N93-71883

Sensor Autodiagnosis and Autocalibration

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P-13

Technology Needs:

- Develop capability to enable in-situ, autonomous sensor failure detection/diagnosis and sensor self calibration

Technology Challenge:

- Model sensor with autodiagnostic/autocal capabilities
- Incorporate autodiagnostic/autocal capabilities without major modification or redesign of sensor

Benefits:

- Increased sensor reliability
- Reduced sensor maintenance requirements
- Enables sensors to be fault tolerant
- Eliminates "false alarm" shutdowns

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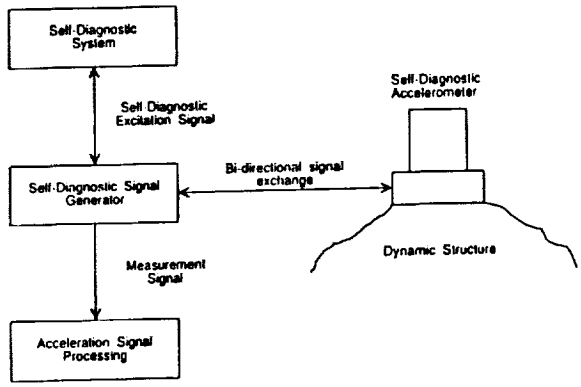
Autodiagnostic and Autocalibration Program

Current Program:

- Develop and implement autodiagnostic/autocalibration capabilities into piezoelectric accelerometer.
- Test on MSFC TTBE.

Augmented Program

- Develop and extend technology to other types of sensors such as:
  - Flowmeters
  - Thermocouples
  - Pressure transducers



Plume Diagnostics

Technology Needs:

- Develop plume diagnostic capabilities for ground test and flight rocket engines.

Technology Challenge:

- Develop engine ground testing plume diagnostic capabilities
- Develop engine mounted optics and spectrometer.
- Develop codes to extract safety, health and performance information from plume spectral data.

Benefits:

- Enables rocket engine safety, health and performance monitoring with a single instrument.

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Plume Diagnostics Program

Current Program:

- Monitoring TTBE spectral emisisons (OPAD).
- Monitoring emissions across the TTBE exit plane.
- Development of nozzle mounted optic assembly and high resolution spectrometer for SSME.
- Develop code to extract species/alloy information from plume spectral data.

