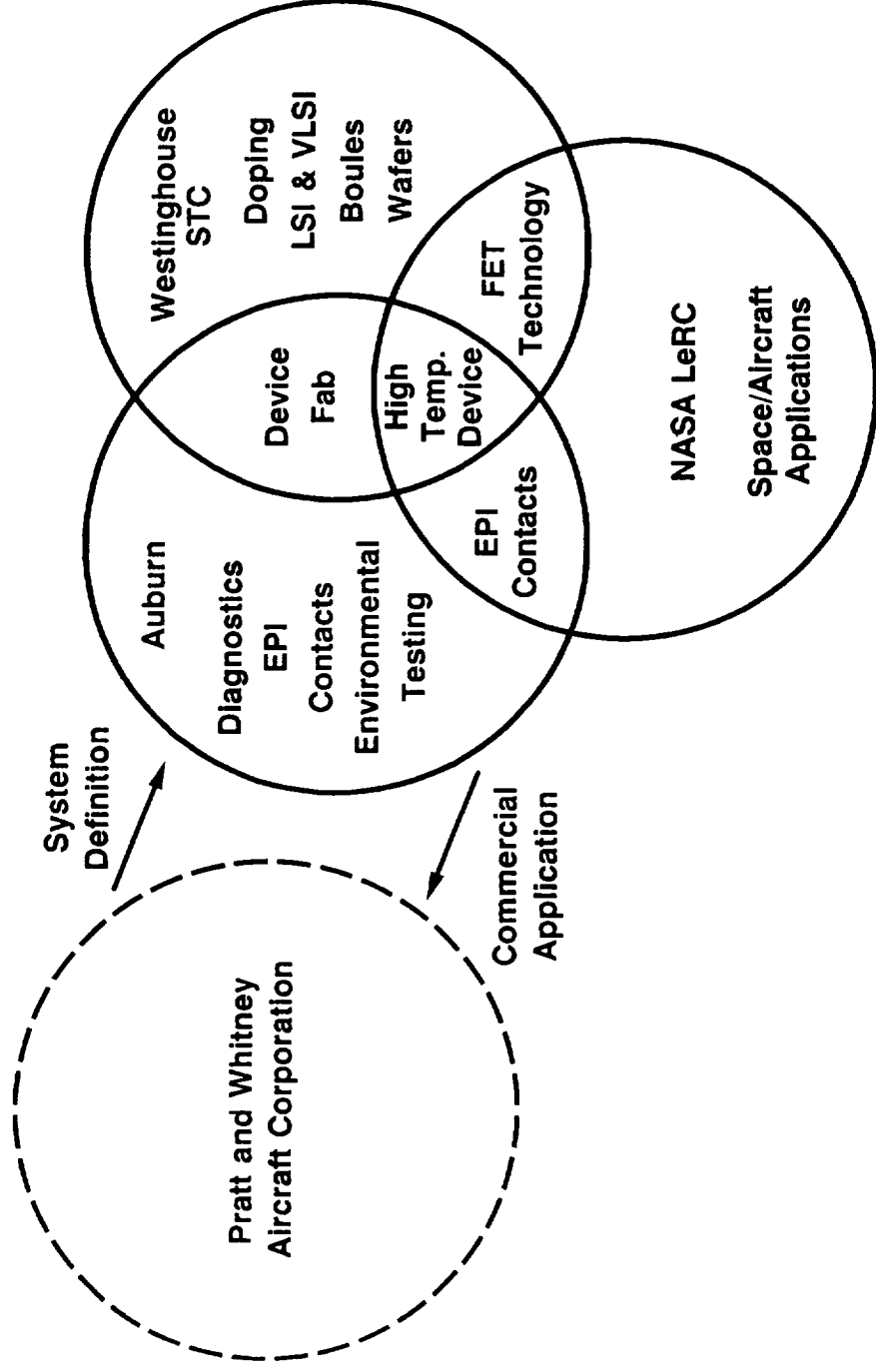
1990

1995



# THE AUBURN CCDS PARTNERSHIP

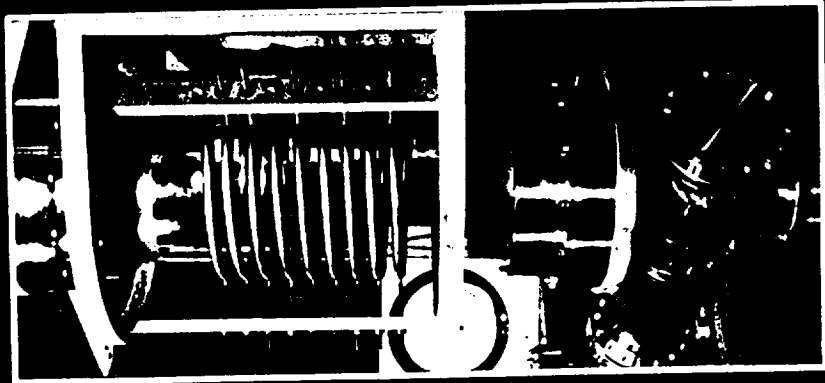
Complementary Skills Linked to Accelerate Silicon Carbide Electronics to Commercialization



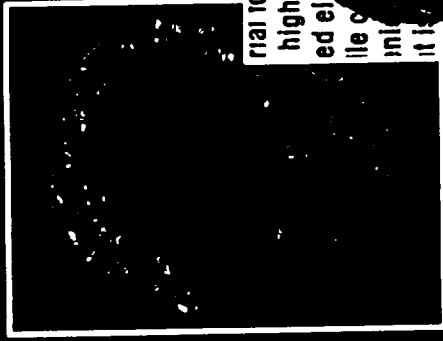


# SIC CRYSTAL GROWTH

- High Power Microwave
- High Temperature Microelectronics
- Rad Hard Devices



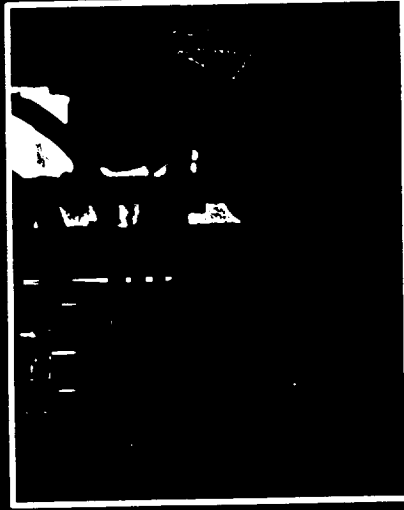
High Purity Growth System



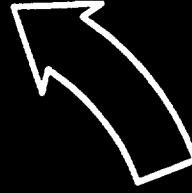
Wafer

material for fabrication of high power high temperature electronic systems. It is grown in a commercial device where