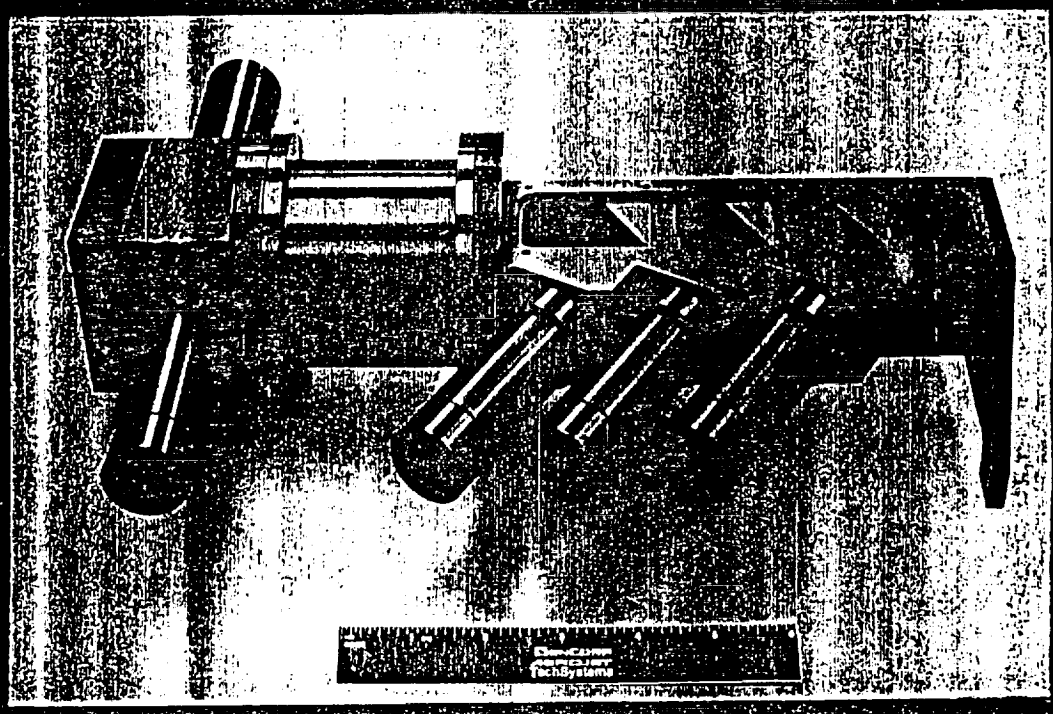
Augmented Program

- Develop code(s) to model and predict spectral emissions from a high pressure/high temperature combustion process.

GENCORP AEROJET

Breadboard FPI Spectrometer Fabrication Is Complete

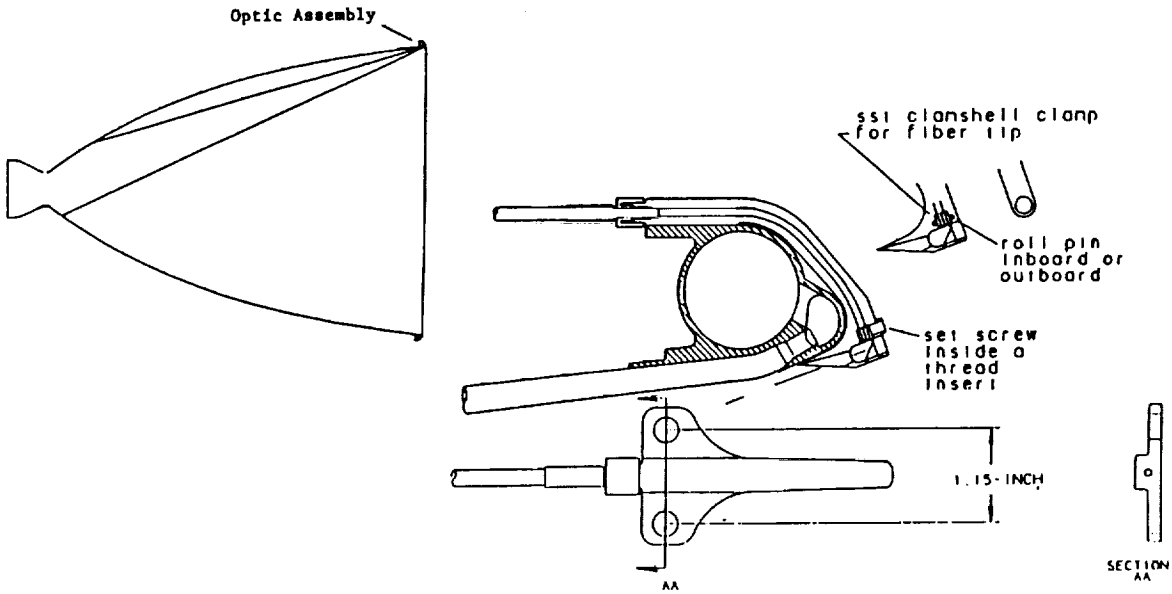
Propulsion Division



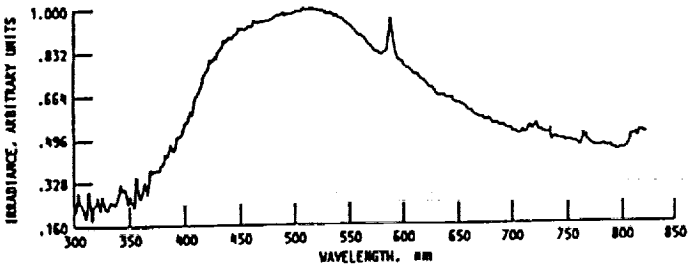
SPACE PROPULSION TECHNOLOGY DIVISION

NASA Lewis Research Center

SSME Nozzle/throat Optic Assembly

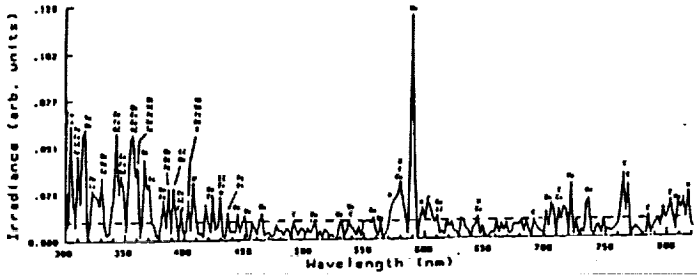


Separation and Extraction of Plume Phenomena



"Raw" Spectrum

Digital Filter



"Processed" Spectrum

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FAILURE MODELING

NEED: CAPABILITY TO MODEL FAILURE AND DEGRADATION BEHAVIOR OF ROCKET ENGINE, BOTH STEADY STATE AND TRANSIENT.

APPROACH:

- DEVELOP GENERIC SUB-COMPONENT FAILURE MODELS (BEARINGS, INJECTORS, MANIFOLDS).
- DEVELOP TOOL FOR LINKING SUB-COMPONENT FAILURE MODELS TO DEFINE THE SYSTEM MODEI..
- VERIFY FAILURE MODEL CAPABILITY USING OPERATION DATA FROM BOTH TEST AND FLIGHT ENGINES.
- USE FAILURE MODELS TO DEVELOP DIAGNOSTIC, PROGNOSTIC, AND CONTROL ALGORITHMS TO BE USED IN HEALTH MONITORING SYSTEM FOR PRESENT AND FUTURE ENGINES.
- USE FAILURE MODELS TO PROVIDE FEEDBACK TO THE DESIGN AND DEVELOPMENT PROCESS.

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FAILURE MODELING

BENEFIT:

- PROVIDE FAILURE DATA TO DEVELOP ALGORITHMS AND HEALTH MONITORING SYSTEMS PRIOR TO ACTUAL ROCKET ENGINE DEVELOPMENT.
- ACTUAL ROCKET ENGINE FAILURES ARE BOTH COSTLY AND INFREQUENT. FAILURE MODELS CAPABILITY WILL PROVIDE A "RICH" FAILURE DATABASE WITH MINIMUM HARDWARE AND SAFETY IMPACTS.

DELIVERABLE:

Current:
- o TOOL FOR LINKING SUB-COMPONENTS TO DEFINE SYSTEM MODEL
- o INJECTOR FAILURE MODEL SPECIFIC TO SSME

Augmented:
- o GENERIC FAILURE MODELS OF KEY ROCKET ENGINE SUB-COMPONENTS
- o VALIDATE FAILURE MODELS CAPABILITY USING SSME DATA

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MASS DATA STORAGE AND RETRIEVAL

NEED:
- o A validated engine flight data recorder, based on either digital or optical theory, that allows for increased bandwidth storage capability. Coupled with validated expert system and data base technologies to provide extensive archival search and retrieval techniques for the massive and disparate data required for diagnostics and prognostics.

APPROACH:
- o Design and develop advanced techniques for fast access and large bandwidth for mass data storage and retrieval.
- o Design and develop techniques and database with smart retrieval capabilities.

MASS DATA STORAGE AND RETRIEVAL

BENEFITS:

- Ability to provide fast access and large mass data storage capability. Required to accommodate future engine and instrumentation needs.
- A highly correlated, compatible, and expandable retrieval system that provides more rapid turn around time, more efficient use of resources more thorough use of review data, and more consistent historical trending records.