Boule

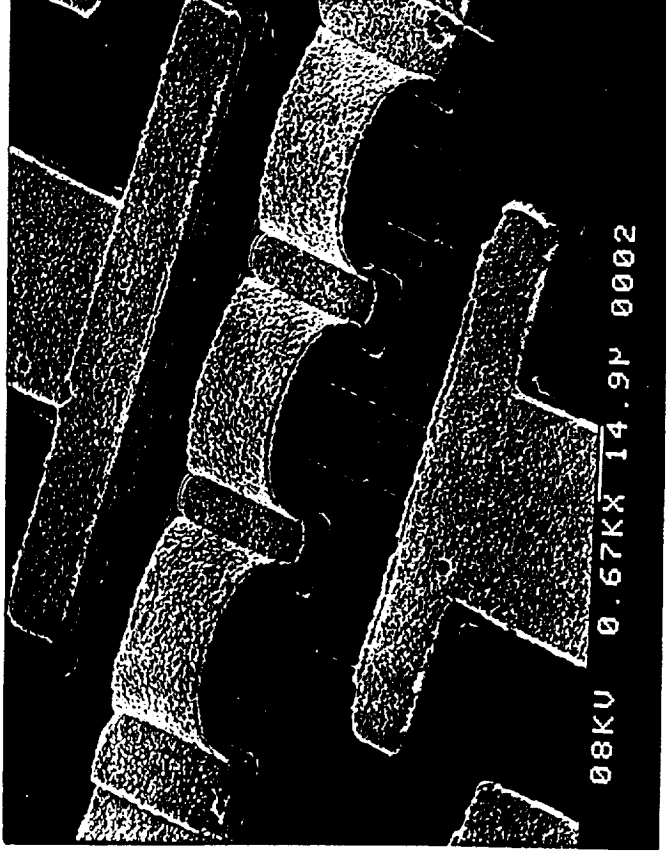


Vapor Transport Growth

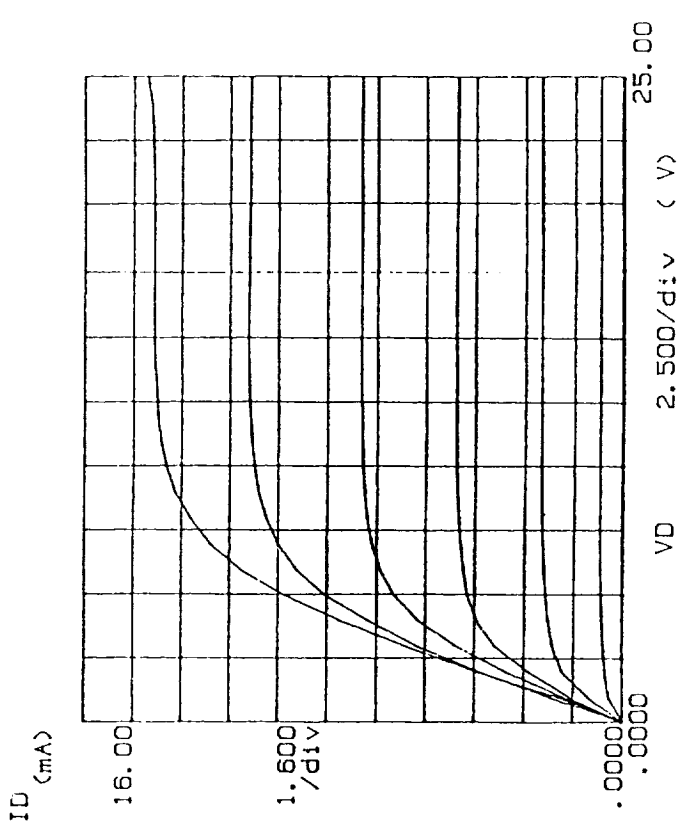


# SiC Device Development At STC For Microwave Power Transistors

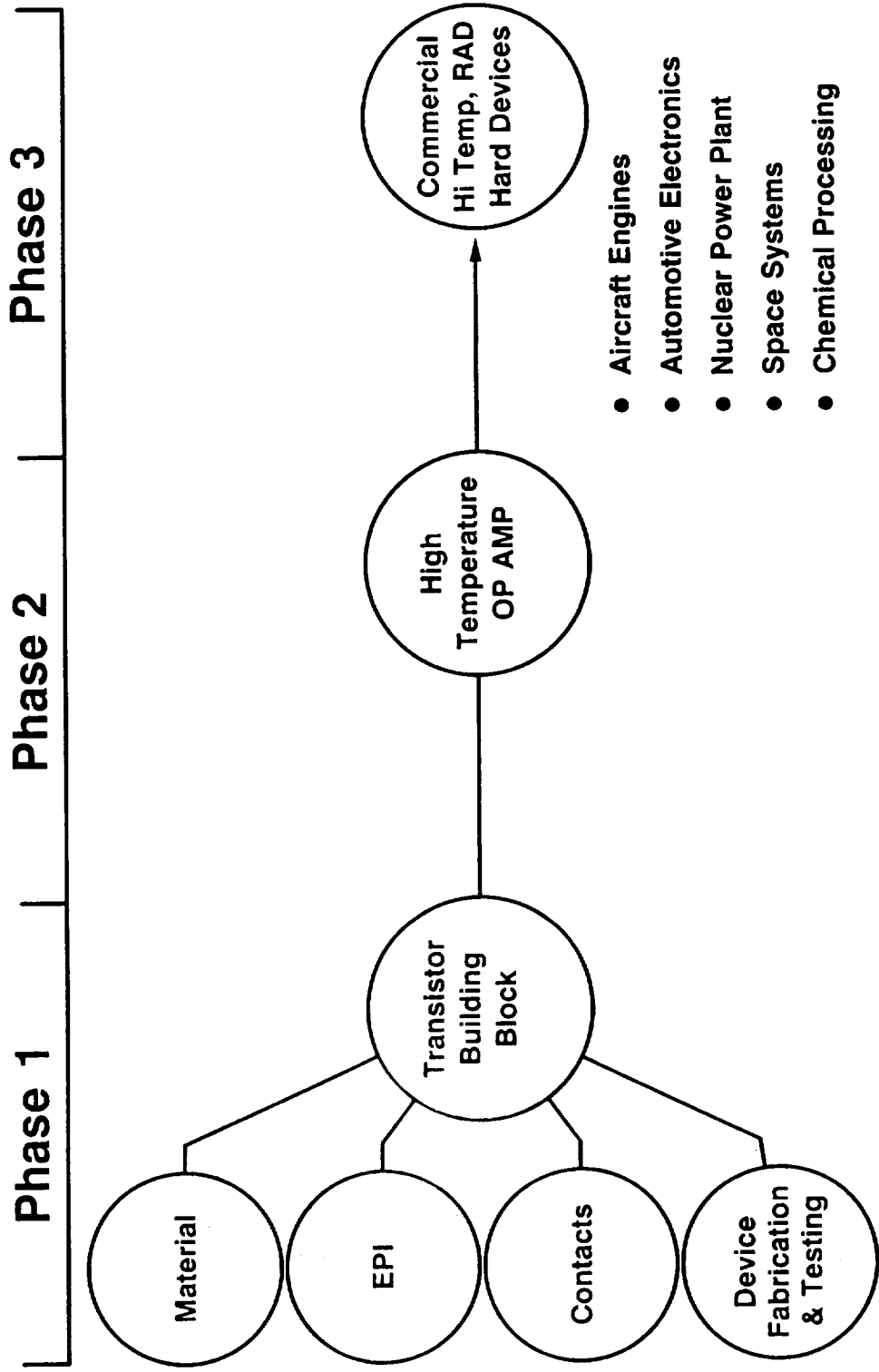
6-Gate  $\mu$ -Wave Transistor



dc Characteristics

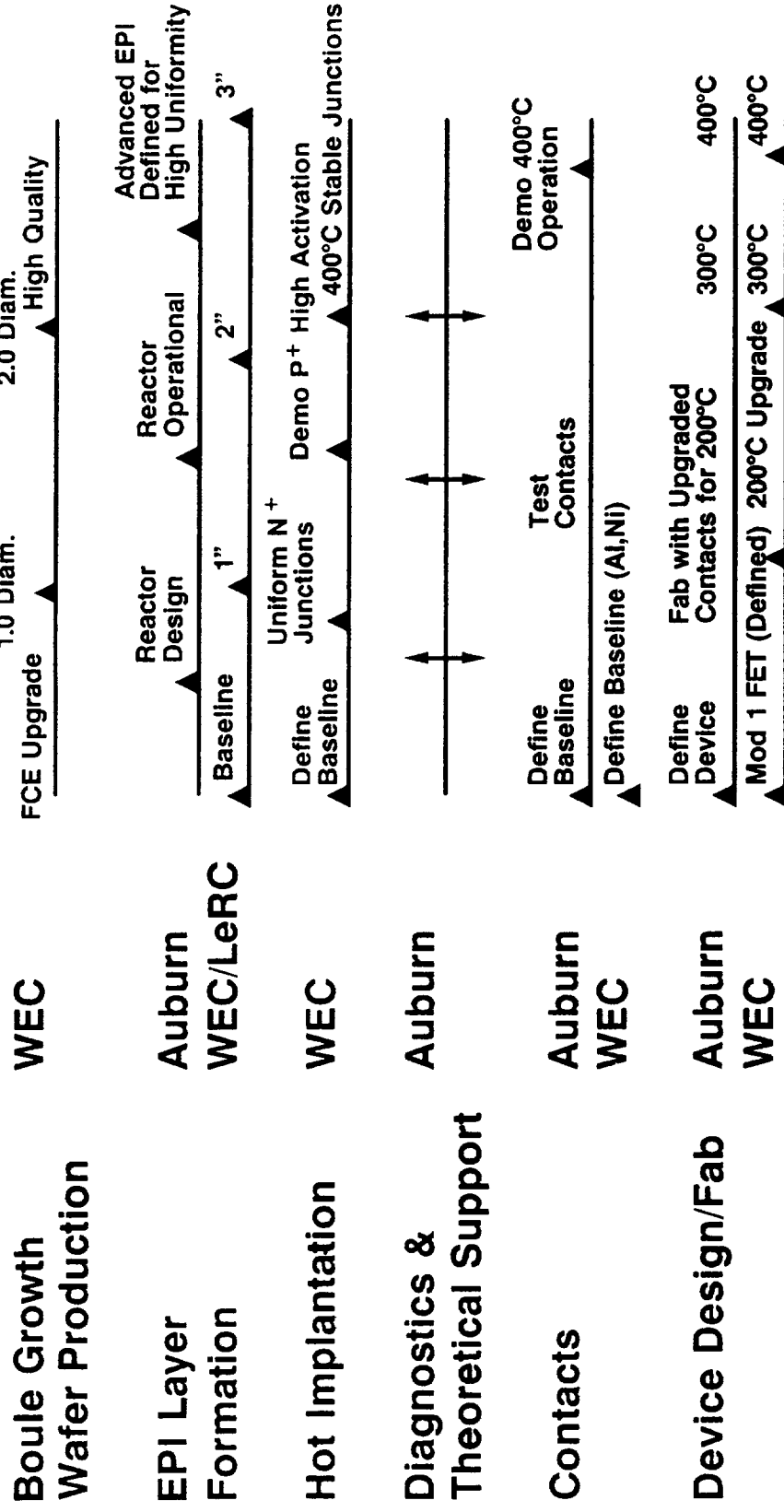
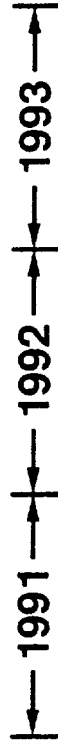


# A SILICON CARBIDE MICROELECTRONIC DEVICE DEVELOPMENT PATH HAS BEEN DEFINED



# THE CCDS PROGRAM WAS INITIATED IN 1991

Goal: Devices that Operate at 200-500°C with Acceptable Lifetime



# THE CCDS SILICON CARBIDE EFFORT IS ON SCHEDULE

- Working Relationships Established
- First Exchange of Devices and Test Data Accomplished

## Auburn

5 Faculty, 4 Students

Committed

Topics

Structure Modeling  
 Contact Metalization Systems  
 Advanced Epitaxy Techniques  
 SiC Growth Kinetics  
 Surface Chemistry  
 Structural Diagnostics

Status

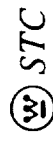
- RBS Analysis of Initial WEC Contact System
- Design of New EPI Reactor Initiated
- Polytype Stability Calculations Made

## Westinghouse

6 Scientists, 4 Technical Support

- Boule Growth Scale-Up
- Low Defect Wafer Production
- Hot Ion Implantation Junction Formation
- Device Design / Fabrication

- Furnace Scale-Up Design Complete
- Furnace Fabrication Initiated
- Successful 1.5" Diameter Boule Growth



# The NASA-CCDS at Auburn University Has Met All of Westinghouse's Expectations

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- Excellent leadership.
- Impressive R&D programs.
- Stimulation of University environment - participation of students.
- Full cooperation of industrial partners.
- Cooperative participation by government labs.
- Opportunity to develop, in partnership with Auburn University, technologies and components for space.