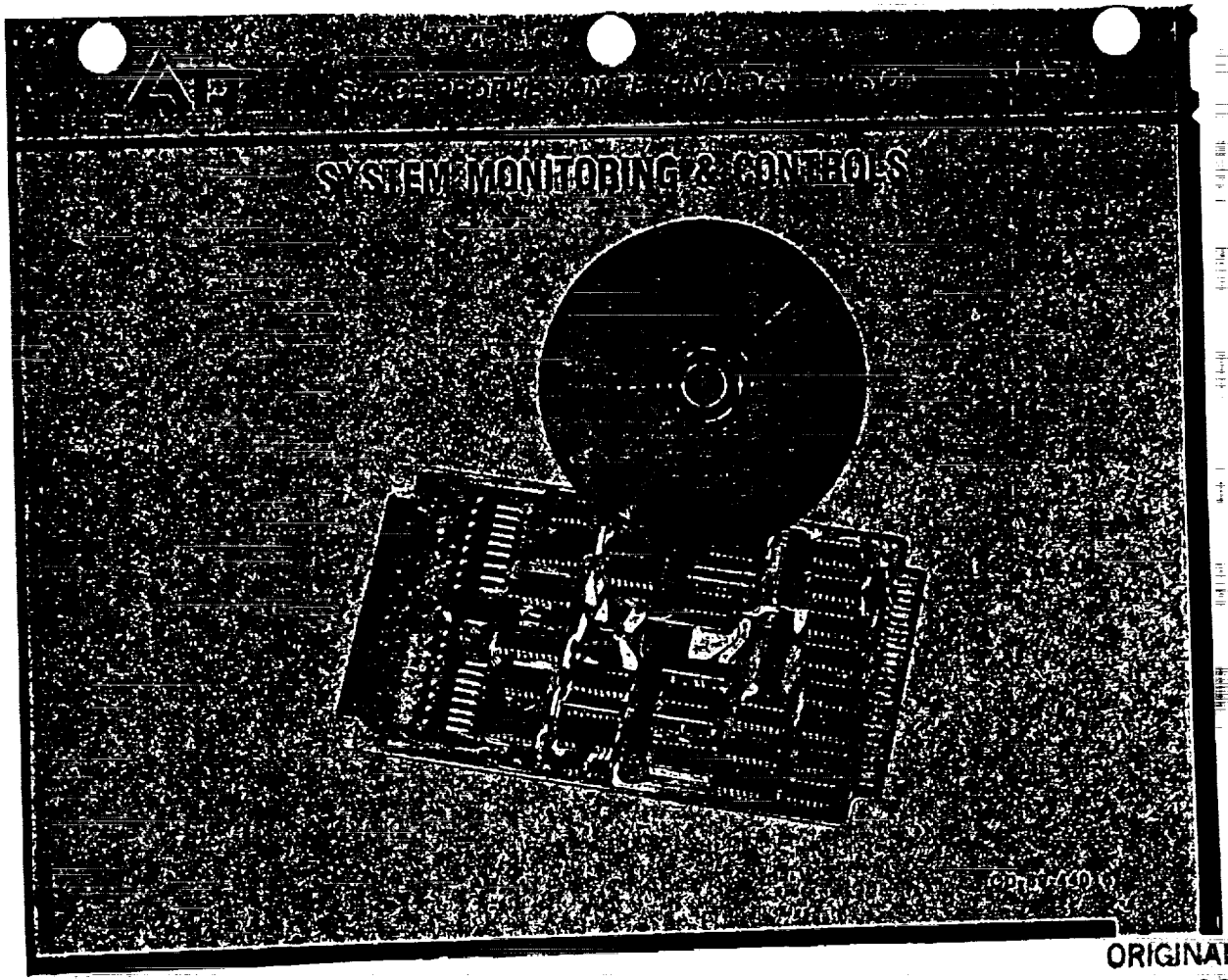
DELIVERABLES:

Current:

- A flight mass data management and storage system for rocket engines.
- An integrated test firing, inspection and historical component and engine database that allows for easy access and retrieval of data for diagnostics, prognostics and maintenance.

Augmented:

- Preprocessing for quicker data retrieval, and sensor measurement validation.



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FIBER OPTIC INSTRUMENTATION BUS

NEED: ADVANCED ROCKET ENGINE INSTRUMENTATION SYSTEM THAT OFFERS SAFER, MORE COMPACT, HIGHER-THROUGHPUT, AND EMI-RESISTANT COMMUNICATION.

APPROACH:

- DESIGN A FIBER-OPTIC INSTRUMENTATION SYSTEM SUITABLE FOR ROCKET ENGINE APPLICATIONS.
- SELECT, DEVELOP OR MODIFY SUITABLE COMPONENTS AND EVALUATE IN RELEVANT ENVIRONMENT
- BUILD AND DEMONSTRATE SENSOR BUS ON COMPONENT AND ROCKET ENGINE TEST BEDS.

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FIBER OPTIC INSTRUMENTATION BUS

BENEFITS:

- PROVIDE INSTRUMENTATION SYSTEM THAT IS FASTER, SAFER, LIGHTER, AND EMI-IMMUNE
- FACILITATE USE OF ADVANCED OPTICAL SENSORS
- IMPROVE STATE-OF-THE-ART IN OPTICAL FIBER TECHNOLOGY

DELIVERABLES:

Current:

- TEST SOME COMMERCIAL FIBER OPTIC COMPONENTS IN CRYOGENIC AND HIGH TEMPERATURES. (ST,MIL-STD, MULTI-FIBER, AND DUAL FIBER CONNECTORS, FIBER CABLES, AND COUPLERS)

Augmented:

- COMPONENTS DEVELOPED AND DEMONSTRATED FOR USE ON ADVANCED ROCKET ENGINES
- INTEGRATED OPTICAL SENSOR BUS DEVELOPED AND DEMONSTRATED FOR ROCKET ENGINE APPLICATIONS

MODEL BASED DIAGNOSTICS

NEED: AUTOMATED MODEL-BASED DIAGNOSTIC CAPABILITY FOR ROCKET ENGINES

APPROACH;

- DEVELOP QUALITATIVE REASONING TECHNIQUES FOR ROCKET ENGINE DIAGNOSTICS:
  - DEVELOP GENERIC TOOL FOR CREATING SYSTEM MODELS AND ANALYZING RESULTS.
  - APPLY TOOL TO ROCKET ENGINE COMPONENTS AND SYSTEMS. DEMONSTRATE CAPABILITIES OF TOOL
- INTEGRATE MODEL WITH HEALTH MONITORING TECHNIQUES TO DIAGNOSE THE SOURCE OF A DETECTED FAILURE.

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MODEL BASED DIAGNOSTICS

BENEFITS:

- PROVIDES MODEL-BASED DIAGNOSTIC ALGORITHMS WHICH CAN EXECUTE IN NEAR-REAL-TIME
- MODEL-BASED DIAGNOSTICS OFFER MORE COMPLETE COVERAGE THAN RULED-BASED TECHNIQUES OF SIMILAR COMPLEXITY

DELIVERABLES:

Augmented:

- ANALYSIS AND DIAGNOSIS TOOLS
- USER INTERFACE FOR SYSTEM DEFINITION AND DISPLAY OF RESULTS
- VERIFICATION OF MODELS OF ROCKET ENGINE COMPONENTS AND SYSTEMS.

SAFETY MONITORING SYSTEM (SMS)

OBJECTIVES:

- Provide increased safety on the test stand, while maintaining a path to flight.
- Complement the current redline system with the SMS to detect anomalies earlier.

APPROACH:

- Validate SMS algorithms.
- Integrate algorithms with hardware.
- Demonstrate anomaly detection on TTB.

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SAFETY MONITORING SYSTEM (SMS)

SMS MAJOR RESULTS

- 100% detection of faults for 15 test cases
- Low false alarm rate
- Covers all phases of SSME operation including power transients
- Robust to sensor loss (clustering)
- Significant improvement in fault detection times
- Not complex

ALGORITHM PERFORMANCE - DETECTION TIME IN SECONDS

TEST NO.	901-110	901-436	901-364	901-307	902-198	902-249	901-225	750-168	901-284	750-259	901-173	901-331	901-222	901-340	SF10-01
CLUSTER	-	302.4	42.7	8.6	5.8	5.2	255.6	300.2	5.2	101.5	102.1	50.2	N/A	405.5	N/A
ARMA	16.0	70.0	210.0	9.0	8.5	160.0	16.0	N/A	9.0	101.5	188.0	233.0	N/A	12.2	104.8
CURRENT RED-LINE	74.1	611.0	392.2	75.0	8.5	450.6	255.6	300.2	9.9	101.5	201.2	233.1	4.3	405.5	104.8

CONTROLS & REAL TIME DIAGNOSTICS

TECHNOLOGY NEED

IMPROVE THE SURVIVABILITY AND DURABILITY OF REUSABLE ROCKET ENGINES THROUGH THE USE OF INTELLIGENT CONTROLS AND REAL TIME DIAGNOSTICS

TECHNOLOGY CHALLENGES

- INTEGRATION OF FAULT DETECTION AND CONTROL MODES TO FORM INTELLIGENT CONTROL WITH INCREASED FUNCTIONALITY AND AUTONOMY
- RELIABLE(I.E. NO FALSE ALARMS), REAL TIME FAULT DETECTION ALGORITHMS
- REAL TIME DIAGNOSTIC ALGORITHMS THAT ACCURATELY PORTRAY ENGINE CONDITION
- IMPLEMENTATION OF DIAGNOSTIC AND CONTROL ALGORITHMS IN COMPUTER HARDWARE
- LIFE EXTENDING CONTROL ALGORITHMS WHICH IMPROVE ENGINE PERFORMANCE AND LIFE
- MODELING AND REAL TIME SIMULATION OF ROCKET ENGINES
- SENSORS FOR CONDITION MONITORING
- ELECTROMECHANICAL ACTUATORS

CONTROLS & REAL TIME DIAGNOSTICS

APPROACH

- DESIGN AND ANALYZE ALTERNATIVE FAULT DETECTION, CONDITION MONITORING, AND CONTROL STRATEGIES.
- IMPLEMENT THE MOST SUCCESSFUL STRATEGIES IN SOFTWARE/HARDWARE PROTOTYPES
- INTEGRATE THE PROTOTYPES INTO A VALIDATION SYSTEM
- VALIDATE THE STRATEGY BY REAL TIME SIMULATION AND ENGINE TEST
- COORDINATE CLOSELY WITH THE OTHER TECHNOLOGY GROUPS, PARTICULARLY INSTRUMENTATION.

PAYOFFS

- IMPROVED SURVIVABILITY FOR PROPULSION SYSTEM
- IMPROVED ENGINE PERFORMANCE AND DURABILITY
- ENHANCED SAFETY FOR PROPULSION SYSTEM AND VEHICLE
- ENHANCED SAFETY FOR GROUND TEST OF ENGINES
- INCREASED CONTROL SYSTEM RELIABILITY, FUNCTIONALITY, AND AUTONOMY
- REDUCED ENGINE LIFE CYCLE AND MAINTENANCE COSTS
- REDUCED CONTROL SYSTEM COST AND WEIGHT

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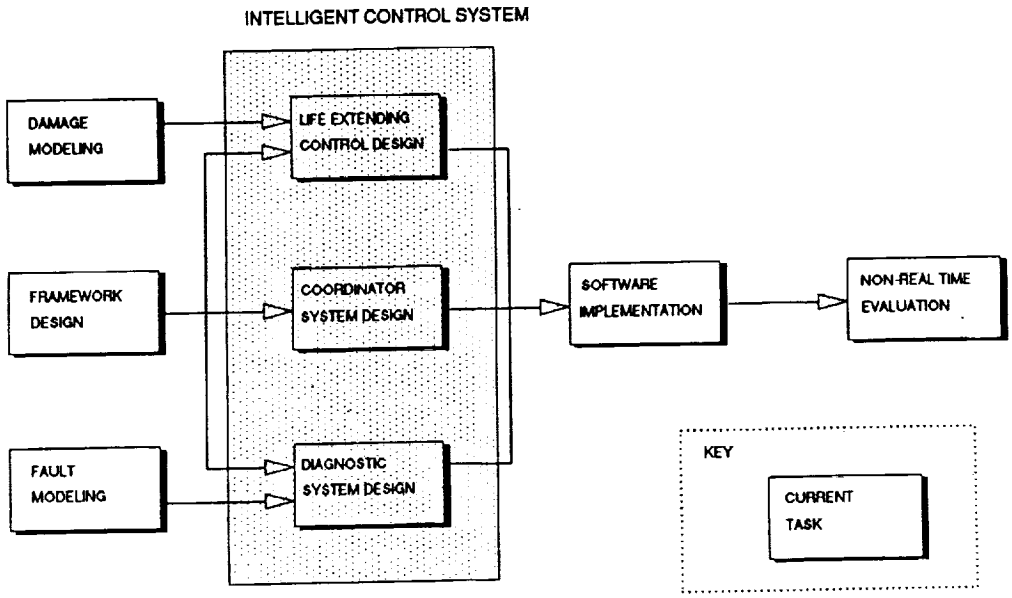
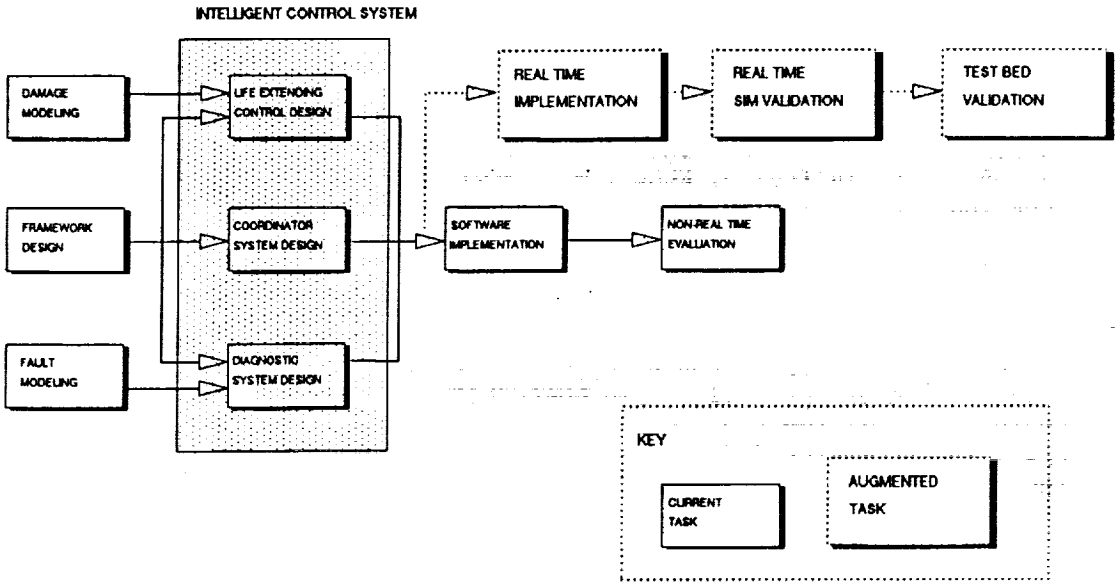
CURRENT INTELLIGENT CONTROLS PROGRAM



AUGMENTED INTELLIGENT CONTROLS PROGRAM



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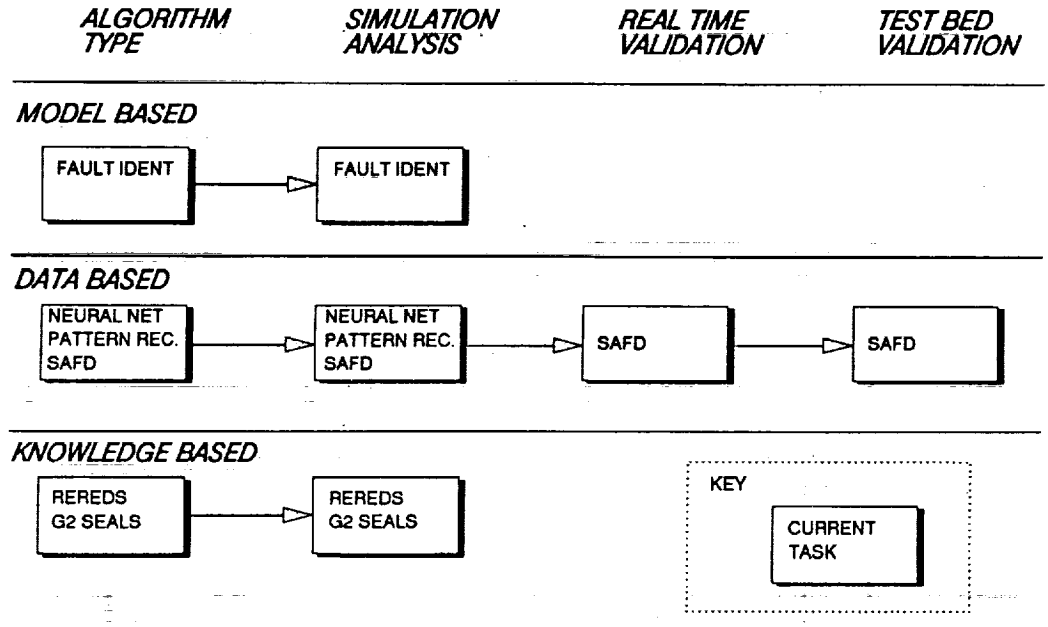
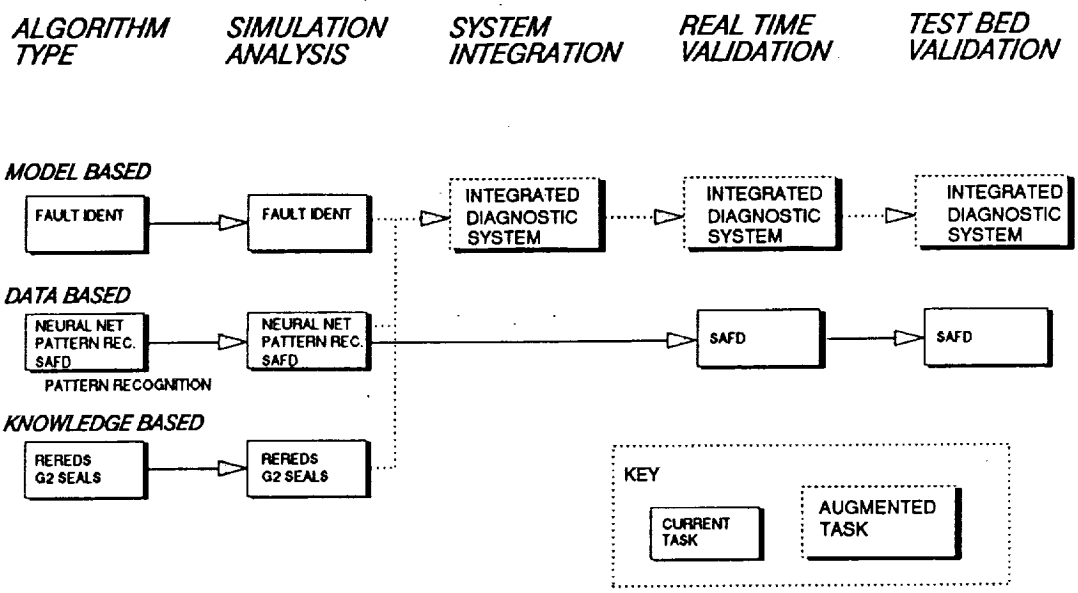
CURRENT REAL TIME DIAGNOSTICS PROGRAM



AUGMENTED RT DIAGNOSTICS PROGRAM



CONTROL AND DIAGNOSTIC SYSTEM HARDWARE

CURRENT PROGRAM

- SIMULATION LAB AND TTBE CONTROL COMPUTERS
- FLOWMETERS
  - TRIBOELECTRIC
  - ULTRASONIC
  - VORTEX SHEDDING
- NON-INTRUSIVE SPEED MEASUREMENT
- GAS LEAK DETECTOR
- MASS DATA STORAGE
- ADVANCED PROPELLANT CONTROL VALVES
- ELECTROMECHANICAL ACTUATOR

AUGMENTED PROGRAM

- COMPLETE TEST BED EVALUATION OF FLOWMETER
- COMPLETE TESTING OF ELECTROMECHANICAL ACTUATOR
- PROCURE AND DEMONSTRATE HARDWARE FOR MASS DATA STORAGE SYSTEM
- PROCURE AND DEMONSTRATE COMPUTERS FOR REAL TIME DIAGNOSTIC SYSTEMS